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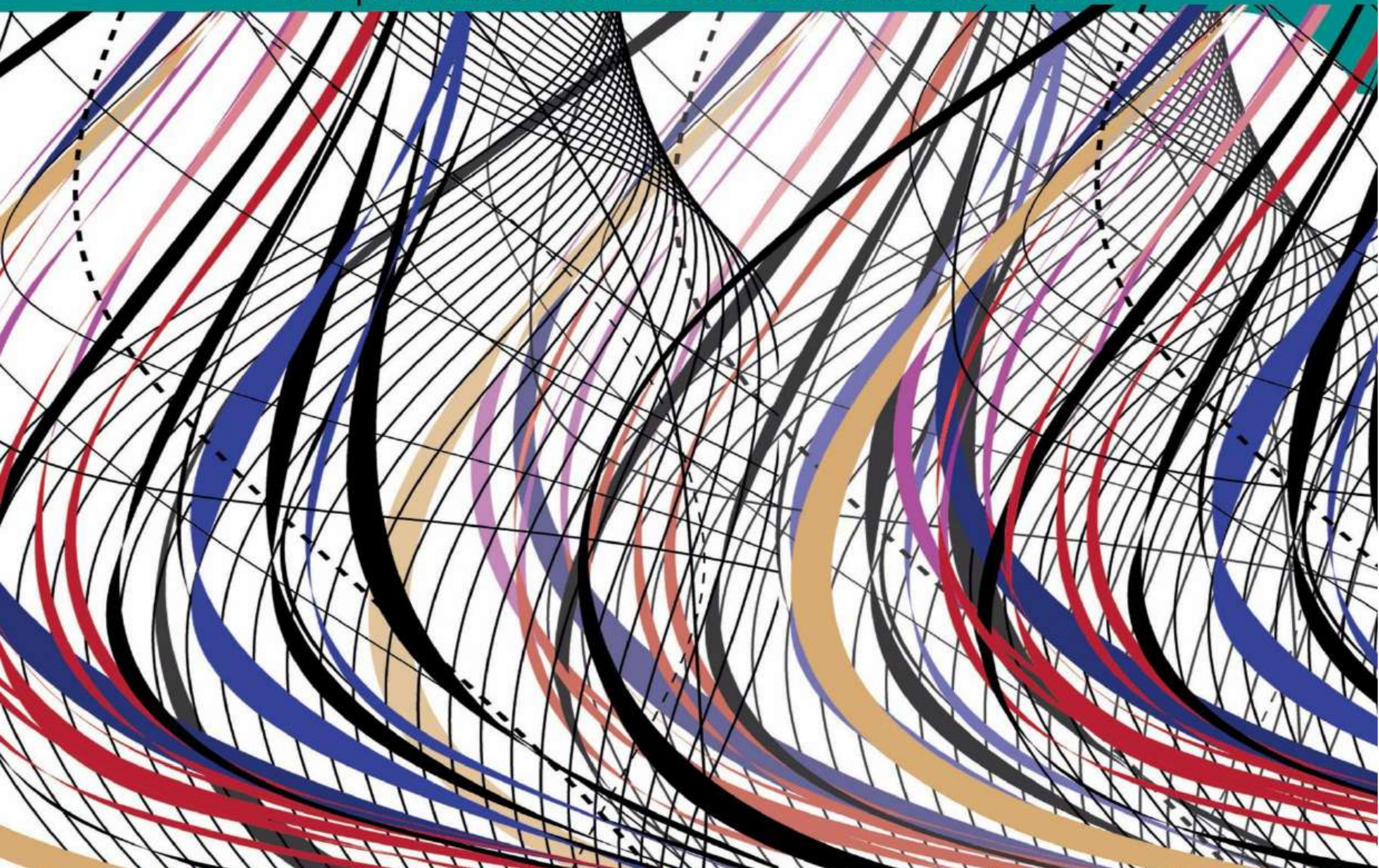

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Financial Competence of Non-Accounting Graduates in the Department of Education in Cabanatuan City

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***Abstract*— *This study sought to evaluate the financial acumen of Department of Education graduates who did not major in accounting. Second, how it impacts their ability to perform at work. The relationship between financial competence and performance rating was described and examined in this study using a descriptive correlation research design. The study's findings indicate that most respondents were females in the age range of 31 to 40, college graduates, and mostly administrative officers with two to three years of experience. They received a score of 39% for knowledge, 53% for skills, 74% for attitude, and 72% for behavior. The average score is 60%, indicating that their level of financial competence is average. The findings indicate a strong positive correlation between financial competence and performance rating, with a correlation coefficient of 0.724. This implies that a person's performance will increase in direct proportion to his level of financial competence. It is necessary to take into account their mediocre level of skill and limited knowledge. Programs for financial education may assist employees in achieving and maintaining a high level of financial competence at work, which will lead to good performance.*

***Keywords*— Assessment, Department of Education. financial competence, performance, qualification and skill mismatch**

I. INTRODUCTION

Financial competence involves the ability to handle money, understand financial institutions' roles, and participate in financial planning. In an ever-progressive professional environment, employees are expected to gauge work with sufficient financial competence. The concept of competency is usually applied to define the whole of individual abilities, skills, behaviors, and knowledge, oriented to effective performance in a particular working environment. (Kolibacova, G., 2014). Companies today require employees who understand their finances and can make a significant contribution to the bottom line.

One of the problems that arise in the appointment of school managers is that the appointment itself is not based on the training and expertise possessed by school heads, which in turn will cause the appointed school heads to manage in a trial-and-error manner. The said school head will also be heavily dependent on the accounting clerk who is known to be more experienced in the school's financial management. Therefore, this would cause problems in the financial management of the school due to the prevailing fact that is lacking knowledge and experience among school heads in preparing school expenditures (Galigao et al., 2019). This is also true in DepEd Cabanatuan.

Like most institutions, the job-skill mismatch is another issue that DepEd Cabanatuan is dealing with. There is no denying that job-skill mismatch remains a problem in the country's labor sector (Villanueva, 2016). The pandemic changed the employment landscape for the Filipinos that continue to exist in the medium to long term. This divergence will increase skills mismatches in the labor market, as workers do not transition easily between sectors given differences in required skills and experiences. (Bird et al., 2021). According to Montt (2015), one underlying factor behind the high rate of job-skill mismatch is education. His study explains the reasons in two distinct concepts, “qualification mismatch", which happens when individuals are formally educated in a particular field and then downgrade to another field just to find work; and "skills mismatch", which results from technical or soft skills mismatch as against those required by the jobs.

In most organizations, there are accounting jobs that don't require a degree in accounting, as long as the person is qualified for the position. According to Liao (2016), jobs like administrator, accounting clerk, bookkeeper, and other supportive roles do not require an accounting degree. The problem with this is that a lack of qualifications may lead to poor job performance. Therefore, an individual who is not well-versed in accounting principles may be limited in their ability to perform these tasks. Financial knowledge can help individuals make relevant financial decisions, efficiently management of money and debt, lower financial stress, and better implementation of strategies to reach financial goals. However, the Philippines' financial literacy is still at a low level, according to the Bangko Sentral ng Pilipinas (BSP) (Agcaoli, 2020). Approximately only 2% of adult Filipinos can correctly answer all financial literacy questions (Financial Literacy Statistics, 2020). In addition, Standard & Poor (S&P) discovered last 2015 that only 25 percent of Filipinos are financially literate, including over 75 million with no insights about insurance, inflation, and the simple idea of savings accounts. The public and private sectors have been exerting efforts to promote financial knowledge; still, the number of Filipinos who invest (in stocks, insurance, or mutual funds) is only between 8 to 10 percent (Enterprises, 2018).

In this day and age, when budgeting and increasing profitability are two of the most important goals for a school's success, educators and school administrators must have a strong grasp of the fundamentals of accounting. DepEd Cabanatuan is responsible for providing the best facilities and most motivating learning environments to the students. To do this, they must appoint employees that can track the schools’ incoming revenue streams and outgoing expenses in real-time, as well as make projections about future finances. Financial management is one of the key elements in the provision of high-quality education. The resources and funds utilized by an educational institution are used to develop its infrastructure and implement initiatives that will be beneficial for the students. As such, it is important to ensure that all expenditures are properly scrutinized and utilized in a way that will best benefit the purposes of an educational institution.

Over time, the workplace has become increasingly complex, as new technologies and practices have been introduced. This means that employees must be able to understand their roles within an organization, how organizations operate, and how changes in these organizations affect their performance. This requires a high level of financial competence. And while having a strong accounting department is crucial, it's also vital to make sure that non-accounting graduates understand financial concepts. With enough financial knowledge, employees can create more value and increase their productivity. Thus, it is critical to assess the level of financial competence of non-accounting majors in DepEd Cabanatuan to help the government in designing effective financial education programs. Furthermore, it is relevant to determine whether being financially competent strengthens or weakens their job performance.

Theoretical Framework

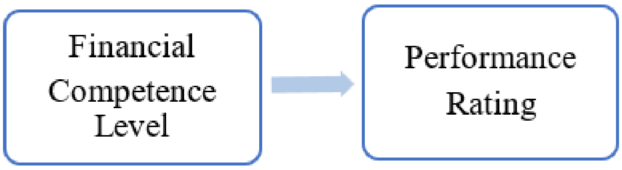

Fig.1. Theoretical Framework of the Study

Figure 1 presents the theoretical framework of the study. The independent variable of the study is financial competence, whereas the dependent variable is the performance rating of non-accounting graduates in DepEd.

Financial competence as an independent variable pertains to the intellectual understanding of different financial concepts such as budgeting, borrowing, and taxation. People with a good level of financial competence are analytical and will be less likely to create poor decisions about financial transactions; therefore, increasing their work productivity. They are more likely to perform in an effective and efficient way. On the other hand, performance rating as the dependent variable of the study concerns the standing of the employee in his line of work. It is the evaluation of the worker’s performance in correspondence to DepEd standards.

By incorporating financial competence into the workplace, corporations and employees reap many benefits, including increased productivity and retention. Financial competent employees tend to have greater focus and less stress, making them more effective (Mohney, 2018).

II. METHODOLOGY

The researchers used a descriptive correlation research design in the study to describe and observe the relationship between financial competence and performance rating among non-accounting graduates in DepEd Cabanatuan. Specifically, the researchers would like to observe the financial competence of non-accounting graduates. Also, the researchers aim to determine the impact of the financial competence level of a person (whether financial competence increases or decreases) on their job performance. 20 non-accounting graduates were purposively chosen to constitute the study. The researchers used an online questionnaire guided by the Eastern Europe Central Asia Policy Initiative (ECAPI) and Consumer Empowerment and Market Conduct (CEMC) Working Group's financial competency matrix for adults. The data gathered from the respondents were analyzed using appropriate statistical tools such as frequency, percentage, and Spearman rho correlation.

III. RESULTS AND DISCUSSION

1. Socio-Demographic Profile of the Respondents

Table 1. Socio-demographic profile of the respondents.

Variables	*f*	%
Highest educational attainment		
Bachelor's Degree Graduate	15	75%
Master's Degree Level	2	10%
Master's Degree Graduate	3	15%
Doctorate Degree Level	-	-
Doctorate Degree Graduate	-	-
Degree taken		
Business and Management	6	30%
Health Sciences	3	15%
Engineering	2	10%
Computer Sciences	4	20%
Biological and Agricultural Sciences	1	5%
Education	3	15%
Arts and Humanities	1	5%
Current work		
Unit Head	1	5%
Administrative Officer	9	45%
Administrative Assistant	4	20%
Administrative Aide	4	20%
Clerk	2	10%
Number of years in the current position		
0-1	3	15%
2-3	13	65%
4-5	2	10%
More than 6	2	10%
Age		
20-30	7	35%
31-40	8	40%
41-50	5	25%
Sex		
Male	7	35%
Female	13	65%

A total of 20 respondents were involved in this study, and the researchers came up with correct results and interpretations following their answers. The researchers looked at three (3) major characteristics of the non-accounting graduates of DepEd. To mention, these are their *background, financial competence (knowledge, skills, attitude, and behavior) and performance.* The sex of the respondent comprised 35% of males and 65% of females, and their ages ranges from 24 to 49. Three out of 20 participants had a master's degree and a majority of them answered that they obtained a degree in these three fields: Business and Management (30%), Computer Sciences (20%) and Health Sciences (15%). Almost half of them are Administrative Officers (45%) with a majority of 2-3 years of service in their current position.

2. The Level of Financial Competence of Non-Accounting Graduates in DepEd

Table 2. ***Level of financial competence of the respondents***

FINANCIAL CAPABILITY COMPONENTS: THEMATIC AREAS	KNOWLEDGE	SKILLS	ATTITUDE	BEHAVIOR	OVERALL
1. ECONOMIC IMPACT	50%	55%	71%	68%	61%
2. BUDGET MANAGEMENT	70%	75%	75%	70%	73%
3. SAVINGS AND LONG-TERM PLANNING	55%	65%	71%	72%	66%
4. DEBT MANAGEMENT	25%	35%	70%	72%	51%
5. SHOPPING AROUND	40%	65%	82%	70%	64%
6. RIGHTS PROTECTION	15%	40%	76%	70%	50%
7. SAFETY	20%	35%	77%	78%	53%
OVERALL	**39%**	**53%**	**75%**	**71%**	**60%**

Table 2 presents the level of financial competence of the respondents. Financial competency was measured in the second part of the questionnaire by following the ECAPI's financial competency matrix for adults. A 14-item assessment was used to determine the knowledge and skills of the participant in these thematic areas: economic impact, budget management, savings and long-term planning, debt management, shopping around, rights protection and safety. The average score of the respondents in the knowledge component was 39% On the other hand, the average score for the skills component was 53%. In determining their attitude and behavior, a 14-item Likert scale was constructed following also the mentioned seven thematic areas. With a Cronbach alpha value of 0.75, the Likert scale developed by the researchers passed the reliability test and signified an acceptable internal consistency in the survey. Their self-perceived attitude was 75% while their behavior component was 71%. The researchers followed Durham University's Blackboard Enterprise Survey in converting the mean of the answers in the Likert scale into percentages. Results showed that the respondents had the highest average in the area of budget management (73%) and the lowest in rights and protection (50%). The knowledge of the non-accounting graduates was relatively low. Contrarily, their self-perceived attitude and behavior are high, and their skills are average. Overall, the financial competence of non-accounting graduates was middle, totalling a score of 60%. For simplicity reasons, the financial competency index and other sub-indexes are scaled lowest (0-20%), low (21-40%), middle (41-60%), high (61-80%) and highest (81-100%). (Alliance for Financial Inclusion, 2017).

3. Financial competence and performance rating.

Table 3. Correlation of financial competence and performance rating.

Correlations

			Fin_Comp	Perf_Rate
Spearman's rho	Fin_Comp	Correlation Coefficient	1.000	.724**
		Sig. (2-tailed)	.	.000
		N	20	20
	Perf_Rate	Correlation Coefficient	.724**	1.000
		Sig. (2-tailed)	.000	.
		N	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3 shows the relationship between financial competence and performance rating. Spearman rho correlation was used to determine the relationship between financial competence and performance rating. The Spearman rho correlation (ρ) is a non-parametric test that is used to measure the degree of association between two variables. (Statistics Solutions, n.d.). The numbers in the table (See table 3) show that the correlation coefficient between the two is 0.724. It is in the range of .70 to .90 which signifies a strong positive correlation between the dependent and independent variables. This concludes that the higher the financial competence of an individual, the greater his performance will be. Output from IBM SPSS derived a value of 0.000 as seen in the row for significance (two-tailed). It denotes that the relationship between the two variables is statistically significant since the P-value (0.000) is less than the alpha (α) value of 0.05.

IV. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were made based on the results and discussions:

1. The average score of the respondents in the knowledge component was 39%. On the other hand, the average score for the skills component was 53%. This indicates that respondents have issues understanding the time value of money, formal and informal ways of saving, investments, simple and compound interest, and other financial topics. Particularly in the aspects of rights & protection, safety, and debt management. Similarly, skills related to debt management and safety are 35%.

2. Their total average for attitude and behavior is 75% and 71%, respectively. This shows that despite privacy concerns and their inability to recognize financial scams and fraud attempts, they are nonetheless cautious and turn down enticing suspicious financial offers from unidentified sources. The total average score of the respondents is 60% which means they have a middle level of financial competence.

3. Spearman rho correlation was used to determine the relationship between financial competence and performance rating. Results show a correlation coefficient of 0.724 which signifies a strong positive correlation between the variables. This means that the more financially competent a person is, the greater his performance will be. The low percentage of their knowledge and the middle level of their skills needs to be considered.

Based on the findings and conclusions, the following was recommended:

1. The Department of Education may opt to provide financial education programs to help the employees attain and maintain a high level of financial competence in their workplace, thus providing good performance.

2. In today's world, it is imperative to teach financial literacy. Financial literacy is the foundation of money-related relationships, and its learning process is long-term. (Fernando, 2022). In line with this, Cabal and Tilan defined financial literacy as the comprehension of a set of economic concepts that can be used to evaluate financial situations and make good financial decisions. To stay up with the many changes in the field of finance and accounting, employees who are not familiar or knowledgeable with financial management should be obliged to take a financial literacy course. In this way, employers can ensure that they only hire people with the qualifications necessary for the position.

3. This paper proposes that teaching financial literacy should focus on enhancing its practical aspects including the development of skills in planning, budgeting, and using financial records in coming up with sound decisions. This study also provides additional knowledge and awareness to different organizations, most especially in the government sector to consider the financial competence and skills of their employees.

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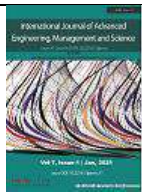

The Government Procurement Law (RA 9184) And Its IRR: Flaws on the Compliance Based on the Observations in the Procurement Bidding Process by the Employees of the Philippine Center for Postharvest and Mechanization Development (PHilMech)

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Abstract— *It has been stated repeatedly that delays in government spending in the past have been caused, in part, by problems with procurement. The PHilMech Budget has been citing procurement as an excuse for underspending for many years. The cumulative disbursement outcome for 2019 was lower than the programmed spending for the year by approximately Php 48 million, or about 23% of utilization in the Regular fund, and by approximately 9 million, or about 9% in the Rice Competitiveness Enhancement Fund. Although not all of the savings result from underspending (i.e., about 21% of the amount is attributable to a combination of greater interest payment savings and net lending, which reflects prudent debt management by the government), the majority is reflected as a decline in agency performance in disbursements and budget utilization. The problem of procurement management delays in PHilMech has been enormous. Its effects were so profound that it frequently slows down the execution of strategic planning. This essay examines the management and procurement law flaws that contributed to the delays in the PHilMech projects' implementation. The analysis's findings showed that poor management, ineffective planning and scheduling, and cash flow and financial difficulties faced by management were the major issues that contributed to delays. Several actions are suggested.*

***Keywords*— bidding process, budget utilization, delays, government spending, procurement**

I. INTRODUCTION

This study examines the issues which beset the implementation of the public procurement law RA9184 and its IRR in the Philippine Center for Postharvest and Development and Mechanization (PHilMech), especially in light of the recent concerns on delays in project implementation and underspending by government agencies like PHilMech.

The limited procurement professionals worked in committees on PHilMech on a basis and returned to their former position upon the completion of the project. It has many weaknesses and results in low performance of public procurement. The low performance of public procurement has a negative impact on the state losses which consist of fictitious Procurement of Goods and Services, partners do not complete work, goods and services do not meet specifications, lack of work volume, price mark up and expenditures not in accordance.

It is necessary to improve the performance of public procurement. The development of procurement professionals is one of the key factors in public procurement that are more quality, timely, and effective. The objectives of procurement professionals' development of activities include increasing efficiency and saving public procurement; guaranteeing the availability of goods and services timely and providing public services as planned, through efficiency and savings will be obtained more and more quality goods and services to give a positive impact on economic growth.

Lack of knowledge skills of procurement personnel affects service quality and procurement efficiency. Procurement personnel must focus on maintaining professionalism. The Procurement unit needs to be changed into a structured organization to facilitate coordination. The role of Government in Public procurement policies is needed to improve long-term procurement efficiency. Inaccurate procurement of goods and services can lead to a case of fictitious Procurement of Goods and Services, low-quality partnerships, unfinished prices and expenditures that are not in accordance with the provisions. Key lessons from experience are investigated through interviews with staff of procurement and end-user in the implementation and execution of the Philippine procurement process. The numerous key informant interviews greatly revealed the difficulties encountered and good practices implemented under the current legislative framework.

The Philippine Public Procurement Framework

The current legislative framework is contained in the Republic Act (RA) 9184 or the Government Procurement Reform Act of 2003. It was signed into law on January 10, 2003. The implementing rules and regulations (IRR) were revised several times: October 8, 2003; September 2, 2009; and, more recently August 25, 2016. The governing principles, as provided by Section 3 of RA 9184, are transparency, competitiveness, streamlined procurement process, accountability, and public monitoring. The following summarizes the reform interventions in the law that support these objectives:

Objectives	**Reform Interventions**
Transparency	Use of the Philippine Government Electronic Procurement System (PhilGEPS)
Competitiveness	Sec.10 of RA 9184 states that Public bidding shall be the default mode of procurement. Article XVI provides alternative methods of procurement
Harmonization of Inconsistent policies, rules and regulations	Creation of the Government Procurement Policy Board (which is an inter-agency body)
Accountability	RA 9184 includes penal and civil liabilities
Checks and balance	Civil society organization participation

Statement of Problem

The cited reasons by government agencies for the low disbursement outturn are various, but a recurring reason is "public procurement issues." A major reason cited is "procurement difficulties due to problems in procurement scheduling, delays in bidding, and incorrect technical specifications and costing." We are thus motivated to help accelerate public investments in high-priority programs and projects by studying what really constrains public procurement in actual practice and finding ways to address the public procurement constraints.

II. METHODOLOGY

The study will be conducted in PHilMech offices. The researcher used the descriptive survey type of research to gather data which will describe the flaws and deviations in the procurement law RA 9184 and its IRR by the PHilMech employees. The opponents are ten (10) BAC members (with BAC Secretariat and Technical Working Group) of the PHilMech and Chief of Offices/ End Users.

The questionnaire will be the main data-gathering instrument. Secondly, sources were reviewed, and interviews were conducted to respond. The questionnaire is made up of observations of respondents on the provision of R.A. 9184 and its IRR.

Results of Procurement Data

One research topic of concern is the comparison of competitive procurement mode versus the alternative modes of procurement. To put the research topic in perspective, note that Competitive Procurement can take a long time and involve a lot of complex paperwork. Furthermore, not all agencies will want to bid on the tender. To undercut competitors' prices, some companies may underbid or provide unreasonably inexpensive goods and services. The proposal is to authorize the adoption of alternative modes of procurement as the default mode in implementing projects aimed at delivering other goods and services to the final beneficiaries or end users. It is expected that some portion of the project budget will involve the procurement of supplies. Thus, we processed the data further to gather all competitive bidding records as one group and the rest or alternative modes as another group.

One shortcoming of the recording system in the PhilGEPs that is not favorable for our purpose is that there is no ID for the "repeat" procurement cases, or those projects which are already on their second or third round of procurement process because the procuring entity's previous tries were not completed or failed for some reason. Thus, we have no way of isolating those which are not on their first try and therefore have a higher probability of success or bidding process completion, that is, we have no way of isolating the reason that a certain record has a Notice-to-Proceed observation or successful procurement completion only because the project bidding is already on its nth try.

III. RESULTS AND DISCUSSION

Table 1. Profile of the Respondents – 7 of the respondents were female and 3 were male, 5 respondents were above 40 years old and 3 respondents have 3 years and above working experience as BAC/TWG and End-Users. It shows how the working experience of BAC/TWG answers the questions regarding the process of procurement law.

Sex of Respondents	Male	3
	Female	7
	Total	**10**
Age of Respondents	30 years old below	3
	30-40 years old	2
	40 and above	5
	Total	**10**
Working experience as BAC/TWG /End Users	Below 1 year	4
	1-3 years	3
	3 and above	3
	Total	**10**

Table 2. It shows the Seven (7) Factors that have an impact on the bidding process that respondents agreed.

Indicators	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
1. Awarding Contracts	6	2	2	0	0
2. Planning	6	2	2	0	0
3. Strength of BAC and TWG	8	1	1	0	0
4. Procurement law Competition	8	2	0	0	0
5. Context of Procurement Planning	6	3	1	0	0
6. Implementation and Execution of Procurement law	5	2	2	1	0
7. Integrity of Procurement	5	2	2	1	0

Figure 1. 10% of the respondents strongly agreed that Awarding of Contracts is one of the causes of delays, 98% for Procurement Planning, 98% that need of strengthening the BAC and TWG, 75% on the need to Encourage the Competition on Procurement law, and 11% of the Spending in the context of procurement planning (budget-planning), 9% that needs to improve the implementation and not but the list the principle of integrity 10%.

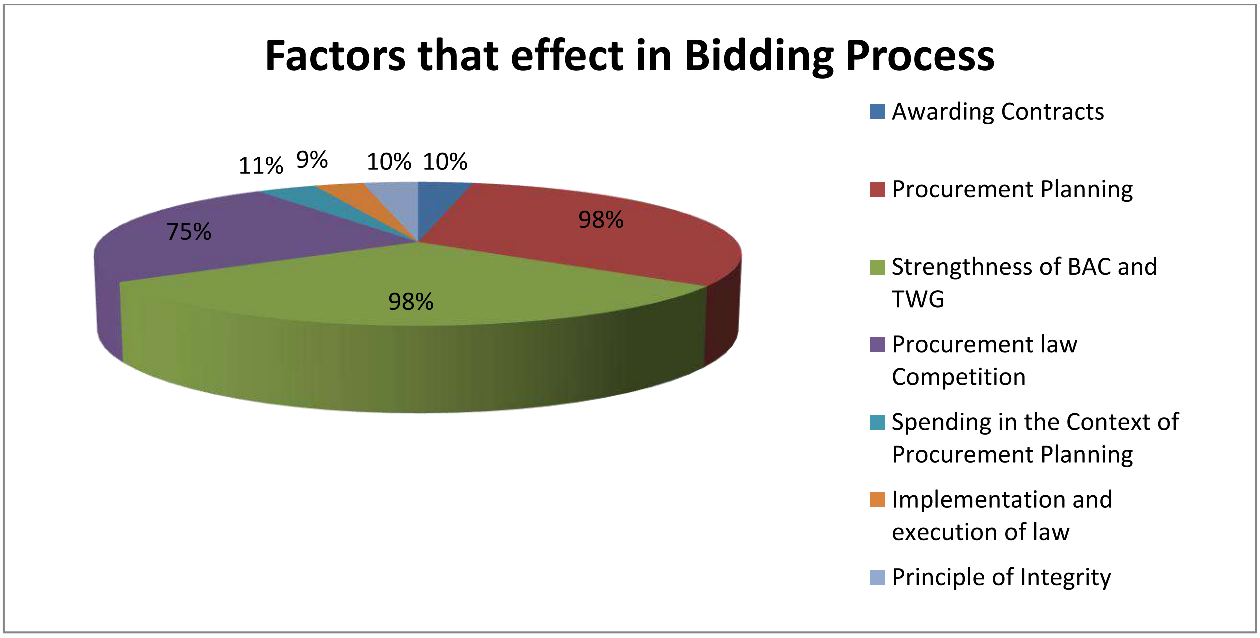

Fig.1. Factors Effects in the Bidding Process

Results of Key Informant Interviews

Highlights of Discussion

1. **The principle in Awarding Contracts.** The key informant clarified the rule when it comes to awarding the contracts. The phrase 'most responsive bid', according to him, is vague and does not capture shades of quality. As an example, one respondent cited that projects are awarded based on quality at the most reasonable price. The end-user states that agencies should not be constrained to consider the price only.
    a. GPPB stated that the guidelines state 'lowest' and 'most responsive bid. Responsiveness in this context refers to the compliance of the bid to the technical specifications set by the procuring entities. Therefore, it is the duty of the procuring entity to ensure that the technical specifications are properly crafted.
2. **Planning as a cause of Procurement Delays.** The point of PHilMechs' Bids and Awards Committee above highlights the most common cause of procurement delays. The body agrees that most of the delays in the procurement system stem from flawed planning. One of the issues discussed is the capacity of government agencies to properly identify the "Approved Budget for the Contract" (ABC). An incorrect ABC would restart the overall procurement process, thus delaying the disbursement of funds.
    a. In detail, the ABC serves as the price ceiling for the contract. Thus, a low ABC would not receive any bids from suppliers. No bids would result in a failure of bidding. The Bids and the Awards Committee (BAC) and the Technical Working Group (TWG) would now restart the whole procurement process (including realigning the budget, revising the Annual Procurement Plans (APPs), redesigning the technical specifications, etc.) before it can be posted again for advertisement. Should the bidding fail again, then the procuring entity can change the mode of procurement from Bidding to Negotiated Procurement. Negotiated Procurement will also have a different process.
    b. As an example, the Procurement Team cited an experience of procuring Tractors. The initial ABC specified only the price of the equipment, but not the import duties and taxes. Therefore, failure of bidding was declared when no supplier signified interest based on the ABC. In this case, poor planning can be traced to the TWG and BAC.
3. **Strengthening the BAC and the TWG.** Related to the poor planning is the lack of capacity of the BAC and TWG in implementing the rules and regulations set by RA 9184.
    a. For one, stated that the TWG is 'ad hoc' in nature. It is usually composed of the end-users who may not have the know-how to properly identify the technical specifications nor the appropriate budget for the good or service needed.

b. In addition, BAC members have a one-year term, renewable at the discretion of the Head of the Procuring Entity (HOPE). Usually, when a new HOPE is designated, the BAC members are also replaced.

c. One respondent stated capacity building continues to be one of their main tasks. They are continually training new members to become BAC members. Although, it must be noted there are currently plans for the professionalization of the procurement officers. Only those who undergo a course on government procurement shall be eligible to be members of the BAC.

d. Another suggested that procuring entities may hire procurement specialists or transaction advisers to aid in streamlining and fast-tracking the procurement process. Further, it would be best if procuring units will be institutionalized in government agencies.

   i. This can be done under the existing rules. It is up to the procuring entities to decide if they choose to hire such consultants. In the law, GPPB-TSO also states that procuring entities can seek the advice of other government agencies with specific expertise.

   ii. Approval as this would require additional plantilla positions. Currently, there are no career service employees for procurement at the strategic level.

e. The procuring entities can also hire procuring agents, as provided by the IRR of RA 9184. But one stated that agencies should also learn the procurement process themselves. They add that most of the agencies are not familiar with transaction advisers, thus it is not even being considered.

4. **Procurement Law should Encourage Competition.** Another respondent from the Bids and Awards Committee stated that the law should be able to encourage competition. Currently, the existing laws do not inspire small firms to grow bigger since they find a segment of government procurement that is essentially only for them.

   For example, Small B (up to Php 10 million in contract price) projects only invite contractors that are licensed as C or D. He asks if they could require an AAA-licensed contractor, even for a Small B project.

   a. In reality, AAA-licensed contractors can compete in Small B projects. There is no provision in the procurement law that limits competition. However, the AAA contractors are usually not interested in those small projects.

   b. Further, License Law is applicable in this case, which also provides for specific guidelines that need to be followed.

   c. In a related point, highlighted the fact that the competition aspect has been regulated by other various legislations since time immemorial. It must be remembered that even if bidders are part of delays, they are not incentivized to grow since the market is governed by laws that promote domestic preference.

5. **Under spending in the Context of Procurement Planning**. One respondent from the BAC stated that factors in under-spending experience include the following: a) the poor planning brought about by uncertainty in the budget that government agencies will receive, and; b) lack of absorptive capacity.

   a. In the current process of government budgeting, the government agencies prepare their estimated budget based on their annual implementation plans and then submit the same. Congress is the power of the purse to approve, increase, or decrease the proposed budget of the PHilMech. According to her, what is traditionally done by different divisions is to overstate their needs and fill their annual plans with indicative projects. This is because divisions are expecting to only approve a certain amount for their proposed plans. Thus, even after some budget cuts, the divisions will still have an ample amount of resources to pursue their annual implementation plans.

   b. However, this uncertainty in the planning-budget programming linkage became a problem as early as when the national government had enough money to allocate. Thus, the overstated annual plans were approved, while others were granted more than what they requested. PHilMech lacks the absorptive capacity to effectively implement the projects they listed in their proposed plans. This was also the cause of the Disbursement Acceleration Program, as implemented by the current administration.

For example, on average, each division was given around 1.5 million pesos annually. Then, there was a year that it was increased to more than 5 million pesos, which caused difficulties in its implementation.

6. Despite this, PHilMech mentioned that there still is a need for improved implementation and execution of the law. Most of the problems in procurement are considered 'human-borne difficulties'. Further, there are hesitations from the side of the procuring entities since they are getting mixed signals from COA and the Ombudsman. GPPB is the policy-making body, but the investigations and enforcement of fines are with COA and the Ombudsman.
7. **Principle of Integrity in Procurement.** The BAC member also mentioned that a significant component in procurement is the principle of integrity. PHilMech asks whether there are mechanisms in place to prevent collusion between agencies and suppliers.
    a. Stated that there are certain provisions in the law that prosecutes those who will be caught colluding. However, he reminded the body that it is by practice in law that those who allege must be the ones to prove. The evidence against an act of collusion must be beyond circumstantial.
    b. Also if accreditation of private bidders is being done. A scheme such as an integrity pledge may be implemented and included as part of the technical specifications.

It was also discussed that good practice in public procurement would be 'whitelisting'. Government agencies should not only blacklist but actively keep a record of compliant and responsive bidders. PHilMech stated that this is currently being practiced by several, but is not adopted consistently.

The PHilMech also would like to shift to a more 'principle'-based implementation of the law, rather than 'rule'-based implementation. Rule-based implementation has caused several confusions and clarifications from agencies addressed to the GPPB. Each procurement activity is unique, and sometimes the existing rules will not allow even the most efficient procurement method. PHilMech admitted that this is how the rules are made as it was crafted with anti-corruption as one of its objectives.

c. Principle-based implementation will be governed by the following principles:

i. Public Monitoring

ii. Accountability

iii. Competitiveness

iv. Transparency

v. Streamlined Process

IV. CONCLUSIONS

Findings from this study provide conclusive evidence that the Procurement law and its IRR have an impact on the Procurement process – that causes delays in the implementation of bidding. More respondents agreed that there is a strong effect in the seven (7) indicators. All stakeholders, the procuring entity, evaluation panel, approving authority, requesting entity, etc. involved in the bidding, evaluation and selection phase are responsible for making every effort to avoid delays in the procurement process. It has to be a collaborative effort.

On the other hand, training for procurement professionals also contains understanding skills in organizational development. Institutional mentoring did by way of the assistance of Human Resources through GPPB training. Thus, a more effective procurement organization can be achieved. With the achievement of professional procurement personnel and supported by effective procurement organizations, it is expected that more quality and production processes will be created. Furthermore, establishing good procurement according to procurement law and its IRR RA9184.

V. RECOMMENDATIONS

1. Pursue deliberate investments in and have a political will for systems change and organizational culture change. The PHilMech under the helm of the Department of Agriculture Secretary is an example of this. When the government was severely criticized by many stakeholders for the delays in the implementation of agricultural machinery projects or any goods and services. The DA Secretary vowed to institute an agency transformation program which will reduce corruption, improve efficiency, optimize resources and realize an overall organizational culture change. To implement the right projects at the right cost and with the right quality, and for these to be delivered right on time and carried out by the right people.

    For example, in the procurement process, the agency removed the requirement for contractors to submit a Mayor's permit, Registration Tax, and DTI. etc., so as to prevent collusion. It also simplified the bidding process by requiring only Updated PhilGEPS. Submitting documents in the past provided a lot of room for discretion and opportunities for disqualification in order to favor a bidder. The PHilMech also implemented the "clustering of projects", that is, related projects are joined and packaged into bigger contract packages in order to attract competent contractors. In the area of project management, the agency also established standard cost estimation manuals for agricultural types of machinery. It also gathered, disseminated and updated price data on goods/machines nationwide.

The PHilMech is one of the attached agencies of the Department of Agriculture, outsourced some project inspection and quality assurance services. The agency also set up a web-based communications system for receiving, replying to, and taking action on any complaint, query, or suggestion. It also conducted selective and purposive auditing by concentrating on the most vulnerable areas and giving sanctions to officials with major lapses. As a matter of policy, it also encouraged whistleblowing and internal reporting of bad behavior. It is also currently running an Organizational Culture Change Project, which includes interpersonal and personal skills development related to core public services values such as integrity, excellence, professionalism and teamwork.

2. Greater investment in planning and other preparatory activities before the actual procurement

   There should be deliberate budgeting for updating project development studies and procurement plans. The investment plans and programs must be communicated very early. Ensure also that expert procurement units are acquired. Tested good practices from implementation must also be upscaled.

3. Innovation orientation in public procurement

   This is part of strategic procurement or catalytic procurement. The strategies are to come from the demand side, which often has an innovation orientation.

Examples are:

- when large-scale use of an innovation is needed, achieving the critical mass of purchase through bundling
- when the government needs to meet a normative policy goal such as sustainability or energy efficiency, ask for leading-edge products and services
- meeting normative policy goal:
- monitoring app

4. Value-for-money procurement

   A thorough consideration of value for money begins with officials clearly understanding and expressing the goals and purpose of the procurement.

   When a business requirement arises, officials should consider whether a procurement will deliver the best value for money. In this approach, we need to consider the relevant financial and non-financial costs and benefits of each submission including, but not limited to:

   a. the quality of the goods and services;
   b. fitness for purpose of the proposal;
   c. the potential supplier's relevant experience and performance history;

      whole-of-life costs.

   d. flexibility of the proposal (including innovation and adaptability over the lifecycle of the procurement); and
   e. environmental sustainability of the proposed goods and services (such as energy efficiency and environmental impact)

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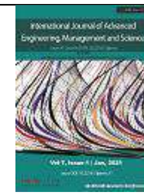

Cost and Benefit Analysis of Solar Panels at Home

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Abstract— *Due to the high utility costs in Cabanatuan City, the solar panel system is rapidly approaching. People in the middle and lower income classes of the country particularly feel the effects of inflation. In order to address the ongoing rise in oil prices and pollution, the government has made the development of renewable energy one of its top priorities. In order to help consumers reduce their utility costs, save money, and produce greener energy, a study on the installation of a solar panel system at home was carried out. The researchers gathered some data from consumers to be utilized as the basis for the contractors' computations, where the adoption of a 3kw on-grid solar panel system was recommended to those respondents with power bills under ₱2,400. The project costs approximately ₱150,000 in total, including installation and permits, and can save approximately ₱2,300 monthly. This investment has a 5.4-year payback period and a total savings of ₱402,000 over a 20-year period. The consumption analysis revealed a sensitive effect on savings and investment payback periods. The study proved that the project's long-term savings can be more than double the initial investment. A SWOT analysis was also performed to highlight the advantages and disadvantages of having an on-grid solar panel, as well as the benefits of clean energy and gas reduction in our environment that future generations could benefit from. The project's cost-benefit is a win-win investment for everyone who wants to save money while also enjoying cleaner air in the long run.*

Keywords— ***alternative energy solution, investment, payback period and savings, solar panel system***

I. INTRODUCTION

Solar panel is one of the most popular alternative energy sources in the current generation. Many people want to take advantage of the opportunity to have it because of its renewable energy derived from the sun, which is now approaching as a result of the high utility expenses experienced by Cabanatuan City residents. It is due to inflation that the country's middle and lower-income classes are particularly affected. The development of renewable energy is one of the government's primary focuses in order to find answers to the ongoing rise in oil prices and pollution. As compared to typical power generating, it generates clean energy. And because of these, several countries, including the Philippines, have steadily increased their use of solar energy.

In the midst of the Ukraine-Russia conflict, the Philippines is suffering from high gasoline prices, as well as increases in the prices of necessities such as food and shelter, as well as a subsequent increase in oil prices. Many Filipinos are looking for alternative resources and are on a tight budget. One concern is the increasing electric cost in Cabanatuan City, which increases every month due to these circumstances. Filipinos need action and always seek help from the government, begging for something to raise the level of the economy. According to Hontiveros (The Philstar, 2022), the government needs to precipitate the rollout of renewable energy projects that will benefit our countrymen.

Solar panels are being considered for usage in some subdivisions and houses. They incorporated it into their marketing approach. However, some households are unsure whether they will be able to afford the panel cost and are unaware of the product's longevity, how much they will invest, and how long the investment will pay off.

In line with this, the study aimed to describe the solar panel installation in terms of average electricity consumption, number of kilowatts to be installed, and materials costing, as well as the associated cost and savings, sensitivity analysis of varying consumption to savings and payback period, and SWOT matrix.

II. METHODOLOGY

The researchers used the descriptive research design in order to describe the cost and benefits of the study. This study gathered data from some residents of Cabanatuan City by using an online network for the survey. The first part of the questionnaire is designed to evaluate the respondents' power consumption in order to estimate the solar power system that will be installed in their homes and obtained one respondent's power bill to compute the annual consumption to be used as a sample to estimate the solar panel to be installed. The second part of the questionnaire is the interviews and observations of the contractors in order to get their recommendation, where the (3) contractors as respondents suggested being used the on-grid solar panel system at home. Social media and the telephone were used for surveys and interviews. The researchers also acquired secondary data about the prices of installation items through web research, specifically on the Lazada App.

The authors computed the cost and savings of this project by calculating the payback period, IRR, and NPV to evaluate the cost benefits of investment in terms of payback period and savings over the project's life span. The potential benefits of saving and the duration of investment will be clarified. Before calculating the NPV, its Internal Rate of Return must be calculated using the Present Value Factor of an ordinary annuity. It is also used to determine whether the project will be accepted or rejected by analyzing if the PV is greater than the investment cost and if the project is feasible and profitable. The researchers also prepared a sensitivity analysis, which will be illustrated in figures 6 and 7, to show the impact of varying electric consumption on cash inflow, savings, and payback period. The researchers also obtained secondary data on the advantages and disadvantages of on-grid solar panels at home, as shown in the SWOT analysis.

III. RESULTS AND DISCUSSION

1. Solar panel installation.

The solar panel system is used to supply electricity to power appliances as alternative energy to reduce or eliminate the utility expenses of homeowners. The on-grid system (grid-tie solar system) is connected to the electricity grid where the unconsumed excess energy by the household will be transported to the grid and will be deducted from the credits earned to the user's bill (cited Newkirk, 2016).

1.1. Average electric consumption

The most common electric consumption may be used for the estimate of the number of solar panels to be installed. For the average monthly electricity bill of the household in Figure 1, 50% of the respondents have below P2400, 42.9% are in the range of P2,500 to 4,900 and 7.1 % are in the range of P10,000 to P12,400 electric bill.

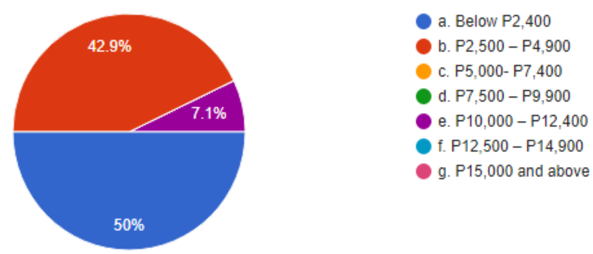

Figure 1: Average monthly electricity bill of a household

1.2. Number of kilowatts to be installed

In relation to the survey above, the household average electricity bill is to be able to estimate the solar panel system that needs to be installed.

The year 2021	Electric bill	kwh
January	2367.53	257
February	1456.22	155
March	1397.46	147
April	3092.26	171
May	1448.17	153
June	1796.81	176
July	3611.85	180
August	1804.63	175
September	3501.55	172

October	1680.37	177
November	3553.88	180
December	2147.49	234
Average	₱ 2,321.52	181

Figure 2: Sample of the electric bill gathered from respondent

The average bill is P2,300 (rounded off) per month for 181 kwh consumption. The computation will be: 181 Kwh/30 days = 6.05 or 6 kwh/day divided by 4 sun hours = 1.5 kw

As mentioned in the article by Buskowits (2021), we can get 4-5 hours of sunlight per day. That is the time to harvest electricity to supply your energy needs. From the computation, the consumption of 181 kwh needs only 1.5 kw of the solar panel system. In the article of J. Davis (2021), generally, there is a system loss when the solar panel is installed and generates direct current (DC) when exposed to sunlight. According to the laboratory test, it produces 10% less when exposed to the sun with no shading. There is also photovoltaic(PV) inverter system loss. The direct current (DC) generated needs to be inverted to alternating current (AC) and it reduces overall generation by 4% through the process of inversion from direct current to alternating current before it can be utilized by our appliances or sent to the electricity grid for a bill credit. The expected total system loss is 14% percent average loss for the residential solar energy system installed. In addition, be careful of investing in a solar panel which is labelled as KVA (Kilo Volt Ampere) because many suppliers use it and not the common term KW (Kilo Watts). The term KVA can be misleading to homeowners because it does not represent the actual power that the solar system can supply (Rex Lu, 2021).

1.3. Materials and their cost

As explained by the three contractors as respondents, for 181 kwh consumption, it is good to have 3kw on grid solar panel systems to be able to meet the electricity need and it can be able to supply the additional and unexpected hours of usage. However, it also covers the expected system loss. The illustration below is a short estimate of the materials needed for the solar panel installation.

Materials	Watts	Dimensions	Weight	No. of Cells	Price Range
Solar Panel (monocrystalline)	330w - 455w	1m x 2m - 1.1m x 2.2m	21kg - 25kg	120 - 144	P7,500 - P9,000
Inverter w/ Limiter (Grid Tie)	2.7 to 5kw				P16,500 - P27,000
Wires, PV cables, Breakers, protection devices					P20,000 - P25,000
Mounting Kit or railing kit					P5,000

Figure 3: Estimates of materials to be used in the installation

The materials included in the recommended package:

Solar Panel

Switchboard

Solar mounting and fixture

Design and labor for installation

Permit and application for an electric company

From the recommendation, the use of a 3kw on-grid solar panel system is given at the cost of more or less P150,000 all-in. Solar is good to use during the daytime, if it is not consumed during the daytime, the harvested electricity is automatically sent to the electric grid, and credited to the user's account at a lower rate. During nighttime, since the system cannot produce power, the user will buy energy on the grid to supply the needed energy at a regular price and that is the process where the electric company offsets the electricity that is credited to the user's account.

The solar panel weight and size depend on the wattage and the roof types of the users where the panel will be placed, the roof must be suitable for it. The solar module usually uses the monocrystalline type of materials, which is considered the most efficient because of its lightweight and less space material which weight more or less 21 kilos in each solar panel. Another factor to consider is the most important, better assure the place of your solar module is free from trees and shades to be able to generate current from the sun. The engineer is the one who estimates the number of solar panels to be used including the design and only authorized and knowledgeable people must install the said system.

The package for 3kw energy consumption with 97% efficiency and a 20years life span. It includes all the materials, design, labor for installation, permit and application for the electric company, a fully functional solar panel system that helps the users reduce or eliminate their electricity bill. This package can power some lights, electric fans, television, washing machine, refrigerator, computer, gadgets, and air conditions (depending on wattage and usage hours). It is necessary to consider the home appliances and devices that will utilize solar energy because it will be the basis of computation for the recommendation of how much wattage of solar panels to be installed. It must be matched to the output needed and best to overestimate to make sure that it will generate excess power to be stored or sent back to the electricity grid.

2. Cost and Savings

The cost and benefits analysis is the decision model to estimate the cost, payback period and savings from the adoption of an on-grid solar panel system as an alternative source of electricity at home. The price of the solar system is a little bit costly and before we invest, we usually want to know when the investment's back. It is very important for us to know the amount of time it will take to recover the investment.

Year	Annual bill	Balance
0	₱ -	-₱150,000.00
1	₱ 27,600.00	-₱122,400.00
2	₱ 27,600.00	-₱ 94,800.00
3	₱ 27,600.00	-₱ 67,200.00
4	₱ 27,600.00	-₱ 39,600.00
5	₱ 27,600.00	-₱ 12,000.00
6	₱27,600.00	₱ 15,600.00
7	₱27,600.00	₱ 43,200.00
8	₱27,600.00	₱ 70,800.00
9	₱27,600.00	₱ 98,400.00
10	₱27,600.00	₱126,000.00
11	₱27,600.00	₱153,600.00
12	₱27,600.00	₱181,200.00
13	₱27,600.00	₱208,800.00
14	₱27,600.00	₱236,400.00
15	₱27,600.00	₱264,000.00

Investment	₱150,000.00
average saving	₱ 2,300.00
Savings for 20yrs.	₱402,000.00
Payback Period	5.43 Years

16	₱27,600.00	₱291,600.00
17	₱27,600.00	₱319,200.00
18	₱27,600.00	₱346,800.00
19	₱27,600.00	₱374,400.00
20	₱27,600.00	₱402,000.00

Fig.4: Payback period and savings

The cost and benefits analysis in the above illustration is to calculate the cost of investment and the benefits in terms of payback period and saving in the life span of the project. The assumption of zero bills will be assumed since 3kw is overestimated for the P2,300 consumptions. The cost of investment for P150,000 will benefit after 5 years and 5 months, which is the payback period and the savings is P402,000 for 20 years.

The Net Present Value (NPV) is a metric to express the value of future savings from a solar installation. This is to evaluate the benefits of the return on the investment to see the profitability of the project. Calculate its Internal Rate return by using the Present Value Factor of an ordinary annuity.

Investment	P150,000
Savings/month	P2,300
No. of mo/year	12
Cash Flow	P27,600
Years	20

PV	(1-(1+R)-N/R	
PVF	5.43	17%
Exact IRR	16.82%	
PV	P155,326.38	
NPV	P5,326.38	

Fig.5: Calculation of PV, NPV and IRR

3. Sensitivity Analysis

The sensitivity evaluation of consumption and its cost shown below was carried out of different assumptions of consumption to observe the impact of the cost prices and kwh consumptions on the cash inflow or savings when adopting the project. This sensitivity can easily understand the possibility of rapid changes in electricity value.

		Effect of Consumption Cost		
Consumption	₱2,300	₱ 10	₱ 15	₱ 20
	-10	-₱100	-₱ 150	-₱ 200
	90	₱ 900	₱ 1,350	₱ 1,800
	190	₱ 1,900	₱ 2,850	₱ 3,800
	290	₱ 2,900	₱ 4,350	₱ 5,800
	390	₱ 3,900	₱ 5,850	₱ 7,800

Fig.6: Sensitivity Analysis of the effect of consumption on cost of consumption

Furthermore, the sensitivity parameters carried out in the analysis in Figure 7 are the monthly and yearly savings and also the payback period. This is to observe the impact of the independent variable on the savings and period of return. The actual assumption of savings was based on the monthly average savings of 2300. The different assumptions that show higher consumption will result in higher savings and shorten the payback period. The 290 kwh to 390kwh monthly are the average consumption to reach the maximum annual consumption with P59,470 annual savings and a 2.5-year return on investment. The negative consumption may not result in negative savings because the unconsumed energy will automatically be sent to the electricity grid that gains a peso credit that may be paid off by the local electric company in cash or will be credited to your next bill.

	₱ 2,300	Monthly savings	Annual savings	Payback Period
Consumption	-10	-₱ 127	-₱ 1,525	-98.4
	90	₱ 1,144	₱ 13,724	10.9
	190	₱ 2,414	₱ 28,972	5.2
	290	₱ 3,685	₱ 44,221	3.4
	390	₱ 4,956	₱ 59,470	2.5
	490	₱ 6,227	₱ 74,718	2.0
	590	₱ 7,497	₱ 89,967	1.7

Fig.7: Sensitivity Analysis of the effect of varying consumption to savings and payback period in the adoption of 3kw Solar Panel on the grid system.

4. SWOT Analysis

Our country is now trying to rebuild our economy from all the tragedies we have been through. One of the main focuses of the government is the viability of developing renewable energy. Figure 8 below shows the SWOT matrix of the solar panel system at home.

Strengths	**Weaknesses**
• Renewable source of energy • Rich in a geographical area • Provide back-up power	• High solar panel cost • Lack of awareness about solar panel • Cannot install for all types of roofs • Can be affected by rain, dust, shadow • No backup when electric grid blackout
Opportunities • Reduces electricity bill • Home improvements • Reduce dependence on fossil fuel • Increasing demand for solar panel	**Threats** • Waste management • implementation of local policy

Fig.8: SWOT Analysis of Solar Panel at home

Strengths

[2] Since the Philippines is located in Southeast Asia, it is a good location for the integration of solar energy. It is unlimited because it is renewable as long as the sun shines. It produces resiliency in households and establishments which can prevent power outages during summer when time consumption increases. Grid tie provides backup power at night and at times when the panel cannot generate energy.

Weaknesses

Our target community such as the middle and lower-income class suffers from poverty which is why investing in this kind of project is difficult for them. The high cost of the solar panel system is considered [8] more expensive than traditional energy resources in terms of simple lights and ways of cooking foods. Lack of awareness about the technology of solar panels also affects the implementation and support from the community. [27] Not all types of roofs can install a solar panel, one must consider the efficiency of a home such as the age and type of the roofs and of course, the shading, be noted that insufficiency of a roof might have additional cost in your installation. However, [26] the weather conditions and dust and shadow can affect the efficiency of the panels. Moreover, the disadvantage of an on-grid solar panel is, it has no backup if the electric grid itself is blacked out.

Opportunities

It is a chance for every household to study and be aware of the technology that can minimize their utility bill and save money. Installing a solar panel can also upgrade your home as a home improvement that gives more value as well as those real estate marketers used. It is an opportunity for us to have cleaner energy where [7] "the research shows that for every kWh of solar power produced, 0.88 kilograms of carbon dioxide are avoided. For every 1.5 kW of installed solar capacity, as much as 1,576 kilograms of carbon emission is prevented. That is equivalent to planting 256 square meters of forests". That is why it is treated as the most environmentally friendly power source because of the benefits to the environment that avoiding carbon dioxide and benefits to people in the new generation which lessen the air pollution that may affect their health (GIZ)(2013). Moreover, it is an opportunity to help the local economy due to an increase in demand for solar panels, it is an additional business that entrepreneurs can enter.

Threats

Disposal of solar panels is still a big problem for us, [5] It can be hazardous if it is improperly disposed of, it is renewable but not waste-free. However, the implementation of the local policy might be affected by the local government which is connected to electric companies since [8] The Philippine Energy Roadmap includes the government's intention to increase the local production of oil, gas and coal until 2030 to secure the energy supply.

IV. CONCLUSION AND RECOMMENDATION

Based on the results and discussion the following conclusion was made:

1. The installation of the solar panel at home is beneficial and would be easier because the contractors also give package deal offers. It is a bit expensive and not all people can afford to invest in a one-time payment project. In addition, there are factors to consider that may affect the installation such as roof type, a location where the sunlight can fully reach the panel and also appliances and devices that will use solar energy. The cost of the system for P150,000 including all materials, designs and installation plus the permit from City Hall and processing of the application to the electric company is a hassle-free and good offer.
2. The installation of solar panels at home is cost beneficial and proven to generate savings and good long-term investment. The package that cost P150,000 to be used for 20 years has a payback period of 5.4 years and may generate savings of P402,000.
3. The sensitivity of consumption has proved effective on saving and its return period, the analysis in which, the high consumption, the higher savings, and shorten the time period of return. The effect of negative consumption will also be additional savings when the electric company paid off or may be credited to your account.
4. The adoption of a solar panel system is a win/win investment especially for this time of high inflation due to oil price hikes and also reducing pollution to the environment which benefits producers of clean energy and source of environment-friendly energy solutions. The improper disposal and the government's intention to increase the local production of oil, gas and coal until 2030 are the only problems on this project

Based on the analysis and conclusion made, the following recommendations were made:

1. Households may look for contractors with an instalment basis that may help them conveniently pay the installation cost.
2. The household with higher consumption is most recommended to have the solar panel installation as a long-term investment.
3. Local government must pay attention to the needs of its people thus they may propose projects in collaboration with the electric company to lessen the suffering of their constituents since they were connected.

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Financial Management Practices of Restaurant Employees in Cabanatuan City

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Abstract**—** *Financial management practices plays a vital role in the whole restaurant operations and services. Financial manager of a restaurant should take financial management seriously and need to be focused on the best approaches towards planning, monitoring, allocating, and budgeting monetary resources based on the availability of funds to provide high quality services standards. Restaurant business needs to have a good financial managers that could really focus and understand food service industry leading to media brand. The findings meant that restaurant employees in Cabanatuan City had high level of financial management practices especially in management of working capital and investment appraisal techniques. Highest educational attainment (r= 1.135) and major field of specialization (r=.173) had found a positive correlation with the level of financial management practiced. Other variables like age, gender, marital status, and training and seminars had no relationships with the financial management practices. The most challenging part of financial manager is the operating expenses and restaurant operations and services as a whole. These challenges are the menu, customer service experiences, uniqueness from other restaurant, marketing strategies operational challenges, inventory and hiring and training staffs. It is recommended to plan programs for the improvement and enhancement of restaurant employees performance and financial management towards restaurant operations.*

Keywords**— *Financial Management Practices, Financial Managers, Restaurant Employees*.**

I. INTRODUCTION

Financial Management of an employee plays a crucial role in their working performances and in their daily life activities. It measures the impact to daily performance of employees not only in the restaurant but also in all organizations. Financial manager of a restaurant should take financial management seriously and need to be focus on the best approaches towards planning, monitoring, allocating, and budgeting monetary resources based on the availability of funds to provide high quality services standards.

Employees who had good financial management show a positive and significant relationship between financial management practices and restaurant business performance (Butt, Hunjra, & Rehman, 2010). Good financial managers of a restaurant always ensure that the restaurant runs effectively, efficiently and smoothly, thus ensures providing better customer experiences and satisfactions. Employees with good financial management, shown better understanding of all business aspects to ensure that they provide quality services.

Good financial managers in a business restaurant are need to be hands-on in all areas that needs financial resources and application. In order to succeed in the restaurant services, great restaurant employees required few essential qualities and skills such as being patience, enhanced energy levels, prompt thinking, strong interpersonal skills, spending more time in restaurant, planning, multi-tasking, passion, record keeping, and inventiveness. And good financial management practices of a restaurant employees involves financial understanding in terms of income, investment, family security, standard of living, assets and savings. According to Szala (2018), there are no replacement for a good restaurant financial management platforms that includes accounting capabilities. Restaurant manager needs to understand the overhead such as property costs, salaries of yours, administrative costs, food production and supplies, utilities including internet service, monthly point of sale costs and any paid advertising.

Several researches about financial management practices had significantly affects organization performance. The financially well managed restaurants are considered had better and good managers that can operationally efficient. Financially management practices of restaurant managers had found positive views and decisions for the betterment of restaurant operations as a whole specifically in providing quality and high standard of services, (Hunjra, 2010).

Restaurant business needs to have a good financial managers that could really focus and understand food service industry leading to media brand. Based on the study of Sajadi (2012) found out that the majority of revenue management practices in restaurant business are perceived as unfair. The practice which is perceived to be most unfair is the policy based on the time spent. On the study of concluded that financial structure and practices of an organization is sustainability, profitability and growth. Financial investment ensures the organization to sustain adequate cash flow to meet its operation expenses and working obligation.

Financial manager play a vital role in business, even small, big, start up or established to run a business. Financial Management needs to understand on how the business is doing financially. Thus, good financial management is essential for success as well as the survival of business (Talentedge, n.d).).

In the view of Strutner (2022), financial management is the practice of making business plan and then ensuring all departments stay on tract. Solid financial management enables the managers of finance to provide data that supports creation of a long-range vision, informs decisions on where to invest and yields insights on how to fund investments, liquidity, profitability, cash runway and more.

In the above notion, the researcher, aims to identify and evaluate of the financial management practices of restaurant employees in Cabanatuan City, in terms of capital structure decision, investment appraisal techniques, dividend policy, working capital management, and financial performance assessment.

II. OBJECTIVES OF THE STUDY

The study aims to identify and evaluate the financial management practices of restaurant employees in Cabanatuan City.

Specifically, it sought to answer the following:

1. What is the profile of the restaurant employee be described?
2. How may the levels of financial management practices of restaurant employees be described.30 in terms of capital structure decision, investment appraisal techniques, dividend policy, working capital management, and financial performance assessment.
3. Is there a significant relationship between the profile of the employees and the level of financial management practices?
4. What are the challenges and issues of students in financial management practices of restaurant employees?

III. RESEARCH METHOD

A descriptive research design was used in the study in accordance to the objectives of the study. The main respondents of the study are the 25 restaurant employees wherein the job descriptions were related to financial management either financial manager, accountant and or any related to accounting. They are the restaurant employees in restaurant business in Cabanatuan City and they were purposively selected using quota sampling method.

The researcher used survey questionnaire and interview guide questions to gather the needed data. He personally administered survey questions and interview. Thus, before he conducting a survey, the researcher is personally asking permission to conduct the study and discuss first the importance of conducting the study.

The survey questionnaire consisted of Likert scale so that respondents can easily response to each questions based on their degree of acceptance: 4- Outstanding; 3-Very satisfactory, 2- Satisfactory, and 1-Need Improvement.

And lastly, all gathered data were encoded, tabulated, analyzed and statistically treated using SPSS tool.

IV. RESULTS AND DISCUSSION

1. Profile of the Restaurant Employee

Majority of the restaurant employee are female, there aged range between 35 to 45 years old, married, with bachelors' degree in Hotel and Restaurant Management. They are more than 10 years in restaurant industry with training and seminars attended related to the industry where they can served and based on the field of specialization towards better organizational performance. Most of them are manager in the restaurant wherein they are responsible to the restaurant financial management and in monitoring of whole restaurant operations.

2. Level of Financial Management Practices of Restaurant Employees

Table 1. Financial Management Practices

Financial Management Practices	Weighted Mean	Interpretation
Capital Structure Decision	2.57	Very Satisfactory
Investment Appraisal Techniques	3.32	Outstanding
Dividend Policy	2.89	Very Satisfactory
Working Capital Management	3.35	Outstanding
Financial Performance Assessment	2.23	Satisfactory
Overall Weighted mean	**2.87**	**Very Satisfactory**

Table 1 shows the level of financial management practices of restaurant employees. As shown the overall weighted mean got 2.87 and verbally interpreted as "Very Satisfactory". Working capital management had obtained the highest weighted mean of 3.35 with verbal interpretation of "Outstanding" while the financial performance assessment had gained lowest weighted mean of 2.23 and verbally interpreted as "Satisfactory".

The findings meant that restaurant employees in Cabanatuan City had high level of financial management practices especially in management of working capital and investment appraisal techniques. Financial managers performed better to ensure that restaurant finances were manage effectively and efficiently towards better restaurant performances and in satisfactions of the customers. Additionally, financial manager ensure to oversees the financial status of restaurant to ensure its continued sustainability. They always supervise important functions of finances such as cash flow, profitability, expenses, utilities, salaries and benefits, and all other expenses. Moreover, they are responsible to financial decisions and control, financial planning, capital management, allocation and utilization of financial resources, disposal of surplus, financial report and risk management.

3. Relationship between the profile of the employees and the level of financial management practices

Highest educational attainment (r= 1.135) and major field of specialization (r=.173) had found a positive correlation with the level of financial management practiced. Other variables like age, gender, marital status, and training and seminars had no relationships with the financial management practices. The findings meant that the highest the level the educational attainment and major field of specialization the better their financial management practices. Restaurant employees with highest educational attainment related to the hospitality services can manage the restaurant operations especially in terms of financial status and operation of restaurant business. They can properly, efficiently manage the finances in terms of planning, budgeting, allocations, savings, utilization and many more on the most benefited on the business operations.

4. Challenges and Issues of Financial Management Practices of Restaurant Employees

The most challenging part of financial manager is the operating expenses and restaurant operations and services as a whole. These challenges are the menu, customer service experiences, uniqueness from other restaurant, marketing strategies operational challenges, inventory and hiring and training staffs.

These are the challenges encountered by the restaurant employees and financial managers because all of the mentioned challenges can greatly be contributed for the better restaurant operations in providing high standard and quality services.

V. CONCLUSION AND RECOMMENDATION

Conclusion

Based on the findings of the study, restaurant employees needs to ensure that can efficiently and effectively utilized finances from planning –operating-saving of the restaurant services and operations. Financial Managers in Cabanatuan City were outstandingly managed restaurant finances for the whole restaurant operations towards providing high quality services that can best providing unforgettable experiences to all customers. They oversees even the small things that could affects restaurant finances and services.

Recommendations

Based on the conclusions, the researchers drawn recommendations:

1. the financial managers should place greater emphasis on the status on the restaurant and employees finances so that

they can provide and support the daily needs and satisfactions of all employees.

2. Always plan and monitor and establish and maintain a solid management structure so that everyone understand their own and team responsibilities towards better performance.

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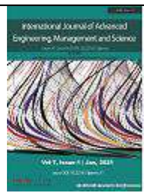

Artificial Neuron Network-Based Prediction of Fuel Consumption in Antananarivo

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***Abstract*— *The ability to modeling fuel consumption forecast is important to improve fuel quantity suitable for users (individuals, businesses, etc.) to prevent fuel shortages. Kerosene, super fuel and gas oil consumptions forecasting models for Antananarivo region were developed. Model is based on Artificial Neural Network (ANN) learning which used advanced machine learning techniques using backpropagation algorithm. Successful time series and trend patterns given by the three ANN prediction models were presented. To predict 18 months fuel consumption in Antananarivo, ANN models' accuracy reaches more than 95% accuracy.*

***Keywords*— ANN prediction, Antananarivo forecasting model, fuel consumption, modeling**

I. INTRODUCTION

According to many researchers, fossil energy remains the most consumed on the planet earth. But earth's reserves of fossil energy resources are limited. These resources will be exhausted before the end of the next century if no strict measure of saving fossil energy consumption applied. In Madagascar, kerosene consumption rises constantly up to 3% per year since 2012, [1]. Thus, it is important to develop predictive models to predict fuel consumption. This alternative can help to improve fuel economy, prevent fuel shortages prematurely and avoid consumption peaks or overconsumption.

Several studies developed fuel consumption prediction models, [2]-[5]. Artificial Neural Network (ANN) becomes increasingly common in predictive studies and neural machine learning is suitable for such analysis, as the model can be developed by learning the patterns of data. Based on ANN, monthly fuel consumption forecast models were developed. These models use backpropagation neural network. This method has proven to be very effective in training multi-layered neural network, [6], [7]. Indeed, such models are able to learn nonlinear mappings between inputs and outputs. Performance measurements of each model are undertaken in order to assess its effectiveness, then to carry out comparative for its validity.

Thus, three models such as Kerosene, super fuel and gas oil consumption prediction models were built to predict fuel consumption in Antananarivo using ANN. The developed models are fully connected univariate models, based on past consumption values and built with multilayer perceptron (PMC).

II. DATA OF FUEL CONSUMPTION

The database used for three models of fuel consumption forecast is the set of 318 measurements monthly data from January 1995 to June 2021 for Antananarivo city [1]. According to this database, fuel consumption over time as shown in Fig. 1 presents slight regularities and similar periodic trend for the 3 types of fuel consumption.

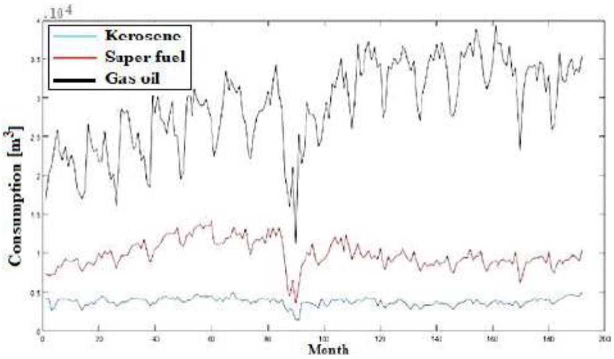

Fig. 1: Fuel consumption in Antananarivo from January 1995 to June 2021

III. PREDICTION METHODOLOGY

ANN were established as a generalization of mathematical models [8], [9], [10]. As shown in Fig. 2, ANN has a parallel and distributed processing structure. In whole, they are formed of three layers: input layer, hidden layer and output layer. Each layer has a couple of neurons. Signals are transmitted between neurons via connecting links. Each connecting link has an associated weight, which in a typical neural network multiplies the transmitted signal. Each neuron applies an activation function (usually nonlinear) to its net input (sum of the weighted input signals) to determine its output signal. The input layer of the backpropagation network consists of m units (X1, ..., Xi, ..., Xm) and one bias unit (X0). The hidden layer consists of n units (NN1, ..., NNj, ..., NNn) and a Polarization unit (NN0), while the output layer has a Y unit, which gives the value to be predicted. Polarization units have the value "1" as input signals. To build a forecasting model, the network processed three steps. First, the training step at the end of which, the network is trained to predict future data on the basis of past and present data. Second, the test step where the network is tested to stop forming or to remain in formation. Third, the evaluation step where the trained network is used to predict future data and to calculate different error measures. The number of neurons in the hidden layer is chosen according to the complexity of the function to be approximated and the performance of each model is evaluated by the RMSE and MAPE errors.

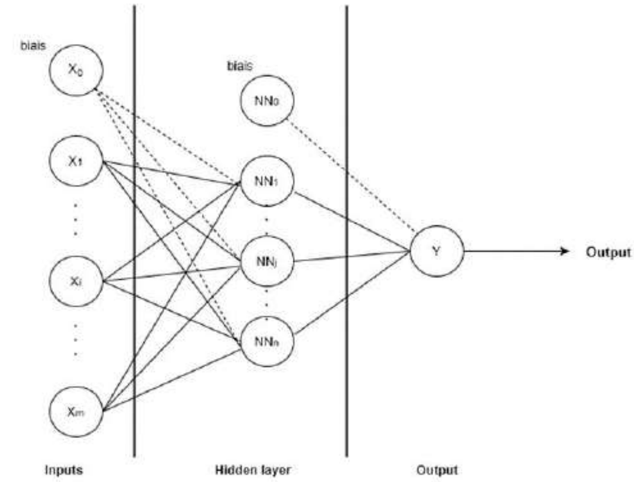

Fig. 2: ANN model for prediction

IV. MACHINE LEARNING

For machine learning, backpropagation algorithm is adopted due to its high performance in prediction, [4], [11]. This algorithm allows the input signal to be broadcast to the output layers, then the error is calculated at the output layer and propagated to the input layer. Training the network by backpropagation consists of three steps:

- Enable the propagation or feedforward of the training model from the inputs to the output,
- Calculate and back propagate the associated error,
- Adjust the weights.

During the feedforward phase, each input unit Xi receives an input signal xi and broadcasts this signal to each of the hidden units NN1; ... NNn. First, the input signal nn_inj for each hidden unit is the sum of each input signal xi multiplied by the corresponding weight wji according to the formula:

$$nn\_in_j = w_{0j} + \sum_{i=1}^{n} x_i w_{ij} \quad (1)$$

Then, each hidden unit calculates its activation function to obtain the signal nnj.

$$nn_j = f(nn\_in_j) \quad (2)$$

Same procedure is applied to the hidden layer and the output layer. Thus, each hidden unit *NNj* broadcasts its signal n_j to the output unit Y_1. Therefore, the input signal *y_in1* is the sum of each signal *nnj* multiplied by the corresponding weight w_{1j}.

$$y\_in_1 = w_{10} + \sum_{j=1}^{p} nn_j w_{1j} \quad (3)$$

Again, the output unit calculates its activation function to obtain the signal y_1.

$$y_1 = f(y\_in_1) \quad (4)$$

During this step, the input layer broadcasts the input signals to the output layer. The second step of backpropagation algorithm is the error backpropagation stage. During this stage, the output unit Y_1 calculates its error $(t_1 - y_1)$. Based on this error, the error information term δ_1 is calculated. Then δ_1 is used to redistribute the error at output unit Y_1 to all units in the previous layer.

$$\delta_1 = (t_1 - y_1)f'(y\_in_1) = \sigma.(t_1 - y_1)\, y_1(1 - y_1) \quad (5)$$

where t_1 is the output target and δ_1 is the slope parameter.

First, the factor is distributed to the hidden units using the following stage. Thus, the output unit Y_1 calculates its weight correction term, which is used to update w_{1j} later during the third stage. The weight correction term is calculated by multiplying the learning rate α with the error information term δ_1 and the signal *nnj* of the hidden unit *NNj*.

$$\Delta w_{1j} = \alpha\, \delta_1\, nn_j \quad (6)$$

Then, the output unit Y_1 calculates its bias correction term which is used to update its bias w_{10} later during the third stage. The bias correction term is calculated by multiplying the learning rate α by the error correction term δ_1.

$$\Delta w_{10} = \alpha\, \delta_1 \quad (7)$$

The following procedure is to propagate the factor δ_1 to all input units $(x_0, \ldots, x_m)$ through the following steps:

Each hidden unit *(NNj, j=1,…, n)* calculates its error by multiplying the output error information term by its corresponding weight w_{1j}.

$$\delta\_in_j = \delta_1\, w_{1j} \quad (8)$$

Then, it calculates its error information term δ_1 using the following formula:

$$\delta_j = \delta\_in_j\, f'\left(nn\_in_j\right) \quad (9)$$

Each hidden unit *NNj* calculates its weight correction term which is used to update its weight w_{ji} later in the third stage. The weight correction term is calculated by multiplying the learning rate α, the error information term δ_1 and the input signal x_i.

$$\Delta w_{ji} = \alpha\, \delta_j\, x_i \quad (10)$$

Then, each hidden unit *NNj* calculates its bias weight correction term, which is used to update its bias w_{j0} later in the third stage. The bias weight correction term is calculated by multiplying the learning rate α and the error correction term δ_1.

$$\Delta w_{j0} = \alpha\, \delta_j \quad (11)$$

Therefore, errors are back-propagated from the output layer to the input layer in order to adjust the weights between the layers.

The third stage of the learning algorithm consists of updating the weights using the weight correction terms calculated during the second stage. This procedure takes place in two steps:

- the output unit Y_1 updates its weights w_{1j} *(j=0, … , n)* using the following formula:

$$w_{1j}(t+1) = w_{1j}(t) + \alpha\delta_1 nn_j + \gamma\left(w_{1j}(t) - w_{1j}(t-1)\right) \quad 12)$$

where γ is the motion parameter.

- Afterwards, each hidden unit *NNj (j=1, ..., n)* updates its weights w_{ji} *(i=0, ..., m)* using the following formula:

$$w_{ji}(t+1) = w_{ji}(t) + \alpha\, \delta_j x_i + \gamma\left[w_{ji}(t) - w_{ji}(t-1)\right] \quad (13)$$

In this case, the network learns and improves its performance by adjusting the weights.

V. IMPLEMENTATIONS

The study covers the period from 1995 to 2021. This period is used to train, test and evaluate ANN models. Models training is based on fifteen years training set from January 1995 to December 2009, while models test covers the period from January 2010 to December 2019. In addition, model evaluation covers the period from June 2019 to June 2021. The implementations in each model use training data to predict future data using the backpropagation algorithm. Data need to be normalized between -1 and 1 using the following equation:

$$Y = \frac{(y_{max} - y_{min})(x - x_{min})}{(x_{max} - x_{min}) + y_{min}} \quad (14)$$

x assumed to have only finite real values and values in each row elements are not all equal. If $x_{max}=x_{min}$ or if x_{max} or x_{min} are non-finite, then $y=x$ and no change occur. Loaded input parameters from configuration file contains five parameters such as learning rate, momentum, sigmoid function slope value, hidden layers number, and corresponding hidden units' number.

VI. RESULTS

Since energy consumption forecast depends on the database which contains previous energy consumption, three univariate ANN models were implemented. These three fuel consumption prediction models require previous values as data input models from kerosene, super fuel and gas oil consumption database in Antananarivo. All models are tested for a different number of network inputs and hidden units. Each model is fully connected, since each input unit broadcasts its signal to each hidden unit. It is found that too few hidden nodes in ANN does not leads to learn complicated functional models, whereas many nodes network is unable to generalize well. After performing several simulations, the best performance criteria evaluations indicated by the lowest two types of error RMSE and MAPE. Parameters displayed in this result section are selected after extensive testing by varying learning rate values and input units' number. When ANN is finally well-trained, the output parameters produce the lowest error values.

6.1 KEROSENE CONSUMPTION PREDICTION MODEL

The parameters values used in kerosene consumption prediction model producing the lowest error values are presented in Table 1. Comparison prediction results are shown in Fig. 3.

Table 1: Parameter values for kerosene consumption prediction model

ANN – kerosene consumption prediction model
Learning epoch: 5000 Optimization algorithm: SCG CPU Time Training: 31 seconds No. inputs 12 No. hidden units 8
Error function Sum of squares RMSE 216.9325 MAPE 6.5860 R 0.945538703547271 (95%)

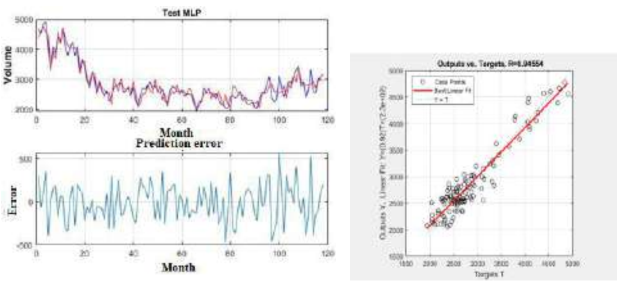

Fig. 3: Comparison and prediction error of kerosene consumption prediction model.

6.2 SUPER FUEL CONSUMPTION PREDICTION MODEL

For super fuel consumption prediction model, the parameters values producing the lowest error values are shown in Table 2. Comparison and prediction error results are shown in Fig. 4.

Table 2: Parameter values for super fuel consumption prediction model

ANN – Super fuel consumption prediction model
Learning epoch: 5000 Optimization algorithm: SCG CPU Time Training: 47 seconds No. inputs 12 No. hidden units 10 Error function Sum of squares
RMSE 412.0136 MAPE 2.8587 R 0.972144922528029 (97%)

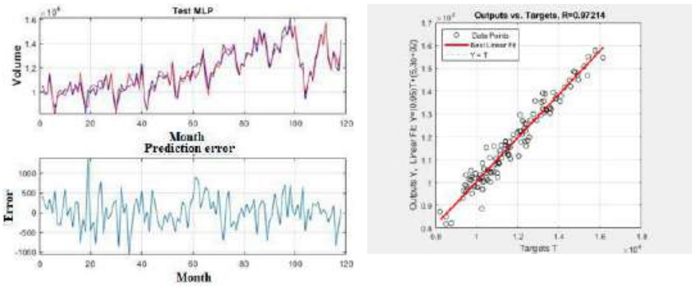

Fig. 4: Comparison and prediction error of super fuel consumption prediction model.

6.3 GAS OIL CONSUMPTION PREDICTION MODEL

For gas oil consumption prediction model, the parameters values producing the lowest error values are shown in Table 2. Comparison and prediction error results are shown in Fig. 5.

Table 3: Parameter values for gas oil consumption prediction model

ANN – Gas oil consumption prediction model
Learning epoch: 5000 Optimization algorithm: SCG CPU Time Training: 56 seconds No. inputs 12 No. hidden units 15 Error function Sum of squares
RMSE 1062.2700 MAPE 1.7881

R	0.981267067972050 (98%)

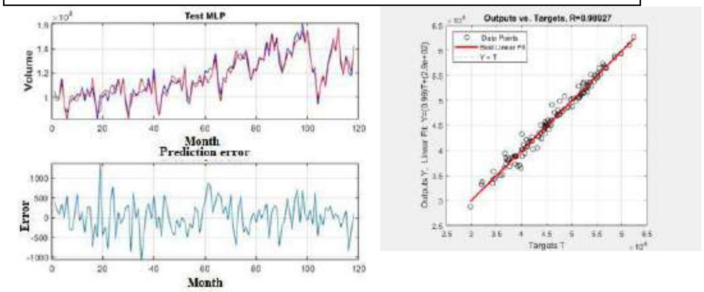

Fig. 5: Comparison and prediction error of gas oil consumption prediction model

6.4 MODEL ASSESSMENT

After performing simulations for each model, output performance gives satisfactory result with more than 95% confidence range to predict energy consumption up to 18 months. In model assessment, prediction especially for super fuel consumption from June 2019 to May 2021 is shown in Fig. 6. According to the study, the accuracy this prediction result reaches more than 97%.

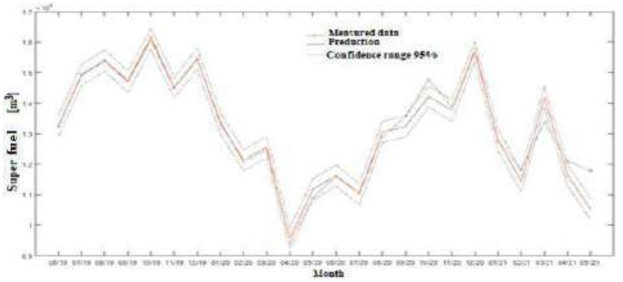

Fig. 6: Data comparison for super fuel consumption forecast

VII. CONCLUSION

Univariate neural network models were used to estimate kerosene, super fuel and gas oil consumptions in Antananarivo region. Each model has run in three stages such as training, testing and evaluation stages. Neural network parameters values and hidden nodes number are chosen with respect to the minimum RMSE. Backpropagation algorithm performed as learning algorithm. This algorithm adjusts efficiently the network weights. Well-trained models using data energy consumption in Antananarivo during the period from January 1995 to June 2021 exhibit satisfactory result. In fact, models are able to estimate kerosene, super fuel and gas oil consumptions in Antananarivo with 95%, 97% and 98% accuracies, respectively.

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Influencing Factors on Power Losses in Electric Distribution Network

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Abstract**—** *Line losses reduction greatly affects the performance of the electric distribution network. This paper aims to identify the influencing factors causing power losses in that network. Newton-Raphson method is used for the loss assessment and the Sensitivity analysis by approach One-Factor-At-A-Time (OAT) for the influencing factors identification. Simulation with the meshed IEEE-30 bus test system is carried out under MATLAB environment. Among the 14 parameters investigated of each line, the result shows that the consumed reactive powers by loads, the bus voltages and the linear parameters are the most influencing on the power losses in several lines. Thus, in order to optimize these losses, the solution consists of the reactive power compensation by using capacitor banks; then the placement of appropriate components in the network according to the corresponding loads; and finally, the injection of other energy sources into the bus which recorded high level losses by using the hybrid system for instance.*

Keywords**—** ***Active power losses, Electric power distribution, Influencing factors, Newton Raphson, Power losses, Sensitivity Analysis***

I. INTRODUCTION

Electricity demand throughout the world doesn't cease to grow up. This is due to the growth of population and industrialization altogether. To meet the electricity needs of all consumers and in order to realize the sustainable energy planning, almost of the distribution system operators are looking to improve energy performance of their networks. One of the great difficulties facing the distributors is the on-line power losses. It means that the performance of electric network depends on power losses minimization.

Most of previous work have just informed about the two kinds of losses in electrical network; that are the technical losses and the non-technical losses [1, 2] .Some papers highlighted the different kind of method concerning losses assessment [3, 4]; whereas some researchers used any different optimization method for the reduction of losses [5, 6], [7], by means of using Genetic Algorithms compensation with capacitors banks [8]. Other literature proposed the importance of network reconfiguration [9] without knowing the factors that caused the issue. However, few of these literatures mentioned a detailed analysis on the identification of key factors influencing losses in the grid, except the study of Ali Nourai [10] but it focuses only on the load levelling from the peak to the off-peak period.

That is the reason why, in this paper, recognizing the source of losses in the network and identifying the influencing factors are the primary step before processing into the network optimization.

Therefore, a meshed distribution from IEEE-30 bus test system is tested and analyzed in this work. The analysis consists to identify the influencing factors of each branch in that electric distribution network. The method of Newton Raphson Load flow (NRLF) combined with the One-Factor-At-A- Time (OAT) of the sensitivity analysis are chosen to perform this analysis. NRLF is used for losses assessment in each branch of the grid whereas OAT is for modifying each input parameters of the model by ±10% around its initial value and observing the effect of each operated modification on the output which is the active power losses. This work is concluded by discussing the results and giving new perspectives for losses reduction and network optimization.

II. POWER LOSSES IN ELECTRIC DISTRIBUTION NETWORK

Electricity generated by the power plants is delivered to consumers throughout the transmission and distribution power lines. During the process of electricity transmission into the consumers, losses are unavoidable. It implies that only some part of electricity transmitted is consumed.

As we know that electric network mainly includes three sectors: the production, the transport network and the distribution network. This last sector accounts higher losses rather than in production and transport sector. From generation to distribution in an electric system, the overall loss threshold considered acceptable for international experts is 10 to 15%. This percentage includes technical losses and non-technical losses. Normally, active power losses should be around 3 to 6%; but in reality, it is about 10% in developed countries and 20% in developing countries [6].

Losses in electric distribution network can be divided into two categories: technical losses and non-technical losses. Non-technical losses are from several sources including power theft, un-billed accounts, errors and inaccuracies in electricity metering systems, lack of administration, financial constraints [2].

Besides, Technical losses in the distribution system are caused generally by the physical properties of the network elements (conductors, equipment used for distribution line, transformer) [4]. The heat dissipation due to current flowing in the electrical network created line losses, which is well known as joule effect: $P_L = RI^2$

Losses in transformer are due to iron losses and copper losses. The iron losses are caused by the cores magnetizing inductance (Foucault current and Hysteresis) that dissipated a power, whereas Copper losses are by the winding impedance inside the transformer.

In other words, the technical losses result from the active and reactive power flow in the network. Active power losses are due to the over loading of lines characterized by the resistance. Low voltages and variation of powers flows in each bus can produce also these active losses. Otherwise, reactive power losses are produced by the reactive elements (the reactance of the line).

On the one hand, total active and reactive power losses are computed with:

$$P_{loss} = \sum_{i=1}^{n_{br}} R_i |I_i|^2 \qquad (1)$$

$$Q_{loss} = \sum_{i=1}^{n_{br}} X_i |I_i|^2 \qquad (2)$$

Where P_{loss} and Q_{loss} are respectively the active andreactive power losses ; n_{br} is the number ofbranches of the system, I_i the current flowing through the branch, R_i the resistance of the branch iand X_i the reactance of the branch i.

On the other hand, the overall active power losses of the entire network are obtained by the differencebetween the active generated power and the active consumed power.

$$Total\ active\ power\ losses = P_g - P_c \qquad (3)$$

For similar reason, the total reactive power losses of the network are equivalent to the reactive generation or consumption of the network. That is to say the sum of the reactive powers injected or absorbed by the generators is equal to the sum of reactive power consumed or generated by the load added the sum of reactive generation or consumption of the network.

$$\sum Q_g = \sum Q_c + \text{reactive generation or consumption of the net}$$

III. METHODOLOGY FOR POWER LOSSES ASSESSMENT AND INFLUENCING FACTORS IDENTIFICATION

3.1 ASSESSMENT OF POWER LOSSES BY NEWTON RAPHSON METHOD

Different technics are used to assess the power losses. As we see in the expressions (3) and (4), the Global losses of the network can be deduced through these equations, in condition that all injected powers (active and reactive) and bus voltage (V,θ) in each bus are known. But the problem is we cannot get easily the voltage at different buses of the system because of the interdependence between the bus voltage and the different powers at load bus. The main difficulty in evaluating power losses in distribution network is the nonlinear relationship between the injections powers at the buses and their variables associated [3]. For this reason, resolution by the power flow (Load flow) is required for a good assessment. Several methods have been used for load flow calculation such as the GAUSS-SEIDEL method, the NEWTON-RAPHSON method, the bi- factorization method of K-ZOLLENKOPF, the relaxation method, the DC-Flow method, ... Among these different methods, we prefer to use the Newton Raphson method because this method converges much faster. In addition, this method can transform the original non-linear problem into a sequence of linear problems whose solutions approach the solutions of the original problem. The solution to the power flow problem begins with identifying the known and unknown variables in the system. These variables (P, Q, V, θ) are the characteristics of each bus in the network that are respectively the active power, the reactive power, the voltage magnitude and the voltage angle. These four variables are dependent on the type of bus. So, two of them must be known in each bus. If P and V are known, that means a generator is connected to the bus, it is called a Generator Bus. In contrary, if no generators are connected to the bus, it is the Load bus (or PQ Bus). Aside this, resolving load flow problem needs one bus that chosen arbitrarily and the value of the voltage (V, Θ) must be fixed before a program execution. This bus is known as Slack-bus.

The common process of load flow computation is summarized on the organigram 1 (Fig. 1) while the specificity of NRLF method [11] and its algorithm details are shown in Fig. 2.

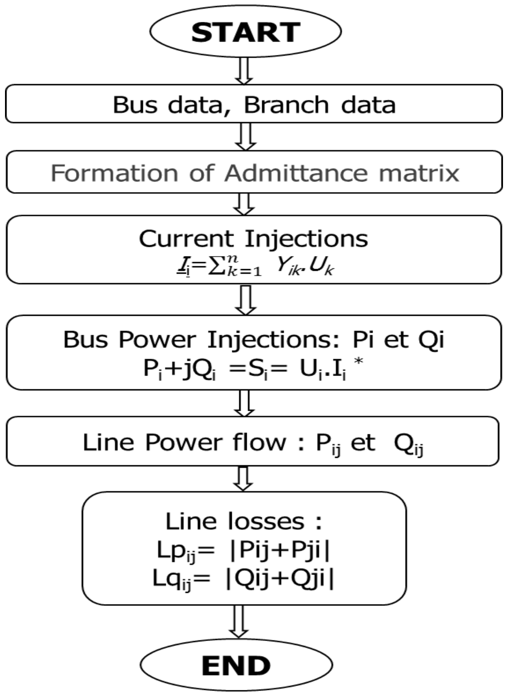

Fig. 1: Organigram of Load Flow

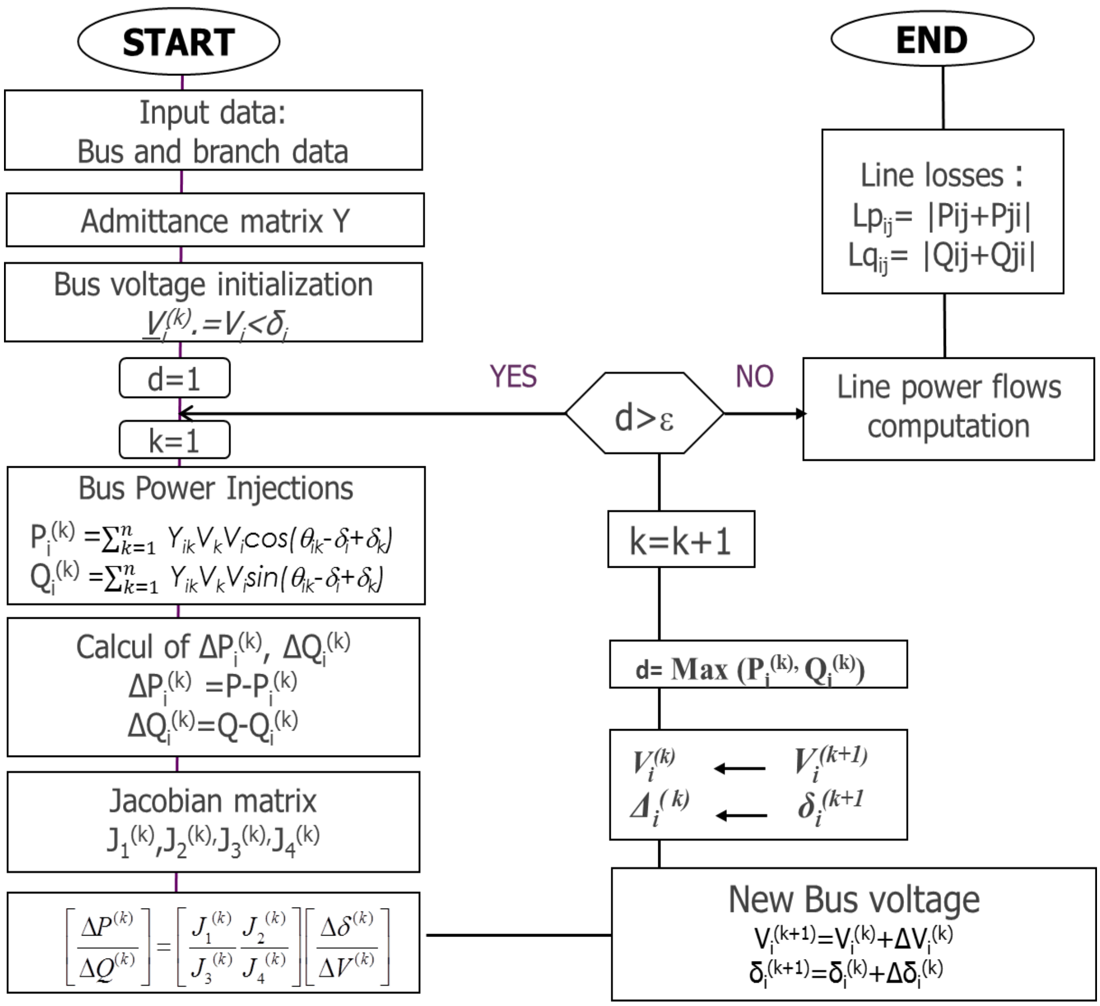

Fig. 2: Organigram of Newton Raphson Load Flow

3.2. SENSITIVITY ANALYSIS BY OAT METHOD

The sensitivity analysis SA is a mathematical tool that observes the output of a model in relation to the variations of different input factors and quantifies their influences on the model. According to Jolicoeur [12], it happens often a lot of parameters in a complex mathematical model, and they do not have the same degree of influence on the model outputs. Some have more important contribution than others. Thus, a sensitivity analysis can help predict the effect of each parameter on model results and classify them according to their degree of sensitivity [13]. There are mainly three different methods of SA: the Local Sensitivity Analysis (LSA), the Global Sensitivity Analysis (GSA) and the Screening Designs (SD). The using of each kind of method depends on the objectives that users want. These methods are widely described with Bertrand and al. in [14] and Kleijnen and al. in [15].

What we are interested in these methods is the "Screening Designs" (SD) which contains the "One-Factor-At-A-Time" method because it is efficient when a model has many input parameters

[12]. It has a purpose to arrange the most important factors among many others that may affect a particular output of a given model. Although OAT approach is to assess the relative importance of input factors with uncertainty, and applied only in linear model [13], this is the reason why Newton Raphson method has been chosen to transform the non-linearity of the load flow problem into a linear application.

In this case, all the linear parameters and the bus characteristics have been contributed to the analysis, because it consists to find the effect of each parameter on active power loss in each branch.

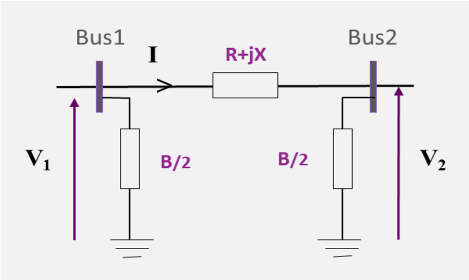

Fig. 3: A two-bus system

Totally, 14 parameters are studied except the voltage angle θ because it was taken automatically as zero during the bus voltage initialization (principle of slack bus).

Table 1: Parameters with their variation range

N°		Symbole	Description of the parameter	Variation range	Unit
1		**R**	Resistance of the branch	[0 :0.33] in pu	Ω/km
2		**X**	Reactance of the branch	[0 :0.61] in pu	Ω/km
3		**B**	Susceptance of the branch	[0 :0.06] in pu	µS/km
4		**a**	Transformer rate	[0.9 :1]in pu	
5		**V(NI)**	Voltage Magnitude in the initial bus	[0.94 :1.6] in pu	kV
6		**V(NE)**	Voltage Magnitude in the initial bus	[0.94 :1.6] in pu	kV
7		**Pg(NI)**	Generated Active power in the initial bus (Node Initial)	[40 :300]	MW
8		**Pg(NE)**	Generated Active power in the extreme bus(Node extreme)	[40 :300]	MW
9		**Qg(NI)**	Generated Reactive power in the initial bus	[-40 :50]	MVar
10		**Qg(NE)**	Generated Active power in the extreme bus	[-40 :50]	MVar
11		**Pc(NI)**	Consumed Active power in the initial bus	[0 :95]	MW
12		**Pc(NE)**	Consumed Active power in the extreme bus	[0 :95]	MW
13		**Qc(NI)**	Consumed Reactive power in the initial bus	[0 :30]	MVar

14		**Qc(NE)**	Consumed Reactive power in the extreme bus	[0 :30]	MVar
15		**θ**	Voltage angle		°

The relative variation rate $V_r(p)$ [16], and the sensitivity index *SI(p)* [12], in a parameter *p* of a model can be computed as these following expressions:

$$V_r(p) = \left|\frac{S_2 - S_1}{S_1}\right| 100 \quad (5)$$

$$SI(p) = \frac{S_{avg}}{E_{avg}} E_2 - E_1 \quad (6)$$

Where:

- E_1 is the initial input parameter;
- E_2 is the tested input value (: ±v% modification; "v" is a given percentage, it depends on the parameters. For the linear parameters R, X, B and the different powers; a variation of +/- 10% is acceptable. And for the bus voltage, a +/- 4% is acceptable because the variation range in p.u for voltages are between 0.90 and 1.10)
- E_{avg} the average between E_1 and E_2
- S_1, S_2 are respectively the outputs value corresponding to E_1 and E_2;
- S_{avg} is the average between E_1 and E_2.

IV. RESULTS

4.1. MESHED DISTRIBUTION NETWORK IEEE-30 BUS

The case study is the 30 Bus Test meshed distribution network from the IEEE [18]. It represents a portion of the American Electric Power System (in the Midwestern US) as of December, 1961. The data was kindly provided by Iraj Dabbagchi of AEP and entered in IEEE Common Data Format by Rich Christie at the University of Washington in August 1993.

This system has 30 buses, 41 branches, 2 synchronous generators in bus 1 and 2 that produce 300,2 MW altogether, 4 synchronous compensators in buses 5,8,11,13 and 4 transformers 132kV/33kV in branches 11,12,15 and 36.

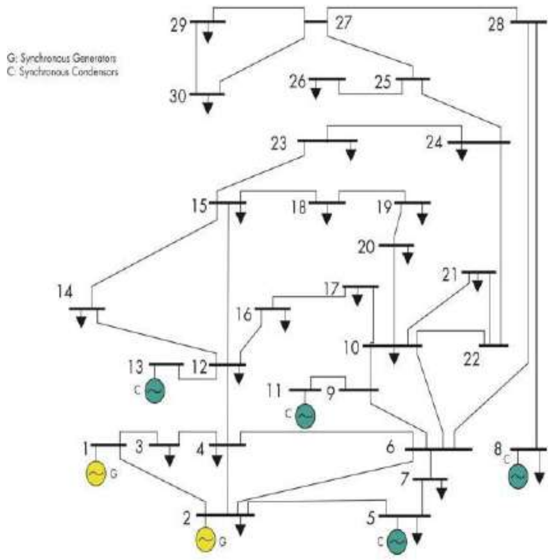

Fig. 4: One-line diagram of the IEEE 30bus

Table 2: Bus data of meshed network IEEE-30 BUS

Bus	Bus Type	V (p.u)	θ	Pg (MW)	Qg (MVAR)	Pc (MW)	Qc (MVAR)
1	1	1.060	0	260.2	-16.1	0	0
2	2	1.043	0	40	50	21.7	12.7
3	3	1	0	0	0	2.4	1.2
4	3	1	0	0	0	7.6	1.6
5	2	1.010	0	0	37	94.2	19
6	3	1	0	0	0	0	0
7	3	1	0	0	0	22.8	10.9
8	2	1.010	0	0	37.3	30	30
9	3	1	0	0	0	0	0
10	3	1	0	0	0	5.8	2

11	2	1.082	0	0	16.2	0	0
12	3	1	0	0	0	11.2	7.5
13	2	1.071	0	0	10.6	0	0
14	3	1	0	0	0	6.2	1.6
15	3	1	0	0	0	8.2	2.5
16	3	1	0	0	0	3.5	1.8
17	3	1	0	0	0	9	5.8
18	3	1	0	0	0	3.2	0.9
19	3	1	0	0	0	9.5	3.4
20	3	1	0	0	0	2.2	0.7
21	3	1	0	0	0	17.5	11.2
22	3	1	0	0	0	0	0
23	3	1	0	0	0	3.2	1.6
24	3	1	0	0	3	8.7	6.7
25	3	1	0	0	0	0	0
26	3	1	0	0	0	3.5	2.3
27	3	1	0	0	0	0	0
28	3	1	0	0	0	0	0
29	3	1	0	0	0	2.4	0.9
30	3	1	0	0	0	10.6	1.9

Table 3: Branch data of meshed network IEEE-30 BUS

Branch	**Bus i**	**Bus j**	**R (p.u)**	**X (p.u)**	**B (p.u)**	**a**
Branch 1	**1**	**2**	0.0192	0.0575	0.0254	1
Branch 2	**1**	**3**	0.0452	0.1652	0.0204	1
Branch 3	**2**	**4**	0.0570	0.1737	0.0184	1
Branch 4	**3**	**4**	0.0132	0.0379	0.0042	1
Branch 5	**2**	**5**	0.0472	0.1983	0.0209	1
Branch 6	**2**	**6**	0.0581	0.1763	0.0187	1
Branch 7	**4**	**6**	0.0119	0.0414	0.0045	1
Branch 8	**5**	**7**	0.0460	0.1160	0.0102	1
Branch 9	**6**	**7**	0.0267	0.0820	0.0085	1
Branch 10	**6**	**8**	0.0120	0.0420	0.0045	1
Branch 11	**6**	**9**	0	0.2080	0	0.978
Branch 12	**6**	**10**	0	0.5560	0	0.969
Branch 13	**9**	**11**	0	0.2080	0	1
Branch 14	**9**	**10**	0	0.1100	0	1
Branch 15	**4**	**12**	0	0.2560	0	0.932

Branch 16	**12**	**13**	0	0.1400	0	1
Branch 17	**12**	**14**	0.1231	0.2559	0	1
Branch 18	**12**	**15**	0.0662	0.1304	0	1
Branch 19	**12**	**16**	0.0945	0.1987	0	1
Branch 20	**14**	**15**	0.2210	0.1997	0	1
Branch 21	**16**	**17**	0.0524	0.1923	0	1
Branch 22	**15**	**18**	0.1073	0.2185	0	1
Branch 23	**18**	**19**	0.0639	0.1292	0	1
Branch 24	**19**	**20**	0.0340	0.0680	0	1
Branch 25	**10**	**20**	0.0936	0.2090	0	1
Branch 26	**10**	**17**	0.0324	0.0845	0	1
Branch 27	**10**	**21**	0.0348	0.0749	0	1
Branch 28	**10**	**22**	0.0727	0.1499	0	1
Branch 29	**21**	**22**	0.0116	0.0236	0	1
Branch 30	**15**	**23**	0.1000	0.2020	0	1
Branch 31	**22**	**24**	0.1150	0.1790	0	1
Branch 32	**23**	**24**	0.1320	0.2700	0	1
Branch 33	**24**	**25**	0.1885	0.3292	0	1
Branch 34	**25**	**26**	0.2544	0.3800	0	1
Branch 35	**25**	**27**	0.1093	0.2087	0	1
Branch 36	**28**	**27**	0	0.3960	0	0.968
Branch 37	**27**	**29**	0.2198	0.4153	0	1
Branch 38	**27**	**30**	0.3202	0.6027	0	1
Branch 39	**29**	**30**	0.2399	0.4533	0	1
Branch 40	**8**	**28**	0.0636	0.2000	0.0214	1
Branch 41	**6**	**28**	0,0169	0,0599	0.0065	1

4. 2. POWER LOSSES BY NRLF

As shown in table 4, the different powers flowing in each bus are obtained.

Table 4: Injected, generated and consumed powers in each bus

Bus	V	Teta	Pi	Qi	Pg	Qg	Pc	Qc
1	1.060	0	260.92	-17.106	260.923	-17.106	0.000	0.000
2	1.043	-5.347	18.3	35.063	40.000	47.763	21.700	12.700
3	1.021	-7.545	-2.4	-1.200	-0.000	0.000	2.400	1.200
4	1.012	-9.299	-7.6	-1.600	0.000	0.000	7.600	1.600
5	1.010	-14.153	-94.2	16.955	-0.000	35.955	94.200	19.000
6	1.012	-11.086	0	-0.000	0.000	0.000	0.000	0.000
7	1.003	-12.872	-22.8	-10.900	-0.000	0.000	22.800	10.900
8	1.010	-11.802	-30	0.693	0.000	30.694	30.000	30.000

9	1.051	-14.113	0	0.000	0.000	0.000	0.000	0.000
10	1.044	-15.699	-5.8	17.000	-0.000	19.000	5.800	2.000
11	1.082	-14.113	0	16.112	0.000	16.112	0.000	0.000
12	1.057	-14.958	-11.2	-7.500	0.000	-0.000	11.200	7.500
13	1.071	-14.958	0	10.392	0.000	10.392	0.000	0.000
14	1.042	-15.850	-6.2	-1.600	-0.000	0.000	6.200	1.600
15	1.037	-15.939	-8.2	-2.500	-0.000	0.000	8.200	2.500
16	1.044	-15.544	-3.5	-1.800	-0.000	0.000	3.500	1.800
17	1.039	-15.860	-9	-5.800	-0.000	-0.000	9.000	5.800
18	1.028	-16.549	-3.2	-0.900	-0.000	-0.000	3.200	0.900
19	1.025	-16.721	-9.5	-3.400	0.000	0.000	9.500	3.400
20	1.029	-16.523	-2.2	-0.700	0.000	-0.000	2.200	0.700
21	1.032	-16.143	-17.5	-11.20	0.000	-0.000	17.500	11.200
22	1.032	-16.129	0	-0.000	-0.000	-0.000	0.000	0.000
23	1.027	-16.328	-3.2	-1.600	-0.000	0.000	3.200	1.600
24	1.021	-16.503	-8.7	-2.400	-0.000	4.300	8.700	6.700
25	1.018	-16.102	0	-0.000	-0.000	-0.000	0.000	0.000
26	1.001	-16.521	-3.5	-2.300	-0.000	0.000	3.500	2.300
27	1.025	-15.594	0	0.000	0.000	0.000	0.000	0.000
28	1.010	-11.745	0	0.000	0.000	0.000	0.000	0.000
29	1.005	-16.818	-2.4	-0.900	-0.000	-0.000	2.400	0.900
30	0.994	-17.696	-10.6	-1.900	-0.000	0.000	10.600	1.900
Total power			17.523 MW	20.911 MVar	300.923 MW	147.110M Var	283.400 MW	126.200 MVar

The results show that the sum of the injected active powers in every bus represents also the same value as the *table 5* shows. That is the total active power losses in that network.

$$\sum P_i = \sum P_g - \sum P_c = (300.923 - 283.400)$$

$$\sum L_{P_{ij}} = 17.523\ MW. \quad (7)$$

This result justifies the two ways for power losses assessment as mentioned in equation (3) and (4)

Table 5: Different power flows and losses between bus i and j

Bus *i*	**Bus *j***	***Pij***	***Pji***	***Qij***	***Qji***	**Active loss *Lpij***	**Reactive loss *Lqji***
1	2	173,1323	-167,9542	-18,1051	33,6124	5,1781	15,5073
1	3	87,7903	-84,6742	6,2574	5,1314	3,1161	11,3892
2	4	43,6294	-42,6178	5,2035	-2,1208	1,0116	3,0826
3	4	82,2742	-81,4163	-3,7639	6,2269	0,8578	2,4629
2	5	82,2857	-79,3408	4.0330	8,3391	2,9449	12,3721
2	6	60,3391	-58,3936	1,3956	4,5078	1,9455	5,9035

4	6	72,1656	-71,5256	-17,5893	19,8156	0,6399	2,2263
5	7	-14,8592	15,0214	11,7887	-11,3796	0,1622	0,4091
6	7	38,2022	-37,8214	-1,1932	2,3626	0,3807	1,1694
6	8	29,5229	-29,4197	-3,1776	3,5391	0,1033	0,3615
6	9	27,6158	-27,6158	-18,6362	20,8404	0.0000	2,2042
6	10	15,7788	-15,7788	-5,4231	6,8873	0.0000	1,4642
9	11	0.0000	0.0000	-15,6508	16,112	0.0000	0,4612
9	10	27,6158	-27,6158	6,7571	-5,9522	0.0000	0,8048
4	12	44,2686	-44,2686	-16,7104	21,9171	0.0000	5,2067
12	13	0.0000	0.0000	-10,2601	10,3919	0.0000	0,1318
12	14	7,8714	-7,7966	2,4345	-2,2791	0,0747	0,1554
12	15	17,9205	-17,7019	6,9303	-6,4998	0,2185	0,4305
12	16	7,2767	-7,2225	3,3453	-3,2313	0,0542	0,1139
14	15	1,5966	-1,5905	0,6791	-0,6736	0,0061	0,0055
16	17	3,7225	-3,7105	1,4313	-1,4032	0,0121	0,0281
15	18	6,0513	-6,0118	1,7324	-1,6521	0,0395	0,0803
18	19	2,8118	-2,8066	0,7521	-0,7417	0,0051	0,0103
19	20	-6,6933	6,7101	-2,6582	2,6918	0,0168	0,0335
10	20	8,9904	-8,9101	3,5711	-3,3918	0,0803	0,1793
10	17	5,3037	-5,2895	4,4337	-4,3967	0,0142	0,0371
10	21	15,7236	-15,6138	9,8441	-9,6077	0,1098	0,2363
10	22	7,5769	-7,5252	4,4916	-4,3849	0,0517	0,1066
21	22	-1,8862	1,8868	-1,5923	1,5936	0,0006	0,0013
15	23	5,0411	-5,0095	2,9411	-2,8771	0,0316	0,0638
22	24	5,6384	-5,5956	2,7914	-2,7249	0,0427	0,0664
23	24	1,8095	-1,8033	1,2771	-1,2649	0,0061	0,0125
24	25	-1,3009	1,3085	1,5895	-1,5762	0,0076	0,0133
25	26	3,5445	-3,5001	2,3665	-2,3001	0,0445	0,0664
25	27	-4,8531	4,8785	-0,7903	0,8389	0,0254	0,0486
28	27	18,1592	-18,1591	-3,3361	4,6151	0.0000	1,2791
27	29	6,1894	-6,1035	1,6677	-1,5055	0,0858	0,1622
27	30	7,0913	-6,9298	1,6614	-1,3575	0,1614	0,3038
29	30	3,7035	-3,6701	0,6055	-0,5424	0,0334	0,0631
8	28	-0,5803	0,5806	-0,2032	0,2041	0,0002	0,0007
6	28	18,7995	-18,7397	-2,9369	3,1485	0,0597	0,2117
Total power losses						**17.523 MW**	**68.867 MVAR**

4.3. INFLUENCING FACTORS ON POWER LOSSES

As we observed on the global representation of the Sensitivity index (Fig. 5); many high peaks have been appeared that indicate the most influencing parameter in the corresponding branch (Tables 6, 7).

A *SI* positive means that the variation of the inputs value is the same direction as the variation in the output whereas a *SI* negative represents an inverse effect between the inputs and the output factors. It could be seen that each branch has its influencing factor which differs from each other.

Table 6: Sensitivity Index of the 14 parameters

	R	*X*	*B*	*a*	*V(NI)*	*V(NE)*	*Pg(NI)*	*Pg(NE)*	*Qg(NI)*	*Qg(NE)*	*Pc(NI)*	*Pc(NE)*	*Qc(NI)*	*Qc(NE)*
Branch 1	0,781	-1,77	0	0	-2,266	-2,121	0	-0,389	0	-0,001	0	2,382	0	0
Branch 2	0,847	-1,842	0	0	-2,305	-2,289	0	0	0	0	0	2,881	0	0
Branch 3	0,788	-1,782	0	0	-2,078	-2,184	0,147	0	-0,012	0	2,094	2,020	0,032	0,412
Branch 4	0,764	-1,758	0	0	-2,296	-2,312	0	0	0	0	2,897	2,318	0,007	0,338
Branch 5	0,882	-1,877	0	0	-2,207	-2,245	0,027	0	-0,0024	-0,002	2,197	2,239	0,014	0,425
Branch 6	0,786	-1,780	0	0	-2,141	-2,271	0,084	0	0,001	0	2,221	0	0,005	0
Branch 7	0,833	-1,827	0	0	-2,498	-2,480	0	0	0	0	2,151	0	0	0
Branch 8	0,705	-1,699	0	0	-2,310	-3,452	0	0	-0,071	0	0,36	0,359	0,503	1,739
Branch 9	0,790	-1,785	0	0	-2,112	-2,116	0	0		0	0	2,530	0	1,290
Branch 10	0,835	-1,829	0	0	-3,445	-3,302	0	0	0	-0,057	0	2,532	0	0,852
Branch 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 17	0,594	-1,588	0	0	-2,142	-2,142	0	0	0	0	2,133	2,163	0,326	1,538
Branch 18	0,558	-1,552	0	0	-2,090	-2,090	0	0	0	0	2,173	2,187	0,391	2,948
Branch 19	0,601	-1,595	0	0	-1,656	-1,655	0	0	0	0	2,289	1,982	0,647	3,668
Branc	-0,049	-	0	0	-	-	0	0	0	0	2,54	2,520	0,786	7,167

h 20		0,848			1,514	1,514								
Branch 21	-2,894	1,532	0	0	7,919	7,919	0	0	0	0	-0,909	-1,03	-2,61	-1,546
Branch 22	0,580	-1,574	0	0	-1,966	-1,963	0	0	0	0	2,284	2,373	0,363	0
Branch 23	0,575	-1,569	0	0	-1,568	-1,568	0	0	0	0	2,622	2,59	0,585	3,573
Branch 24	0,568	-1,562	0	0	-2,736	-2,736	0	0	0	0	1,812	1,884	0,213	0
Branch 25	0,638	-1,632	0	0	-2,624	-2,624	0	0	0	0	1,735	1,963	0,214	0
Branch 26	0,721	-1,715	0	0	-3,273	-3,273	0	0	0	0	0,690	0	0,561	0,755
Branch 27	0,616	-1,610	0	0	-2,365	-2,365	0	0	0	0	1,690	1,690	0,665	2,823
Branch 28	0,588	-1,582	0	0	-2,393	-2,393	0	0	0	0	1,732	0	0,648	0
Branch 29	0,565	-1,570	0	0	-1,619	-1,619	0	0	0	0	0,597	0	1,069	0
Branch 30	0,575	-1,569	0	0	-1,688	-1,688	0	0	0	0	0	2,545	0,737	4,234
Branch 31	0,375	-1,369	0	0	-2,634	-2,634	0	0	0	0	1,856	2,095	0	3,235
Branch 32	0,583	-1,578	0	0	-0,467	-0,466	0	0	0	0	3,696	3,365	1,231	11,25
Branch 33	0,468	-1,463	0	0	-1,155	-1,155	0	0	0	0	3,305	0	-0,045	0
Branch 34	0,339	-1,333	0	0	-2,432	-2,432	0	0	0	0	0	1,484	0	3,807
Branch 35	0,536	-1,530	0	0	-2,557	-2,557	0	0	0	0	0	0	0	0
Branch 36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 37	0,528	-1,523	0	0	-2,448	-2,448	0	0	0	0	0	2,60	0	0
Branch 38	0,526	-1,520	0	0	-2,458	-2,458	0	0	0	0	0	0	0	1,036
Branch 39	0,528	-1,523	0	0	-2,471	-2,471	0	0	0	0	2,690	2,181	0,127	0,890
Branch 40	0,684	-1,687	0,13	0	-17,78	-18,74	0	0	2,208	0	-10,11	0	0,778	0
Branch 41	0,838	-1,833	0	0	-2,156	-2,156	0	0	0	0	0	0	0	0

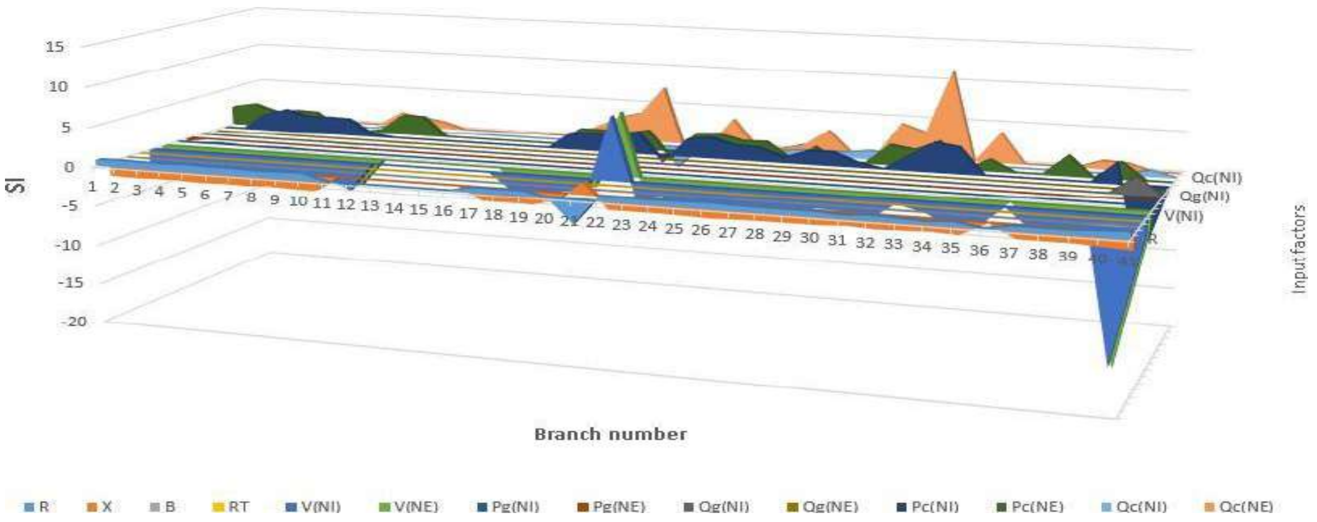

Fig. 5: Global representation of the factor effect on each branch according to the SI values

Table 7: *Relative variation rate of the 14 parameters*

	R	*X*	*B*	*a*	*V(NI)*	*V(NE)*	*Pg(NI)*	*Pg(NE)*	*Qg(NI)*	*Qg(NE*	*Pc(NI)*	*Pc(NE)*	*Qc(NI)*	*Qc(NE)*
Branch 1	7,653	20,414	0	0	9,115	9,115	4,188	4,188	0,018	0,018	25,97	25,970	0,098	0,177
Branch 2	8,378	21,442	0	0	9,279	9,279	1,610	1,611	0,017	0,017	26,051	26,051	0,034	1,893
Branch 3	7,799	20,743	0	0	8,772	8,771	1,414	1,414	0,129	0,129	22,479	22,479	0,319	2,529
Branch 4	7,446	20,433	0	0	9,310	9,301	1,651	1,651	0,021	0,021	26,221	26,221	0,057	2,073
Branch 5	8,739	21,885	0	0	9,203	9,205	0,261	0,262	0,025	0,024	23,723	23,723	0,137	1,990
Branch 6	7,769	20,643	0	0	9,266	9,266	0,804	0,804	0,015	0,015	24,010	24,010	0,049	2,552
Branch 7	8,332	21,049	0	0	10,09	10,09	0,922	0,922	0,228	0,228	24,108	24,108	0,051	0,108
Branch 8	6,948	19,643	0	0	14,33	14,33	1,136	1,136	0,753	0,753	3,511	3,511	4,915	8,767
Branch 9	7,914	20,742	0	0	8,532	8,532	0,555	0,555	0,027	0,027	27,664	27,666	0,162	5,959
Branch 10	8,284	21,309	0	0	14,29	14,29	0,009	0,009	0,598	0,598	27,430	27,430	1,675	4,247
Branch 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 17	5,818	18,252	0	0	8,656	8,656	0,046	0,046	1,311	1,311	22,186	22,186	3,358	9,781
Branch 18	5,446	17,734	0	0	8,438	8,438	0,086	0,086	1,764	1,764	22,653	22,653	4,039	12,27
Branch	5,927	18,367	0	0	6,626	6,626	0,215	0,215	4,619	4,619	24,010	24,010	6,783	22,01

19														
Branch 20	0,523	9,359	0	0	6,044	6,043	0,196	0,196	6,517	6,517	26,559	26,559	9,703	32,70
Branch 21	24,07	14,905	0	0	26,59	26,59	29,619	29,619	23,99	23,99	9,368	9,368	24,15	7,519
Branch 22	5,672	18,122	0	0	7,907	7,907	0,162	0,162	2,895	2,895	23,7759	23,779	4,206	13,38
Branch 23	5,642	17,977	0	0	6,266	6,265	0,351	0,351	5,953	5,953	26,605	26,605	6,363	22,74
Branch 24	5,575	17,925	0	0	11,19	11,19	0,125	0,125	2,294	2,295	17,853	17,853	1,818	1,770
Branch 25	6,297	18,801	0	0	10,70	10,70	0,094	0,094	1,583	1,584	18,664	18,664	2,063	3,066
Branch 26	7,030	19,717	0	0	13,53	13,54	0,169	0,169	6,508	6,508	7,030	7,030	7,495	3,881
Branch 27	6,079	18,548	0	0	9,602	9,601	0,009	0,009	0,173	0,174	18,137	18,137	6,544	15,91
Branch 28	5,791	18,190	0	0	9,721	9,720	0	0.012	0.065	0.065	18,631	18,63	6,369	15,84
Branch 29	5,723	18,373	0	0	6,476	6,475	0	0	2,108	2,108	6,0241	6,024	10,54	17,17
Branch 30	5,631	18,007	0	0	6,763	6,763	0,142	0,142	4,942	4,942	25,728	25,728	8,717	29,44
Branch 31	3,643	15,539	0	0	10,75	10,75	0,056	0,056	0,967	0,967	22,979	22,979	4,805	15,25
Branch 32	5,720	18,123	0	0	1,825	1,825	0,325	0,325	14,504	14,50	39,667	39,667	15,61	65,43
Branch 33	4,579	16,677	0	0	4,579	4,579	0,380	0,380	13,580	13,58	38,827	38,827	11,85	24,68
Branch 34	3,282	15,101	0	0	9,889	9,889	0,002	0,002	0,321	0,321	17,451	17,451	7,489	17,63
Branch 35	5,233	17,552	0	0	10,42	10,42	0,145	0,145	3,087	3,087	15,376	15,376	3,948	0,110
Branch 36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 37	5,171	17,412	0	0	9,956	9,956	0,002	0,003	0,231	0,232	23,284	23,284	2,019	6,087
Branch 38	5,137	17,405	0	0	9,998	9,998	0,003	0,003	0,233	0,233	23,650	23,650	1,723	5,459
Branch 39	5,169	17,417	0	0	10,05	10,05	0,003	0,003	0,236	0,236	24,118	24,118	1,354	4,673
Branch 40	6,779	19,491	1,27	1,27	113,9	113,9	0,847	0,747	23,30	23,30	227,542	227,542	93,64	278,8
Branch 41	8,371	21,399	0	0	8,715	8,715	0,030	0,030	0,169	0,169	22,903	22,903	0,497	1,046

Some specific branches are presented in Fig. 6 to Fig. 9 to show the effect of the parameters through V_r and *SI* values.

The most highlights branches are the branch 21 and the branch 40 which are affected by the bus voltage and the reactive powers in the extreme bus.

In the first branch of which the two generators are connected to the buses, there is no effect of the reactive powers as shown in the Fig. 6 (a), (b).

Concerning the branch 21, high rate of V_r appeared in each parameter due to the variation of voltage magnitude beyond the limits. For the branch 40, V_r of the bus 28 is very high due to the effect of reactive power at the bus 8.

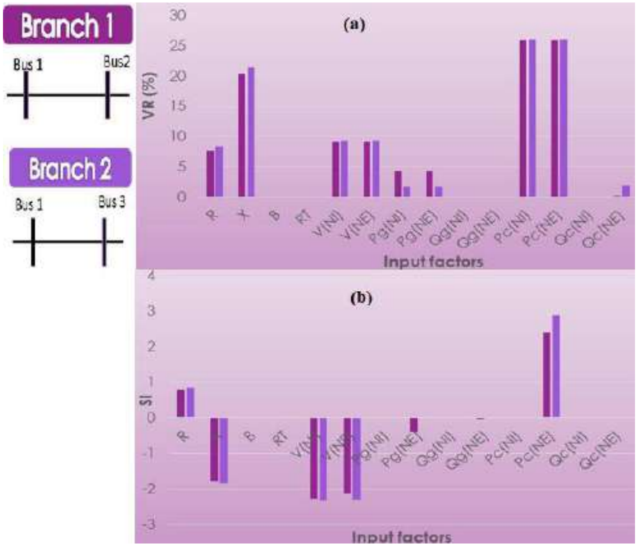

Fig. 6: Input factors in branches 1 and 2: (a) Relative variation rate, (b) Sensitivity Index

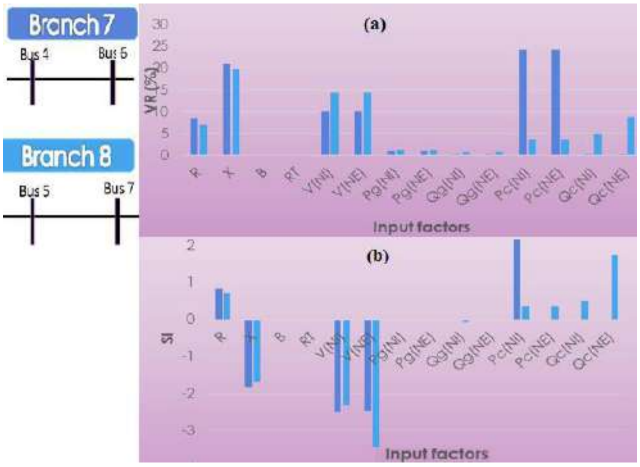

Fig. 7: Input factors in branches 7 and 8: (a) Relative variation rate, (b) Sensitivity Index

V. DISCUSSION

In this case by the given data from (Fig. 4),synchronous compensators are placed by network operators in buses 5, 8, 11 and 13. But according to the research of *Dharamjit and al.* [17], compensators are injected at the network in buses 13,22,23 and 27.

At this work, we have found that there is some issues related to voltage, generated and consumed reactive powers in buses 8,16,17 and 28. So, it will be better if any other energy sources or compensators are injected to these buses.

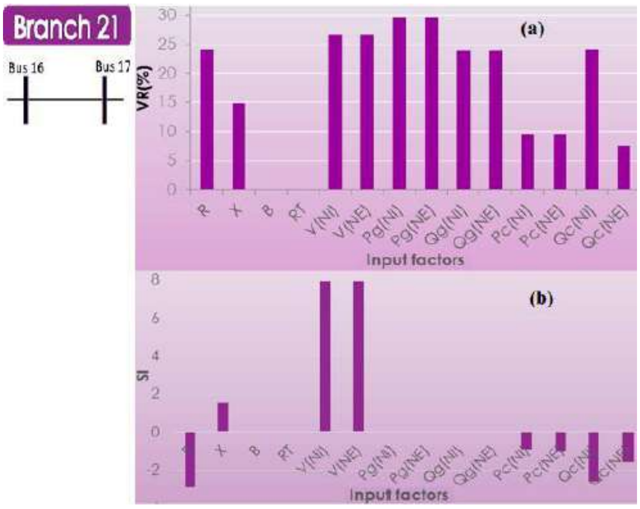

Fig. 8: Input factors in branch 21: (a) Relative variation rate, (b) Sensitivity Index

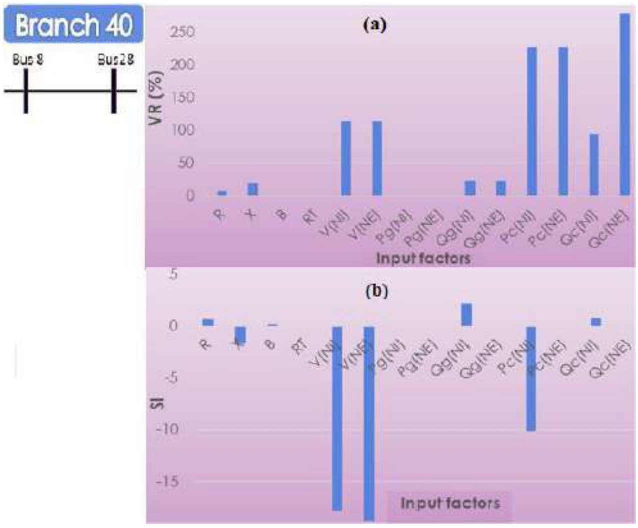

Fig. 9: Input factors in branch 40: (a) Relative variation rate, (b) Sensitivity Index

VI. CONCLUSION

Using NRLF method was chosen, in this work, to quickly assess the power losses on the 41 branches of the IEEE 30bus meshed distribution network. Identifying these losses with their influencing factors could help electricity distributors to find the issue of each branch in order to apply an optimization of their networks.

Among the parameters investigated of each branch during the analysis by OAT, the result shows that the most influencing parameters are:

- the consumed reactive powers;
- the bus voltages;
- and the linear parameters.

In fact, the application of OAT method also allows us to know the interdependence between the variations of bus voltage and the reactive power consumptions.

Concerning the required solution to optimize these losses problems, three mains suggestions are given such as:

- the reactive power compensation by using capacitor banks for the branch which have reactive powers issues;
- the injection of energy sources into the low bus-voltage, like hybrid system or renewable energy;
- the reconfiguration of the network according to the suitable loads if necessary.

Finally, the application of these proposal optimizations requires more economical and technical analysis in order to avoid excessive investment and meet demand.

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Hybrid Electric with a Smart Platform Source Modeling

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***Abstract*— *This paper develops how to manage and to save electric energy produced by hybrid sources. Research focuses on the detailed hybrid system component modeling. HOMER software is used for study feasibility and RETScreen software for results validation. Smart platform automatically chooses energy sources to be used by a home electric system in prioritizing renewable energy. Multi-sources system includes photovoltaic, wind turbine and generator. Switching and control between thermal and renewable energy sources are ensured by a microcontroller. Based on electric energy need, modeling can manage various energy sources by running each source independently showing its best performance. Therefore, this research allows the chosen villages to get out of blackout stress thanks to smart platform which is able to provide high availability of electricity from a hybrid system combined with battery storage.*

***Keywords*— Electric energy, renewable energy, thermal energy, battery storage**

I. INTRODUCTION

Nowadays, diesel generator is the most widely used technique for isolated sites electrification. However, access to these sites is usually long and difficult. Moreover, maintenance costs and fuel supply are very high. Solution consists to link hybrid system and diesel generator with two renewable energy sources (Wind Power, PV). Again, this solution is often the most cost-effective option. This paper focuses on providing permanent power supply of an isolated site which may be located on various sites in Madagascar. RETScreen software sized the system and detailed modeling of hybrid systems and its system components including the entire system study are presented.

II. METHODOLOGY

2.1. Hybrid systems overview

Hybrid systems are characterized by system function principle, by used various sources and whether exists storage device presence. Wind, solar or hydraulic energy are most frequently associated with a generator in hybrid systems involved a source of renewable energy. They are often autonomous, as they are made for isolated sites. The overall electric hybrid system can be structured as shown in figure 1. In this structure, sources and outlays can be added or removed according to the system topology. The power grid or the fuel cell could be for example the auxiliary source [1].

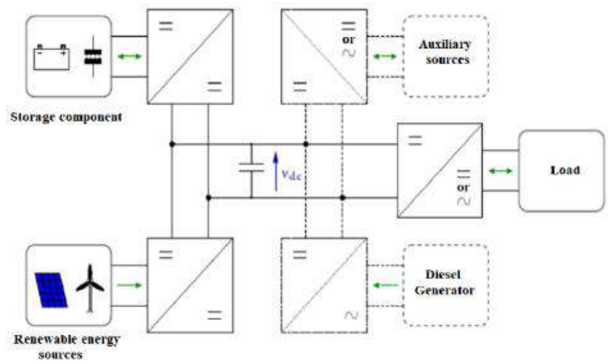

Fig 1: Hybrid system structure

There are three most popular hybrid systems in the world:

- Hybrid systems combining renewable energy sources: This option usually groups either wind combined with solar energy or hydropower with wind energy. Wind energy exploitation lays on its high availability whereas sun energy is available only few hours a day. Among these two options, the first option is more interesting in such way that many authors have conducted work and studied on the modeling of this system [2].

- Hybrid systems combining renewable energy sources with conventional energy sources: The electrical generation system using diesel generator as an additional energy is often the case in electric hybrid system. Conventional generators are used as backup generators in the system. Although, it is more cost-effective in isolated sites, model assessment can be more complex. Since, this system is conceived from the intermittency of renewable energy, it should use extra generators, [3].
- Hybrid systems combining renewable energy with storage systems: Associated with a storage system, this system reduces the problems related to climate variations. Studies made by several authors indicate that this system requires good management of these sources, [4]. Electric hybrid system configuration varies according to the process principle. Its configuration is based on buses (bus CC or CA or CC/CA). Some related study states configuration examples, [5], [6].

A. Photovoltaic cell modeling ***[7] [8]***

Figure 2 shows the basic solar cell model, [5]. This model represents the principle of sun light energy conversion into electric energy.

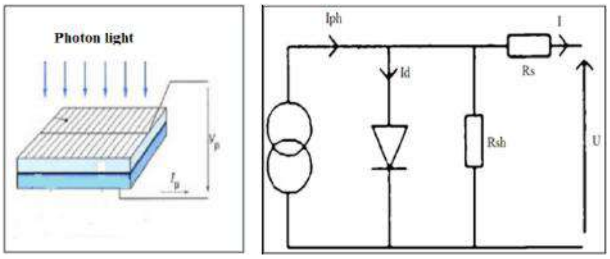

Fig 2: Photovoltaic cell equivalent circuit

By applying node's law to this circuit, intensities of circuit I and on diode I_d are given by:

$$I = I_{ph} - I_d \quad (1)$$

$$I_d = I_{od}.\left(e^{\frac{q.(U+Rs.I)}{k.T}} - 1\right) \quad (2)$$

where,

I_{ph}: electric power generated by the light [A]

I_{od} : Intensity of diode saturation power [A]

R_S: Resistance series [Ω]

k: Boltzmann constant ($k = 1, 38.10^{-23}$)

q: electron charge ($q = 1, 602.10^{-19}$ C)

T: Cell temperature [K]

B. Wind energy modeling

Wind turbines convert aerodynamic energy into electric energy. In a wind turbine two conversion processes take place. The aerodynamic power (available in the wind) is converted into mechanical power and then, again converted into electric energy. Wind systems facilities produce powers from kW (for mini wind systems) up to MW (for large wind systems). The kinetic energy in the wind is converted into mechanical energy by torque production. Since the energy provided by the wind is of kinetic energy, its amplitude depends on both air density and wind speed. Figure 3 shows a wind turbine model, [5].

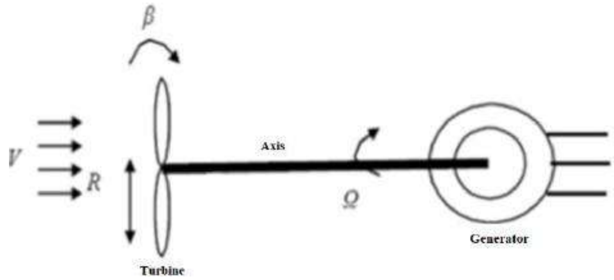

Fig 3: Wind turbine model

The wind kinetic energy is given by the formula:

$$CE = \frac{1}{2} m V^2 \quad (3)$$

where,

m: mass of air ($m = \rho.V.S.dt$) [kg],

ρ: density of the air [kg m^{-3}],

S: blades surface [m^2],

V: wind speed [m s^{-1}].

Knowing that P_w is the power developed by the turbine as

$$P_W = \frac{dE_C}{dt} = \frac{d}{dt}\left(\frac{1}{2}\rho.V^3.S.dt\right) \quad (4)$$

$$P_W = \frac{1}{2}\rho.V^3.S \quad (5)$$

Let C_p be the quotient between the mechanical power P_m and the power developed by the turbine P_w. The mechanical power is less than the developed power, and:

$$C_p = \frac{Pm}{Pw} < 1 \quad (6)$$

C_p depends on the speed ratio λ, the turbine rotation speed (which depends on specific speed), and blade inclination angle β. The mechanical power recovered at the wind turbine is given by:

$$P_m = \frac{1}{2} Cp.\rho.V^3.S \quad (7)$$

C. Battery model

The following electrical parameters characterize model battery:

- Ampere-hours (Ah) rated capacity C can be extracted from battery, under predetermined conditions of discharge.
- Charge status
- Charging (or discharging) plan which is the parameter reflected by the fraction between the battery nominal capacity and the electric power whether it is charged or discharged.

D. *Generator modeling*

A generator modelling takes account combustion engine and electric generator's association. The type of fuel and the power delivering ability make generators different from one another. In this study, Diesel Generator (DG) is used as its fuel consumption which varies linearly with consumed power as it refers in manufacturer data. The modeled generator is SIDERIS brand having power 2.5kVA with a range of 1.5 l/h, [9]. To model Diesel Generator, consumption-based simulation on the generator rated power is applied.

E. Microcontroller

According to BIGONOFF, microcontrollers are microprocessor type units for information treatment to which are added internal devices allowing their components to make edits deprived of adding internal components [10]. Today, they are located in most professional or public applications according to their need. Among the mostly used microcontrollers, there are:

- CMOS microcontrollers as the PIC 16F84A of Microchip [11],
- 16HC11 of Motorola with a large number of devices such as counters, PWM, digital analog converters, digital inputs and outputs, serial links, etc.
- Microcontrollers based on the 8051 architecture from Intel (ST, Atmel, Philips) with their advanced calculation capabilities. This family of microcontrollers has 8 bits and is an industry standard in its own right.
- Arduino microcontroller, FPGA and the raspberry. These are advanced platforms.

III. RESULTS

Figure 4 displays the hybrid system configuration. The system uses battery as storage component.

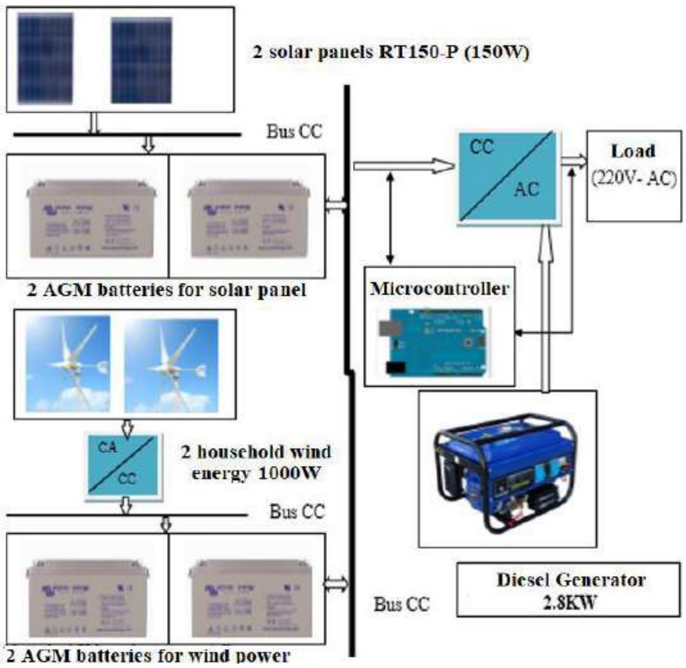

Fig 4: Hybrid system configuration

F. Hybrid system status representation

The hybrid system representation state is a powerful tool to model linear or non-linear system operation in continuous or discrete-time. It also has the advantage of maintaining the chronological representation of the phenomena [12], [13]. Figure 5 shows the hybrid system structure in smart platform.

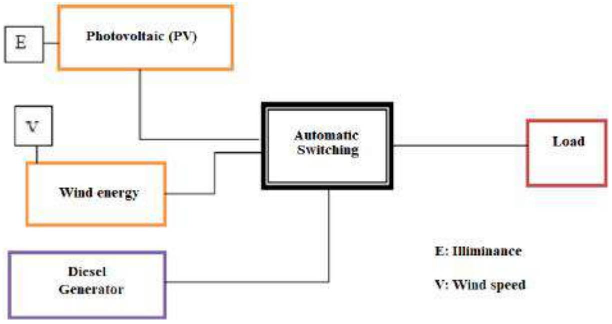

Fig 5: Hybrid system structure

The hybrid system consists of photovoltaic, wind energy, and diesel generators. Produced power by two renewable sources depends on the illuminance *E* and on the wind speed *V*. V_m and E_m are respectively the startup speed of the turbine and the minimum value of the illuminance. The renewable source stopped automatically when the sensor detects the electrical power line P_m corresponding to high values where power rises above the lower threshold. The switching system forms a dynamic system which in continuous evolution with power variation $P = x$, and in discrete evolution with transition running passage from renewable system to generator. Power curve $P = x$ according to type of load is modeled in Figure 6.

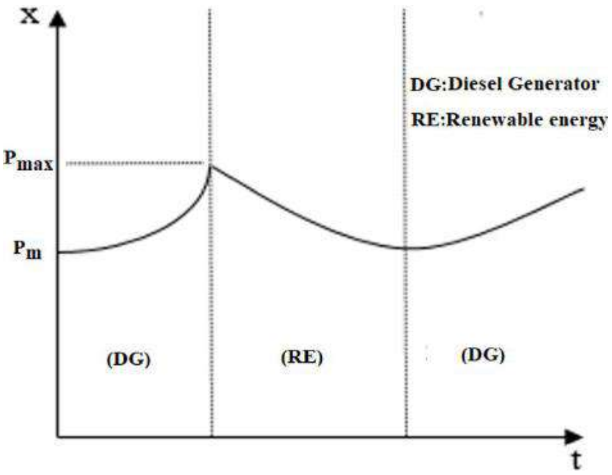

Fig 6: Renewable system power path

Power evolution can be modeled by the following differential equations:

$$\begin{cases} \dot{x} = -k_1 x + a & if\ generator\ DG\ works \\ \dot{x} = -k_2 x & if\ (PV + wind\ power)\ works \end{cases} \qquad (8)$$

with *a* and *k* are two real positive nonzero constants.

Passage from one state to other is triggered by P_m value as it is shown in Figure 7.

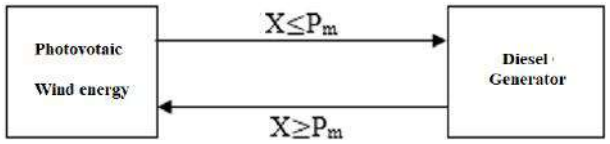

Fig 7: Condition swapping energy model

Since ideal condition for the system operation has been considered, evolution model can be determined. It requires very accurate sensor (power sensor) or gauge circuit to detect the switching threshold P_m and the energy used by the outlay P_{ch}. Once this threshold is detected, system state changes instantly.

System control

The system control model is described by equation (8) where:

- x = x1 when only Diesel Generator runs, and
- x = x2 when PV and wind power run.

The hybrid system control equation becomes matrix equation as follow:

$$\dot{x} = \begin{pmatrix} \dot{x}1 \\ \dot{x}2 \end{pmatrix} = \begin{bmatrix} -k_1 & 0 \\ 0 & -k_2 \end{bmatrix} \begin{pmatrix} x1 \\ x2 \end{pmatrix} + \begin{pmatrix} a \\ 0 \end{pmatrix} \qquad (9)$$

Assume that $B = \begin{pmatrix} a \\ 0 \end{pmatrix}$ and $A = \begin{bmatrix} -k_1 & 0 \\ 0 & -k_2 \end{bmatrix}$, the command matrix *[A] (B) [A]^2 (B)..., [A]$^{n-1}$ (B)* are of full rank. And if this command matrix is linearly independent, then the electric hybrid system is completely controllable [12].

G. Switching

The autonomous switching is characterized by the phenomenon where the system state changes discontinuously when the power produced by renewable source reaches a threshold or is less than the energy required by the load. Switching system function displays on Figure 8.

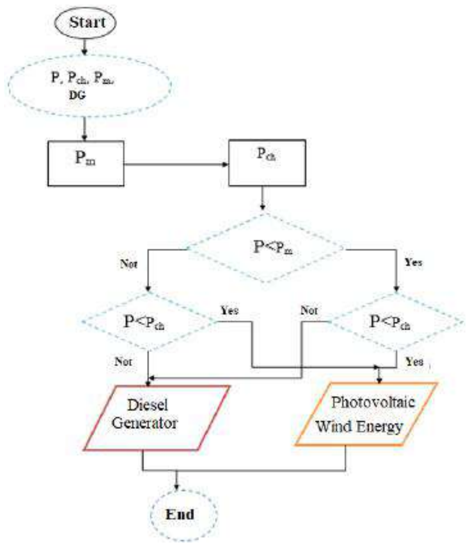

Fig 8: Switching system function

H. Modeling with simulink

a. Photovoltaic generator

Photovoltaic generator simulation uses mathematical equation to build simulink model to characterize a photovoltaic cell. Model corresponding Simulink block diagram is shown in Figure 9.

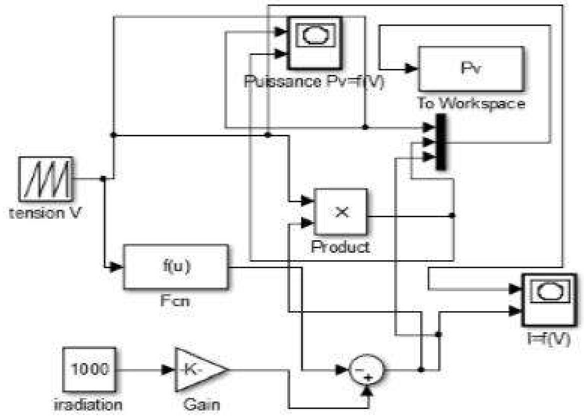

Fig 9: Block diagram of a photovoltaic cell.

Based on the photovoltaic cell model in Figure 9, RT-150P module composed by 4 groups block model of 9 cells connected in parallel (36 cells) displays in Figure 10. This model is based on an equivalent electrical circuit with the Matlab/Simulink software

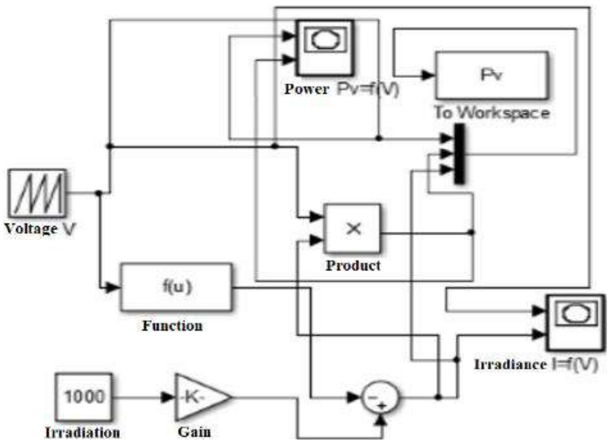

Fig 10: Solar panel RT-150P model

Using 36 photovoltaic cells, Figure 11 shows solar irradiation *I(A)* and Power-voltage pace *Pv(W)* characterizing photovoltaic cell. These curves are obtained from *Pv = f (V)* and *I = f (V)* at medium irradiance 1000W/m^2 and temperature T = 25ºC.

The characterization of the photovoltaic cell has been defined for illuminance E = 1000W/m^2 and temperature T = 25 ° C. Power curve characterizing a photovoltaic panel depends on the variation of current-

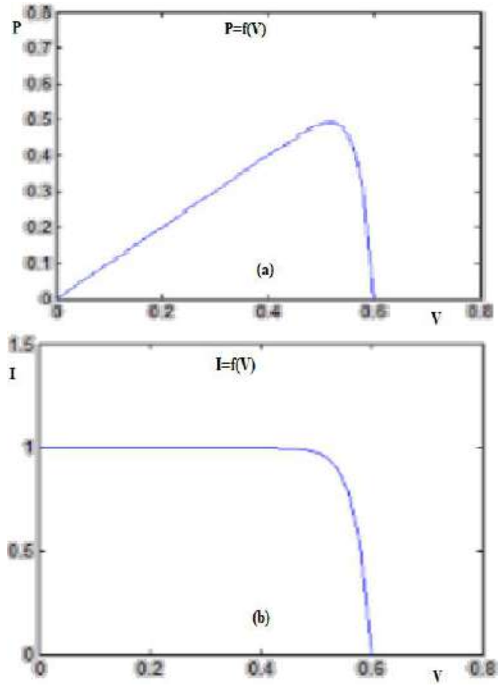

Fig 11: Characteristics of a cell for solar irradiation of 1000W/m2 at 25 ° C: (a) P = f (V), (b) I = f (V)

According the curves in Figure 11, a photovoltaic cell provides 1A electric current and voltage 0.6V at the cell terminals. Using module RT-150 P composed of 4 x 9 cells, Figure 12 shows voltage and power characteristics.

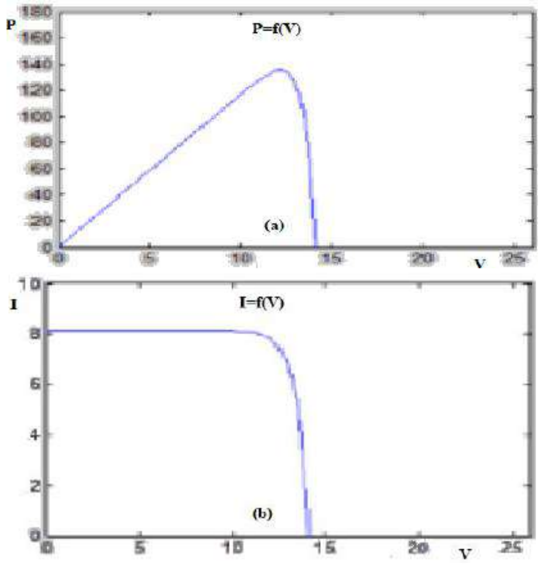

Figure 12: Module RT-150 p features: (a) power-voltage, (b) current-voltage

voltage (Figure 12(a)). Power reaches a maximum peak 140W when current-voltage at 12V. Besides, the current is maximum at the open circuit (voltage zero) and zero at the maximum voltage (Figure 12(b)).

b- Wind turbine

Figure 13 shows the block pattern of the wind turbine to simulate its operation.

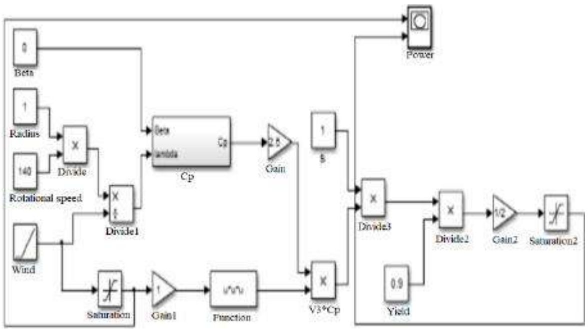

Fig 13: Wind turbine block diagram

For the wind turbine, electric power production rises with wind speed till it reaches the highest threshold 1000W, (Figure 14).

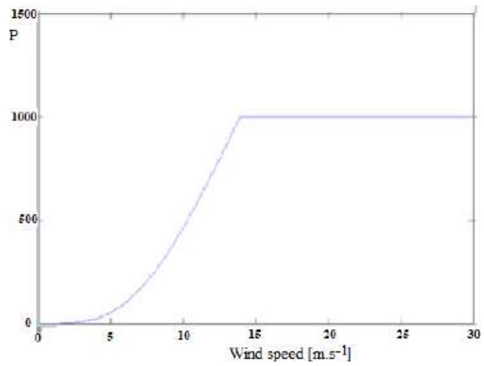

Fig 14: Wind turbine power variation over wind speed

The maximum power or nominal power P_n produced by the wind generator is obtained from nominal speed $V_n \approx 14$ m.s^{-1} (50.4 km.h^{-1}). The startup speed V_d is 2 m.s^{-1}.

c. Battery model

Figure 15 shows a battery model under Matlab/Simulink platform.

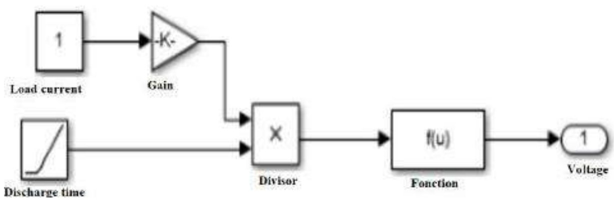

Fig 15: Battery block model

b. Diesel Generator model

Diesel Generator model under Matlab/Simulink platform is given in Figure 16.

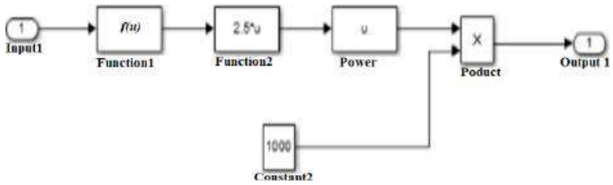

Fig 16: Diesel Generator block model.

c. Arduino microcontroller model

Arduino microcontroller is used for switching circuit command. Its block model under Matlab/Simulink that represents the system (sensor - Arduino-Relay) is shown in Figure 17.

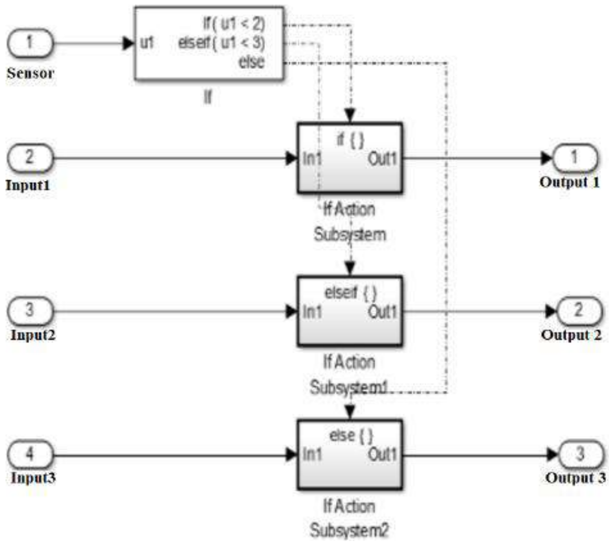

Fig 17: Arduino-sensor model

Arduino output values of Arduino-sensor model (Figure 17) according to data delivered by current sensor is represented on table 1.

Table 1: Arduino output values

Current intensity	Output 1	Output 2	Output 3
I<4A	5 V	0 V	0 V
I<6A	0 V	5 V	0 V
I>=6A	0 V	0 V	5 V

Using the Arduino model, current intensities are displayed on microcontroller digital output. Time offset was set to 0. Captured graphs of output 1, output 2 and output 3 with current intensities I<4A, I<6A and I>=6A are shown in Figure18 (a), (b), (c) respectively.

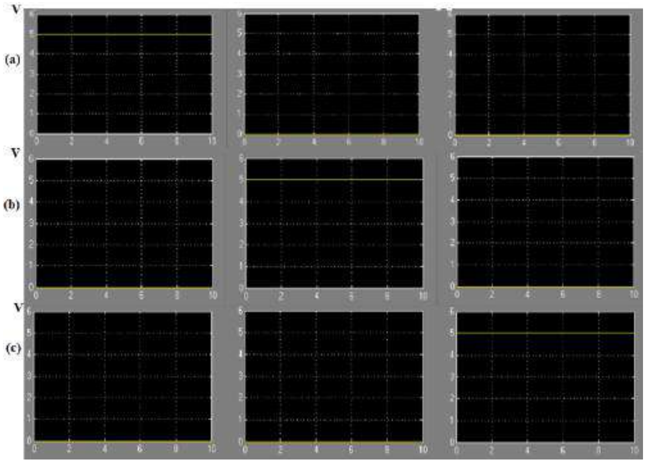

Fig. 18: Microcontroller model output voltages: (a) I<4A, (b) I<6A, (c) I>=6A

I. Modeling of the electric hybrid system

After developing all components of hybrid system like hybrid source and switch module, it remains to connect these components to find out overall system functioning and carry out an analysis according to various parameters related to the system (load, battery state, climate data, etc.). Figure 19 illustrates the whole block model of the hybrid system on Matlab/Simulink platform.

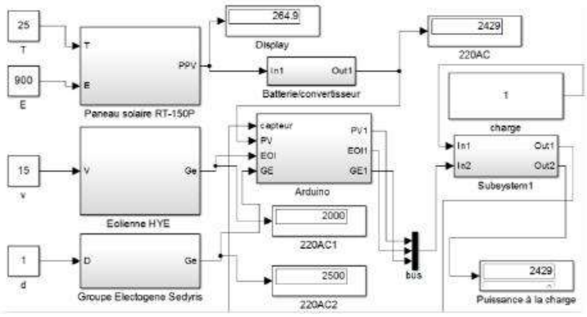

Fig 19: Block model of hybrid system on Matlab/Simulink

Block model of hybrid system analysis is performed through simulation in varying load power. When power load grasps 500W (Figure 20 (a)), hybrid system connected load is average. Similarly, if power load rises up to 1000W (Figure 20 (b)), connected load is still considered to be average. In these cases, renewable sources itself fits to ensure the power supply in order to satisfy load capacity. But if power load becomes greater than 2000W (Figure 20 (c)), energy needs have to be powered by Diesel Generator.

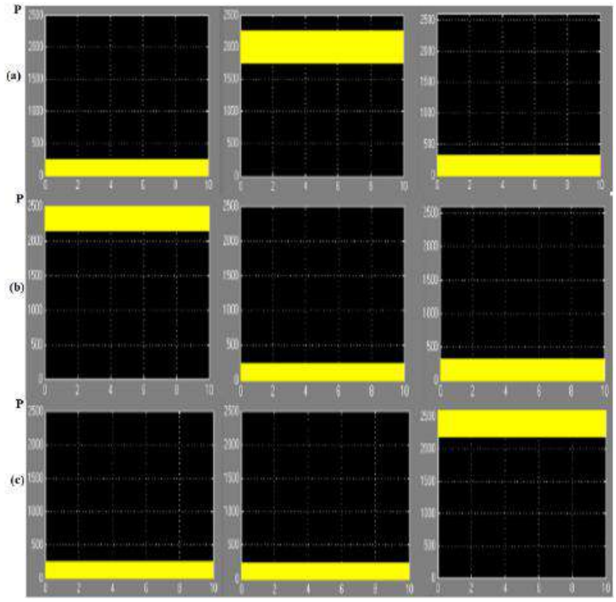

Fig 20: (a) load <500W, (b) load < 1000W, (c) load >= 2000W

Daily Load profile

During the day, load electric power varies and is not constant throughout the day. Table 2 presents estimate daily energy needs of a given household. It describes electricity demand from the site that includes light and other electrical devices. The daily energy consumption E_c of a household estimate about 2332W.

Table 2: Estimate daily energy consumption of a household

Devices	Number	Power unit (W)	Daily use delay (h)	Power (W)	Energy (Wh/d)
LED lamp	4	18	6	72	432
Radio	1	8	15	8	120
TV set	1	20	6	20	120
Load speaker	1	250	6	250	1500
Laptop	1	50	3	50	150
				Total	2332

Assume that the daily load distribution is given by the Table 3.

Table 3: Daily load profile

Hours	Power (kW)	Hours	Power (kW)
0 h - 1h	0	12h - 13h	0.270
1h - 3h	0	13h - 14h	0.278
3h - 4h	0	14h - 15h	0.320
4h - 5h	0.432	15h - 16h	0.013
5h - 6h	0.552	16h - 17h	0.014
6h - 7h	0.580	17h - 18h	0.200
7h - 8h	0.730	18h - 19h	0.500
8h - 9h	0.028	19h - 20h	1.123
9h - 10h	0.063	20h - 21h	1.123
10h - 11h	0.060	21h - 23h	0.200
11h -12h	0.270	23h - 0h	0.008

Figure 23 shows the daily functioning distribution of three generators according to the daily load profile.

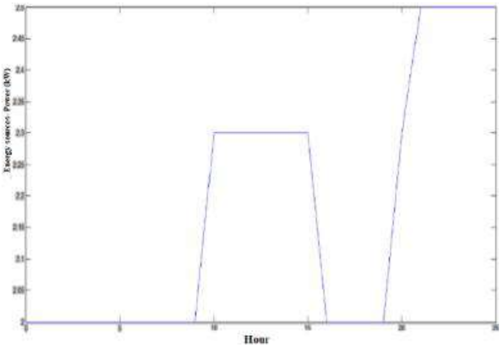

Fig 23: Daily functioning distribution of three generators according to load profile

IV. DISCUSSION

The use of multiple technologies offers the best method to determine each system characteristic. Hybrid electric system performance is influenced firstly by its design the component dimensioning, secondly the component type, architecture and thirdly, the choice of process strategy. To evaluate efficiently the system performance, parameters such as fuel economy, kilowatt hour cost, outages number and duration, stops number for maintenance need to be investigated. C. Darras suggested that the optimal configuration for hybrid systems should be determined by minimizing the kilowatt hour cost [14]. Ashok has developed a reliable system model based on a hybrid optimization model for renewable electricity production [15]. For example, to find an optimal hybrid system among various combinations of renewable energy, minimizing the cost of the entire life cycle leads to a good result.

In this study, the current system formed by multiple hybrid electric source designed in Matlab/Simulink. This smart platform technology connected power to the various loads where its value served as trigger parameter for switching energy sources. As long as the load is less than 2000W, only renewable can be enough to supply the energy need. In case that the load requires a lot of energy more than 2000W, Diesel Generator intervene to power the load. The platform chooses automatically the source depending on loads capacity. In fact, according to the daily load profile, photovoltaic generator dominates at noon. In the evening, Diesel Generator provide power in the system because the load requires considerably more electric. Since renewable energy such as solar energy and wind energy are available and inexhaustible, this study allows to reduce fossil energy dependence and contribute to the sustainable development.

V. CONCLUSION

Hybrid system modeling on Matlab/Simulink can represent system diagram in blocks and simulation under this software allows system analyses. According to the results, the combination of the two energy sources connected to a secondary system (generator) creates a substantial energy profit (daily presence of food). To sum up, this paper develops electricity power system combined with autonomous process. The used hybrid system brought significant development essentially to the power supply diversification that may affect positively the environment.

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Teaching Chinese Culture in English-a CLIL approach

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Abstract— *This paper explores the integration of content and language learning in the context of teaching Chinese culture to English majors. Drawing on literature from Content and Language Integrated Learning (CLIL), the paper proposes three key considerations for effective integration: identifying and justifying integration methods, addressing mismatches between language proficiency and cognitive ability, and adopting an inquiry-based approach to teaching and learning. The paper argues that successful integration depends on a symbiotic relationship between content, cognition, communication, and language, as well as the development of intercultural awareness. The paper concludes that while integration is a complex process that requires strategic planning and reflective evaluation, it can enhance the effectiveness of language learning and content acquisition, providing learners with a meaningful context for language and culture learning.*

Keywords— ***CLIL, Chinese culture, English majors, integration***

I. INTRODUCTION

The importance of preserving and promoting Chinese cultural traditions has been repeatedly emphasized in President Xi Jinping's speeches. During the 95th anniversary of the founding of the Communist Party of China (CPC) on July 1, 2016, he introduced the phrase "cultural confidence", a concept intended to supplement the CPC's previous declaration at the 18th National Congress that China should maintain confidence in its ideological and theoretical systems and institutions, along with socialism with Chinese characteristics. Cultural confidence is a systematic concept that encompasses a country or nation's confidence in its cultural values and vitality, emphasizing traditional values and all the material and spiritual wealth that the people have created throughout the country's history. To uphold the concept of cultural confidence, the CPC demands a strong conviction in the historical, traditional, and current socialist culture. Given this context, significant importance has been attributed to the instruction of Chinese culture within higher education institutions. Following the proposition of the concept of cultural confidence, the matter of effectively implementing Chinese culture teaching while enhancing the language skills of English majors has become an urgent issue that needs to be addressed. Content and Language Integrated Learning, or CLIL is "an approach to teaching the content of curricular subjects through the medium of a non-native language" (Llinares & Murcia, 2013, p.2). A CLIL course enables learners to acquire knowledge and comprehension of the curricular topic while also learning and utilizing the target language. It is worth noting that the term "content" takes precedence in CLIL, as it is the foundation on which language learning is built. By studying a certain subject, learners acquire knowledge and comprehension of various aspects in this subject. This teaching approach aligns well with the nature of teaching Chinese culture as a course for English majors and CLIL has the potential to provide valuable insights and ideas for the effective teaching of Chinese culture. This paper provides an overview of the current state of teaching Chinese culture through English as a part of curriculum for English majors, and draws on relevant research on CLIL to explore the alignment between CLIL and Chinese culture teaching. Based on this exploration, a theoretical framework for teaching Chinese culture using CLIL is proposed, and the practical implementation of this framework is discussed.

II. CURRENT STATE OF CHINESE CULTURE TEACHING IN ENGLISH IN CHINESE UNIVERSITIES

In this part, the state quo of Chinese Culture teaching to English majors in Chinese Universities will be analyzed through the “cultural aphasia” among English Majors and the Guide for teaching Chinese Culture in English.

2.1 “Cultural Aphasia” among English Majors

The curriculum for English majors in most universities in China has long been criticized for its neglect of Chinese culture as there are clear indications that the teaching of Western cultures has been given top priority. Most researchers of foreign language education in Chinese universities have pointed out the symptom of “cultural aphasia” among English majors, a term referring to the phenomenon of one-way cultural exchange in English teaching, where learners can easily talk about Christmas but struggle to express Chinese New Year in their daily communication due to limited exposure to their own culture through English. The concept was first proposed by Professor Cong from Nanjing University, who believed that there is a one-sided understanding of intercultural communication in English teaching in China. Cong (2000) pointed out that "the multilevel English teaching in our country has only strengthened the introduction of material culture, institutional customs, and various levels of spiritual culture from English-speaking countries, while the English expression of Chinese culture as a communicative subject is basically ignored." It’s common to find that many students are well-versed in the history and celebration of Western holidays and can express themselves fluently in English. This phenomenon is due to the detailed description of Western history and holidays in English teaching. In contrast, there is little mention of Chinese history, such as the Silk Road, Peking Opera, calligraphy, folk culture, and other traditional Chinese cultural essences. Most textbooks for English majors in China lack content related to Chinese culture. There are few resources available for developing and writing textbooks on Chinese and local culture. A review of more than 20 years of textbooks from two of China's leading publishers of foreign language materials, the Shanghai Foreign Language Education Press and the Foreign Language Teaching and Research Press, found that there are very few textbooks available for teaching Chinese culture in foreign language programs. Most of the existing resources are intended for translation majors. This suggests that there is relatively little demand for Chinese culture content in foreign language programs at most universities in China, and limited research has been conducted on this topic. As a result, textbooks of Chinese culture in English are in a large demand in Chinese colleges in recent years.

2.2 Guide for teaching Chinese Culture in English

However, there is also a lack of a clear system for teaching Chinese culture in terms of objectives, content, methods, and evaluation in English teaching syllabus, which has resulted in insufficient attention to the content of Chinese culture in teaching design, textbook compilation, and assessment. Therefore, it is necessary to clarify the system for teaching Chinese culture in English to improve students' understanding of Chinese culture and cross-cultural communication skills. In 2020, the "Teaching Guide for Undergraduate Foreign Language and Literature Majors in General Higher Education Institutions" (Guide hereafter) was formulated as a top-down framework of curriculum for English majors in Chinese universities. The Guide (2020:19) provides fundamental theoretical support for teaching Chinese culture. The first principle is to foster virtue and talent, which requires improving the English education system with Chinese characteristics, style, and grandeur. The second principle is to serve the national development strategy, where English majors must meet the needs of Chinese culture going global and the Belt and Road Initiative by learning Chinese and local cultures. The third principle emphasizes the path of connotative development, requiring English teaching to value humanities and social sciences and lay a solid foundation in Chinese language and culture. Lastly, the fourth principle emphasizes continuous innovation in teaching methods, which requires teachers to enhance their own cultural literacy and constantly innovate teaching content and methods. In particular, the Guide includes "Chinese Culture Overview" as a core course for English majors. It also establishes the "Comparative and

Cross-Cultural Studies" and "National and Regional Studies" as directions of development. They provide courses related to Chinese culture such as "Comparative Study of Chinese and Western Cultures," "Introduction to Chinese Classical Thought," "Special Topics in Chinese and Western Comparative Literature Studies," "Special Topics in Cross-Cultural Communication between China and the World," and "Contemporary Chinese Diplomacy." Additionally, the Guide also adds Chinese classics to the English major reading list, such as the English translation of "Dream of the Red Chamber," "Analects," "A Short History of Chinese Philosophy" and so on. Moreover, based on the Guide, each university can construct relevant local cultural courses for English majors in various forms, combined with the regional culture on which the university relies. The construction of such courses is of practical significance for improving the Chinese culture curriculum for English majors, promoting Chinese culture as well as building local culture, and effectively integrating English teaching and Chinese culture teaching.

III. CLIL AS A THEORETICAL CONCEPT IN TEACHING CHINESE CULTURE

CLIL is an approach to language teaching that involves teaching content and language simultaneously, with the goal of improving students' language proficiency while also deepening their understanding of academic content. In China, there is a common misconception that some teaching practices are considered CLIL even though they do not meet its requirements. For instance, some English teachers use the term "CLIL" to describe content-based language teaching (CBL), which involves incorporating subject matter into language instruction. However, CBL is typically taught by language teachers, assessed as language teaching, and does not make any formal contribution to the subject curriculum, which is not in line with the principles of CLIL. However, even within Europe, CLIL is a broad term which embraces a variety of different school practice. Ball et al. (2015, p.2) suggested the “hard” and “soft” CLIL programs as key versions, with “hard” CLIL taught by subject teachers with a strong emphasis on the acquisition of subject knowledge, “soft” CLIL taking up only part of the curriculum time allocated to the subject, valued for its language benefits and often involving language teachers. The teaching of Chinese culture to English majors, offered for a short period-usually half a year certainly belongs to the soft type. Therefor, it involves language teachers in several possible roles and highlight collaboration between subject and language.

3.1 Connecting culture learning and language learning

A useful starting point is to consider the content of learning Chinese culture. In a CLIL context, the definition of content is not as rigid as selecting a subject from a conventional school curriculum. The concept of content is more adaptable and accommodating to different disciplines and topics. Factors such as teacher availability, language support and social demands of the learning environment may require a different selection of content. Therefore, the definition of "content" in CLIL varies depending on the context of the learning institution. In a CLIL context, content can encompass a wide range of approaches, from directly incorporating elements of a statutory national curriculum to developing a project centered around topical issues that integrate various aspects of the curriculum (such as Chinese festivals, Chinese buildings, or Chinese geography). Content in CLIL can also be thematic, interdisciplinary, cross-curricular, or emphasize citizenship education. CLIL presents prospects for learning and enhancing skills that extend beyond the conventional curriculum. The nature of these opportunities varies based on whether the CLIL context prioritizes a content-led, language-led, or a combination approach. Nevertheless, it is essential to acknowledge that neither the content nor the language aspect should be disregarded or overshadowed, and the interrelationship between them must be recognized. More often than not, syllabuses and programs all have their aims and objectives, often with articulated goals and outcomes for teaching and learning. For example, the Chinese culture course would include almost all the following subjects, such a as historical figures and stories, traditional Chinese festivals, the four Great/major inventions, traditional Chinese medicine and Chinese culinary culture. But these alone do not address the how of content learning - only the what of content teaching. Vygotsky (1978) introduced the term `zone of proximal development' (ZPD) to describe the kind of learning which is always challenging yet potentially within reach of individual learners on condition that appropriate support, scaffolding and guidance are provided.

In educational settings influenced by social-constructivist theories, the teacher's primary responsibility is to facilitate cognitive challenge within each student's ZPD. This requires the teacher to strike a balance between providing cognitive challenge and gradually decreasing support as the learners advance in their learning. Therefore, for content learning to be effective learning, students must be cognitively engaged.

In a CLIL class, teachers will have to consider how to actively involve learners to enable them to think through and articulate their own learning of Chinese culture. This in turn implies that learners need to be made aware of their own learning through developing metacognitive skills such as learning to learn. CLIL classrooms that foster interaction are characterized by collaborative activities, student-led inquiries, and critical thinking. In such classrooms, students are expected to work together, utilizing their individual strengths and compensating for weaknesses. Therefore, they must acquire the skills necessary to collaborate effectively and operate successfully in groups.

3.2 Language Learning in Chinese Culture Courses

In a conventional foreign language learning environment, the instruction of language is traditionally focused on studying grammar rules and reading written materials. In the latter part of the 20th century, second language acquisition theories influenced a range of approaches used for learning foreign languages (Richards and Rodgers, 2001). Recent investigations into broader theories of learning have begun to influence the way we think about effective language learning and teaching. Such theories include socio-cultural theory, interactionism, and connectionism. Savignon (2004) identifies principles of communicative language learning that are applicable to CLIL, as language acquisition is perceived to occur in authentic contexts for practical use. Savignon's argument stresses the significance of using language in genuine interactive situations to enhance communicative abilities, rather than excessively emphasizing grammar, thereby indicating that the objective of language learning includes language use. In other words, to be considered CLIL, students must be capable of utilizing the language of instruction to learn content beyond just grammatical structure. But the question still stands: if learners lack the necessary proficiency in a second or additional language, how can they effectively use it for this purpose? As previously discussed, it is essential for learners in CLIL settings to make progress in both their content and language learning in a systematic manner. Therefore, using language for learning and learning to use language are both necessary. However, there may be a discrepancy between the cognitive abilities of learners and their language proficiency in many CLIL settings. Snow, Met, and Genesee (1989: 205) proposed a helpful approach of differentiating between content-obligatory language (crucial for understanding the content) and content-compatible language (which supports both the content and language goals of the curriculum) to facilitate teachers in sequencing their language and content aims. To plan strategically in this way, teachers must clarify the correlation between content and language objectives. A conceptual representation - the Language Triptych - makes these connections. It has been constructed to take account of the need to integrate cognitively demanding content with language learning and using (Coyle, 2000, 2002). It supports learners in language using through the analysis of the CLIL vehicular language from three interrelated perspectives: language of learning, language for learning and language through learning.

Language of learning refers to the language necessary for students to comprehend fundamental concepts and skills related to a particular subject matter or theme. Using the framework of systemic functional linguistics (Halliday, 2004), genre is defined as a "social activity in a particular culture" that is expressed through language, which forms a register (Llinares and Whittaker, 2006:28). As a result, language teachers need to focus on functional and notional levels of difficulty that align with the content, rather than solely relying on grammatical complexity. For example, students need to use the subjunctive mood in theme of Chinese art. In a CLIL environment, the learner needs to be supported in understanding the concept of “subjunctive mood”. This can be achieved through using certain examples sentences involving Chinese art. The selection of example sentences used will depend on the content. Using the subjunctive mood for authentic purposes in a CLIL class arguably enables the learners to use language appropriate to the content in a meaningful way, which can then be further explored for grammatical cohesion in the language class.

The concept of language for learning pertains to the language skills required to function in a foreign language context. Mastering the use of this language can prove to be a challenging task for both the teacher and the student, as each one has their respective responsibilities to fulfill. To be able to use the foreign language proficiently, learners need to adopt effective strategies. In a CLIL environment, it is important to help learners acquire the necessary skills for effective communication, including working in pairs or groups, asking questions, debating, chatting, thinking, and memorizing. Without the ability to use language to support their learning and collaborate with others, learners will struggle to achieve quality learning outcomes. Developing a range of language functions related to the content, such as describing, evaluating, and drawing conclusions, is crucial for successful completion of tasks. It is important to incorporate strategies for promoting independent use of the CLIL language, such as group discussions and debates, into both the teaching and learning processes.

Language through learning asserts that language and thinking are essential for effective learning. When learners are prompted to express their comprehension, a more profound level of learning can occur. The CLIL classroom requires a higher level of discourse, interaction, and dialogic engagement compared to traditional language or content-based classrooms. In CLIL environments, as new concepts and ideas emerge, they often require new language to express them. This language needs to be recognized, revisited, and strategically developed by both teachers and learners. In other words, learners require language to facilitate and enhance their thinking processes as they acquire new knowledge, as well as to advance their language proficiency.

3.3 Integrating content and language learning

The 4Cs Framework in CLIL integrates four contextualized building blocks: content (subject matter), communication (language learning and using), cognition (learning and thinking processes) and culture (developing intercultural understanding and global citizenship) (Coyle, 1999). According to Crandall (1994: p. 256), Students cannot develop academic knowledge and skills without access to the language in which that knowledge is embedded, discussed, constructed, or evaluated. Nor can they acquire academic language skills in a context devoid of [academic] content. The 4Cs Framework emphasizes the interdependence of content, cognition, communication, and language in effective CLIL instruction. According to this framework, successful CLIL takes place when there is a symbiotic relationship between these four elements. Firstly, students must progress in their knowledge, skills, and understanding of the content being taught. This means that they are not only learning the language, but they are also acquiring new knowledge in a specific subject area. Secondly, engagement in associated cognitive processing is necessary for effective CLIL. This refers to the mental processes involved in understanding and processing new information in the target language. Thirdly, interaction in the communicative context is crucial. Students need to interact with one another and with the teacher in order to use the language in authentic situations. This includes cooperative group work, discussions, debates, and other communicative activities that allow for language use in context. Fourthly, development of appropriate language knowledge and skills is essential. Students need to develop the language skills necessary to understand and express themselves in the target language in order to engage in the cognitive and communicative processes. Finally, the acquisition of a deepening intercultural awareness is critical in CLIL. This involves an understanding and appreciation of different cultures and perspectives, and how they relate to the content being taught. This awareness is developed through the positioning of self and 'otherness' in the context of the content being taught. Overall, the 4Cs Framework provides a comprehensive approach to effective CLIL instruction by highlighting the importance of content, cognition, communication, and language, as well as intercultural awareness.

IV. CONCLUSION

In conclusion, I propose three key considerations for the integration of content and language learning in teaching Chinese culture to English majors. Firstly, educators must identify and justify the means by which integration will be achieved, taking into account individual learning contexts and projected outcomes. This may seem like an obvious point, but the reality is that integrating content and language learning is a complex process that requires strategic planning and reflective evaluation. There are no easy solutions or formulas for success. Secondly, whatever the capability of learners, effective learning demands cognitive engagement at the appropriate level for individuals. in the CLIL classroom, it is probable that the language proficiency of learners may not correspond to their cognitive abilities. As a result, mismatches may occur, where either the language level is too challenging or not challenging enough when compared to their cognitive level. If the language level is too complex, it may impede effective learning. Conversely, if the cognitive level is too low for the given language level, learning may be limited. The third implication for integration in the CLIL classroom is the adoption of an inquiry-based approach to teaching and learning. In some cases, language practitioners may lead the CLIL program, and there is a risk of neglecting or diluting the specific content demands. Conversely, in other cases, content teachers may lead the program, and the linguistic demands may be at risk of being undermined. To address this issue, an inquiry-based approach can be used to strike a balance between content and language demands. This approach involves encouraging learners to inquire, explore, and discover, enabling them to construct their knowledge and make connections between different areas of learning. This approach provides a meaningful context for language learning and content acquisition, thereby enhancing the effectiveness of the CLIL approach.

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International Student Mobility and Covid-19 Pandemic: Challenges and Opportunities in Southeast Asia

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Abstract— *The influence of Corona Virus (COVID-19) pandemic is significant in international higher education, especially student mobility. Due to the travel restrictions and campus closure, many students changed or cancelled their plan of studying abroad. Thus this study was therefore conducted primarily to determine the opportunities and challenges of the international mobility of students during the Covid-19 pandemic to draw prospects and recommendations to further enhance the progress of this educational endeavour and as well as, sustainable collaborations in Southeast Asia. The study used descriptive method because the study was associated with large sample sizes, respondents asked the same questions, and concentrating to quantity responses, which ensures that the entire data collection can be analyzed fairly. 35 respondents from institutions in the SEAMEO Network participating in the SEA-TVET Consortium within Southeast Asia were surveyed in this paper, and a questionnaire was used as the main data-gathering instrument for the study. Descriptive method of research and statistical tools were considered. The finding showed that the institution's program for international student mobility was affected by the COVID-19 worldwide pandemic and greater part of the respondents encounter Travel and Government restrictions since the COVID-19 pandemic had disrupted most facets of lives including education. This had resulted in many schools and institutions of higher learning (IHE) being forced to cancel physical classes, and controlled international travel, with many nations keeping their borders closed to non-residents. Nevertheless, International Student Mobility in South East Asia was complemented using technological advancement for students such as online language or internet education and webinars in this pandemic. The researchers concluded based on the findings that the challenges and opportunities were both adapted by the institutions for International Student Mobility during pandemic in South East Asia.*

***Keywords*— SEA-TVET, pandemic, student mobility, COVID-19, International Student exchange program education, travel, government, South East Asia, webinar, restriction**

I. INTRODUCTION

The influence of CoronaVirus (COVID-19) pandemic was significant in international higher education, especially student mobility (Altbach & de Wits, 2020; Mok, 2020). Due to the travel restrictions and campus closure, many students changed or cancelled their plan of studying abroad.

In the last decades, great significance had been devoted worldwide to student mobility, involving initiatives like Erasmus+ in Europe, International Student Exchange Program (ISEP) in the United States of America, University Mobility in Asia and the Pacific (UMAP) for the Asia-Pacific region, Higher Education in the ASEAN Region (SHARE), which was supported by the European Union, the ASEAN International Mobility of Students (AIMS) Programme and the South East Asia Technical and Vocational Education and Training (SEA-TVET). Among many others, there were forms of internationalization in higher education for which various institutional approaches had been adopted to inspire students to consider education in a foreign country, either on a short-term basis, study tour or educational exchange, or for a longer period in degree programmes. Internationalization has emerged in higher education systems globally because the higher education sector needs to be receptive to the requirements of globalization, which were increased from underdeveloped to developed countries. Consequently, higher education institutions (HEIs) had essentially assimilated their international and inter-cultural dimensions and principles. International activities at these institutions had been designed to attain the aforementioned purposes of student mobility.

According to the International and Affiliate Student Tutor in the Department of Geography, UCL, (Johanna Waters, 2021) this past eight months had been quite challenging. They had seen first-hand the disappointment of students getting their overseas placements either cancelled or moved online. Students travelling to Europe or either in other countries that were supporting international student mobility have had to get to grips with fluctuating Foreign and Commonwealth Office advice and its impacts on potential visa applications and insurance – all things we previously took for granted as relatively straightforward and unproblematic. Some students, desperate for their year abroad, have chosen to defer their studies and return next year to try again, with all the uncertainty surrounding that decision. So, despite international student mobility being a research, Covid-19 had also directly impacted other work areas.

Similarly, as a regional cooperative body, the Association of Southeast Asian Nations (ASEAN) had envisioned the significance of student mobility in the region. However, structural differences remain one of the challenges in its implementation. Thus, this study determined the opportunities and challenges of the international mobility of students during the Covid-19 pandemic to draw prospects and recommendations to further enhance the progress of this educational endeavour and as well as, sustainable collaborations in Southeast Asia. This research study explored the situation and problems faced by Southeast Asia in terms of international student mobility during covid-19 pandemic and what challenges and opportunities were encountered.

Objectives of the Study

This research study aimed to:

1. Describe the profile of respondent schools in terms of

1.1 Name of Institution

1.2 Country

- Indonesia
- Malaysia
- Philippines
- Thailand
- Vietnam
- Others__________________

1.3 Type of Institution

- Private
- Public (Government owned)

1.4 School participation in SEA-TVET exchange programme?

- 1st batch
- 2nd batch
- 3rd batch
- 4th batch
- 5th batch

1.5 Number of students sent abroad (out-going) per SEA-TVET batch

- 1-5
- 6-10
- 11-15
- 16-20
- 21 and more
- Others__________________

1.6 Number of students received (incoming) from abroad per SEA-TVET batch

- 1-5
- 6-10
- 11-15
- 16-20
- 21 and more
- Others__________________

2. What challenges to international student mobility did the institution encounter during this pandemic?

- Travel Restrictions
- Lockdown
- Health Barriers
- Financial Barriers
- Language Barriers
- Government Restrictions
- Others________________

3. What programs for international student mobility are implemented by the institution during this pandemic?

- Webinars
- Virtual Student Exchange
- Not Applicable
- Others_____________

II. MATERIALS AND METHODS

The study used the descriptive research design. According to Shona McCombes (2019), Descriptive research aims to accurately and systematically describe a population, situation or phenomenon. It uses a quantitative research method by collecting quantifiable information to be used for statistical analysis of the population sample. It can answer what, where, when and how questions, but not why questions. A descriptive research can use a wide variety of research methods to investigate one or more variables. The study delimited its respondents to institutions in the SEAMEO network and current member institutions which submitted the letter agreement for the 5th batch SEA-TVET program. Using random sampling technique, 35 institutions participated in the conduct of this research. Likert scale was utilized in determining the challenges and opportunities in international student mobility.The interpretation of Likert scale was based on the degree of agreement where the options are Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree.

Table 1 Point, Range and Verbal Analogy

Range	Verbal Description
1.00 – 1.80	Strongly Disagree
1.81 – 2.60	Disagree
12.61 – 3.40	Neither
3.42 – 4.20	Agree
4.21 – 5.00	Strongly Agree

III. RESULTS

This shows the summary of the degree of agreement of Higher Educational Institutions as per the challenges and opportunities of student mobility in Southeast Asia. These are presented in tables following the sequence of the specific research problem.

I. Demographic Profile of the Respondent

Table 2 Country of the Institution

Country of the Institution	Frequency (f)	Percentage (%)
Indonesia	22	62.86
Philippines	9	25.71
Malaysia	3	8.57
Thailand	1	2.86
Vietnam	0	0
Total	**35**	**100**

Table 3 Type of Institution

Country of the Institution	Frequency (f)	Percentage (%)
Public (Government owned)	18	51.43
Private	17	48.57
Total	**35**	**100**

Table 4 School participation in SEA-TVET exchange programme

School participation in SEA-TVET exchange programme	Frequency (f)	Percentage (%)
1st batch	8	9.64
2nd batch	13	15.66
3rd batch	23	27.71
4th batch	24	28.92
5th batch	15	18.07

Table 5 Number of students sent abroad (out-going) per SEA-TVET batch

Number of students sent abroad (out-going) per SEA-TVET batch	Frequency (f)	Percentage (%)
1-5	14	40.00
6-10	13	37.14
11-15	3	8.57
16-20	4	11.43
21 and more	1	2.86
Total	35	100

Table 6 Number of students received (incoming) from abroad per SEA-TVET batch

Number of students received (incoming) from abroad per SEA-TVET batch	Frequency (f)	Percentage (%)
1-5	16	45.71
6-10	8	22.86
11-15	5	14.29
16-20	4	11.43
21 and more	1	2.86
None	1	2.86
Total	**35**	**100**

Table 7 What barriers to international student mobility do the institution encounter during this pandemic?

What barriers to international student mobility do the institution encounter during this pandemic?	Frequency (f)	Percentage (%)
Travel Restrictions	31	25.62
Government Restrictions	31	25.62
Health Barriers	25	20.66
Lockdown	24	19.83
Financial Barriers	8	6.61

Language Barriers	1	0.83
Mastery of topics delivered via online media	1	0.83

Table 8 What programs for international student mobility are implemented by the institution during this pandemic?

What programs for international student mobility are implemented by the institution during this pandemic?	**Frequency (f)**	**Percentage (%)**
Webinars	28	48.28
Virtual Student Exchange	22	37.93
Not Applicable	5	8.62
International Credit Transfer and Guest Lecture Series	1	1.72
Joint Research	1	1.72
Immersion	1	1.72

II. Challenges and Opportunities

Table 9 Challenges of International Student Mobility during Covid 19 Pandemic

	Item Statement (Challenges)	Weighted Mean	Verbal Interpretation
1	The institution’s program for international student mobility has been affected by the COVID-19 pandemic	4.66	Strongly Agree
2	International student mobility program of the institution did not push through because of lockdowns in our area/country	4.34	Strongly Agree
3	International student mobility program of the institution did not push through because of strict health restrictions of exchange (receiving) countries.	4.2	Strongly Agree
4	International student mobility program was hampered by language restrictions.	2.63	Neutral
5	International student mobility program was hampered by cultural differences.	2.4	Disagree
6	The institution has not developed regulations for international student mobility amidst COVID19 pandemic.	2.63	Neutral
7	The government does not allow physical travel for international student mobility.	4.34	Strongly Agree
	Overall Weighted Mean	3.6	Agree

Table 10 Other Challenges not Indicated

Government Restrictions
Vaccine, travel ban, unpredictable wave of pandemic
Internet access
Fair
Difficulty to prepare for accommodation (based on our last experience)
Travel bans and personal experience joining student mobility
Safety

Table 11 Opportunities of International Student Mobility during Covid 19 Pandemic

	Item Statement (Opportunities)	Weighted Mean	Verbal Interpretation
1	The institution has developed regulations for international student mobility amidst COVID-19 pandemic.	**3.86**	Agree
2	The institution had joined/participated/facilitated in international student mobility on a face to face level during COVID19 pandemic.	**4.11**	Agree
3	The institution had joined/participated/facilitated in international student mobility virtually during COVID19 pandemic.	**2.49**	Neutral
4	The institution has standing collaborations/agreement with foreign institutions to engage in international student mobility amidst COVID19 pandemic.	**3.97**	Agree
5	The institution has standing collaborations/agreement with foreign institutions to engage in international student mobility post-COVID19 pandemic.	**4**	Agree
6	The institution has collaborated with other organizations to provide virtual internships.	**3.74**	Agree
7	The institution is engaged in technological advancements for students such as online language and/or internet education and webinars.	**4.37**	Strongly Agree
8	The institution is willing to participate in face to face international student mobility should restrictions lighten.	**3.89**	Agree
	Overall Weighted Mean	**3.83**	Agree

IV. DISCUSSION

The following discussion show the summary of the results of the study and the degree of agreement of institutions as to challenges and opportunities to international student mobility in Southeast Asia.

Demographi Profile: Country of the Institution

Table 2 shows that 22 or 62.86 percent of the respondents were from Indonesia, while there were no respondents coming from Vietnam. This implied that Indonesian institutions are keen in participating in international student mobility programs as evidenced in a report by International Consultants for Education and Fairs (ICEF) that the most recent UNESCO data shows that there were just over 45,000 Indonesian students abroad in 2017, there are indications from other sources that this figure may be understated. The US Commercial Service uses IIE data to estimate that that there were over 69,000

Indonesian students abroad in 2018/19, with 9,130 in the US. Most Indonesian students abroad are enrolled in undergraduate programmes, but it be can be anticipated more demand for post-graduate studies as a result of the Indonesian government's greatly increased funding for the Endowment Fund. This data is also evident in a SEA-TVET directory report involving majority of participants (65) indonesian institutions engaged in the 5th Batch SEA-TVET Student Exchange progrmme.

Demographi Profile: Type of Institution

Table 3 shows that 18 or 51.43 percent of the respondents are from Public or Government owned institution, while the remaining 17 or 48.57 percent are from Private Institutions. From a study by Wong & Wu (2011), Internationalization has emerged as one of the top priorities for higher education institutions around the world. In the Philippines, Internationalization is beginning to be a core part of SUCs' organizational program development but is still in the initial phase, that is, SUCs are internationalizing within their own system. (Rivera, 2019)

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Passengers' Perspective of Philippine Airlines Within Nueva Ecija

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Abstract— *Philippine Airlines, which was established in 1941, is historically famous as the flag carrier of the Philippines and is the oldest airline in Asia. Great customer experience is associated with great significance in this industry. Which is why customer is the most important factor in the industry given by the fact that the success of an airline depends on the perception of the customers. The purpose of this study is to investigate the passengers' perception of Philippine Airlines from their personal experience towards the service quality they are providing. Descriptive research method is used in gathering the needed information for this stud and a total of 100 respondents particularly passengers of Philippine airlines. The results reveal that females, aged under 20 years old, single and earned 50 thousand and above per month are travel more than males do, although by nature, men have always been more adventurous than women. They have the power to do anything and that includes travelling, if they wish. In fact, that majority of them get to fly every once in a while, they still receive the air services they deserve. This result discloses that most of the respondents purchase their tickets below 20 thousand not only because most of our respondents fly in economy class but also because they have confidence that the airline will provide them good service quality despite their seat class. Majority of the respondents are satisfied and greatly assisted by the personnel in terms of their custom service in both departure and arrival area under the ground services. They were very satisfied with the responsiveness of the cabin crews and overall performance in terms of their inflight services.*

Keywords— ***Passengers, Perspective, Philippines Airlines, Quality, Services***

I. INTRODUCTION

One cannot deny that the aviation industry is currently a booming business and it continues to expand not only to our country but all over the world.

Great customer experience is associated with great significance in this industry. Which is why customer is the most important factor in the industry given by the fact that the success of an airline depends on the perception of the customers. Therefore, companies have to understand that people have different needs and wants in order to deliver unique experience. In this competitive industry, airlines must be committed in providing a total quality travel experience to all of their customers. Giving special importance to customer's perception of the airline and understanding them would help determine the factors of services that needs to be enhanced and improved in order to possess healthy growth and better development of the airline company.

Philippine Airlines, which was established in 1941, is historically famous as the flag carrier of the Philippines and is the oldest airline in Asia. Philippine Airlines charts its course in aviation history towards becoming the country's largest airline company and a five-star full-service legacy carrier by 2020. They endeavor to create a product that would make them truly proud and their customers satisfied. Philippine Airlines' aim is to accord their customers an experience which they would remember them by, through a consistent effort to enhance their service delivery and regular trainings of their employees. They constantly try to improve their current systems and policies with customers in mind.

Maintaining a distinctive competitive advantage is becoming more difficult as similar strategies are being followed by all leading airlines, which is why customer experience is the perfect tool against competitors. Driven by competition, airlines focus at improving their service quality and securing customer loyalty. It is also essential to build trust and create personal relationships with your customers.

Perceived quality therefore forms the customer's judgment regarding an entity's overall success. It gives the entity a competitive edge in the ordinary course of its operations. Perceived quality results from comparing the customer's expectations with how they perceive the service that was delivered. If the product or service meets the needs of the customer, then the customer is deemed to be satisfied but if the minimum expectation is not met, then the customer is said to be dissatisfied (Zeithalm and Bitner, 2003).

There are dozens of factors that could benefit in the success of an airline and customer satisfaction is one of them. It is a reflection of how a customer feels about your services. If you do not care about their perception and satisfaction about your services, then do not expect them to show interest or care with your services, either.

Quality of service significantly drives the airline image and what passengers believe about the service and how they perceive it has the strongest impact on the image of the airline (park et al., 2005). Customer satisfaction of a firm will be increased by improving the customer service factor and as a result, the company's performance would be better. In other words, providing poor service will lead to negative influence on the image and survival of a service company (Boshoff and Staude, 2003).

The purpose of this study is to investigate the passengers' perception of Philippine Airlines from their personal experience towards the service quality they are providing. It seeks to understand and manage the importance of customer perception and identify ways on how to improve the attributes the airline is lacking.

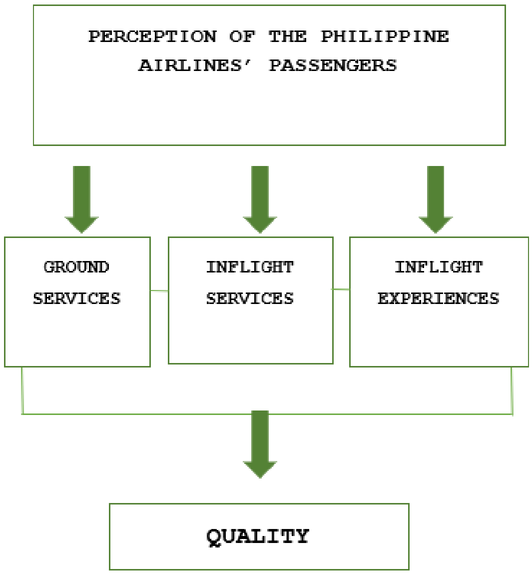
II. CONCEPTUAL FRAMEWORK

STATEMENT OF THE PROBLEM

The purpose of this study is to investigate the passengers' perception of Philippine Airlines from their personal experience towards the service quality they are providing. It seeks to understand and manage the importance of customer perception and identify ways on how to improve the attributes the airline is lacking.

Specifically, it sought to answer the following:

1. **What are the socio-demographics of the respondents in terms of:**
   1.1 gender;
   1.2 age group;
   1.3 civil status;
   1.4 occupational status; and
   1.5 household income?
2. **What are the respondents' travel information with Philippine Airlines in terms of:**
   2.1 frequency of flying;
   2.2 purpose of passengers' travel;
   2.3 air travel classification;
   2.4 seat class that they usually take;
   2.5 when do they book their plane tickets;
   2.6 how do they book their plane tickets;
   2.7 ticket allowance; and
   2.8 refunds?
3. **What are the respondents' perspective with regards to the service quality of Philippine Airlines in terms of:**
   3.1 ground services;
   3.2 inflight services; and
   3.3 inflight experiences?



III. SIGNIFICANCE OF THE STUDY

The findings of this study were significant to the following:

Future Researchers. This study will act as a great reference and starting point if they are to conduct the same topic. It will also give the future researcher additional ideas and knowledge.

Future Customers. This study will act as an instrument in bringing light to the issues the airline is facing and avert future customers from encountering such inconvenience in the airline.

Airline industry. The end result of this study will allow the ones responsible for the management of the airline to have better comprehension in possible ways of obstructing the problems from occurring again. This will give them the opportunity to ameliorate their quality of service and obtain better satisfaction from the customers.

Tourism Students. This study will serve as a great resource to bring forth clear and wide understanding to the tourism students and also awareness on how airports and airlines work when it comes to providing and improving the quality of their passenger services that will be significant and useful for those students who are interested in the same industry when they graduate.

SCOPE AND DELIMITATION

This study was aimed to evaluate the perception of passengers in Philippine Airlines in terms of their ground and inflight services. This is to identify the issues they have encountered and making the customers' experiences as a tool in improving their passenger services.

The questionnaire was made completely by the researcher to gather the data, conducted only among one hundred (100) passengers that flew with Philippine Airlines before.

DEFINITION OF TERMS

The following terms are defined to have clearer understanding of the study:

Airline Industry – providing of air transport for passengers and cargo by using of aircraft.

Aviation Industry – activities surrounding mechanical flight and the aircraft industry.

Comfort – condition of mind of passengers which expresses satisfaction with the thermal environment.

Competitiveness – situations or activities in which people or firms compete with each other, and a strong desire to be more successful than others.

Customer Loyalty – extent to which customers consistently have positive emotional experience, physical attribute-based satisfaction and perceived value of an experience.

Customer Perception - marketing concept that encompasses a customer's impression, awareness and/or consciousness about a company or its offerings.

Customer Satisfaction - a measure of how well services or products, provided by an organization, meet or exceed the expectations of customers.

Frequency – the role of something that occurs or repeated over a particular period of time.

Ground Service – the wide range of services provide to facilitate an aircraft flight, which also includes both customer service and ramp service functions.

Inflight Experience – the overall entertainment or services the passengers encountered that also determines their overall perception or satisfaction.

Inflight Service – this is done and served, or shown during an air voyage, both free and paid that adds to the passenger's experience and their convenience.

Perspective - a particular way of viewing things that depends on one's experience and personality.

Philippine Airlines – the flag carrier of the Philippines; largest airline company in the country

Service Quality – measures how well a service is delivered and how it conforms to the customer's expectations.

IV. REVIEW OF RELATED LITERATURE AND STUDIES

Presented in this chapter are the related foreign and local literatures and studies that would be of great help in the pursuit of this undertaking. Those that were included in this chapter helped the researcher in familiarizing information and to have a better understanding in terms of wider perspective on the study being conducted.

Local Literature

Every industry requires better quality service, which is crucial in the airline industry. It is a known fact that airline industry plays an important role for the development of the economy. This industry offers vast amount of services for the satisfaction of the people, it has a great significance in terms of moving people or goods in places that are not accessible by vehicles, more especially when long distances are involve. Nowadays, almost anyone can experience the services offered by the airline industry with not much difficulty.

According to the WCC Aviation Company, the airline industry in the Philippines continues to be a booming business. They also stated that this year, 2018, "it is projected that the growth of the industry is going to be robust through various joint-agreements with our neighboring countries, as well as the expansions underway."

One of these expansion projects is the re-fleeting plan of the top airlines in the country— Philippine Airlines and Cebu Pacific. Philippine Airlines, in particular has been considering of acquiring an aircraft that is appropriate for long-haul, “which would increase the number of passenger traffic”

Another is the launching of a new airbus by the Philippine Airlines. “The Airbus A350’s all-new design includes the latest innovations in aviation that improve operational performance. The aircraft offers true long-range capability, more fuel efficiency, lower carbon emissions, and less noise versus previous-generation aircraft. It is also equipped with the most efficient aero-engine flying today.” The airbus can accommodate up to 295 passenger and flies at 500 knots.

Airline industry face challenges like any other existing industries. Recently, AirAsia underwent through criticisms on social medias as the “worst” and “lousiest” airline after a Facebook user named Claudette Cledera shared her unpleasant experience by posting it on her social media account. According to Cladera, (2017), She had the worst experience with the AirAsia management situated at the Puerto Princesa airport. The security guard from the said company, allegedly, disrespectfully took Cladera’s carry-on suitcase without saying a word, then weighted it and said the luggage already exceeded the limit for hand-carry luggage. However, Cladera was shocked when she saw that her suitcase went over 7 kilograms (kg). She claimed that when she and her parents checked her suitcase again, it only weighted approximately 4 kilograms (kg). Tons of netizens assumed that the management made an atrocious act to swindle from their customers, which made the people lose their trust and certainty on the company. Another Facebook post floated around the internet, (in December 2017), The Cavite Governor, Mr. Remulla slammed AirAsia for being the “lousiest airline in the world”. Remulla said that his 88-year-old mother-in-law, Vilma Diaz, was charged HK$60 (Php. 384) and an additional HK$450 (Php. 2,882) just so somebody would assist her. Remulla expresses his resentment by stating, “Do airline passengers have rights? When you are old and weak, airlines like AirAsia will not provide you a wheelchair. They will not lend you any” The governor added, “They will not care unless we boycott. Senior citizens are given rights in the Philippines by all the other airline except AirAsia *na mukang pera* (greedy). Many netizens concurred with Remulla’s post and suggested that AirAsia to review their company’s policy. Another incident that affected the airline industry was the issue regarding the technical glitches in Cebu Pacific that caused the check-in system to go off-course. The incident results long lines and overcrowding on the check-in procedures which caused displeasure among the passengers due to jam-packed space, some of the passengers had to be checked-in manually. Nonetheless, the low-cost carrier explained that, “they have experienced a problem with its own fiber optic lines, resulting in downtime in its check-in system.” They explained briefly what caused the mishap and express their apology to the passengers involved, moreover, the management execute actions to resolve the situation immediately.

These circumstances are few of the issues that the airline industry is currently facing, and it shows that service quality is one of the main factors that greatly affects the progression of the industry. The role of service quality is crucial in terms of customer satisfaction, it is the key factor for sustainable development and continuous growth of the economy. Customer satisfaction has a great impact on influencing the perception of the stakeholders as well as the audience, through transferring of information with the use of Social medias and other materials.

According to Kapdesk, (2016) customer satisfaction begins with customer service. In order to meet customer satisfaction, one should provide high-quality service in every assistance that will be offered.

Foreign Literature

Service quality is broadly perceived as a multidimensional concept because every customer analyzes diverse set of dimensions on company’s product or services. An author defined service quality as “An assessment of how well a delivered service conforms to the client’s expectations.” It is said to be considered as a critical dimension of competitiveness as stated by Lewis (1989).

Customer satisfaction, on the other hand, is defined as an emotional feeling by the consumers after experiencing a certain service which in turn leads to an individual overall attitude towards purchasing of service (Oliver, 1981). Presence of quality service and remarkable customer satisfaction are significant aspects of every industry. Zahari et al., (2008) suggested that service quality is an important subject in both the public and private sectors, in business and service industries.

Airline industry is one of the leading service-based industry in the market and it is a known fact that the airline market has becoming competitive due to free competition and several airline choices. Thus, providing high quality service and building pleasant perception are crucial factors of company’s survival and competitiveness. Since Park et al (2009) mentioned, delivering good service quality is essential in airline industry due to it can impact customer satisfaction, customer loyalty and the choice of company. Customer satisfaction in airline industry has become fundamentally important and the free competition made it more peering. Customers are the sole judges of service quality, so it is crucial that companies meet customers’ expectations to provide them satisfaction. Airline companies cannot rely fully on their service standards because it may not meet the customers’ expectations.

Hence, we can say that when the expectations of the customers are more than the quality of service offered, it is when dissatisfaction occurs.

Passenger satisfaction is one of the substantial assets for air business in today’s competitive environment. When passengers are satisfied with products or services received, they will buy more and frequently (Archana & Subha 2012; Namukasa, 2013)

These days, airline industry is becoming more safer and more efficient, it is evidently prospering caused by rapidly growing tourists. Naturally, every industry faces different challenges and issues. Over the past couple of years, airlines have experienced major disruptions caused by everything from electrical fires to catastrophic disease outbreaks. Furthermore, there are challenges caused by the shifting of economic and political climates. According to Zhang, (2018) these are some of the issues that the airline industry is facing at this moment:

Congestion: The increase in the number of flyers along with the airlines' strategic shift towards increase of frequency of flights, which means more planes and more passengers. This results in crowded airport terminals and an increase in the number of delays.

Terrorism: Even though the frequency of terrorist acts targeted at airliners has gone down, incidents like the shoe bombers and the tragic events of 9/11 serve as a reminder they remain a substantial and persistent threat. As a result, airlines and security services around the world have to remain vigilant. Over the past 15 years, security screening procedures have become increasingly stringent. This has resulted in longer checkpoint wait times and complaints from the traveling public.

Passenger comfort: In many respects, the industry's search for greater profitability has been to the detriment of passenger comfort. For investors, the lower the unit costs the better. For airlines, an effective way to reach that target is to stuff more seats into each plane. In addition, airlines have become much more disciplined when it comes to flooding the market with additional flights. The capacity discipline along with a greater number of seats per plane has resulted in full planes with less room for individual passengers.

Politics: Since airlines serve as a bridge between nations or even as a flying ambassador for its homeland, it is all but inevitable that they wind up in the middle of political scuffles. Strife between nations usually results in a hit to the operations and profitability of airlines.”

Technology: Technology has been great for airlines. Biometrics is going to be a changer for airport experience. While hybridization is expected to usher in a new age of flight. Technology has already helped revolutionize everything from in-flight entertainment to freeing flights crews from their cumbersome flight manuals. However, as the airline industry and the infrastructure that serves it becomes increasingly dependent on technology, it's also going be even more vulnerable. Insufficient investment in technology infrastructure over the past decade has resulted in a spate of computer outages that can cripple an airline's operations for days on end. With the growing threat of cybercrime, the airline industry will have to work much harder to stay ahead of the curve.

Labor relations: An airline's employees are its lifeblood. Which is why poor labor relations can cripple an airline both financially and operationally.

Pilot shortage: As airlines around the world expanding their fleets, everyone is looking for people to do the flying. But there doesn't seem to be enough people around to fill those jobs. After all, it takes a tremendous amount of time and money to train a pilot. One airline executive clarified the situation by saying there isn't a shortage of pilots, there's a shortage of good, qualified pilots.

Fume events: This occur when toxic smoke or odors from the plane's engines find their way into the cabin. "A toxic fume event can result in immediate incapacitation and have a long-term adverse impact, and it can affect everyone on board," Allied Pilots Association President Captain Dan Carey said in a statement.

Pets: Over the past couple of years, the sharp increase in the number of animal-related incidents on board planes has increased dramatically. Delta Air Lines reported an 84% spike since 2016. Recent incidents include the mauling of a passenger by an emotional support dog on a Delta flight and the death of a puppy on board after it was placed in the overhead compartment.

Fuel prices: Fuel is an airline's greatest cost. The industry's new-found profitability has certainly been helped by a sharp decline in oil prices in 2014. However, crude prices are rebounding. Even though it may not reach its previous heights, airlines will have to learn how to survive in a higher cost environment.

Climate change: In 2017, Hurricane Harvey devastated Texas. Stuck in the middle of the storm was United Airline's mega hub in Houston and roughly 10,000 of its employees. Fortunately, the airline and its employees were able to get back on their feet. But as our climate changes, the number of extreme weather events has increased dramatically.

It is a well-known fact that every industry has their own challenges and issues. Consequently, they undertake effective set of actions to deal and resolve the matter successfully for the continuous development and satisfaction of the stakeholders. In order to strive for better service, airlines created strategic alliances to achieve global connectivity. Now to provide better service the carriers have started to disassociate services that were included in the price in the past. This has created a possibility for the customer to avail better services and flexibility of planning, thereby improving services (Hadjetian, 2015)

Local Studies

Great number of people observed that "traveling is one of the exquisite experiences that a person might have in their extent of living" but how can a tourist appreciate traveling if their expectations have not met and resulting to dissatisfaction.

According to a study entitled, "Guide to Sleeping in Airports", Ninoy Aquino International Airport, now named as Manila International Airport— Terminal 1 in the Philippines was considered as one of the worst airports in the world in 2013. Travelers and airline passengers cast aspersions for its tumbledown facilities and atrocious services. A few even dubbed Manila International Airport as the "Worst airport in Asia" Francisco (2018) stated that, it was determined by its lack of comfort facilities, crowded terminals, lack of food services and unpleasant surroundings.

Rhoades (2012) suggests that one of the most critical issues facing the airline system today is the ground access. Almost every airline passengers' satisfaction begins and ends on the ground area of an airline. Hence, in order to meet their expectations, the role of service quality should be particularly supervised with highest quality possible. Clean or a pleasant surrounding has a great impact on the perception of the passengers along with their satisfaction. Francisco (2018), claimed that cleanliness can be the "strength and weakness" of an airline. Every passenger anticipates a clean and systematized surrounding therefore, it is necessary for every airline to observe the cleanliness services they execute.

Ingram (2012) stated that, "increasing staff training and refining the airline ambiance is the best way to improve service quality." Each airline is different and faces its own set of unique challenges. Hence, solutions must be tailored based on the airline's strength and weaknesses along with deep understanding of the passengers.

Foreign Studies

Enrichment of passenger comfort in an airline industry is certainly challenging. One cannot repudiate the fact that a passenger's satisfaction holds diverse outcome. Satisfaction begins with one's expectations being met, which can be achieved by utilizing high quality service. Providing a quality service to airline customers starts with setting standards into customer satisfaction. These standards include the following airline services: accessibility, amenities, cleanliness, customer service, comfort and safety.

Darcy (2016) divides the term access into three dimensions: Physical access, sensory access and communication access. Enclosed by all three categories, the supplying of access should not be regarded as a problem area. Instead, access provision needs to be viewed as an inclusive marketing process, which allows tourism players to realize the potential of 'accessibility' for the marketing of tourism products and services to the widest possible client base (Darcy, 2016).

Accessibility in tourism industry is defined by Darcy and Dickson (2009) as an ongoing endeavor to ensure tourist destinations, products and services are accessible to all people, regardless of their physical limitations, disabilities or age. Eichhorn (2010) stated that, ensuring access to travel and tourism opportunities for people living with a disability as well as for the entire population requires knowledge and design structures that are inclusive for all citizens.

According to Ma et. Al. (2015), Customer Service is one of the most important notion of service marketing. Furthermore, Clottey and Coller (2008) stated that, service quality has consequently been identified as one of the most important issues in the service industry.

A study from the University of Botswana, entitled "Customer satisfaction in the airline industry" noted that, "Customer satisfaction is considered one of the most important factors by organizations to improve performance. The airline industry is not an exception to these organizations. In fact, customer satisfaction comes as part of the important factors to counteract the challenges associated with the airline industry." Oliver (2017) stated that satisfaction is the consumer's fulfillment response. It is a discernment that a product or service produced a high level of fulfillment that had successfully met the customers' expectations. When customers are satisfied from the service offered, the probability of the loyalty of the customers will most likely to rise. Delivering high level of service quality is a must to achieve high level of customer satisfaction and receive a positive perception by the customers.

V. RESEARCH METHODS AND PROCEDURES

This chapter presents and discusses the research methods used for this study, the respondents, the research locale, data gathering procedure and statistical treatment of the data.

RESEARCH DESIGN

Descriptive research method is used in gathering the needed information for this study. Specifically, the researcher utilized a questionnaire type of descriptive research method which enabled the researcher to gather information from the respondents without the respondents having any difficulties in answering the questions regarding their perception in the service quality of Philippine Airlines.

RESEARCH LOCALE

This study was conducted in the province of Nueva Ecija.

Map of Nueva Ecija

THE RESPONDENTS

The respondents of this study were previous passengers of Philippine Airlines within Nueva Ecija, consisting of one hundred (100) respondents.

RESEARCH INSTRUMENT

This study utilized a questionnaire for confirmation to gather the data needed.

The questionnaire is comprised of three parts.

The first part involves the respondents' information about their socio-demographic profile which includes the gender, age, occupational status and household income.

The second part of the questionnaire asked about the respondents' travel information in terms of their frequency of flying, purpose of their travel, their air travel classification, seat class they usually take, the day they usually book their tickets, cost of tickets and if they experienced any refunds or not.

The last part of the questionnaire incorporates and determines the quality of service performance the airline executed in terms of their ground services, inflight services, and also asked about the overall inflight experience of the respondents.

It was evaluated and measured by using the numeric scales with the following interpretation:

5 – Very Satisfied (VS), which means that the respondent is pleased with the condition all the time

4 – Satisfied (S), which means that the respondent is pleased with the condition most of the time.

3 – Neutral (N), which means that the respondent is neither pleased or dissatisfied.

2 – Dissatisfied (D), which means that the respondent is unhappy with the condition most of the time.

1 – Very Dissatisfied (VD), which means that the respondent is unhappy with the condition all the time.

DATA GATHERING PROCEDURE

The researcher constructed a questionnaire that was distributed to the total of one hundred (100) respondents within Nueva Ecija who were the previous passengers of Philippine Airlines. The questionnaire was then retrieved and computed to identify the respondents for the study, with their provided answers going through the process of using statistical treatment, where the results were tallied, tabulated, and interpreted by the researcher.

STATISTICAL TREATMENT OF THE DATA

The following statistical treatment was used for the socio-demographic profile and travel information of the respondents:

a. **Percentage** – this is used to determine the percentage of the existing data

$$\text{Percentage (\%)} = \frac{\text{frequency}}{\text{number of respondents}} \times 100$$

b. **Frequency of Distribution –** this was utilized to count the occurrences of the variables using categorized information in a systematic way.

Under this is the statistical treatment used for the respondents' perspective of the service quality of Philippine Airlines:

c. **Weighted mean –** this is obtained by dividing the total weighted score by the total frequency.

The formula is:

$$WM = \frac{TWF}{N}$$

In which WM = weighted mean

TWF = total weighted frequency

N = total number of respondents

In order to determine the satisfaction level of the respondents, a rating scale has been devised, as follows:

SCALE	WEIGHTED MEAN	VERBAL INTERPRETATION
5	4.51-5.00	Very Satisfied
4	3.51-4.50	Satisfied
3	2.51-3.50	Neutral
2	1.51-2.50	Dissatisfied
1	1.00-1.50	Very Dissatisfied

PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

This chapter shows the result of the study encompassing the socio-demographic profile of the respondents; the travel information of the respondents; and the perspective of the respondents in the service quality of Philippine Airlines.

Table 1: Socio-Demographic Profile of the Respondents

Table 1.1 – Gender of the Respondents

Gender	Frequency (f)	Percentage (%)
Male	47	47.00
Female	53	53.00
Total	**100**	**100.00**

Table 1.1 shows that 47 percent (47%) of the respondents are looked over as male, while the remaining 53 percent (57%) are female.

The results reveal that females travel more than males do, although by nature, men have always been more adventurous than women. They have the power to do anything and that includes travelling, if they wish. Some women travel to develop humility and compassion as they discover new ways of life to travel the world. A few reasons of their travel are to improve and enhance their personal growth and independency, reflect, seek for adventure and also experience and learn about the destination's culture and lifestyle.

If they are not traveling alone, they are traveling in small groups like families or with other women for bonding experiences. (Linda Landers, 2018). According to Forbes, 80% of all travel decisions are made my women. Regardless of who they travel with, who pays for the trip, or where they go. 75% of those who take cultural, adventure or nature trips are women. Women also travel differently than men do. 87% of women say they go for the beautiful scenery, compared with 72% of men. (Yesawich, Pepperdine, Brown % Russell, 2017). Women travel more because they have more money to spend, and it is because they have less vacation days and want to make the most of the time off.

Table 1.2 – Age of the Respondents

Age	Frequency (f)	Percentage (%)
Under 20	67	67.00
21-35	13	13.00
36-50	15	15.00
50 & above	5	5.00
TOTAL	**100**	**100.00**

Table 1.2 shows that 67 percent (67%) of the respondents are under 20 years old, 13 percent (13%) are 21-35 years old, 15 percent (15%) are 36-50 and the remaining 5 percent (5%) are 51 & above.

This result shows that greater part of the respondents who travel are under 20 years old because they have the higher desire and curiosity to experience building up their independence, enhance their social capability, try new things and learn different cultures and things they wouldn't at home because teenage years are not only the peak to adulthood but are also the perfect time for traveling.

According to Sarah Hinder (2015), a family travel expert, few reasons why teenagers take interest in family trips is because it allows them to experience the diverse cultures and ways of life. Sometimes, the culture shock and first-hand experience of how others live life is a humbling and important lesson for teenagers to realize that not everything is about them. It teaches perspective and respect. It can also be an empowering experience particularly for young people. Adapting to a foreign environment for the first time can sometimes be a frightening experience, especially for those who have never been outside the comforts of home. However, navigating foreign streets, engaging with locals and diverse cultures are skills that are both confidence-building and empowering- teens will find that they are more capable, mature and confident that they once thought. Studies have shown that spending quality time and creating closer bonds with affectionate, understanding parents result in several lasting benefits for teens. These include lowered chances for engaging in harmful risk-taking behaviors and lower rates of anxiety and depression.

Table 1.3 – Civil Status of the Respondents

Civil Status	Frequency (f)	Percentage (%)
Single	73	73.00
Married	20	20.00
Widowed	7	7.00
TOTAL	**100**	**100.00**

The table indicates that seventy-three or 73 percent (73%) of the respondents are single, twenty or 20 percent (20%) of them are married while, seven or 7 percent (7%) of them are widowed.

This result implies that people without commitments has more confidence and freedom in terms of traveling and gaining more experience.

According to Abta's latest annual Holiday Habits survey (2018), one in nine holidaymakers reported that they took a holiday on their own in the previous 12 months, the author also stated that it is a much more convenient experience if one travels alone, without any responsibilities. Brech (2018) suggests that "No dating, no drama" with regards to traveling.

Table 1.4 – Occupational Status of the Respondents

Occupational Status	Frequency (f)	Percentage (%)
Student	68	68.00
Employed	30	30.00
Unemployed	2	2.00
TOTAL	**100**	**100.00**

Table 1.4 indicates that sixty-eight or 68 percent (68%) of the respondents are students, thirty or 30 percent (30%) are employed while two or 2 percent (2%) are unemployed.

This result shows that majority of the respondents are students implying that in current time, most people who purchase the services offered by the Philippine Airline are undergraduate owing to the fact that traveling is most beneficial to students because it helps them to be independent, confident and gain vast amount of experiences.

According to Rodriguez (2013), It's difficult to travel once you are out of school. The hardships of finding a job, securing a home, paying bills, and settling down with a family are realities that impede peoples' abilities to travel.

Table 1.5 – Household Income of the Respondents

Household income	Frequency (f)	Percentage (%)
Below 10,000	11	11.00
11,000-25,000	16	16.00
26,000-35,000	29	29.00
36,000-50,000	14	14.00
50,000 & above	30	30.00
TOTAL	**100**	**100.00**

Table 1.5 shows that eleven or 11 percent (11%) of the respondents' household earns within the range of ten thousand pesos (P10,000) and below, sixteen or 16 percent (16%) earns eleven thousand pesos (P11,000) to twenty thousand pesos (P20,000), twenty-nine or 29 percent (29%) earns twenty-six thousand pesos (P26,000) to thirty five thousand pesos (P35,000), fourteen or 14 percent earns thirty-six thousand pesos (P36,000) to fifty thousand pesos (P50,000) and lastly, thirty or 30 percent (30%) of the respondent' household earns fifty thousand pesos (P50,000) and above.

This result shows that the household income that has the highest range of earnings has more ability of purchasing services in terms of air travel. People nowadays, seek to travel by air especially when they possess good amount of money. It means the higher the income, the higher the possibility to travel.

"High-income households comprise almost half of the market, which makes consumer under 40, indulge the opportunities of traveling" Harteveldt (2015) Moreover, Montali (2017) suggests that "Travel demand is booming and with the global economy on an upswing, travel brands are looking to build relationships with consumers that can afford a bit more when it comes to transport, accommodations, in-destination activities and other travel products and services."

2. Travel Information of the Respondents

Table 2.1 – Frequency of Flying of the Respondents

How frequent do the respondents fly	Frequency (f)	Percentage (%)
Occasionally	84	84.00
Frequently	16	16.00
TOTAL	**100**	**100.00**

Table 2.1 indicates that eighty-four or 84 percent (84%) of the respondents occasionally travels by air while the remaining sixteen or 16 percent (16%) travels frequently.

This result implies that despite the fact that the majority of the respondents get to fly every once in a while, they still receive the air services they deserve. Moreover, frequent flyers possess more opportunities in terms of experiencing services the airline offers.

According to Seah (2014), people nowadays, especially those who work fulltime and the undergraduates do not possess a lot of free time to spare in terms of travelling resulting to occasional travel.

Table 2.2 – Respondents' Purpose of Travel

Purpose of travel	Frequency (f)	Percentage (%)
Business Purposes	12	12.00
Educational Purposes	0	0.00
Vacation	43	43.00
Special Occasions	21	21.00
Holiday	5	5.00
To visit Friends/ Families	18	18.00
TOTAL	**100**	**100.00**

Table 2.2 shows that the respondents that has the percentage of 12 percent (12%) travel for business purposes, 43 percent (43%) travel for vacation, 21 percent (21%) travel because of special occasions, 5 percent (5%) travel for holidays, 18 percent (18%) travel for the sole purpose of visiting their families and friends and none for educational purposes.

This result reveals that majority of the respondents travel for vacation which implies that most respondents desire for relaxation and recreation.

According to Imafidon (2018), nowadays, most people utilize the benefits of vacation to reduce stress, improve productivity and creativity and widen their perspective.

Table 2.3 – Respondents' Air travel Classification

Air Travel Classification	Frequency (f)	Percentage (%)
Domestic Flight	71	71.00
International Flight	29	29.00
TOTAL	**100**	**100.00**

Table 2.3 sums that seventy-one or 71 percent (71%) of the respondents travel domestically while twenty-nine or 29 percent (29%) travel internationally.

This result shows that majority of the respondents availed domestic flight. This implies that most respondents find it more convenient to travel locally rather than traveling to foreign countries. Furthermore, they appreciate the natural resources, sceneries and attractions that our country offers.

Wilson (2017) stated that, "domestic travel offers certain advantages, especially in large countries." The writer also suggests that traveling internationally can be difficult in most of the world due to the fact that there is a need to arrange such things as Visas and it is sometimes necessary to plan longer months in advance.

Table 2.4 – Seat Class of the Respondents

Seat class	Frequency (f)	Percentage (%)
Economy	95	95.00
Business Class	5	5.00
First Class	0	0.00
Total	**100**	**100.00**

Table 2.4 shows that ninety-five or 95 percent (95%) of the respondents take economy as their seat class, while the remaining five or 5 percent (5%) take business class. Moreover, there were no respondents who experienced the distinctive quality of first class.

This result implies that majority of the respondents choose the standard option hence, most affordable alternative that the airline company is offering. Despite of being the lowest cost available, the service quality offered is nevertheless, at the highest quality.

Juddery (2017), cited that "the cost of economy class has become so cheap it could be considered a quicker alternative to driving or taking a train but with a better service quality" The author added, "in the event of a plane crash for an instance, economy class is considerably safer. A study by *Popular Mechanics* magazine surveyed all crashes from 1971 to 2013 and found that survival rates in the rear seats were 69 percent, as opposed to 49 per cent at the front."

Table 2.5 – When do the Respondents book their ticket

Booking of Tickets	Frequency (f)	Percentage (%)
Same week of departure	32	32.00
1-3 months before	53	53.00
4-8 months before	15	15.00
More than a year before	0	0.00
TOTAL	**100**	**100.00**

Table 5 shows that 32 percent (32%) of the respondents book their tickets the same week of their departure. The 53 percent (53%) 1-3 months before, the 15 percent (15%) 4-8 months before, and none for more than a year before.

This result discloses that most of the respondents book their tickets 1-3 months before, mostly from domestic flight, to get the best deals possible since the prices can increase.

Since most of our respondents travel in domestic flights, booking tickets very much in advance is not required.

According to Ashwin Jayasankar (2016), domestic flights are 27% cheaper when booked more than one month in advance, as compared to last minute.

Table 2.6 – How do the Respondents book their ticket

Way of booking tickets	Frequency (f)	Percentage (%)
Airline counter	6	6.00
Online travel discount	66	66.00
Travel agency	28	28.00
TOTAL	100	100.00

Table 2.6 shows that 6 percent (6%) of the respondents book their tickets through the airline counter. The 66 percent (66%) of the respondents book their tickets through online travel discount, and the 28 percent (28%) are through the travel agency.

The result shows that most of the respondents' way of booking their tickets is through online travel discount mainly because of the discounts and deals they offer. Their prices can be often cheaper than booking direct and their tickets typically get issued almost immediately. Sites such as TravelGo, Traveloka, Expedia, Agoda, Skyscanner offers tickets and reservation for Philippine Airlines flights.

There are few reasons why customers prefer to book airline tickets online according to Taylor Odgers, (2017) a Marketing Specialist. First is, customers can find detailed information on any product. Consumers like to see reviews and learn of the specific details about their purchases and clerks aren't always available or in the know. Second is the ability to find products and booking online is available. Consumers and travelers are living busy lives and aren't always able to go into a shop or make time to call and ask questions to make reservations during business hours. Third is that online bookings are accessible to customers from anywhere. Tourism consumers also need more accessibility as many traveling customers can come from different time zones and speak different languages. Fourth is, it is convenient for sharing and storing important information. Booking tours and hotel rooms often require several important documents meaning they can receive all of these important documents and notifications on their phone or computer and have instant access when they need it. Lastly, customers want control over their buying experience.

Table 2.7 – Ticket Allowance of the Respondents

Ticket Allowance	Frequency (f)	Percentage (%)
Below 20k	78	78.00
21k-30k	13	13.00
31k-50k	4	4.00
51k & above	5	5.00
TOTAL	100	100.00

Table 2.7 shows that 78 percent (78%) of the respondents purchase ticket fare that costs 20,000 below, the 13 percent (13%) 21k-30k, the 4 percent (4%) 31k-50k and the 5 percent (5%) 51k & above.

This result discloses that most of the respondents purchase their tickets below 20 thousand not only because most of our respondents fly in economy class but also because they have confidence that the airline will provide them good service quality despite their seat class. Not only do they prefer an affordable price but also thinks that spending more money on the destination itself is much important than the ticket allowance.

According to Philippine Airlines, they regularly run promotional sales on many of their popular routes and applies these discounts to give promo fares and cheap flight tickets to their passengers. These sales usually happen on significant weekends with public holidays like Independence Day. Even when they are not running a promo sale, you can find great deals and low-cost airfares by using Skyscanner Philippines to search and compare their prices and the other airlines.

Table 2.8 – Do the respondents asked for a refund

Ticket Refund	Frequency (f)	Percentage (%)
Yes	0	0
No	100	100.00
TOTAL	100	100.00

Table 2.8 shows 100 percent (100%) of the respondents answered 'No' in experiencing any ticket refund with the airline and none for the respondents experiencing any ticket refund.

The result shows that the reason our respondents did not experience any ticket refund is because they hold such a great reliance with the airline, and also, none of them decided to cancel their flights due to any personal issues and were sure to take the flight during that time.

According to Philippine Airlines, they exert their utmost efforts to ensure that their customers' flight departs and arrives on time.

3. Quality of Airline Services

Table 3.1 – Respondents' level of satisfaction with regards to the Quality of Ground Services of Philippine Airlines

Quality of Ground Services	WM	VI
DEPARTURE		
Check-in process	4.34	S
Security Screening	4.54	VS
Emigration	4.42	S
Customs	4.54	VS
Boarding	4.50	S
ARRIVAL		
Baggage Carousel	4.47	S
Immigration	4.59	VS
Customs	4.61	VS
OWM	**4.50**	S

Table 3.1 illustrates the Quality of the Ground Services of Philippine Airlines based on the perceptions of the past passengers of the airline.

This table that contained the different ground services in the Philippine Airline received an overall weighted mean of 4.50 with the verbal interpretation of Satisfied. The result reveals that the respondents are satisfied in terms of the service quality of the ground services in Philippine Airlines. The table also indicates that the customs in the arrival procedures has the highest weighted mean of 4.61 with the verbal interpretation of Very Satisfied while, the check-in process has the lowest weighted mean of 4.34 with the verbal interpretation of Satisfied.

Furthermore, majority of the respondents felt that the custom services in the arrival procedures had fulfilled their expectations. They were very satisfied with regards to the assistance offered by the personnel and the comfort in terms of the process that occurred.

On the other hand, majority were satisfied with the check-in services offered by the airline yet, it received the lowest weighted mean in terms of the quality of ground services.

According to Cruz (2018), some past passengers of Philippine Airlines claimed that the check-in process of the airline had some issues in terms of proper queuing and handling long stagnant lines. But nevertheless, the ground employees provided high quality and friendly service.

Table 3.2 - Respondents' level of satisfaction with regards to the Quality of Inflight Services of Philippine Airlines

Inflight Services	WM	VI
Courtesy of Cabin Crews	4.59	VS
Grooming and Appearance of Crews	4.65	VS
Responsiveness of the Crews	4.67	VS
Pilot's communication w/ the passengers	4.52	VS
Quality of Flight Meals	4.16	S
Entertainment programs offered	3.84	S
OWM	**4.41**	S

The service quality of the airline's overall weighted mean with regards to their Inflight Services were 4.41, where the Responsiveness of the Cabin Crews (4.67) with a verbal interpretation of Very Satisfied exhibits the highest attribute in inflight services while Entertainment Programs offered (3.84) with a verbal interpretation of Satisfied as being the lowest. Larger part of the respondents answered that they are very satisfied with the responsiveness of the cabin crews for they respond positively to their complaints, they also listen and cater to their needs. They also said that the cabin crews manage disruptive passengers very well while the minority are not really satisfied with the entertainment programs offered by the airline because it does not completely serve as a great alternative to entertain and divert themselves with their favorite shows and movies on the screen whenever they do not feel like using their mobile devices.

Table 3.3 – Respondents' level of satisfaction with regards to their Inflight Experiences with Philippine Airlines.

Inflight Experience	WM	VI
Atmosphere of the craft	3.75	S
Luggage Space	4.36	S
Comfort of seating	4.38	S
Cleanliness of the aircraft	4.35	S
Noise level of the aircraft	4.06	S
OWM	4.18	S

The overall weighted means in terms of the service quality of the airline with regards to the respondents' inflight experience were 4.18, where the Comfort of Seating (4.38) with a verbal interpretation of Satisfied as the highest in their inflight experience.

It shows that the respondents are satisfied with the comfort of their seating during their flight, although most of them fly in economy class, because they manage to find ways to get themselves comfortable even without a generous leg room. They either wear comfortable clothes, bring a travel pillow with them, they also keep their luggage in the overhead locker to keep the space by their feet free, and some of them also have their own strategies in getting the best seat.

VI. SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

This chapter contains the summary of the research work undertaken, the conclusion drawn and the recommendations presented by the researcher.

This research work was undertaken to ascertain the perception of the passengers with regards to the role of service quality provided by the Philippine Airlines.

The data were gathered using standard questionnaires. The checklist on socio-demographic covered the following variables: gender, age group, civil status, occupational status, and range of household income. The questionnaire also covered the travel information of the respondents along with their perspective of the service quality of the airline.

The data were subjected to statistical treatment. The frequency and percentage were used specifically in dealing with the nominal data generated by personal characteristics checklist. Weighted Arithmetic Mean was used particularly in dealing with the ordinal data produced by the perspective of the respondents' checklist.

Summary of Findings

After the data have been treated and interpreted, the significant findings of the study are as follows:

1. Socio-demographic profile of the respondents

1.1 Gender

Out of 100 respondents, fifty-three or 53 percent (53%) of the respondents are looked over as female while, the remaining forty-seven or 47 percent (47%) are male.

1.2 Age group

The data reveals that majority of the respondents falls under the 'below 20' age group category, which garnered sixty-seven or 67 percent (67%) of the respondents. On the other hand, the age group category '50 and above' received the lowest percentage which garnered only five or 5 percent (5%) of the respondents.

1.3 Civil Status

Majority of the respondents were revealed as single, which received the percentage of seventy-three (73%) while, seven or 7 percent (7%), which was the lowest, belongs to the widowers.

1.4 Occupational Status

Most of the respondents falls into the student category which received the percentage of sixty-eight (68%) while, minority of the respondents were looked over as unemployed.

1.5 Household Income

The data reveals that sixty-eight or 68 percent (68%) of the respondents' household income ranges from Php. 50,000 and above while, eleven or 11 percent (11%) of the respondents' household income ranges from Php. 10,000 and below.

2. Travel Information of the Respondents

2.1 Frequency of flying

The data shows that the eighty-four or 84 percent (84%) of the respondents occasionally travels by air, while respondents with the percentage of sixteen (16%), travels by air frequently.

2.2 Purpose of travel

Majority of the respondents' motivation for air travel were revealed to be for vacation purposes, which garnered the percentage of forty-three (43%). While, minority of the respondents' motivation for air travel is revealed to be for holiday purposes which had the percentage of five (5%)

2.3 Air travel Classification

The data reveals that most of the respondents with the percentage of seventy-one (71%) travels with Philippine Airlines domestically while, the remaining twenty-nine or 29 percent (29%) of the respondents travel internationally.

2.4 Seat Class

Majority of the respondents, which garnered the percentage of ninety-five (95%) was revealed to be seated on the economy class while, the remaining five or 5 percent (5%) of the respondents were seated on the business class.

2.5 When do they book their plane tickets

The data shows that fifty-three or 53 percent (53%) of the respondents book their flight one (1) to three (3) months before their actual flight while, the lowest percentage of respondents which received fifteen (15%) book their flight four (4) to eight (8) months before.

2.6 Way of booking tickets

Most of the respondents book their fare tickets through online travel discounts garnering the percentage of sixty-six (66%). On the other hand, six or 6 percent (6%) of the respondents book their fare tickets directly through the airline counter.

2.7 Ticket Allowance

The data reveals that seventy-eight or 78 percent (78%) of the respondents have ticket allowance that ranges from twenty thousand (Php 20, 000) and below. While, four or 4 percent (4%) of the respondents' ticket allowance ranges from thirty-one thousand pesos (Php. 31, 000) to fifty thousand pesos (Php. 50, 000)

2.8 Ticket Refunds

The data shows that a hundred or 100 percent (100%) of the respondents did not have any issues regarding the actual fare ticket resulting to zero (0) percent ticket refunds.

3. Quality of Airline Services

3.1 Ground Services

The data reveals that with regards to the quality of the ground services of the Philippine Airlines, respondents were satisfied with the overall service quality that the airline performed, which exhibits an overall weighted mean of 4.50 with the verbal interpretation of Satisfied. The customs service on the arrival area received the highest weighted mean among all the other ground services garnering a weighted mean of 4.61 with the verbal interpretation of Very Satisfied. On the other hand, the service that received the lowest weighted mean is the Check-in process on the departure area with the verbal interpretation of Satisfied.

3.2 Inflight Services

Majority of the respondents felt that they were satisfied with the quality of inflight services executed by the crews and staffs of the airline which received an overall weighted mean of 4.41 where the Responsiveness of the Cabin Crews (4.67) with a verbal interpretation of Very Satisfied indicates the highest weighted mean in inflight services while Entertainment Programs offered (3.84) with a verbal interpretation of Satisfied as being the lowest.

3.3 Inflight Experience

Most of the respondents viewed the quality of service in terms of inflight entertainment offered by the airline, as satisfying which acquired an overall weighted amount of 4.18 with verbal interpretation of Satisfied. Comfort of Seating obtain the highest weighted mean which garnered the total of 4.38 with verbal interpretation of Satisfied. Moreover, Noise Level of the Aircraft received a weighted mean of 4.06 with verbal interpretation of Satisfied as the lowest.

VII. CONCLUSION

The following conclusion is drawn based on the findings of the study mentioned above:

1. Most of the respondents of this study are female and falls under the age of 20 years old. Regarding in educational attainment, majority of the respondents are students, and mostly earning a household income of Php 50,000 & above.

2. Larger part of the respondent travels occasionally in domestic flight and fly in economy class with a vacation purpose. Most of them book their ticket 1-3 months before, and they prefer booking their tickets through online travel discount with Php. 20,000 and below mostly as their ticket allowance. All of the respondents also didn't experience any ticket refund.
3. Majority of the respondents of this study are satisfied and greatly assisted by the personnel in terms of their custom service in both departure and arrival area under the ground services.
4. Majority of the respondents are very satisfied with the responsiveness of the cabin crews and overall performance in terms of their inflight services.
5. Majority of the respondents' inflight experience are satisfied with the comfort of seating during their flight.

VIII. RECOMMENDATION

The following recommendations for this study are offered by the researcher regarding the quality of services that needs improvement based on the findings and conclusions.

1. The airline should take proper responsibility and take actions in terms of their check-in process with the constant occurrence of unorganized queuing and long stagnant lines. When it comes to processing passengers' transactions, they should be more attentive and fast-moving. The lines should be arranged by

passengers with priority lane, with large group of families, with online check-ins and others who only have concerns to prevent from receiving complaints and making the passengers annoyed.

2. The airline must provide different trainings for incompetent employees and crews to enhance their capabilities and ensure the satisfaction of the passengers.
3. In inflight services, entertainment programs are very important since it serves as their alternative when they don't use their mobile devices. The airline must have a variety of movies or shows offered. It would also be great if they are updated, so they would be more engrossed with watching.
4. The respondent's main problem during their inflight experience is the noise level of the aircraft since especially during the take-off and landing. It is more likely a pain to them, since being disrupted from their sleep or personal space could be really unpleasant. The airline, specifically the aircraft manufacturers should identify solutions to reduce the impact and maintain the safety and health of the passengers.

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Farmers' Awareness and Perceptions in Agritourism Participation in Calaanan Bongabon Nueva Ecija: A basis of Marketing Development Plan

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Abstract— *Agriculture is one of the top sources of livelihood of the residents of Calaanan Bongabon, Nueva Ecija, and since the area which is surrounded with great scenery, agritourism is slowly being introduced. With the potentials that agritourism has for the area and for the farmers, the researchers came to assess the awareness and perceptions of the farmers in agritourism participation in Calaanan, Bongabon, Nueva Ecija. The proponents derived the responses from twenty participants using quantitative research design. The result showed that there was high level of awareness to participate in agritourism specifically in awareness on the opportunity to develop connections to urban dwellers to rural culture and lifestyles. The farmers perceived agritourism as possible help to farmers to increase their standard of living. Moderate level of willingness to participate in agritourism was noted, this is due to challenges in lack of capital, the technical know-how on managing agritourism business, and unidentified target customers and others. This study has recommendations to address the challenges which may also be a basis of marketing development plan.*

***Keywords*— Agritourism, awareness, perception, participation, challenges, development plan.**

I. INTRODUCTION

A type of tourism known as agritourism, which focuses on intrinsic factors related to agriculture and takes advantage of the special characteristics of rural and agriculturally rich areas, is growing in popularity in practically every province. Farmers were one of the program's major beneficiaries. In addition, future caregivers may have employment alternatives due to agricultural tourism, which will minimize the demand for agricultural work. When it comes to the motivation behind farmers' decisions to welcome tourists to their farms, if this is viewed as an interventionist movement, it is unclear what compelled them to make this move. Farm tourism is commonly defined as the provision of a farm for recreational as well as leisure utilization, and the utilization of rural regions in the context of agritourism is crucial for both rural growth and long-term sustainability.

Moreover, agricultural tourism, often known as farm tourism, is becoming more and more significant as a rural growth strategy. Identifying and fixing systemic weaknesses is crucial for the proper development of this expanding sector. According to Kilinc et al. (2018), creating additional jobs, alleviating poverty, and fostering the growth of the local economy are some of the positive effects of the contributions made by the tourism industry. Also, a significant increase in this industry benefits agritourism as well. As a result, innovations in agritourism are growing throughout most of the country, particularly in sectors related to animal production, farming, and heritage landmarks. First and foremost, it's essential that we prevent locals from emigrating to urban areas, especially the young population. Concurrently, find a solution to the disparities in living conditions between the rural and urban populations. The growth of rural communities can be greatly aided by the agritourism sector. In fact, rural America is one of the most promising regions for the expansion of the hospitality industry. The growth of local livelihoods must take into account the fact that domestic migration is not the only factor driving rural tourism. Due to the increased competition for coastal tourism and the scarcity of resources in non-coastal areas, agricultural tourism is frequently favored. Hence, the fact that people living in rural areas have low incomes, poor working conditions, a high unemployment rate, and more seasonal jobs has naturally increased interest in rural tourism, which creates additional income for rural people, especially farmers. As stated by Brune, Knollenberg, & Moreno (2019), the prime objective of agritourism is to aid in a stable supply of revenues throughout the year and ultimately benefit the local dwellers and the nation's economy. It is undeniably true that an improvement in the living standards of the indigenous populace has a positive impact on the nation's economic health.

Farmers' objectives and traits are the driving factors of agritourism growth, as they are what make it sustainable. Since farmers' preparedness is the first crucial stage in the growth of agritourism, it is important to comprehend their willingness before any form of execution.

Furthermore, agritourism was rather linked to the driving forces behind farmers' urge for agriculture development. According to Tew and Barbieri (2012), the observed advantages of agritourism are common to many farm business and household characteristics; hence, it is essential to look into these characteristics because they influence farmers' perspectives. In addition to that, tourism-related variables, such as the profile of possible tourists and the responsibilities of full-time whereas for component farmers, that could have a significant impact on farmers' desires to start spice tourism, also weren't taken into consideration. These difficulties must be considered when creating a new tourist destination.

Thus, this study's objective is to ascertain whether farmers in developing countries without any existing agritourism ventures are willing to start up such ventures. Focusing on emerging economies is essential because farmers constitute a large proportion of the poor in these societies. In developing nations, agritourism is seen as a strategy for both rural development and eliminating poverty. Nevertheless, the majority of research on agritourism to date has been undertaken in economically advanced countries, concentrating on well-established agritourism locations. Subsequently, the fundamental objectives of this research were to investigate farmers' incentives and willingness prior to the development of agritourism in Calaanan, Bongabon Nueva Ecija.

Calaanan is a barangay in the municipality of Bongabon , in the Province of Nueva Ecija. Its population was about 3.85% or 2,575 in year 2020 census. Majority of the population are farmers, and farm owners. They are the producers of agricultural products such as rice, onion, corn garlic and etc. Thus, many of the farm owners are connected to agritourism in the said municipality because they are aware that Bongabon is one of the tourist spots in the province of Nueva Ecija. They foster a greater appreciation and awareness between a traveler, the land visited and the people who live on it.

With this notion, the study aims to determine the farmers' awareness and perceptions in participation in agritourism in Calaanan, Bongabon Nueve Ecija.

Objectives of the Study

This study aims to determine the level of awareness, perceptions and willingness of farmers to participate in agritourism in Calaanan, Bongabon Nueva Ecija as basis of marketing development plan.

Specifically, it will seek to answer to the following questions:

1. How may the profile of farmers be described in terms of:
   - 1.1. age;
   - 1.2. sex;
   - 1.3. civil status;
   - 1.4. highest educational attainment;
   - 1.5. number of children;
   - 1.6. occupation;
   - 1.7. monthly income; and
   - 1.8. farming land area in hectare?
2. How may the level of awareness of farmers to participate in Agritourism in terms of:
   - 2.1. Revenue;
   - 2.2. diversifying business;
   - 2.3. economic influx; and
   - 2.4. opportunity to develop connections?
3. How may the perceptions of farmers in agritourism be described in terms of:
   - 3.1. Importance;
   - 3.2. Barriers; and
   - 3.3. Benefits?
4. What is the level of willingness of farmers be described in participating in agritourism?
5. Is there a significant relationship between profile of respondents in awareness and perceptions?
6. Is there a significant difference between the level of awareness and perceptions of farmers about agritourism?
7. Based on the findings of the study, what marketing development plan may propose?

Hypotheses of the Study

1. There is no significant relationship between profile of respondents in awareness and perceptions.

2. There are no significant differences between the level of awareness and perceptions of farmers about agritourism.

II. RESEARCH METHOD

The researchers utilized quantitative research design to determine the level of awareness and willingness of farmers to participate in agritourism in Calaanan, Bongabon Nueva Ecija. The respondents of the study are the 20 farm owners and they were selected using purposive sampling to meet the objectives of the study.

A personally develop survey questionnaire were used as research instrument to gathered the needed data. Since the tool is personally developed it undergone to pilot testing and content validity using CronBach Alpha. The reliability and validity results was 0.94 which means high reliability and validity.

In data gathering, the researchers personally administered the survey so that they can extract honest and reliable responses. Before they give the survey, they discussed and explained the importance and objectives of the study.

The survey questionnaire consisted of Four-point Likert scale as shown below:

Rating Scale	Weights Assigned	Interpretation	Description
4	3.25 – 4.00	High Level	Strongly Agree
3	2.50 – 3.24	Moderate Level	Agree
2	1.75 – 2.49	Fair Level	Disagree
1	1.00 – 1.74	Low Level	Strongly Disagree

And all data gathered were statistically treated using SPSS tool.

III. RESULTS AND DISCUSSION

1. Profile of Farmers

Based on the findings gathered, majority of the farmers at Calaanan, Bongabon Nueva Ecija were at age range of 45 to 55 years old, indicating that the majority of them were still in their working years. The respondents are by their fairly productive ages, better positioned to go about their farming activities with much ease.

Most are male and married with 4 to 5 children. This implies that majority of the respondents had fair household size, which is within the national average of 4 persons. Also, marriage predisposes an individual to become more responsible since they must cater for their family needs. This finding is also in line with Ominikari, Onumadu and Nnamerenwa (2017) posited that being married confers some amount of stability to an individual in a household.

In terms of education, majority of the respondents reached college levels. They own the farmland they cultivate. Most of them have 2 to 4 hectares. Their income depends on the status of the cropping period and land area.

The findings meant that most of the farmers in Calaanan, Bongabon were farm owners. Their monthly income is not fixed since they are dependent on the cropping season. This level of annual income is not sufficient enough to make farmers in the area to be seen as a more profitable occupation. This finding is consistent with the finding of Hamadina and Hamadina (2015) who opined that income from farming activities is often low and affects the poverty status of small holder farmers. This finding is also consistent with the finding of Chukwuneye (2016) and Onu (2016) who in their studies observed low annual income status among farmers.

2. Level of Awareness of Farmers to Participate in Agritourism

Table 1. Level of Awareness to Participate in Agritourism

Level of Awareness	Weighted Mean	Interpretation
Revenue	3.13	Moderate Level
Diversifying Business	2.76	Moderate Level
Economic Influx	3.53	High Level
Opportunity to Develop Connections	3.65	High Level
Overall Weighted Mean	**3.27**	**High Level**

Table 1 shows the data on the level of awareness of farmers to participate in agritourism. As shown in the table the overall weighted mean got 3.27 and verbally interpreted as “High Level”. The opportunity to develop connections got the highest weighted mean of 3.65 and verbally interpreted as “High Level”, whereas diversifying business got the lowest weighted mean of 2.76 and interpreted as “Moderate Level”.

The findings meant that farmers in Calaanan, Bongabon, Nueva Ecija had found high level of awareness to participate in agritourism specifically in awareness on the opportunity to develop connections to urban dwellers to rural culture and lifestyles. They foster connections through research-based knowledge and education to learn to produce agricultural products and promoting entrepreneurial spirit linked in rural areas. Thus, resulting to offer agritourism opportunities that widely recognized economic benefits of participating Agritourism specially for rural areas.

According to Phillips (2010), many farms around the country are diversifying their offerings and enhancing profitability by adding agritourism. He stated that agritourism is an enterprise at a working farm or agriculture plant conducted for the enjoyment of visitors that generates income for the owner. It has more benefits such as creating name recognition for their agricultural products, educating consumers about farming, generating financial incentives for the protection and enhancement of farms and natural amenities and generating spillover economic development opportunities.

3. Perceptions of Farmers in Agritourism

Table 2. Perceptions of Farmers in Agritourism

Perceptions	Weighted Mean	Interpretation
Importance	3.44	High Level
Barriers	3.45	High Level
Benefits	3.33	High Level
Overall Weighted Mean	**3.41**	**High Level**

Table 2 presents the data on the perceptions of farmers in agritourism. As shown, the overall weighted mean got 3.41 and verbally interpreted as “High Level”. Barriers on perceptions of farmers in agritourism got highest weighted mean of 3.45, followed by importance of 3.44 and benefits of 3.33 and all with verbal interpretations of “High Level”.

The findings revealed that the perceptions of farmers in Agritourism in Calaanan Bongabon, Nueva Ecija were found high level in all aspects.

In terms of barriers, the farmers perceptions are in high level in the involvement of capital and difficulty to attract shareholders and customers. But they understand in the importance and benefits of agritourism to help farmers to increase their standard of living that create more employment opportunity and generate additional income in the community. And to promote economic growth and development and avenues to escape poverty for the majority of the families in Calaanan, Bongabon.

The findings were supported by World Nomads (n.d.), claimed that agritourism had significant impact to the revenue, diversifying business and providing a stable income for the farmers. It also helps the community to preserve their local food and traditions and protects farmland from developers.

4. Level of Willingness of Farmers in Participating in Agritourism

Based on the responses of the respondents-farmers, majority of them rated 5 to 6 their willingness to participate in agritourism which means moderate level of willingness.

Because on the other side, they are not ready to participate due to different reasons such as capital, managing business in agritourism form, target customers and many more.

In the study of Bhatta, Itagaki & Ohe (2019), revealed that farmers’ willingness to participate in agritourism is statistically determined in farmer age group those aged between 20 to 40 because they are significant connections between agritourism-related element and agricultural sharing. Additionally, willingness to participate in agritourism was affected by different factors such as level of education, gender and social activities. Specifically, those who are oriented towards land sharing are relatively eager to participate, relatively educated and more likely to be men because they are on decision making in line with the farming activities.

5. Relationship between Profile of Respondents and Level of Awareness and Perceptions in Participating Agritourism

Highest educational attainment of farmers had significant relationship with the level of awareness and perceptions in Agritourism participation. And other profile variables had found no significant relationship.

The findings meant that the highest educational level of farmers the better their awareness and perceptions and more likely to participate in agritourism.

In similar to the results of study of Bagi and Reeder (2012) revealed that the higher the level of education of the farmers, the more likely their participation in agritourism. This may be because uneducated or less educated farmers are ignorant of the benefits of agritourism and community activities.

6. Differences between the Level of Awareness and Perceptions of Farmers about Agritourism

Based on the findings, there is no significant differences on the level of awareness and perceptions of farmers about Agritourism.

The findings revealed that farmers have the same level of awareness and perceptions in participating agritourism. They are all agreed that agritourism helps farmers in the community to increase income, to have more job opportunities and preserved farmland and foster more connections.

7. Output of the Study

Based on the findings of the study, the researchers may propose marketing development plan to strengthen agritourism in Calaanan, Bongabon, Nueva Ecija. It also helps farmers to strengthen and heighten level of awareness and perceptions to participate in Agritourism.

IV. CONCLUSIONS AND RECOMMENDATIONS

Conclusion

On the findings of the study, the researchers concluded that farmers in Caalanan, Bongabon Nueva Ecija shows high level of awareness and perceptions in agritourism. They are willing to participate agritourism as long as they are aware on the benefits to the farm owners and community and will be given the proper support and training.

Recommendations

Based on the conclusions, the researchers recommended to understand well the agritourism business. Farmers should attend more seminars and trainings that could help them enlighten and increase the knowledge and awareness in agritourism business that surely satisfy goals and target markets. And should have development plan and programs before entering to any agritourism business leading to better agritourism participation.

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Comparison of Different Simulation Tools for Load Flow Analysis in Power Systems

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***Abstract*— The comparative analysis provides valuable insights into the capabilities and limitations of different simulation tools, helping to improve the accuracy and efficiency of load flow studies, ultimately contributing to the reliable and secure operation of modern power systems. In this paper load flow analysis of IEEE 9 bus system is performed on three different software tools i.e. Power world simulator (PWS), MATLAB, MATPOWER. The results of load flow analysis of all three tools are compared. The economic load dispatch problem is also resolved in PWS and MATPOWER software. The results are promising and efficient when compared with latest ones.*

***Keywords*— Load Flow Analysis, Power Systems, Power world simulator, DigSILENT.**

I. INTRODUCTION

Load flow analysis is a fundamental tool in power system planning, operation, and control. Various simulation tools have been developed to perform load flow analysis, each with its own unique features and capabilities. The comparative analysis is conducted on a set of standard power system test cases, representing different system configurations and operating conditions. The selected simulation tools include well-established commercial software packages as well as open-source tools. To ensure a comprehensive evaluation, the comparison encompasses both traditional load flow algorithms, such as Newton-Raphson and Gauss-Seidel, as well as advanced techniques like fast decoupled load flow and sparse matrix methods. The strengths and weaknesses of each simulation tool are identified and discussed, along with recommendations for specific applications or scenarios.

This paper compares popular power system analysis software such as PSS/E, ETAP, and DigSILENT Power Factory for load flow analysis. It evaluates various factors including accuracy, computation time, and ease of use. **[1]** The authors compare different power system analysis software, including PSS/E, DigSILENT Power Factory, and Power World Simulator, for load flow studies. The study focuses on accuracy, convergence characteristics, and computational efficiency. **[2]** This paper presents a comparative study of various power system simulation software tools, including PSS/E, ETAP, DigSILENTPowerFactory, and PowerWorld Simulator. The comparison is based on load flow analysis accuracy, stability analysis capabilities, and computational efficiency. **[3]** The authors compare the performance of PSS/E, DIgSILENTPowerFactory, and OpenDSS for load flow analysis. The paper evaluates accuracy, computation time, and stability analysis features. **[4]** This paper compares PSS/E, DIgSILENTPowerFactory, and MATLAB/Simulink for load flow analysis. The authors evaluate accuracy, convergence behavior, and ease of use. **[5]** The authors compare PSS/E, DIgSILENTPowerFactory, and MATLAB/Simulink for load flow studies. The study focuses on accuracy, computation time, and robustness under varying system conditions. **[6]** This paper provides an overview of Power-World Simulator and its capabilities for power system analysis. It discusses the simulation of the IEEE 9-bus system using Power-World Simulator and focuses on power flow analysis, contingency analysis, and voltage stability analysis. The study demonstrates the use of Power-World Simulator as a powerful tool for simulating and analysing the IEEE 9-bus system. **[7]** This paper investigates the optimal power flow (OPF) analysis of the IEEE 9-bus system using Power-World Simulator. The study aims to optimize the generation and dispatch of power while considering system constraints. It explores different OPF techniques and discusses their application to the IEEE 9-bus system using Power-World Simulator. **[8]**This paper focuses on contingency analysis of the IEEE 9-bus system using Power-World Simulator. It analyses the system's response to various contingencies such as generator and line outages. The study demonstrates the use of Power-World Simulator's contingency analysis capabilities to assess system reliability and identify critical contingencies. **[9]** This research investigates voltage stability analysis of the IEEE 9-bus system using Power-World Simulator. It examines the system's voltage stability margin and identifies potential voltage collapse scenarios. The study utilizes Power-World Simulator's voltage stability analysis features to assess system voltage stability and propose control strategies for voltage improvement. **[10]** This paper introduces the Power System Analysis Toolbox (PSAT) for MATLAB, which includes various modules for power system analysis. It demonstrates the simulation of the IEEE 9-bus system using PSAT and MATLAB. The study focuses on power flow analysis, transient stability analysis, and optimal power flow using PSAT's functionalities in MATLAB. **[11]** This research paper presents a transient stability analysis of the IEEE 9-bus system using MATLAB/Simulink. The study models the system components and implements stability analysis algorithms in Simulink. It investigates the system's response to disturbances and evaluates stability limits using MATLAB/Simulink simulations. **[12]** This paper focuses on voltage stability analysis of the IEEE 9-bus system using MATLAB. **[13]**It develops a voltage stability index based on the system's load ability margin and performs sensitivity analysis to assess voltage stability limits. The study demonstrates MATLAB's capabilities in analysing and predicting voltage stability in power systems. **[14]** This paper introduces MatPower, a MATLAB-based power system simulation and analysis package. It discusses the simulation of the IEEE 9-bus system using MatPower and highlights its capabilities for power flow analysis, optimal power flow, and contingency analysis. **[15].** This research focuses on voltage stability analysis of the IEEE 9-bus system using MATPOWER. It investigates the system's voltage stability limits, identifies critical buses, and proposes control strategies for voltage improvement. **[16]** This paper explores optimal power flow analysis using MatPower for the IEEE 9-bus system. It formulates the OPF problem and solves it using MatPower's optimization capabilities, considering various system constraints **[17]**

The research Objectives of the works are:

- To perform load flow analysis of IEEE 9 bus system
- To compare the result of load flow analysis of 9 bus system in various simulation tools

II. SOFTWARE TOOLS FOR LOAD FLOW ANALYSIS

Load flow analysis is one of the basic power system analyses in the stage of planning, design and operation of power systems. This is used to calculate the steady state performance of the system under various possible operating conditions and study the effects of changes in equipment configuration.

The three methods for load flow studies mainly

- Gauss siedel method
- Newton raphson method
- Fast decoupled method.

Three software tools are used to simulate the systems.

- Power World Simulator,
- MATLAB and
- MATPOWER

Power World Simulator (PWS)

An effective software programme for simulating and analysing electrical power systems is called Power-World Simulator. It offers a comprehensive platform for modelling, simulating, and optimising many elements of power systems for engineers, researchers, and system operators. Power-World Simulator has grown to be a well-liked option for system analysis, planning, and operation in the power industry because to its user-friendly interface and sophisticated capabilities. Using Power-World Simulator, users can define buses, generators, transmission lines, transformers, loads, and other components to build intricate models of power systems. It enables both steady-state and dynamic modelling, allowing for the analysis of system behavior over a range of timescales and operating circumstances. To faithfully mimic the intricate relationships within the power system, the software incorporates industry-standard methods and solution methodologies. Power flow analysis is one of Power-World Simulator's main features. It computer dispatch, or system designs on the overall system operation by looking at the power flow.es the voltages, currents, and power flows in the system, giving information about how well it is working and spotting potential problems such voltage violations, power losses, and congestion. Engineers can evaluate the effects of adjustments to load demand, generator etc.

MATLAB Simulation

MATLAB is a high-level programming language and software environment used for algorithm creation, data analysis, and numerical calculation. Its initial purpose was for matrix manipulation and linear algebra operations, and its name stands for "Matrix Laboratory". However, it has since grown to include a variety of features and applications. Here in MATLAB a IEEE-9 Bus system was designed and simulated and the results were verified with the base case results.

MAT Power

The University of Wisconsin-Madison's Power System Engineering Research Centre (PSERC) created MAT-Power, a robust and extensively used MATLAB-based software package. It offers a complete set of features and resources for modelling, analyzing, and improving power systems. As open-source software, MAT-Power is freely available to power systems researchers, engineers, and students. Users can carry out numerous analyses with MAT-Power, such as power flow analysis, optimal power flow (OPF), and contingency analysis. With the use of power flow analysis, it is possible to calculate the steady-state voltages, currents, and power flows in a power system, giving important insights into the operation and behavior of the system. The OPF feature enables generation and dispatch optimization, considering elements like generating costs, transmission losses, and system limits, in order to arrive at an ideal operating point. The impact of component failures or outages on system stability is evaluated using contingency analysis, which also exposes potential weaken.

III. RESULT AND DISCUSSION

The IEEE- 9 bus test system is adopted in this paper to analyze and compare the load flow analysis performed on the three different software as mentioned.

IEEE 9 Bus System

In power system analysis and modelling, the IEEE 9-Bus system is used, as shown in figure 1, as a benchmark. With nine buses, three generators, and numerous transmission lines, it serves as a simplified representation of a power transmission system.

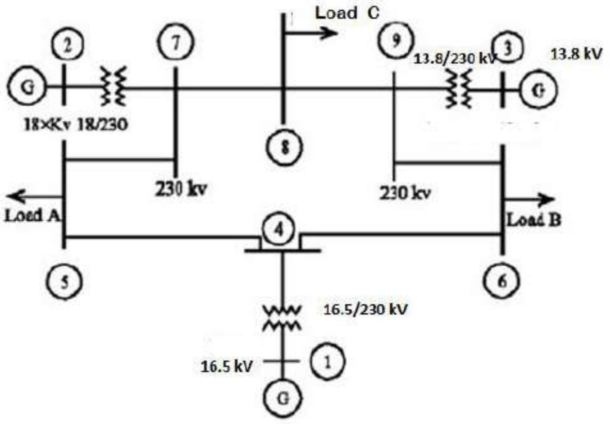

Fig.1: Single Line Diagram of IEEE – 9 Bus System

CASE A: -

IEEE 9 Bus Simulation in Power World Simulator

A sophisticated software programme called PowerWorld Simulator is frequently used for power system analysis, simulation, and optimisation. Engineers, academics, and system operators can analyze and visualize complicated power systems using its user-friendly interface and a variety of strong features. The 9 bus model in PWS software is shown in figure 2. The simulation result of IEEE 9 bus system in PWS software is depicted in table 1.

Table 1: - Load Flow Result of IEEE 9 Bus in Power World Simulator

Sr. No.	Bus No.	Nom. (KV)	p.u. (V)	Volt (KV)	Angle (Deg)	Load (MW)	Load (Mvar)	Gen (MW)	Gen (Mvar)
1	Bus 1	16.50	1.04000	17,160	0.00	0	0	71.63	27.91
2	Bus 2	18.00	1.02500	18.450	9.35	0	0	163.00	4.90
3	Bus 3	13.80	1.02500	14.145	5.14	0	0	85.00	-11.45

4	Bus 4	230.00	1.02531	235.821	-2.22	0	0	0	0
5	Bus 5	230.00	0.99972	229.936	-3.68	125.00	50.00	0	0
6	Bus 6	230.00	1.01225	232.819	-3.57	90.00	30.00	0	0
7	Bus 7	230.00	1.02683	236.971	3.80	0	0	0	0
8	Bus 8	230.00	1.01727	133.971	13.4	100.00	35.00	0	0
9	Bus 9	230.00	230.00	1.03269	237.519	2.44	0	0	0

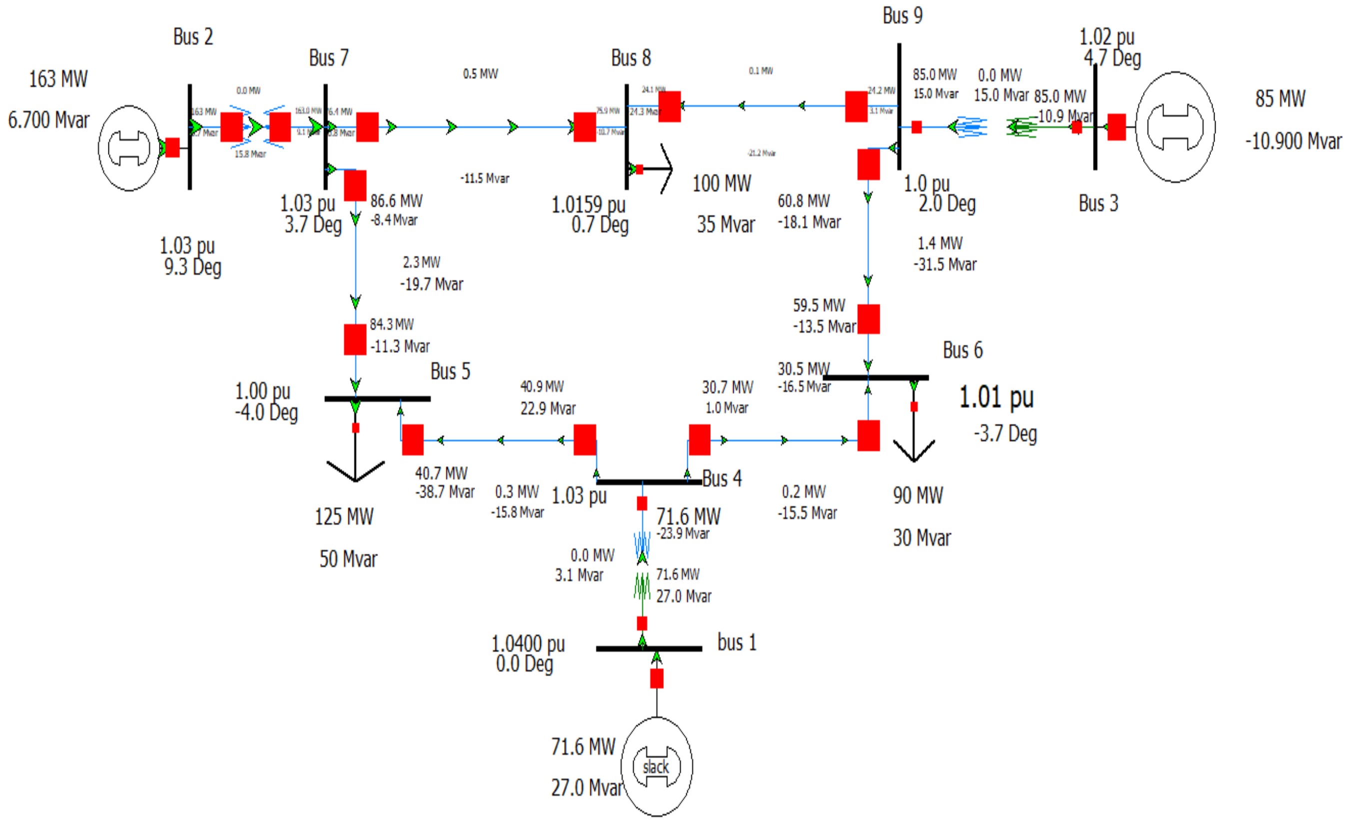

Fig.2: IEEE 9 Bus Simulated Model in PWS

CASE B :-

IEEE 9 Bus Simulation in MATLAB

A well-known benchmark system for power system analysis is the IEEE 9-bus system, and MATLAB offers a potent framework for simulating and analysing this system. The IEEE 9-bus system is simulated in MATLAB using the following overview:

Modelling the IEEE 9-bus system in MATLAB involves specifying its many parts, such as the buses, generators, loads, and transmission lines. The parameters for each component, such as the bus voltages, generator characteristics, load requirements, and line parameters, serve as a representation of that component.

Data Input: The IEEE 9-bus system's data can be entered through an interface provided by MATLAB. Matrix or data structure input can be used to enter the system parameters into MATLAB, including the bus admittance matrix, generator data, load data, and line parameters. As a result, it is simple to alter and manipulate the system data throughout the simulation.

Load Flow Analysis: In order to solve load flow analysis in the IEEE 9-bus system, MATLAB provides built-in functions and toolboxes. The bus voltages, line flows, and power injections in the system are calculated iteratively by these functions, like pf_newton or pf_gauss.

The simulation result of IEEE 9 bus system in MATLAB software is illustrated in table 2.

Table 2 :- Load flow result of IEEE 9 bus in MATLAB

Bus #	Voltage		Generation		Load	
	Mag (pu)	Ang (deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.040	0.000	71.64	27.05	-	-
2	1.025	9.280	163.00	6.65	-	-
3	1.025	4.665	85.00	-10.86	-	-
4	1.026	-2.217	-	-	-	-
5	1.013	-3.687	-	-	90.00	30.00
6	1.032	1.967	-	-	-	-
7	1.016	0.728	-	-	100.00	35.00
8	1.026	3.720	-	-	-	-
9	0.996	-3.989	-	-	125.00	50.00
Total:			319.64	22.84	315.00	115.00

IEEE 9 Bus Simulation in MAT Power

The IEEE 9 bus system is simulated in MATPOWER and result are shown in table 3

Table 3: - Load flow result of IEEE 9 bus in MATPOWER

Bus ID	V_{base} (Kv)	V_{ref} (pu)	Vangle (deg)	P(MW)	Q(Mvar)	V_LF(pu)	Vangle_LF(deg)	P_LF(MW)	Q_LF(Mvar)
BUS_1	16.5	1.04	0	0	0	1.04	0	72.1888	26.7986
BUS_4	230	1	0	0	0	1.0261	-2.2265	0	0
BUS_5	230	1	0	125	50	0.9962	-4.0021	125	50
BUS_6	230	1	0	90	30	1.0131	-3.701	90	30
BUS_7	230	1	0	0	0	1.0259	3.6201	0	0
BUS_9	230	1	0	0	0	1.0324	1.8665	0	0
BUS_8	230	1	0	100	35	1.016	0.6336	100	35
BUS_2	18	1.025	0	163	0	1.025	9.1727	163	6.6901
BUS_3	13.8	1.025	0	85	0	1.025	4.5577	85	-10.7842

Economic Load Dispatch

Economic Load Dispatch (ELD) is an optimization problem in power systems that aim to determine the optimal generation schedule for power plants, taking into account various factors such as the system load, generator constraints, and fuel costs. ELD problem is resolved in two software:

- MATPOWER
- Power World Simulator

The results of both software are shown in table 4:

Table 4:- Comparison of ELD Results in PWS and MATPOWER

	PWS	**MATPOWER**
Real Power Loss (MW)	3.20	3.307
MW Generation	318.20	318.20
Total Hourly Cost	5293.98$/hr	5293.98 $/hr

IV. CONCLUSION

Based on this research, three power simulation tools MATPOWER, MATLAB and Power World are compared here. By evaluating the performance of the tests through the above mentioned software tools, it is concluded that they all yielded good and fairly reliable results for bus voltage magnitude and its phase angles. It has been determined that the most accurate data for the IEEE 9 bus comes from Powerworld, followed by MATPOWER. ELD was also performed in two softwares namely PWS and MATPOWER and results are compared in which it is found that PWS software gave the minimum value for the economic load dispatch with minimum losses.

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Implementation of Preventive and Corrective measures in SCADA based Wind Turbines

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***Abstract*— *Wind energy is becoming increasingly important in addressing energy demand and environmental sustainability. It is driven by the outstanding offshore wind resource and the need to minimize carbon emissions from energy generation. A growing interest in wind turbine condition monitoring, which allows condition based rather than reactive or scheduled maintenance, stems from the difficulty of accessing and maintaining wind turbines offshore. Vibration analysis and oil debris detection are currently used wind turbine condition monitoring methods. The extra expenditures might be enormous when considering the number of turbines normally put in offshore wind farms, and specialist interpretation is usually required. However, extending SCADA data-based analysis could bring significant value to condition monitoring at little or no expense to the wind farm operator. This Research Paper focuses on wind turbine condition monitoring using only SCADA data. An early detection of operational defects or breakdowns allows for regular maintenance or repair, decreasing downtime and potentially preventing further damage. Comparing incoming operational SCADA data with results for relevant variables, like component temperature, produced from applicable models trained on SCADA data from a healthy wind turbine, yields useful component condition indicators. Anomalies in the variables of interest in the SCADA data indicate impending breakdowns. This method is used to derive machine-to-machine comparison of component condition Compared to developing separate turbine models, this saves significant computing work and model complexity. A real-time wind turbine power curve is also created using SCADA data and compared to a reference power curve to quickly discover abnormal behavior based on slight variations in the power curve.*

***Keywords*— SCADA, Wind Turbines, Offshore wind activity**

I. INTRODUCTION

Wind energy has grown quickly as a major green power source in recent decades, aided by new and cost-effective technologies. As shown in Figure 1-1, the worldwide wind energy capacity factor has grown steadily over the past several decades, reaching 282GW by the end of 2021, an increase of 18.7% over the capacity factor at the end of 2021 [1]. At the same time, the size of commercial wind turbines has steadily increased, with a rated power of up to 7.5MW for remote applications [2]. Moreover, in the future years, several new offshore turbine types are anticipated to produce energy over 15MW [3].

This Section will briefly discuss the motive for climate change mitigation and adaptation, followed by considerations of wind energy's significant significance in government policy and industry deployment in the United Kingdom. The research rationale will subsequently be given special attention. After that, the fundamentals of wind farm operation will be briefly discussed, followed by a discussion of turbine sub-assembly failure rates and related downtime since they inspire monitoring systems, which is also the topic of this Research Paper. Following that, the Research Paper format will be described, and my research-related papers will be mentioned after this Section.

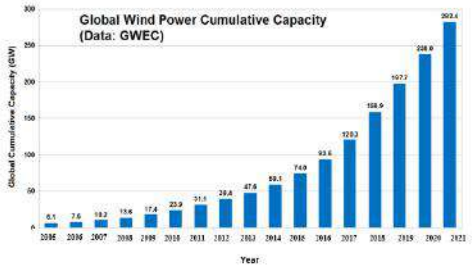


Fig.1.1: Cumulative wind power capacity throughout the world [1]

1.1. DRIVERS OF RENEWABLE ENERGY

The decline of fossil fuel sources and a worldwide commitment to limit carbon emissions to combat climate change have fueled a significant expansion of the clean energy industry in recent years. The Copenhagen Accord [4] of 2009 established a primary goal of keeping global warming below 2 degrees Celsius. Following that, the EU passed the energy and environmental package policy, also known as the 20-20-20 directive, [5], which aims for a 20% decrease in EU greenhouse emissions from 40 % by 2030, a 20% share of EU power consumption powered by renewable resources, and a 20% increase in EU energy efficiency by 2020As part of the EU strategy, the UK government has stated its commitment to expanding renewable energy deployment by supporting the Sustainable Energy Regulation and the UK's goal of supplying 15% of energy demand from renewable sources by 2020, which was set in 2009.

Another primary motivator for renewable energy adoption is energy security, which refers to the endless potential of renewable energy sources at a reasonable cost. [7]. Renewable energy's increasing penetration will decrease reliance on conventional energy and safeguard domestic customers from price volatility in fossil fuels, resulting in a more stable and dependable national energy supply market.

1.2. THE SIGNIFICANCE OF WIND ENERGY

The Renewables Obligation, [8], was established by Ofgem (the UK regulator) as a primary support mechanism to encourage the development of large-scale renewable deployment to ensure national energy security and achieve agreed-upon decarbonization goals. This requirement was enacted in 2002. It requires qualified UK energy providers to produce a growing proportion of power from renewable resources via Renewable Obligation Certs (ROCs). According to reference [8], wind farms in the UK were granted more ROCs than generation facilities based on three other renewable technologies; wind-based production also contributed to a higher percentage of new generating capacity certified by Ofgem than many other technologies.

Figure 1.2 shows statistics from the Department of Energy and Climate Change (DECC) for renewable energy generation growth in the UK, which clearly shows the rapid development of wind energy over the last decade and confirms its growing importance in contributing to total renewable power generation and achieving the national energy security goal. This statistic also shows that the offshore contribution has had an effect in recent years. The next part will go through the details of the UK's offshore wind power deployment strategy.

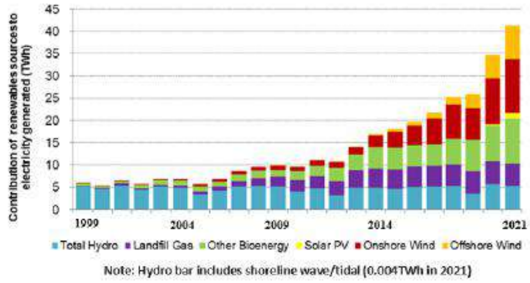


Fig.1.2: In the United Kingdom, Increased renewable energy production (TWh) [9]

1.3. PROBLEM STATEMENT

Prevailing wind turbine condition monitoring procedures, such as vibration analysis and oil debris detection, involve costly sensors. The additional costs can be essential noticing the number of turbines usually installed in wind farms and in addition, expensive proficiency is normally requisite to understand the results. On the other hand, the possibility to extend the SCADA data study method is significant and could add worth to the condition monitoring with no need for wind farm worker. Higher Wind Turbines repair cost than timely maintenance prior to fault occurrence.

1.4. RESEARCH OBJECTIVE

This investigation will emphasis on wind turbine condition monitoring that uses whole data from SCADA systems. The objectives of the present study are:

1. To identify rising wind turbine operational faults or failures before they progress to disastrous failures, therefore preventative maintenance or corrective action can be planned in time. Though decreasing downtime and potentially eliminating wider damage.
2. Suitable component condition indicators are acquired by relating received operational SCADA data with the results for appropriate variables, like component temperature that show component state, obtained from related models trained on SCADA data from a perfect wind turbine.

3. Initial failures are diagnosed through irregular behavior in the variables of interest manifest in the SCADA data.
4. This perspective is initially applied to individual wind turbines, and then expanded to involve other wind turbines functioning under same situations to obtain component condition indicators through inter-machine comparison. This is illustrated to streamline major savings in statistical effort and model complication related to the repetitive expansion of separate turbine models.
5. Moreover, a real time wind turbine power curve is implemented based on SCADA data, and related with a reference power curve to detect irregular actions, through slight changes in the power curve, in a timely way.

1.5. SCOPE OF STUDY

The following section will briefly cover UK offshore deployment before discussing the rationale for wind turbine condition monitoring, namely the use of Supervisory Control and Data Acquisition (SCADA) data to assess the health of wind turbines.

1.5.1. Offshore wind farms are being built in the United Kingdom

With its abundant offshore wind resources, the United Kingdom has grown to become the world's most significant offshore wind energy industry, with a total installed capacity of 4.6GW spread over 24 wind farms as of May 2013 [10]. Offshore deployment in the United Kingdom is divided into three rounds [11]. Figure 1.3 depicts the proposed offshore wind operations sites, with the various rounds colored differently, while Table 1.1 summarises the related development plan.

Round 1 installations are already complete, with site choices usually near the coast. Round 2's two sites are usually bigger and further from the beach, and some are still being built [11]. As illustrated in Figure 1.3, Round 3 sites are much more ambitious and complex than Rounds 1 and 2, with significantly bigger deployment zones, most of which are in deeper water and farther offshore [11]. Table 1.1 shows that after all three phases are completed, and their expansions are added together, the UK offshore capacity will reach 49GW.

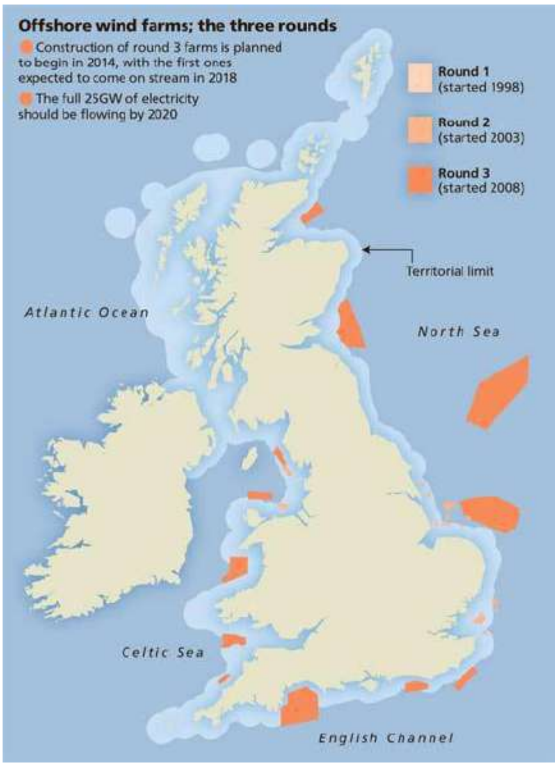


Fig.1.3: Offshore wind activity in the UK [12]

Table 1.1: The Crown Estate"s offshore wind leasing rounds [13]

Round	Year announced	Original capacity (GW) (from public announcements)
Round 1	2000	1.5
Round 2	2003	7.2
Round 3	2008	32.2
Scottish territorial waters	2008	6.4
Round 1 and Round 2 extensions	2009	1.7
Total	**49**	

1.5.2. Monitoring the condition of wind turbines is justified

The obvious advantage of going offshore is the improved wind profiles above sea level. Because of the increased wind speeds, a higher capacity factor is anticipated offshore. Because of the foundation and installation expenses scale, offshore wind turbines are often more significant than those utilized onshore. Furthermore, there is less turbulence offshore than onshore since there are no barriers above sea level. Furthermore, compared to onshore turbines, the noise and visual intrusion from offshore turbines are considerably less severe, resulting in better public acceptability.

However, there is a cost, and the most significant disadvantage of offshore wind is the astronomically high costs of constructing and accessing offshore wind turbines during installation and maintenance. The expenses of renting the repair vessel and related staff will be significant.

In the worst-case situation, when component replacement is needed, a crane vessel is usually required for installation.

According to the study in reference [14], as turbine capacity increases, the failure rate increases, which may be a problem for offshore turbines since high-rating machines are preferred for the reasons stated above.

Turbine availability is defined as the proportion of time the system is working correctly. At the same time, there is available wind [15] and is influenced by a variety of factors such as turbine dependability, maintenance plan, and site accessibility. Apart from the wind conditions, the produced income is directly proportional to the availability of turbines. For example, onshore turbine availability may approach 98 percent thanks to the service organization and routine maintenance activities (about four times a year) that can be done quickly due to the ease of access [15] and unexpected repairs in the event of faults or component failures. On the other hand, Offshore availability is considerably lower since routine maintenance activities are less feasible due to the significant expenses involved, and unexpected repairs may be significantly delayed due to lack of access due to bad weather conditions. Furthermore, extreme sea conditions may impede repairs due to the higher average winds, resulting in more significant income loss than onshore turbines during downtime when broken turbines are unreachable for repair.

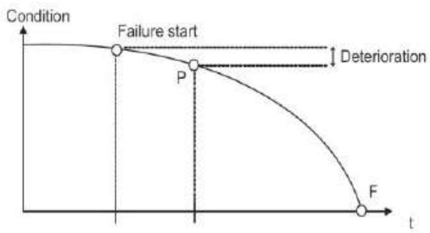


Fig.1.4: Deterioration state of the component [16]

Instead of the conventional mix of responsive repair and planned maintenance approach, the growing tendency for offshore deployment, along with low offshore availability and accessibility, suggests the need for an effective and dependable condition-based maintenance scheme for wind turbines. To illustrate the development of component degradation, reference [16] uses a so-called P–F curve, as shown in Figure 1.4. The first time this degradation can be observed, ahead of total failure at the time "F," is at point "P," with a particular degree of deterioration as determined by the curve. Because it provides for better maintenance scheduling, the time gap between P and F is critical for the successful deployment of condition-based maintenance. Furthermore, from an economic standpoint, the sooner a possible abnormality is discovered, the less downtime there will be and the subsequent damage to other components of the turbine. For example, ignoring a worn bearing may result in the catastrophic collapse of a whole gearbox, resulting in significant expense and delay.

Approaches that can detect problems early and provide the turbine operator with time to schedule a repair before incipient abnormalities turn into catastrophic failures would help decrease turbine downtime and increase availability.

This Research Paper describes two successful condition monitoring methods: a historical states-based prediction technique for turbine main drive train components and an operational power curve-based strategy to overview turbine performance. A 10-minute SCADA data analysis backs up both methods.

1.5.3. Significance of SCADA data

Most modern wind farms have a Supervisory Control And Data Acquisition (SCADA) system, which logs general turbine operational and meteorological data for each wind turbine and any meteorological masts within the wind farm, usually in a 10-minute averaged form, and then sends these measurements in real-time to a remote central computer via a communication system [17]. For more than 35 years, SCADA data has been utilized in the power generating industry. Its function in wind turbine applications is to monitor turbine operations such as turbine cut-in, cut-out, and emergency stop [18]. SCADA data has the distinct benefit of providing a comprehensive picture of the turbine, from the rotor, such as rotational speed and pitch angle, through the drive train, such as gearbox oil and bearing temperatures, and the generator's power output. The SCADA system also keeps track of environmental variables like wind speed and ambient temperature. This vast amount of data is a significant source of information on the turbines' operating health, which may be utilized as a part of a comprehensive turbine condition monitoring system.

In reference [19], a study of commercially available wind turbine condition monitoring systems (CMS) reveals a strong tendency toward vibration signal-based methods. The vibration monitoring primarily focuses on the turbine drive system, including spinning equipment. Other methods for monitoring critical components include oil debris studies for gearboxes and fiber optic-based strain assessment for blades. These methods will be covered in the next Section.

SCADA-based condition monitoring is considerably cheaper than conventional CMS due to the absence of costly instruments such as accelerometers for acquiring vibration signals and metal particle sensors for oil analysis. Because the SCADA data is already there, there are no extra expenses. Furthermore, owing to the difference in sampling rates, there is a considerably more significant amount of data to be analyzed with a conventional CMS than with a

SCADA system and a greater need for data storage. According to reference [19], a vibration monitoring system's sampling frequency surpasses 10kHz, while a typical SCADA system samples at a rate of less than 0.002Hz. Therefore, the 10-minute averaged value of SCADA data was utilized in this Research Paper.

However, proper diagnosis is not always possible due to the SCADA data's low sample rate. The breadth of information supplied by the SCADA data across the main components [18] may compensate for this limitation in analytical depth. SCADA data should add confidence to the suggested findings from the current CMS and provide significant value to wind turbine status monitoring at little or no expense if effective and reliable methods are used.

II. LITERATURE REVIEW

Because of its potential to increase turbine availability and reduce downtime, much effort has gone into wind turbine condition monitoring. A common trait is the capacity of robust condition monitoring tools to detect deviations from intended system performance effectively. This Section introduces standard wind turbine status monitoring strategies, such as approaches based on turbine physics and data-based modeling that can be applied utilizing SCADA data. To develop an accurate engineering model that can be used for condition monitoring, physical models require considerable and detailed knowledge of the engineering science of the relevant system or a sub-assembly. Such physics of failure models can derive the exact anomaly signals needed for diagnosis [30]. On the other hand, data-based modeling relies on operational system measurements rather than detailed physical knowledge of the system.

In contrast, broad technical knowledge may help guide the selection of data parameters and their acceptable range. Most wind turbines capture many SCADA data. Usually, every 10 minutes, so valid data is available for free in theory. Furthermore, data-based modeling can learn complex inter-relationships among variables, including any nonlinearities, and embed the central system features in the model architecture, sometimes with the help of artificial intelligence or machine learning techniques, with an appropriate selection of variables. Both of these approaches will be compared and contrasted in the context of wind turbine condition monitoring. In the following sections, they will be introduced and discussed, focusing on SCADA data-based modeling.

2.1. TECHNIQUES BASED ON SYSTEM PHYSICS

Traditional physics-based, or physics of failure, models are typically built using equations representing the underlying physics, as in reference 20 [31], which gives a physics-based model of a gearbox and uses it to detect faults in wind turbine gearboxes. To measure the component's remaining fatigue life, the physics that can depict the evolution of damage for a specific component must be adequately understood [31]. However, obtaining this knowledge might be difficult in some cases [30]. The concept of physics-based modeling is broadened here to incorporate methodologies based on physical system data and measurements gathered with the help of extra sensors and equipment. Vibration signal analysis, oil debris analysis, blade tension measurement, and acoustic emission could all play critical roles in the commercial wind turbine health monitoring, according to a survey carried out and published in reference [19]. These strategies rely on sensors that collect relevant measurements and a precise system specification, such as component design and fatigue life, to be realized. Each of the approaches will be introduced and discussed in turn in the following sections.

2.1.1. Analysis of vibration signals

Vibration monitoring in wind turbines refers to the complete turbine drive train, including rotating machinery. The vibration signals are obtained through accelerometers positioned on or near essential components such as high and low-speed bearings. Figure 2.1 shows a typical accelerometer configuration for vibration monitoring in a 3-stage gearbox wind turbine drive train.

The vibration data are frequently subjected to frequency-based analysis, and the resulting spectrum provides a clear indicator of the component state, making fault detection for specific components easier. Significant harmonics may occur in the spectrum if the component's quality deteriorates, or the energy stored in the sideband of the spectrum may grow. To gain a better understanding of which part of the spectral signal corresponds to regular operation and which part is caused by component deterioration, very detailed knowledge of 21 drive train parameters is required, including the dimensions for each sub-assembly within the gearbox and the number of gear teeth for all stages of the gearbox [32].

The Fast Fourier Transform, Cepstrum processing (which involves the inverse Fourier Transform), bearing envelope analysis transforms are all expert of tracking specific frequency components under varying rotor speeds due to their inherent ability to provide greater low-frequency resolution and temporal resolution.

Aside from frequency domain techniques, anomaly detection can also be done using time-series analyses of vibration signals, such as those described in reference [34], where an increasing trend in the time series representing the enveloped high-speed shaft axial vibration amplitude signal indicates the development of an impending gearbox bearing failure.

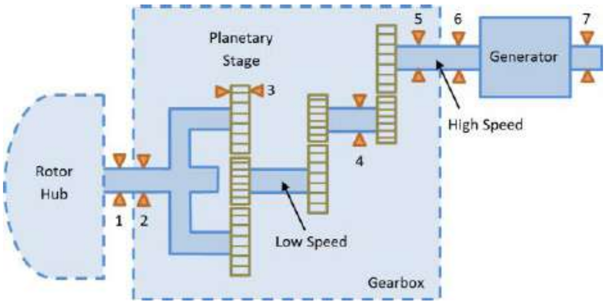


Fig.2.1: An example of an accelerometer configuration in a wind turbine drive train with a three-stage gearbox [33].

2.1.2. Examination of oil slicks

Oil debris analysis could also be an excellent way to keep track of gearbox health. It's occasionally used with vibration analysis to provide a complete gearbox 22 condition monitoring system to detect gearbox issues faster and more accurately [34]. Debris detected in the gearbox lubrication fluid can be interpreted as a sign of gearbox component wear or damage, with particles of varying sizes and materials indicating different types and locations of damage. The induction sensor is a regularly used instrument for determining the size and volume of ferrous and nonferrous particles in lubricating oil [35]. The oil is usually pumped through the filter system after particle counting to remove the junk before being returned to the gearbox.

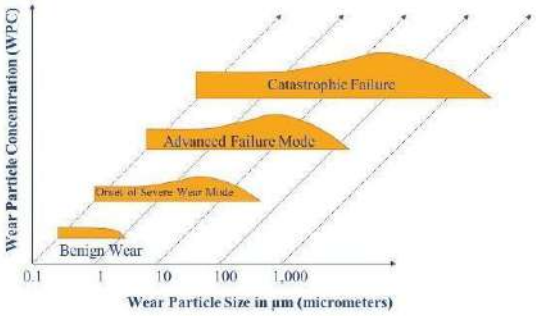


Fig.2.2: Gearbox damage as a function of wear particle size [36]

Figure 2.2 depicts the evolution of gearbox damage in terms of wear particle size, demonstrating that detecting large ferrous wear particles (greater than 100 microns in size) can provide an early signal of probable gearbox subassembly wear. However, for medium and small particle size ranges, the oil counting particle increment rate will be more valuable than the absolute value of cumulant. The increase in the particle (ferrous 50-100 microns) count increment rate before the final failure shows the degeneration of the intermediate shaft, according to reference [24].

2.1.3. Measurement of blade strain

Strain assessment is a quick and easy approach to look at blade loads and, as a result, predict their remaining fatigue life. To measure the blade bending moment in reaction to either the blade weight or the incident wind, relevant sensors can be placed on the tension side, the compression side, the blade edge, or most typically around the blade root (in-plane and out of the plane, respectively).

Using standard strain gauges to detect blade strain is a typical and established method. These provide an electrical signal that corresponds to the local strain and is determined by the sensor's form. The conducting element of a traditional foil strain gauge is designed to be longer vertically than horizontally, resulting in greater vertical sensitivity to conductor geometry change. Because the resistance within the strain gauge is susceptible to temperature variations, the ambient temperature also acts as a substantial error source for the strain gauge measurement. The temperature effect can theoretically be minimized for isotropic materials with consistent temperature distributions by properly selecting half- or full-bridge strain gauge arrangements. These, however, do not apply to composite blades [37]. Strain gauges are likewise unreliable in the long run in reference [32]. Fiber optic sensor technology, on the other hand, has a longer life span and more accurate measurements. However, the current applicability of such strain gauges is limited due to their high cost [32]. Prices are predicted to decline as technology advances, and optical fiber sensors play an important role in wind turbine blade condition monitoring, particularly in independent blade pitch control.

2.1.4. Acoustic emission

The sound made by a tired or stressed object is known as acoustic emission. There are two types of acoustic monitoring: passive, in which the component itself generates the excitation, and active, in which the excitation is applied externally [32].

The acoustic sensors are mounted to the turbine components under inquiry 24 using a medium that works as an excellent acoustic coupler, such as flexible adhesive with low sound attenuation. Condition monitoring for wind turbine blades would most likely be passive. Acoustic emission monitoring and vibration monitoring are closely related [32], and some modern systems combine the two techniques to produce a more accurate state indicator.

Reference [38], for example, employs a combination of these two methodologies to monitor the status of a wind turbine gearbox and generator shaft. In addition, the use of acoustic emission signals to detect possible blade fatigue in essential places like the blade root [39] is also every day.

2.2. MODELING BASED ON SCADA DATA

SCADA data-based modeling is relatively easy to construct and generalize when compared to vibration analysis, oil debris analysis, strain gauge measurement, which all require detailed engineering knowledge and knowledge of the operating characteristics of the monitored component. SCADA data-based approaches, as previously stated, do not require any new sensors and are hence inexpensive to install. The increased use of machine learning techniques in recent years and the variety of artificial intelligence methodologies available have facilitated SCADA data-based modeling [40].

To create successful models for anomaly detection, the inter-relationships between essential operational parameters represented by SCADA data must be recognized (or learned). The interaction among essential factors is represented by each neuron's weight and bias parameters in parametric models like Artificial Neural Networks (ANNs), which are set through training on historical data.

Several strategies have been effectively applied to the domain of SCADA-based wind turbine condition monitoring, including the ANN, Support Vector Machine (SVM), Bayesian network (BN), and the NSET, which will be discussed in the following sections. These techniques were created for other purposes, but they may easily be applied to wind turbine SCADA data. Relevant research findings and potential difficulties will be examined in greater depth for each technique. Finally, there are ways to monitor conditions that rely on operational power curves. These are a subset of SCADA data analysis. They may not always pinpoint the problematic component, but they can alert you to a variety of problems that affect power generation performance. Such approaches, given at the end of this Section, provide a simple and effective means of monitoring the overall turbine status in general.

Artificial Neural Network (NN) models, which are biologically inspired by the mechanisms of human brains, are parametric models that use weight and bias factors. NN models can be used for data classification, and regression, where the output variables are class labels and the outputs are continuous values. In any scenario, the neuron parameters are determined by a training procedure, which is frequently carried out using the backpropagation algorithm.

Input, hidden, and output layers each include a group of neurons [41]. In some cases, the hidden layer has numerous layers. In Figure 2.4, R represents the number of items in the input vector, and W and b represent the neuron's weight vector and bias, respectively.

In the output layer, the weighted sum is supplied input to the neurons [42]. The three most commonly utilized transfer functions for multilayer neural network models are log-sigmoid, tan-sigmoid, and linear. Table 2.1 summarizes their algebraic approaches and graphs.

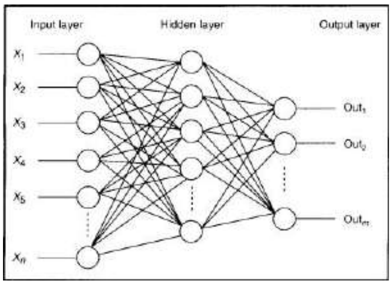


Fig.2.3: Feed-forward neural network model architecture example [41]

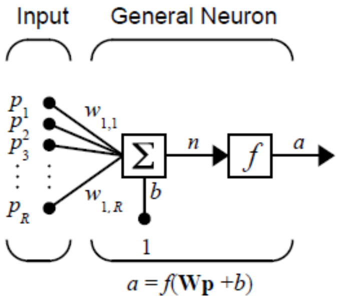
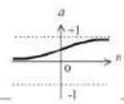
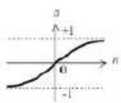
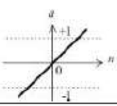


Fig.2.4: A general neuron's inner structure with R inputs [42]

Table 2.1: Three typically used transfer functions in NN models' neurons [44]

	Transfer function algorithm	Transfer function illustration
Log-sigmoid	$a = logsig(n) = \frac{1}{1+e^{-n}}$	
Tan-sigmoid	$a = tansig(n) = \frac{2}{1+e^{-2n}} - 1$	
Linear	$a = purelin(n) = n$	

Recurrent neural networks, unlike feed-forward neural networks, allow for dynamic temporal processing by leveraging an internal state with memory to account for historical inputs via feedback loops [43]. Backpropagation techniques, which continually modify the weights and biases in each neuron to minimize the output error, have helped NN models make a substantial breakthrough in model accuracy [44]. [42] provides a list of gradient or Jacobin-based backpropagation techniques for NN model training, along with full descriptions. The Levenberg-

Marquardt 27 algorithm is the quickest of all the training functions available for small networks. Still, it is not suitable for extensive networks because of its memory and calculation time requirements.

2.2.1. Support vector machine

Vapnik presented the support vector machine (SVM) as a moderately new machine learning technology in 1995. Like the NN model, it is capable of data pattern recognition, such as classification and regression, for nonlinear and high-dimensional data. However, unlike the NN model, which involves the discovery of the architecture and numerous related parameters, the SVM requires minimal parameters and is not prone to false (local) minima detection due to training optimization using a convex function [45]. For non-linearly separable input vectors, the SVM maps them onto a higher-dimensional feature space where hyperplanes can achieve optimal segregation [46].

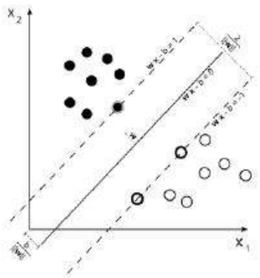


Fig.2.5: A basic illustration of linearly separable 2-dimensional data separated by a line

Figure 2.5 shows an example of 2-dimensional linearly separable data, with the empty and full circles representing two separate data classes. An endless number of lines might be used to separate the two classes, but SVM utilizes the maximum-margin line, as shown in Figure 2.5, since it allows for noise and has the most tolerance for data mistakes on both sides. As demonstrated by the boldly ringed dots, the support vectors are the data points closest to the separating line, and they set the bottom and top decision bounds for each data class. Equations (2-1), (2-2), and (2-3) express the generalized separation hyperplane and associated areas for distinct classes in higher dimensions.

$$\mathrm{W} \cdot \mathrm{x}_i + b = 0 \quad (2\text{-}1)$$

$$\mathrm{W} \cdot \mathrm{x}_i + b \geq 1 \quad (2\text{-}2)$$

$$\mathrm{W} \cdot \mathrm{x}_i + b \leq -1 \quad (2\text{-}3)$$

W and b are the hyperplane's parameters, while vector w is the plane's average vector. There is a corresponding output y_i for each input xi corresponding to one of the two classes, i.e., $y_i = 1$ for Equations (2-2) or 1 for Equations (2-2) (2-3). Equations (2-2) and (2-3) can thus be joined to form Equation (2-4).

$$y_i(\mathbf{W} \cdot \mathbf{x_i} + b) - 1 \geq 0 \quad (2\text{-}4)$$

To attain the maximum margin, they must be minimized, similar to minimizing [48]. Due to its convex shape, this application of this word produces a quadratic optimization with an unambiguous global minimum and no local minima. The parameters are calculated to use a Lagrange algorithm based on the training data, and the results can then be utilized to categorize additional testing data.

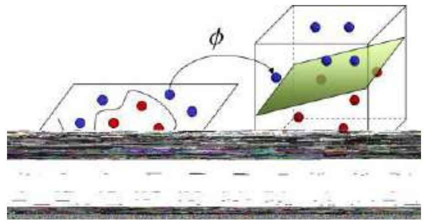


Fig.2.6: Data separation by transferring into a higher-dimensional feature space [47]

In reality, most training data are not linearly separable, as seen in Figure 2.6, where the red hollow and blue solid points indicate two separate classes. There are no straight lines in two-dimensional space that can fully separate these two groups in this scenario. However, the data becomes linearly separable by transferring the data into a higher dimensionality space, known as the feature space, and employing an appropriate nonlinear kernel function. A separating hyperplane can be constructed to complete the separation task, as shown in Figure 2.6. The Gaussian radial basis kernel, the polynomial kernel, and the sigmoid kernel are all popular choices for kernel functions [48].

In situations where misclassifications exist for a small population randomly distributed in the training data, the kernel approach to clear data separation would likely lead to over-fitting and thus lack of general applicability. A soft margin is used in such situations by introducing a positive slack variable to relax the constraints of the decision boundaries, as shown in Equations (2-5) and (2-6). The accompanying objective function is also changed to Equations (2–7), where the second term is a regularization term that limits model complexity and prevents overfitting. Parameter C represents a compromise between the slack variable penalty and the margin size [48].

$$\boldsymbol{W} \cdot \boldsymbol{x}_i + b \geq 1 - \xi \quad \text{for } y_i = 1 \quad (2\text{-}5)$$

$$\boldsymbol{W} \cdot \boldsymbol{x}_i + b \leq -1 + \xi \quad \text{for } y_i = -1 \quad (2\text{-}6)$$

$$\min \tfrac{1}{2}\|\boldsymbol{W}\|^2 + C\textstyle\sum \xi_i \quad \text{s.t. } y_i(\boldsymbol{W} \cdot \boldsymbol{x}_i + b) - 1 + \xi_i \geq 0 \ \forall_i \quad (2\text{-}7)$$

A factual and constant output is created using Equation (2-8) based on the training data for SVM to conduct regression. The position of the observations, i.e., whether above or below the hyperplane, is indicated by two slack variable penalties, ξ^+ and ξ^-, and the related objective is given by Equation (2-9) [48]:

$$y_i = W \cdot x_i + b \quad (2\text{-}8)$$

$$\min \frac{1}{2}\|W\|^2 + C\sum(\xi_i^+ + \xi_i^-) \quad \text{s.t. } \xi_i^+ \geq 0, \xi_i^- \geq 0 \quad (2\text{-}9)$$

SVMs have been widely used in various fields, including image and text recognition and categorization [49] and astronomy [50]. SVM was first used for defect detection in 1999, and the reliability of the associated detection was found to be increased [51]. In reference [52], Gangsar and Tiwari provide an overview of SVM applications to diagnose roller bearings, induction machines, turbopumps, and a variety of other mechanical machinery.

The time-domain vibration data from the main turbine shaft under five different failure types are employed as model inputs in reference [53], resulting in a successful SVM-based fault diagnosis for a direct-drive wind turbine. The SVM model is trained by creating a mapping relationship between the characteristic input vectors and the failure categories. Research of gear fault identification is presented in reference [54], which compares the model performance of ANN and SVM based on time-domain vibration signals. The comparisons are carried out under various load situations and model setups, with the findings demonstrating a better classification in most cases.

SVM provides accuracy. It is also claimed that, in comparison to ANN models, the training time for SVM models is substantially shorter in all scenarios evaluated. SVM analysis of SCADA data for condition monitoring has received little attention until recently. SVMs should be readily applicable to wind turbine condition monitoring utilizing SCADA data, given their excellent performance and ability to extract data features without too much previous information due to their artificial intelligence nature. Other strategies, such as k-nearest neighbor and random forest modeling, have been successfully applied to wind turbine status monitoring, as shown in references [55, 56].

2.2.2. Technique for estimating nonlinear states

The Nonlinear State Estimation Technique (NSET) was first devised for monitoring nuclear power plants and has since been effectively used [57]. It presents a state-based vector recognition technique. The state vectors represent historical sensor readings for variables closely related to the model at a particular timestamp.

Unlike parametric models like ANN and SVM, which require model parameters to be fitted during the training process, The NSET model learns data associations by comparing input signals to historical state vectors. A set of data known as training data is used to pick representative state vectors, which are then stored in a memory matrix.

Even though parametric models require less computational effort for output estimation than non-parametric models because the model architecture is defined in advance, a significant advantage of non-parametric models over parametric models is the ease with which the embedded functional relationship can be modified in the event of changes in the operating region. If parametric models account for any changes in the functional connection between variables corresponding to a new operational state, retraining is required. For example, retraining a NN model might take a long time and yield inconsistent results due to random initialization and the problem of inherent local minima [58]. Non-parametric models, on the other hand, such as the NSET, may easily adjust to changes in the active region by simply adding related state vectors to the memory matrix [58].

NSET was chosen to monitor the critical turbine components in the research presented in later Sections because of its ease of use and enormous potential for wind turbine condition monitoring, evidenced by its successful application to the health monitoring of nuclear plants [57] and rotational machinery [59].

In reference [60], the NSET is used to detect anomalies in a wind turbine generator utilizing SCADA data, with the generator winding temperature as the condition indicator. The memory matrix in this paper was created using a proposed state vector selection approach. While the selected candidate vectors only cover a small percentage of the available training set, they cover the whole operating zone of the turbine most effectively. Several nonlinear functions can be utilized as the nonlinear operator for model output estimation. Still, the Euclidean distance is the most usually used, as it is in reference [60], due to its excellent performance, as shown in reference [61]. Nataraj et al. implement the nonlinear operator in reference [62] as a Gaussian kernel function, which necessitates the optimization of an additional bandwidth parameter during model output estimation. Reference [62] similarly claims that the impact of operator choice on algorithm performance is negligible. As a result of its simplicity, the Euclidean distance is frequently used as the nonlinear operator; for example, reference [63] shows a successful NSET application to turbine gearbox anomaly detection utilizing SCADA data. Reference [60] employs an arbitrary multiple of the maximal validating residual as an anomaly detection criterion, whereas reference [63] uses the more rigorous Welch's hypoResearch Paper test to discover any significant performance deviations based on the NSET model estimation. In the context of false alarms, reference [38] uses a Gaussian error function to calculate the chance of discovering an actual abnormality.

It should be emphasized that in all of the publications mentioned above, NSET has been introduced and presented as an auto-associative model. The outputs of an auto-associative model are designed to imitate their inputs throughout an adequate dynamic range, as shown in Figure 2-8's schematic diagram. State vectors representing the dynamic system in regular operation during the memory process are chosen.

The model is capable of denoising inputs/observations that may contain noise or reflect a system anomaly and producing absolute values of parameters that correspond to system operation under normal conditions based on the learned relationship. The departure of these fault-free model outputs from operational data (observations) with incipient faults can subsequently be utilized to detect unusual behavior.

2.2.3. Techniques based on operational power curves

A wind turbine curve is a relationship between wind turbine power production and the matching wind speed encountered by the turbine rotor. It is a primary but significant indicator for determining a wind turbine's operational health. Power curves can be produced reasonably using the currently available wind farm SCADA data, which is a big plus for condition monitoring. SCADA data is typically gathered at 10-minute intervals and is thus compliant with IEC Standards [64] for power curve calculation in this vital area.

Until now, developers (torque buyers) have primarily utilized power curves to guarantee that the turbines supplied by original equipment manufacturers (OEMs) meet their specifications. The company's power curve is an essential component. In addition, regularly updated power curves can also give a handy way to determine whether operating wind turbines are still performing correctly with the proper procedures.

The nonparametric k-nearest neighbor (kNN) technique is utilized to create the reference power curve for additional anomaly detection in reference [55]. The similar strategy was used in reference [65] to construct a wind farm level reference to monitor overall site operating state. Principal component analysis was performed in conjunction with the kNN algorithm to reduce the input data dimension by selecting only the most informative wind speed components. For large training data sets, such as those recommended by [65], the kNN technique has the problem of requiring significant processing overhead.

Reference [66] treats the relationship between wind speed and power generation along a wind farm as unpredictable. A probability distribution of wind farm power generation is created based on wind speed and direction. The generated distribution could be used to model expected power production.

Recognition of blade and yaw system flaws based on power curve monitoring is documented in reference [67], where a Copula model-based method is used for reference power curve construction due to its excellent performance in characterizing nonlinear relationships such as the one between wind speed and the power output as represented by the power curve. In addition, a sequential probability ratio test is used for anomaly detection.

Reference [68] takes a similar technique, using the IEC standard's "system of bins" to construct the power curve and a Copula-based model to clean the power curve measurements by automatically removing outliers to achieve a more precise reference curve. To aid in discovering abnormalities, a bin by bin statistical comparison utilizing hypoResearch Paper testing is performed, and they are interpreted using a proposed power curve fault logic. Unlike reference [67], which converts power curve measurement data to the Copula domain, this study analyzes power curve performance data in the original measurement domain, resulting in a more relevant and straightforward interpretation. This study has been expanded, and the results will be given in Section 3.

One of the potential drawbacks of power curve-based analysis is that the wind speed measurements in SCADA data sets will not always meet the IEC criteria for power curve determination. The standard, for example, specifies a preferred meteorological mast position 2.5 rotor diameters upwind of the wind turbine. In contrast, SCADA wind speed data is recorded using a nacelle-mounted anemometer located directly behind the rotor and suffers from wind speed loss and added turbulence due to the turbine wake. The correction of such wind speed readings and the data pre-processing that goes along with it will be covered in the next Section. The authors highlighted the importance of ambient temperature on model performance in reference [69] due to its impact on power output through air density.

It is better to follow the IEC performance standard and make an air density correction to account for ambient temperature. This will also be discussed in the following section.

2.3. MONITORING POWER CURVES FOR WIND TURBINES

For both commercial and technical purposes, power curve measurements from the SCADA system are well-established. Concerns about maritime accessibility have heightened the need of monitoring wind turbine maintenance and functioning using accurate wind speed and power data.

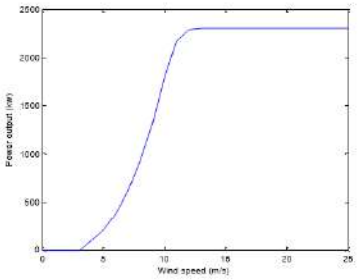


Fig.2.7: Power curve of a typical manufacturer

Figure 3.1 shows a manufacturer's power curve for a 2.3MW pitch-regulated commercial wind turbine with cut-in and cut-out wind speeds of 3m/s and 25m/s, respectively, and a nonlinear relationship between wind speed and output power. The turbine produces no electricity at wind speeds below and above the cut-in and cut-out values. The central controller maintains optimal power coefficient by adjusting generator torque between cut-in and rated wind speeds. The blade pitch angle is adjusted to limit the turbine output power over the rated wind speed [70].

This section will cover the fundamentals of the power curve and data rectification, and uncertainty presentation. To eliminate outliers in the reference data, a Copula-based joint probability model will be used to capture the complex nonlinear relationship between power production and wind speed. It will lead to more reliable fault detection in the future, which will use a bin-by-bin real-time power curve comparison method. A primary fault logic for understanding parts of power curve deviations will be given, followed by a case study of successful yaw misalignment detection to demonstrate the efficacy of the suggested method. Finally, the proposed method's application to pitch performance condition monitoring will be explored briefly.

2.4. DATA PRE-PROCESSING AND GRAPHING OF POWER CURVES

The SCADA system was used to collect 10-minute averaged measurements of nacelle anemometer wind speed, turbine power output, ambient temperature, and atmospheric pressure. The air density, to which the power in the wind is proportional, and to which the turbine power output, P, can be expected to be proportional during below-rated operation are determined by the latter two measurements:

$$P = \frac{1}{2}\rho\pi R^2 v^3 C_P \qquad (2\text{-}10)$$

The radius of the turbine rotor is R, and the free wind speed of the rotor is v, which differs from the nacelle anemometer reading; and Cp denotes the power coefficient.

To reflect the true relationship with the turbine output power described in Equation, the wind speed measurement from the nacelle anemometer must be rectified to the free-stream rotor wind speed (2-10). In addition, the collected power curve measurements must also be corrected to standard air density conditions to make fair comparisons between operating power curves (15 and 101.325kPa). The details for both of these corrections will be presented in the following sub-sections. First, in Section 2.1.3, a power curve based on corrected data, with error bars illustrating the data's uncertainty.

2.4.1. Wind speed correction using a nacelle anemometer

For the annual energy output estimation and power curve performance tests to be reliable, accurate wind speed measurements are required. According to the IEC standard, the meteorological mast should be placed between 2 and 4 rotor diameters upwind of the testing turbine, with a range of 2.5 rotor diameters and a height of about the hub height [64]. However, due to the complex terrain and the high cost of buying and implementing the meteorological mast [71], these specifications are mainly used for initial contractual obligation verification of turbine manufacturers' power performance [65]. Therefore, they are rarely met for individual turbine-measuring purposes in reality.

As a result, wind farm owners prefer to obtain wind speed data from the turbine nacelle anemometer. However, because the rotor disc itself disrupts the incident wind, the nacelle anemometer reading cannot precisely represent the turbine rotor's free-stream wind speed. As a result, using the link between anemometer and meteorological mast readings, a wind speed conversion from anemometer measurement to free-stream value is established [71, 72, and 73]. The established relationship could only be transferred to other turbines of the same make and type if the rotor settings and nacelle anemometer mounting stay unchanged, and the terrain is flat, according to reference [72]. However, the authors assert that linear regression is sufficient for the mast-nacelle anemometer relationship in their references [71, 73].

Because wind turbines are designed to operate at optimal CP for the below-rated region, and the value of CP is related to the axial flow induction factor, which indicates the proportion of wind speed that is slowed at the rotor, by Equation (2-11), where the maximum CP occurs when a = 1/3 [74], the nacelle anemometer measurement can theoretically be about a third lower than the meteorological mast reading.

2.4.2. Correction of air density

Because the power absorbed by the turbine rotor is related to the density of air traveling through it, any power curve-based research must first apply an air density correction to the data. The air density correction for actively managed wind turbines is solely done with relation to wind speed, according to IEC standard 61400-12-1 [64].

$$V_C = V_M \left[\frac{\rho}{1.225}\right]^{1/3} \quad (2\text{-}12)$$

V_M and V_C, respectively, denote the measured and adjusted wind speeds. The equation can be used to compute the ambient air density .

$$\rho = 1.225 \left[\frac{288.15}{T}\right]\left[\frac{B}{1013.3}\right] \quad (2\text{-}13)$$

T is the thermal gradient in degrees Fahrenheit, and B is the barometric pressure in millibars, both of which are 10-minute averaged SCADA data values. B is usually considered the standard value of 1013.3 mbar, leaving T as the only important parameter for calculating air density.

Because the corrected measurements were taken under standard air density circumstances, they may be utilized for comparison. However, it's worth noting that the air density corrected wind speed differs from the corrected anemometer wind speed discussed in the preceding section and that the anemometer wind speed correction, if necessary, should come first.

2.4.3. Uncertainty sources

The IEC standard [64] specifies the use of the "method of bins" to construct the power curve. In 0.5 m/s wind speed bins, SCADA data is pooled and averaged, with error bars for each bin illustrating uncertainties. According to reference [75], the uncertainties associated with power curve measurement can be categorized into two categories: Category A, which considers the standard deviation of the scatter in each bin, and Category B, which considers the instrument's knowledge. Because the accuracy of power curve-related sensors is lacking in most SCADA systems, only uncertainties connected with Category A are included in this Section's analysis. Therefore, the power curve measurements will include the uncertainties associated with Category B, which the figure will represent. For each wind speed bin j, the main uncertainties, Sj, in Category A are for power variation, and the corresponding formula is presented in Equation (2-14).

$$S_j = \frac{\sigma_j}{\sqrt{K_j}} \quad (2\text{-}14)$$

Where σ_j is the energy measurement's standard deviation in the j^th bin, and the number of points in this bin is K_j. $1/\sqrt{K_j}$ is a term that refers to a unit of measurement.

Theorem's uncertainty measure [75] is determined by the number of occurrences in the bin.

Figure 2.2 shows two-month power curves from a 2MW pitch-regulated wind turbine generator (Turbine 2). Figure 2.5 depicts the comparable power curve from binning, with error bars denoting uncertainties. The large error bars at the high wind speed (values > 20 m/s) bins are not required because the maximum power output is well controlled and set by the turbine management system [76]. In these specific bins, the paucity of points illustrates the irregular nature of the extraordinarily high wind speeds.

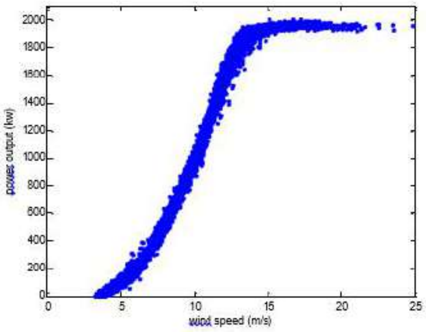


Fig.2.8: Scatter plot of Turbine 2 power curve measurements

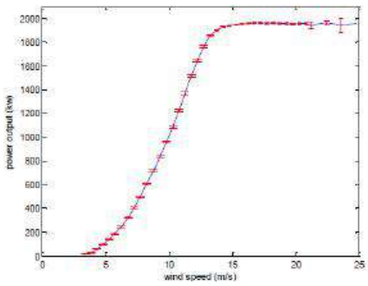


Fig.2.9: Turbine 2 power curve with error bars indicating data uncertainty

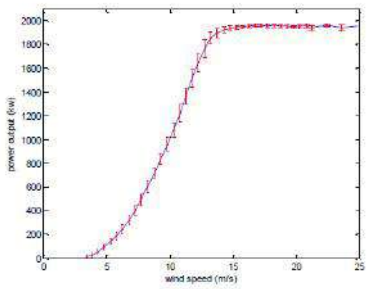


Fig.2.10: Turbine 2 power curve with error bars demonstrating data dispersion

In Figure 3.4, the power curve has been re-plotted, with error bars indicating the unaltered value. The magnitude of the error bars, in this case, represents the data spread for reasons that will be addressed in Section 2.5.3, majority of significant results occur around and somewhat below 13.5 m/s.

2.5 CONSTRUCTION OF A REFERENCE POWER CURVE USING A COPULAS-BASED MODEL

Slight variations in the power curve must be observable to enable early fault detection, and an accurate power curve reference is necessary to ensure the reliability of subsequent problem detection. Due to the consideration of both environmental factors (such as wind shear, wind veer, and turbulence) and the effect of bias errors associated with instruments as mentioned in the previous section, the reference power curve in this Section is constructed based on turbine operational data rather than manufacturer's data.

Most SCADA data displays ten-minute averaged power-wind speed pairings (as binned to construct power curves) that are far from most locations and can thus be considered outliers. There are a variety of explanations for such "inaccurate" data. A typical example is when a turbine's status changes halfway through ten minutes, such as a turbine cut out. As a result, the mean output will be significantly reduced, yet the recorded wind speed will remain unchanged, as shown in Figure 3.3 for Turbine 1. Unfortunately, not all SCADA data systems detect such state changes. It means that, before determining the final power curve, other methods must be applied to exclude such data. Copulas, which can characterize multivariate nonlinear connections in multivariate probability distributions based on individual univariate probability distributions [77], are used here.

2.5.1. Using Copula Statistics to Express Dependency

Sklar coined the word Copula to describe the process of combining a multivariate data set's complicated nonlinear dependency structure with its unidimensional marginal distributions [78]. The cornerstone for the construction of Copula models is Sklar's theorem [77], which states that if a joint cumulative distribution function (CDF), F, exists for the random variables (x_1, x_2, x_n) Rn, then there must be a Copula function C such that:

$$f(x_1, x_2, \cdots, x_n) = c(u_1, u_2, \cdots u_n) \times f_1(x_1) \times f_2(x_2) \times \cdots f_n(x_n) \qquad (2\text{-}16)$$

The ith marginal CDF for the ith random variable is Fi(xi). If Fi(xi) are continuous, the Copula function C is unique; otherwise, C is merely unique within the marginal distribution's value range. [79]. The Copula function is defined on the unit hypercube, (i.e. (0 1)n 0 1), because the univariate marginal distributions lie inside interval (0 1) [80]. The joint probability density function (PDF) can be constructed by differentiating both sides of Equation if the joint CDF, F, the marginal CDF, Fi, and the Copula function, C, are all differentiable (3-6). For simplicity, the joint PDF, f, is given as:

Where f_1 indicates the ith marginal PDF and the original marginal CDF, Fi, is represented by u_1. The Copula density function that unites them is denoted by c.

2.5.1.1. The Frank Copula

The data are assumed tail dependence influences the choice of Copula. Tail dependence is described as the link between the two marginal distributions in the bivariate case. The distribution is tail-dependent when one distribution exceeds a certain threshold and the other exceeds it with proportional likelihood [81]. Tail dependency appears as a tightening of the dispersion of data around the distribution's extremes, whereas low tail dependence appears as a higher degree of scatter.

The multivariate joint distribution based on various Archimedean Copulas is shown in reference [82], which is discussed in depth in reference [83]. The Clayton Copula has a higher lower tail dependency, the Gumbel Copula has a more considerable upper tail dependency, and the Frank Copula is symmetric in both tails. As indicated in reference [67], the Frank Copula Model's distribution pattern and tail dependency features match the power curve variables. So this Copula is picked. cFran(u1, u2) is defined as follows:

$$c_{Frank}(u_1, u_2, \delta) = \frac{\delta \eta e^{-\delta(u_1+u_2)}}{[\eta - (1-e^{-\delta u_1})(1-e^{-\delta u_2})]^2} \qquad (2\text{-}17)$$

Where $\eta = 1 - e^{-\delta}$. The Frank Copula [83] shows a bivariate dependence between variables whose values are higher, as seen in Figure 2.5. Maximum likelihood can be used to find the parameter.

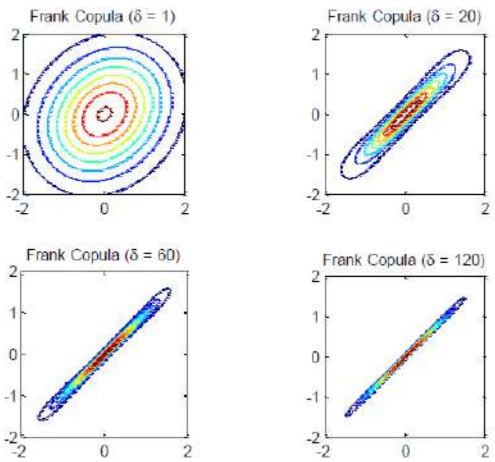


Fig.2.11: The effect of variable dependency on δ value

2.5.1.2. The Gaussian Mixture Copula Model (GMCM)

The GMM probability density φ is given by and consists of a weighted sum of M Gaussian density components.

$$\varphi(x_1, x_2, \cdots, x_n; \quad) = \sum_{k=1}^{M} \alpha_k N(x_1, x_2, \cdots, x_n; \theta_k) \qquad (2\text{-}18)$$

Where αk denotes the weights of various components, and all elements of k add up to one. The modality number is indicated by parameter M, which will be determined in Section 2.5.2.1. $\theta k = \{\mu k; Zk\}$, where μkk denote the mean vector. Zk is the covariance matrix for the kth component [84]. As well as k-valued statistics for each Gaussian component. Linear dependency can only be represented by a multivariate Gaussian. However, it is clear that mixed components with a more complicated dependency structure would provide a better fit.

A Gaussian Mixture Copula Model (GMCM) [80] can characterize nonlinear multidimensional statistics. It is constructed from a GMM with no inferred covariance. The GMCM density function, which is obtained from Equation (2-18), is defined as:

$$c_{GMCM}(u_1, u_2, \cdots, u_n; \theta) = \frac{\varphi(\Phi_1^{-1}(u_1), \Phi_2^{-1}(u_2), \cdots, \Phi_n^{-1}(u_n); \theta)}{\prod_{i=1}^{n} \varphi_i(\Phi_i^{-1}(u_i))} \quad (2\text{-}19)$$

Where φi and −1 denote the GMM's marginal density and inverse distribution along each dimension, respectively. As indicated in Equation, the parameter set is optimized by maximizing the log-likelihood function of the GMCM Copula function (2-19).

Equation (2-16) uses the fitted Copula density function to construct the joint probability distribution: (2-17) for the Frank Copula model; and (2-19) for the GMCM.

2.5.2. Copulas for power curve density modeling

A two-dimensional joint probability density function is used to connect the marginal distribution of wind speed and turbine power production. The following are the basic steps for Copula-based outlier removal:

1. Power curve readings are pre-processed

This entails removing null entries and then air density correcting the raw data.

2. Determination of model order

To make fitting the GMCM easier, the modality number is calculated using the self-organizing map described in Section 2.5.1.1.

3. GMCM installation

[80] proposes a GMCM parameter optimization approach based on Expectation-Maximization (EM) [85], followed by a gradient descent optimization. This is due to the non-convex log-likelihood function for the GMCM density function. The EM Maximizing stage does not ensure global optimum investigation, necessitating the Gradient Descent method using beginning conditions supplied by the EM solution within an iterative loop. This work maintains the GMCM parameter estimation algorithm.

4. Rejection of outliers

A probability contour based on the achieved density distribution is used to filter outliers of power curve data. The robustness of GMCM is demonstrated by utilizing the Bayesian Information Criterion to compare GMCM, Frank Copula, and GMM quality of fit (BIC).

2.5.2.1. Model order selection

When utilizing mixture models like GMCM, the best data modality is essential. Miljkovic [86] came up with the self-organizing map (SOM) concept.

It was utilized here because it can cluster data unsupervised. SOM's main goal is to project high-dimensional data into a low-dimensional (usually 2D) space where data clustering and topology may be seen and understood [86].

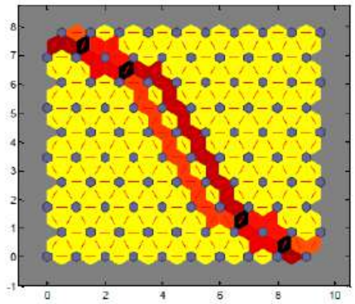


Fig.2.12: Turbine 2 SOM neighbor weight distances

To guide the ideal model's modality selection, the Turbine 2 data set (Figure 2.6) is analyzed for its number of modes. This graph reveals three separate data zones: near cut-in (3.5 m/s), above rated (13.5 m/s), and in between.

A two-dimensional SOM depicts the data clustering. Figure 2.6 depicts the learning outcome as neighbor weight distances, with blue hexagons representing neurons and red lines linking them. In the background color scheme, darker colors represent longer distances between neurons, whereas brighter colors represent shorter distances. Color-coding shows two distinct triangles at the bottom left and top right, with a weaker triangle in the centre, nearly perpendicular to the diagonal. Dark color bands separate them.

Although the weight distance plot does not accurately duplicate the original data, the model order for this power curve data is three, which matches the original assumption of three components to the power curve. In the future, this part of model order determination could be avoided because virtually all commercial power curves have the same features.

2.5.2.2. Fitness assessment

Once the data type is identified, as mentioned in the preceding section, GMCM can automatically cluster data. The model's fitness is evaluated using the same SCADA data as in Section 2.1.3 for Turbine 2. For model selection, the Bayesian Information Criterion (BIC) [87] is used. $L(\Theta|x_1, x_2, \cdots, x_n)$, which sums the log of all data points' probabilities and offers a straightforward and easy-to-calculate goodness-of-fit measure [88]. Over-fitting is avoided by using a penalty term called $plog(N)$, which considers the model's complexity. BIC is defined as follows:

$$BIC = -2L(\Theta|x_1, x_2, \cdots, x_n) + plog(N) \qquad (2\text{-}20)$$

Where the log-likelihood function,

$$L(\Theta|x_1, x_2, \cdots, x_n) = \sum_{i=1}^{N} \log f(x_1(i), x_2(i), \cdots, x_n(i)|\Theta) \qquad (2\text{-}21)$$

In Equations (2-20) and (2-21), N represents the sample size, which is 7257. The number of parameters is denoted by p. $p = 1$ for the Frank Copula, while Equation (2-22) [89] can derive it for the GMM and GMCM.

$$p = M(1 + n + \frac{n(n+1)}{2}) \qquad (2\text{-}22)$$

Where M is the modality number (3 in this example), and n is the data dimension (2 in this case). This gives a p value of 18.

	Bayesian Information Criterion value
GMCM	110597
Frank	112415
GMM	114993

As mentioned in Section 2.5.2.2, the GMM is included here because of its capacity to cope with multimodal data. Table 2.1 shows the BIC values for these three models, revealing that the GMCM model has the lowest BIC. Furthermore, while the While the Frank (or Archimedean) Copula could only handle bivariate data, the GMCM can handle multivariate distributions, allowing for more variables for applications like environmental factors. Finally, for outlier rejection, the Gaussian Mixture Copula Model is adopted.

2.5.3. Example of power curve outlier rejection using the GMCM

The GMCM's goodness of fit for power curve measurements was demonstrated in the previous section. The bivariate probability distribution that is obtained can then be used.

A reference power curve can be built by excluding any statistically significant outliers in the power curve observations. This section includes an outlier rejection example of the power curve shown in Figure 2.3 for Turbine 1 to demonstrate the usefulness of the suggested strategy.

As indicated by the size error bars, the most scatter occurs around rated power. The turbine is constantly changing between below-rated operation, where speed is varied to maximize aerodynamic efficiency, and above rated power, where electronic control limits current and power from the generator [90]. Because the variance at the extremes is reduced, tail reliance is unlikely to be a significant source of the mistake. Therefore, a probability contour level of three standard deviations is deemed adequate for data in the 0.5 m/s wind speed bin closest to rated wind speed. Outliers are defined as points that fall outside this contour and are deleted accordingly.

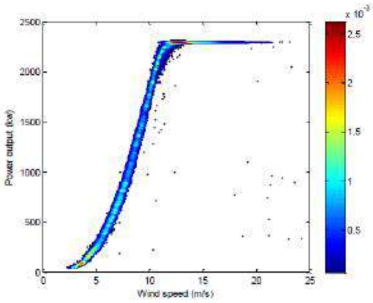


Fig.2.13: Example of GMCM fitting to a power curve from Turbine 1

2.6. ONLINE POWER CURVE CONDITION MONITORING ON A BIN-BY-BIN BASIS

This section uses a power curve comparison/tracking approach to discover significant statistical variations from the reference power curve bin by bin. First, for each entering 10-min SCADA data set, essential filtration removes power curve combinations containing incorrect measurements such as negative or null values. Then, the valid data with air density correction are fed into the suggested power curve comparison method, which will be discussed in the next section. Finally, the Welch hypoResearch Paper test is used to discover anomalies in each wind speed bin.

2.6.1. Realization of a rolling power curve

For online monitoring, a rolling power curve concept was created with accuracy and efficiency in mind. It is essentially a bin-by-bin real-time updating and detecting turbine power output variation. The same 0.5 m/s wind speed bin interval is employed here and a choice of 5 fixed locations per bin, as this gives the optimal balance of accuracy and efficiency. A three-dimensional storage cell is used for each wind speed bin to save the value of wind speed, power output, and date&time information. For each incoming 10-min power curve data pair with air density corrected, the data in the storage cell is continually updated following the first-in-last-out rule. Any significant deviations from the reference curve will be recorded with the anomalous power curve values for the specific bins and the associated date and time information.

When two neighboring wind speed bins trigger the alarm simultaneously, the empirical findings are logged in the alarm log. The use of two neighboring detections reduces false alarms generated by isolated noise, but there is a trade-off between speed and accuracy. The Welch hypoResearch Paper test, which will be discussed next, is used to see if any given bin's reference and rolling power levels are inconsistent at a statistically significant level.

2.6.2. Welch's hypoResearch Paper test for anomaly detection

Welch's t-test is an extension of the Student's t-test used when the variances of two testing samples are anticipated to be uneven, according to [91]. As a result, statistically significant variances in each wind speed bin are identified using this method.

$$t = \frac{\overline{X_{ref}} - \overline{X_{test}}}{\sqrt{\frac{S_{ref}^2}{N_{ref}} + \frac{S_{test}^2}{N_{test}}}} \quad (2\text{-}23)$$

The power average and standard deviation and the sample size of the bin are represented by $\bar{X}$, S, and N, with the subscripts ref and test representing reference and testing data, respectively when $t > t_\alpha\,(v)$, where $t_\alpha(v)$ follows the student's t distribution with significance level, α, and the number of degrees of freedom, v, the chance of the test average falling below the reference average is regarded significant.

$$v = \frac{\left(\frac{S_{ref}^2}{N_{ref}} + \frac{S_{test}^2}{N_{test}}\right)^2}{\frac{S_{ref}^4}{N_{ref}^2(N_{ref}-1)} + \frac{S_{test}^4}{N_{test}^2(N_{test}-1)}} \quad (2\text{-}24)$$

Note that the method may easily be extended to encompass over-performance, which is typical and suggestive of sensor error or wrong calibration, as detailed in the next section's power curve fault logic. Therefore, the over-performance detection criterion is stated as $t < -\,t_\alpha\,(v)$, and the corresponding alteration is to add it.

The significance level chosen will impact the balance between quick defect detection and dependability in terms of avoiding false positives. As a result, it cannot be determined a priori; instead, it must be chosen based on practical experience and trial and error. In addition, other anomaly detection requirements, such as imposing minimum limitations on the number of individual anomalous bin values, can be introduced to assist reduce false positives.

2.7. FAULT LOGIC FOR GENERAL POWER CURVES

Technical issues with the wind turbine or sensor defects can cause significant power curve deviations. Still, they can also be caused by exceptional environmental conditions such as high wind shear or veer and turbulence.

A simple but exciting example is a power curve that exceeds the Betz limit below rated wind speed but works at rated power above rated wind speed. The power control and power measuring system appear to be operating correctly and accurately, as the power is, as predicted, above rated. And there's no reason to suppose this isn't the case when the wind turbine isn't rated correctly. Thus the only logical explanation is that the anemometer on the wind turbine isn't reading correctly (not uncommon with cup-type anemometers).

Below is a very rough but general defect logic to show how condition monitoring analysis based on comparisons between a cleaned reference power curve and an updated, ideally real-time, power curve for the same turbine might be read. Although it is well known that environmental factors have been considered to some extent when using operational data as a reference, these concerns are only included in the fault logic below in extreme cases.

1) Deviations from the reference power curve could indicate: a) Wind speed below the rated value: anemometer or power transducer calibration fault. b) Wind speed over the rated value: controller setting error, power transducer calibration error

Investigation of the value of Cp can provide additional confirmation. For example, a Cp value more significant than the Betz limit (16/27) indicates that the measuring sensor (anemometer or power transducer) is malfunctioning.

2) Consistent deviations from the reference/power manufacturer's curve for the below-rated zone could indicate blade breakage, improper blade pitch setting or control, yaw system difficulties, or very severe wind shear or wind veer [92].

3) High turbulence can cause significant deviations over the reference power curve in the low wind speed zone, decreasing below the reference curve above rated power [92].

2.8. CASE STUDY OF YAW MISALIGNMENT

This section includes a case study of a wind turbine with rotor yaw misalignment to demonstrate the proposed method. Three months of fault-free operation from a pitch-regulated variable-speed wind turbine (dubbed "Turbine 3") with a nominal rating of 2.5MW was used to create the reference power curve. All of the power curve readings presented here have been corrected for air density, and the SCADA wind speed is considered the free-stream value.

As seen in the power curve fault logic in the previous section, yaw misalignment will result in a power output deficiency. The highly simplified cos cubed theory [93], which stipulates that the power output is scaled by the cube of the cosine of yaw error, accurately predicts the extent of this power shortfall (differences between wind direction experienced by the rotor and the nacelle direction). It should be noted that this metric is occasionally, but not always, recorded in SCADA data because it is frequently used.

As a result, it is not recorded as a control variable. On a ten-minute average basis, the SCADA data available for Turbine 3 in this investigation included yaw error and nacelle position.

According to the cos cubed law, a yaw mistake of 20 degrees, which is exceedingly improbable given acceptable turbine yaw control, will result in a considerable power shortfall of 17%. Because a wind farm operator is unlikely to accept such a power disadvantage, a yaw error threshold of 20 degrees was established. Figure 2.15 depicts a time series of absolute yaw error from an operational wind turbine. The yaw inaccuracy continuously exceeds 20 degrees for timestamps 200 to 240, as can be seen. Figure 3-16 demonstrates that the nacelle position was stuck in a fixed position (about 200 degrees) for an extended period, with no yaw action, while the wind direction fluctuated usually.

The hypoResearch Paper test set at a 99.5 percent confidence level, i.e., a significance level of 0.005, compares the real-time power curves for this period to the reference power curve created above. This is a rough estimate based on intuition and the assumption that the determined likelihood and statistical modeling are reasonable. The fact that it is tentative reflects the lack of field trial data. However, the ultimate value is unlikely to differ significantly. As indicated by the red points in Figure 2.8, the total number of abnormal bin values across the whole power curve at each time point, as determined by this 99.5 percent criterion, is represented as a time series, along with the corresponding value of the absolute yaw error. This method would have generated an alarm at 03:00 on April 15, 2009, 6 hours after the initial unusual yaw detection at 21:00 on April 14, 2009. Therefore, it has been proved that power curve tracking may be used to identify a serious performance issue reliably.

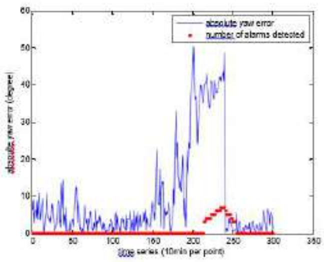


Fig.2.14: The absolute yaw inaccuracy for Turbine 3 as well as the total number of anomalous bins found

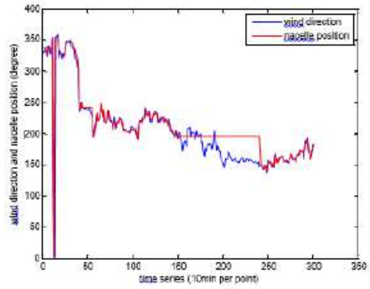


Fig.2.15: Wind speed and nacelle location for Turbine 3

The problem in this example was improper yaw control, which could have been caught promptly with the correct SCADA data. However, as previously stated, yaw error is frequently left out of SCADA data. As a result, it may be claimed that 6 hours is excessive. This may be decreased by utilizing less robust detection, such as lowering the hypoResearch Paper test confidence bounds, but the outcome would inevitably be more false alarms. Given that SCADA-based condition monitoring is still in its infancy, and operators are concerned about excessive amounts of alarms (see, for example, reference [32], it appears prudent to err on the side of robustness with a slightly less responsive algorithm design.

2.9. THE PROPOSED METHOD'S APPLICATION TO PITCHING PERFORMANCE CONDITION MONITORING

The suggested online power curve condition monitoring approach is used to monitor pitching performance, defined by the pitch angle – wind speed operating curve, based on the successful identification of a significant power curve deviation as proven in the preceding section. The primary goal is to see if the pitching mechanism is managed correctly and running. In Welch's t-test, any performance deviation in the wind speed bin will result in a statistically significant value, triggering the alarm.

Anemometer faults, pitching-related issues such as controller error (e.g., setup error), or hydraulic system error could all cause variations from the reference pitch angle – wind speed curve (e.g., hydraulic oil leak). All of these categories could be confirmed by comparing the power curve performance to the reference. For example, if the anemometer inaccuracy is the cause of the pitch deviation, the related power curve plot should show a shifted version of the reference data. Likewise, other factors will result in a power deficit displayed on the power curve plot.

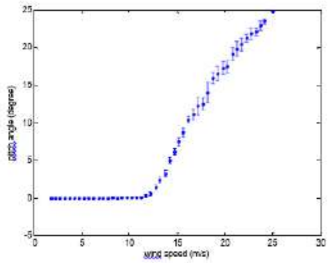


Fig.2.16: Pitch angle – wind speed reference with error bars for Turbine 3

This section validates the suggested method by using a pitch performance monitoring example for Turbine 3. Because the pitching operation is dependent on generated power, which is proportional to the related air density, the wind speed measurement should be corrected for air density before any studies, as shown in Section 2.1.2. Figure 2.10 shows a pitch angle – wind speed reference built from three months of healthy data with outliers removed using the GMCM.

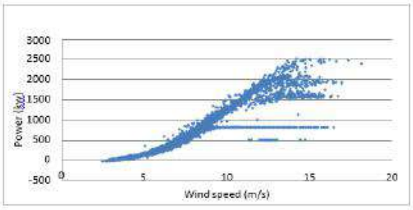


Fig.2.17: Power curve scatter for Turbine 3 testing data

The corresponding detection result of the Turbine 3 testing data is displayed in Figure 2.11, where the curtailment flag time series is plotted with the aggregate alarm number detected (with a high level indicating non-curtailment and vice versa). As the derating flags approach low levels, the restriction from early pitching is efficiently picked up. This indicates the efficacy of the technique that was devised.

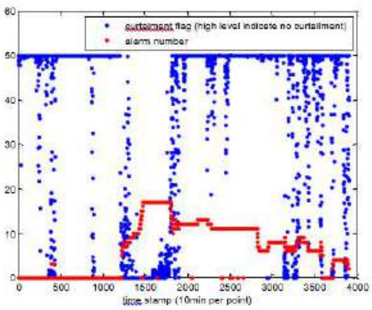


Fig.2.18: Pitching performance detection results for Turbine 3

Early pitching can be confused with true pitch abnormalities without a restriction indication in the SCADA. While power curves can identify curtailment, the process is time-consuming. A curtailment flag is necessary to process pitch angle data and power characteristics accurately.

III. METHODOLOGY

3.1. APPLICATION OF THE NSET MODEL TO SUBASSEMBLY DEFECT DETECTION FOR INDIVIDUAL TURBINES

The Nonlinear State Estimation Tool (NSET) is a state-based vector recognition technique that can track wind turbines' health. The NSET model's algorithm and associated memory matrix building for models will be described first in this Section, followed by the introduction of anomaly detection using NSET estimate. The proposed method's usefulness will next be illustrated with applications to anomaly detection in wind turbine gearbox and generator failure.

3.2. DETECTION OF ANOMALIES USING THE NSET MODEL: METHODOLOGIES

The following are the critical analysis techniques carried out to implement a specific model:

1) Using a combination of domain knowledge [94] and correlation analysis, identify all the factors strongly associated with the model output parameter of interest.

2) Using the framework presented in Section 2.2.2, create a state memory matrix from the training data.

3) Validate the built model with a validating data set as described in Equations (2-1) and (3-7) below, and then establish fault detection algorithm thresholds based on the results.

4) Use Equations (3-2) and (3-7) to evaluate the authorized testing data and then record any alarms generated by the defect detection method described in Section 3.1.3.

Each stage is described in further detail below and illustrated using case studies in later sections of this Section to clarify the methods and show the technique's potential for wind turbine defect identification.

3.2.1. Algorithm NSET

A state memory matrix D, represented by Equation (3-1), is used [60]. Each row captures the readings from a single sensor, and each column (vector) represents a system operating condition observed at a specific moment. It's worth noting that, as is customary, the sensor readings for model output are also included in the matrix used to compute the similarity between the current input and historical states.

$$D = [X(1)\ X(2) \cdots X(m)] = \begin{bmatrix} x_1(1) & x_1(2) & \cdots & x_1(m) \\ x_2(1) & x_2(2) & \cdots & x_2(m) \\ \vdots & \vdots & \ddots & \vdots \\ x_n(1) & x_n(2) & \cdots & x_n(m) \end{bmatrix} \quad (3\text{-}1)$$

There are m observation vectors for the n sensor variables in the memory matrix. The matrix can then be used to simulate the performance of a turbine component, and the NSET can produce reasonable estimates as long as the matrix has valid and correct data that covers the normal operating range of the item being modeled. In our example, a wind turbine [57]. In the following part, we'll go over the specifics of matrix building. The output $Xest$ is created from the product of the memory matrix **D** and a weighting vector $\mathbf{W} = [w1\ w2 \cdots wm]^T$ for each new input vector X_{obs}, as shown in Equation (3-2). The superscript "T" specifies the transposition of matrices, and all the vectors are, by default, column vectors.

$$X_{est} = D \cdot W = w_1X(1) + w_2X(2) \cdots + w_mX(m) \quad (3\text{-}2)$$

The degree of similarity between the input and each state in the matrix is captured by the weighting vector. Equation 1 shows the residual difference between the measured output and the model estimate X_{est} (3-3).

$$e = [e_1\ e_2 \cdots e_n]^T = X_{obs} - X_{est} = X_{obs} - D \cdot W \quad (3\text{-}3)$$

Using a typical least-squares approach, the estimation of the weighting vector, W, can be derived by minimizing the sum of squares of the residuals, as indicated in Equation (3-4).

$$\sum_{i=1}^{n} \varepsilon_i^2 = \varepsilon^T \cdot \varepsilon = (X_{obs} - D \cdot W)^T \cdot (X_{obs} - D \cdot W) \quad (3\text{-}4)$$

$$= X_{obs}^T \cdot X_{obs} - X_{obs}^T \cdot D \cdot W - W^T \cdot D^T \cdot X_{obs} + W^T \cdot D^T \cdot D \cdot W$$

The first-order derivative of $\sum^n_{i=1i2}$is adjusted to zero to minimize its value (i.e., to achieve maximum model accuracy), as indicated in Equation (3-5); the corresponding derivation can be found in reference [95].

$$\frac{d\sum_{i=1}^{n} \varepsilon_i^2}{dW} = -2D^T \cdot X_{obs} + 2D^T \cdot D \cdot W = 0 \quad (3\text{-}5)$$

which results in:

The universal least-squares solution for the weight vector is given by equation (3-6). The difficulty of inverting the so-called recognition matrix (DT D), which emerges from a possible linear link between state vectors in the memory matrix [61], poses a problem. This problem can be solved by substituting a nonlinear operator for the dot product within the bracket in Equation (3-6). The modified NSET weight vector W is written as:

$$W = (D^T \cdot D)^{-1} \cdot (D^T \cdot X_{obs}) \quad (3\text{-}6)$$

$$W = (D^T \otimes D)^{-1} \cdot (D^T \otimes X_{obs}) \quad (3\text{-}7)$$

Since the Euclidean distance surpasses the other nonlinear operators in reference [61] in prediction accuracy, the nonlinear operator ⓧ calculates the Euclidean distance of the operands, as indicated in Equation (3-8). In reference [60], the same distance metric is used.

$$x \otimes y = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2} \quad (3\text{-}8)$$

The arithmetic described above can be considered a procedure for calculating the closest possible vector to the observation vector that can be produced by combining the vectors in the memory matrix in a linear fashion. The Euclidean norm is used to calculate distances in this n-dimensional space. It's hard to imagine how a linear combination of memory matrix vectors may extrapolate to an area of space outside the memory matrix's domain.

3.2.2. Construction of a state memory matrix

The choice of model variables and the building of the memory matrix are both significant since they directly impact the NSET model's correctness and efficiency. To choose essential variables for a specific model, domain knowledge and correlation analysis are used.

After selecting relevant variables to include in the model, the state memory matrix must be constructed by selecting measured state vectors from the available operational data. Training in other models, such as neural networks, is similar to this procedure. Three factors must be considered. To begin, the selected data should include enough states to span the entire range of regular operation, including expected behavior under extreme conditions, to get a good model representation and performance. Second, the potentially massive number of states involved can make the matrix operations required in the process computationally time-intensive. Finally, increasing the number of states beyond a certain point is known not to affect model correctness. As a result, a data selection technique, such as the one provided in [60], should be employed to choose state vectors from the training data set in an even and efficient manner. The number of states in the model can be drastically reduced with this method, making it considerably more effective while still being representative. The matrix size is determined the same way as the cluster number decision in reference [69].

In this study, the validation accuracy was plotted versus the matrix size. It is a simple way to prevent creating needlessly huge memory matrices. Section 3.4.1 will illustrate an example of memory matrix sizing. Last but not least, no repeated states in the memory matrix are allowed because this will cause a singularity in the matrix inversion needed to solve for the weighting matrix (Equation (3-7).

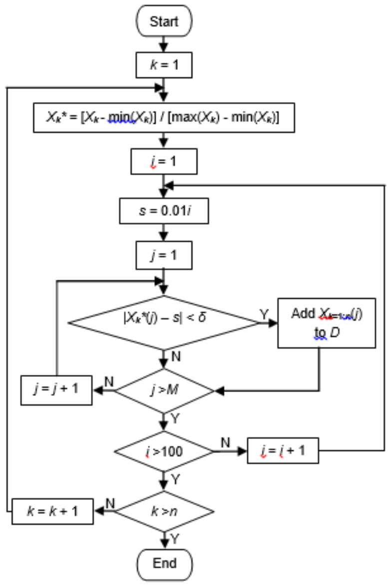


Fig.3.1: A flow plan for selecting data for memory matrix generation

Figure 3.1 shows a flow diagram for a matrix creation technique in which data is chosen uniformly for each normalized variable ranging from 0 to 1 [60]. Xk indicates a row vector that stores M readings for each of the n different sensors, where M denotes the number of state vectors in the training data and n has the same meaning as shown in the equation (3-1). The increment in this work is set to 0.01, which means that the value range of each variable of interest is divided evenly into 100 parts, with values closer to the dividing line being chosen. The memory matrix is then updated with the relevant historical state vector, which contains the records for all variables. The procedure explained above is applied to each of the required training variables to create a preliminary matrix. The memory matrix is then adjusted to remove any state vectors that have been seen before. The memory matrix building is now complete.

3.2.3. Algorithm for detecting faults

The built model is then applied to the validation data set, which must not have been used in the training process. The residuals obtained are then passed through an infinite impulse response (IIR) low pass filter to remove noise in the form of spikes in the residuals caused by transitions in the turbine's operational state rather than turbine faults.

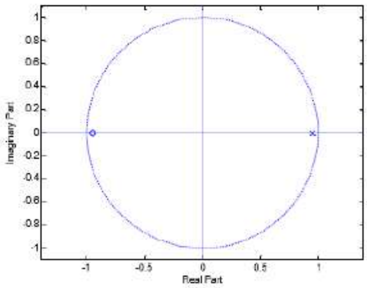


Fig.3.2: In the Z-plane, a pole and zero demonstration of the selected low pass filter

Figure 3.2 shows the pole-zero diagram for this low pass filter, with the pole denoted by a small circle and the zero indicated by a cross, respectively, at (0.95, 0) and (- 0.95, 0) within the unit circle. Low-frequency signals will flow through the pole on the positive side of the horizontal axis. In contrast, high-frequency signals will pass through the zero on the negative side of the horizontal axis cut off the high-frequency signals, allowing the low-pass filter to function. The equation shows a similar Z-domain expression given the pole and zero of this filter (3-9).

$$H(z) = \frac{Y(z)}{X(z)} = C \times \frac{z + 0.95}{z - 0.95} \qquad (3\text{-}9)$$

Where parameter C determines the magnitude of this filter's frequency response, and $z = e^{j\Omega}$, which in effect moves along the unit circle in the complex Z-plane as the signal frequency, Ω, fluctuates from $-\pi$ to π as illustrated in Figure 3.2. The parameter C is derived under the assumption of unit response to DC signals, in which case $H(z) = 1$ and $z = 1$ since $\Omega = 0$, resulting in $C = 1/39$.

So,

$$\frac{Y(z)}{X(z)} = \frac{1}{39} \times \frac{z + 0.95}{z - 0.95} = \frac{1}{39} \times \frac{1 + 0.95z^{-1}}{1 - 0.95z^{-1}} \qquad (3\text{-}10)$$

Equation (3-10) can be rearranged to produce,

$$Y(z) = 0.95z^{-1}Y(z) + \frac{1}{39}X(z) + \frac{0.95}{39}z^{-1}X(z) \qquad (3\text{-}11)$$

The time-domain formulation for this low pass filter is obtained using the inverse Z transform presented in reference [96] and expressed in Equation (3-11). (3-12). Figure 3.3 depicts the relevant frequency response for the developed filter.

$$y[n] = 0.95y[n-1] + \frac{1}{39}x[n] + \frac{0.95}{39}x[n-1] \qquad (3\text{-}12)$$

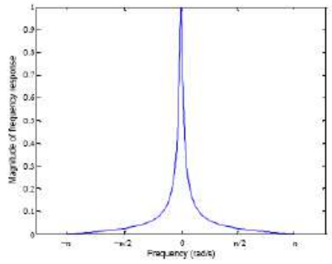


Fig.3.3: Within one period, the magnitude of the low pass filter's frequency response

Although NSET can represent a wide range of components and parameters, it is most commonly used to represent component temperatures, where elevated temperatures that can lead to overheating are a sign of a problem [34]. Only the positive residuals matter in these situations. The maximum of the filtered residual and the related standard deviation are analyzed using Welch's t test to discover statistically significant anomalies.

Welch's t-test is an extension of the Student's t-test that can be used when the variances of two testing samples are anticipated to be uneven, as discussed in the previous Section. A one-sided hypoResearch Paper test is utilized for the turbine gearbox model since only overheating is of concern, while unexpectedly low gearbox temperatures are ignored. The rise in the residual average above the reference average is considered significant if the statistic $t > t_{\alpha}(v)$, where $t_{\alpha}(v)$ follows the Student's t distribution established in the previous Section and the t statistic is given by:

$$t = \frac{\overline{X_{test}} - \overline{X_{ref}}}{\sqrt{\frac{S_{test}^2}{N_{test}} + \frac{S_{ref}^2}{N_{ref}}}} \qquad (3\text{-}13)$$

Where $\bar{X}$, S, and N denote the residual average, residual standard deviation, and window length, respectively, the subscripts "ref" and "test" denote validation and testing data.

3.2.4. The modified NSET algorithm

A modified version of NSET is proposed in reference [81], and this will be referred to as the modified NSET model hereafter in the Research Paper, in addition to the NSET algorithm as introduced in Section 4.1.1, which will be referred to as the standard NSET model later in the Research Paper. The modified model's algorithm is shown below, highlighting variations from the standard model.

Because the condition indicator for the system under consideration is likely to take on abnormal values as the system deteriorates, it has been suggested that this suggestive variable be removed from the state memory matrix that is used to calculate the weighting vector. W^is now the adjusted weighting vector:

$$\hat{W} = (\hat{D}^T \otimes \hat{D})^{-1} \cdot (\hat{D}^T \otimes \hat{X}_{obs}) \qquad (3\text{-}14)$$

Where $D^\wedge$ is the updated memory matrix described in Equation (3-15), where $[x_1(1)\ x_1(2) \cdots x_1(m)]$ is the vector for the indicative variable that has been removed, the observation vector receives the same treatment, resulting in the updated version $X^\wedge obs$.

$$\hat{D} = [\hat{X}(1)\ \hat{X}(2) \cdots \hat{X}(m)]$$

$$= \begin{bmatrix} x_2(1) & x_2(2) & \cdots & x_2(m) \\ x_3(1) & x_3(2) & \cdots & x_3(m) \\ \vdots & \vdots & \ddots & \vdots \\ x_n(1) & x_n(2) & \cdots & x_n(m) \end{bmatrix} \qquad (3\text{-}15)$$

In this situation, the model estimation, X_{est}, is the product of the standard memory matrix (Equation 4-1) with the updated weighting vector (Equation 3-2). (3-16).

$$X_{est} = D \cdot \hat{W} \qquad (3\text{-}16)$$

Because the indicative variable, which is directly affected by the physical state of the monitored component, is masked out in the estimation process and the results are based on measurements from valid sensors only, the modified NSET model is thought to produce more reliable results than the standard model [57].

Various implementation options for the NSET model will be discussed in the following sections: A comparison of the standard NSET model and the modified model will be presented; the NSET results will also be compared with those from the Neural Network model; the need for additional null and maximal state vectors will be justified; the impact of reduced parameter and time-lagged variable on model performance will be justified; the contributions of manipulative factors, such as memory matrix normalization and parameter weighting, to model improvement, will be investigated.

3.3. SCADA DATA FROM WIND FARMS AS A BACKGROUND FOR NSET APPLICATIONS

This Section examines the turbine gearbox and generator using NSET models and the associated anomaly detection described in the preceding part. These two critical components are explored here because they were previously recognized as being responsible for much of the turbine downtime and because their temperatures are typically included in SCADA data. The SCADA data is from a wind farm in the United Kingdom with 26 identical 600kW fixed-speed stall regulated wind turbines. The layout of this wind farm is depicted in Figure 3.4, with 26 turbines denoted by blue dots and two meteorological masts denoted by red crosses.

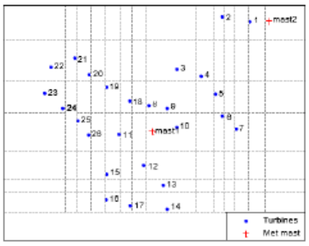


Fig.3.4: Wind farm layout

Table 3.1: Analytical events list

Turbine No.	Anomalous component	Failure time
T8	Generator	Nov. 2006
T16	Gearbox	Jan. 2006
T17	Gearbox	Apr. 2005

The gearbox and generator events used in the analysis are listed in Table 3.1. Domain knowledge is used to make an intuitive input selection for the gearbox and generator models. The rotor of a wind turbine captures partial kinetic energy from the incident wind. It converts it to mechanical energy, transmitted to the turbine drive train. The gearbox steps up the rotational speed to a suitable level to drive the generator, converting the energy into its final electrical form. The mechanical load of the gearbox, as shown by its temperature, is directly related to the turbine power output, as can be seen from this process. A situation identical to this exists.

The temperature will be related to the generator's electrical load, indicated by the voltage and current (or equivalently power output). Because the temperature of the gearbox or generator is impacted by its immediate surroundings, the nacelle temperature is taken into account in both circumstances. Table 4.2 shows both models' available 10-min SCADA data, with the essential parameters checked.

Table 3.2: For the gearbox and generator model, a list of accessible SCADA data in a 10-minute format

SCADA tag	Gearbox model	Generator model
Wind speed (m/s)		
Active power (kW)	✓	✓
Reactive power (kVar)		
Gearbox bearing temperature (°C)	✓	
Gearbox cooling oil temperature (°C)	✓	
Generator winding temperature (°C)		✓
Nacelle temperature (°C)	✓	✓

3.4. APPLICATION OF NSET TO A CASE STUDY OF A WIND TURBINE GEARBOX

T3, T4, T5, T7, and T10, five healthy turbines in the wind farm, are averaged to create a sample model training dataset that identifies a healthy turbine across its entire operational range. Three months of training data are used [97]. Similarly, three months from the beginning of April to the end of June 2005 were picked for this training process, with 11246 eligible states. For validation, one month of operational data from the fault-free turbine T1 is used, from which statistics can be extracted for further fault identification using Welch's hypotheses test. The testing data comes from two turbines, T16 and T17, that have proven gearbox failures, as shown in Table 3.1. In testing scenario II, operational data is used up to half a year before T16's final failure. In contrast, only one month of T17 testing data is available for analysis in testing case I.

Table 3.3 Pearson's correlation coefficients between gearbox model input and output parameters

Output parameters / Input parameters	Gearbox cooling oil temperature
Gearbox cooling oil temperature (°C)	1
Gearbox bearing temperature (°C)	0.9491
Power output (kW)	0.8282
Nacelle temperature (°C)	0.6891

Any wear and damage to the gearbox will generate additional heat, which will then be transferred to the cooling fluid. As a result, it should monitor the wind turbine gearbox, using the gearbox cooling oil temperature as a condition indicator and, therefore, the model output. The model inputs should be closely tied to the model output to develop an appropriate representation for the turbine component. Except for nacelle temperature, which has a slightly weaker correlation, Table 3.3 lends confidence to the variable selection of model inputs by displaying high correlation coefficients between the proposed input parameters and the model output. This parameter is not as closely related to gearbox oil temperature as the others, but it represents ambient temperature's effect on the model output. Therefore it has been kept.

Null and invalid readings in SCADA records can be caused by mistakes in the SCADA system or measurement sensors, as previously described. Therefore, a rudimentary filtration excludes these entries and makes the helpful analysis, as shown in Table 3.4. This table shows the percentage of values deleted during this training, validation, and testing data method. After the filtration, the range of values for the four proposed variables is also supplied.

It should be noted that because nacelle temperature is affected by ambient temperature, low values (below 0) of nacelle temperature may exist during the winter season, and simple filtration to eliminate such data is ineffective. However, the minimum nacelle temperature data in this case study is 1, which is above the threshold level. Therefore no negative temperatures have been subtracted.

The high amount of data discarded in this filtering procedure suggests poor data quality, which will be explored in Section 4.3.10 and its possible impact on model performance. However, there should be no negative consequences because comparing different model alternative always uses the same filtered data sets. Table 3.4 also shows that the maximum gearbox cooling oil temperature in both testing situations is higher than that in the training/validation set. Because the model's extrapolation capability is unknown, introducing a maximal vector covering a more comprehensive data range may increase the model's ability to extrapolate to higher temperatures. In this scenario, the maximal vector [582.2, 69.0, 62.0, 24.4] was chosen from data for a single healthy turbine outside of the 3-months of training data (the variable values are presented in the same order as in Table 3.4). In addition, a new null vector, [0 0 0 0], has been added to the matrix to improve model performance when the oil temperature lowers gradually during periods of non-generation induced by low wind speed or turbine shut down.

3.4.1. Determining the size of the memory matrix

Because the NSET is essentially a state-based vector recognition technique, the related model accuracy should be proportionate to the matrix size. The total number of states in the matrix increases as the proximity requirement increases, according to the state memory matrix building process described in Section 3.2.2. The validation residuals' Root Mean Square (RMS) value is used as an accuracy metric for model estimation in this case, and it is plotted against the appropriate matrix size in Figure 3.5 by adjusting the parameter.

Table 3.4 shows the filtration criteria for the selected variables in the gearbox case study, as well as the outcome

Data usage	Variables	Filtration criteria	Value range after filtration		Percentage of values being removed (%)
			min	max	
Training set (T3, T4,T5, T7 and T10, April – June 2005)	Active power (kW)	> 25	25.01	596.30	33
	Gearbox bearing temperature (°C)	> 0	38.80	61.80	
	Gearbox cooling oil temperature (°C)	> 0	32.98	54.43	
	Nacelle temperature (°C)	> 0	3.95	28.40	
Validation set (T1,January 2006)	Active power (kW)	> 25	25.00	633.50	35
	Gearbox bearing temperature (°C)	> 0	26.00	60.00	
	Gearbox cooling oil temperature (°C)	> 0	22.08	55.00	
	Nacelle temperature (°C)	> 0	3.40	21.00	
Testing set in case I(T17: April 2005)	Active power (kW)	> 25	25.65	586.25	42
	Gearbox bearing temperature (°C)	> 0	41.00	60.00	
	Gearbox cooling oil temperature (°C)	> 0	32.17	61.00	
	Nacelle temperature (°C)	> 0	4.91	19.51	
Testing set in case II(T16: August 2005 –January 2006)	Active power (kW)	> 25	25.02	659.47	36
	Gearbox bearing temperature (°C)	> 0	11.00	69.00	
	Gearbox cooling oil temperature (°C)	> 0	19.48	67.00	
	Nacelle temperature (°C)	> 0	1.00	29.17	

This figure shows that expanding the matrix size beyond 1000 state vectors does not affect model correctness, making this size a suitable choice; in reality, the matrix in this study comprises 989 states, resulting in a matrix D size of 4989.

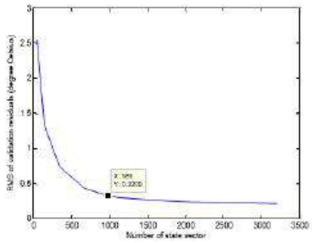


Fig.3.5: Determining the size of the memory matrix

3.4.2. Validation of the model

As shown in Figure 3.6, the basic NSET model is validated using one month of data for the standard, fault-free operation of turbine T1. In Figure 3.6(a), the high agreement between model estimations (shown by the blue line) and observations (shown by the red curve) demonstrates the correctness of the NSET model. The blue curve in Figure 3.6(b) plots the corresponding residuals, with the bulk of the residuals varying.

Except for a few isolated large spikes, the range is within acceptable bounds. Wind turbine operating transitions, such as those from the conclusion of a non-production period during which the oil temperature progressively declines to ambient temperature, produce corresponding model estimation discrepancies. Except when the turbine starts to function when the 10 minute averaged power output might easily surpass the filtration threshold, and the oil temperature takes time to return to the normal range due to thermal mass, most non-production linked data can be deleted by simple filtration.

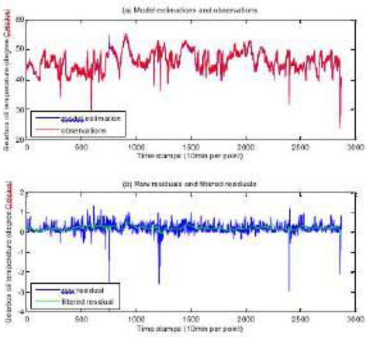


Fig.3.6: T1 validation findings for standard NSET

Because these isolated residual spikes do not signal actual system problems. The undesired noise is removed using a suitably constructed IIR low pass filter, as described in Section 3.2.3, in the form indicated by Equation (3-12). The green curve in Figure 3.6(b) depicts the filtered validation residual along with the raw value. The maximum of the filtered residual and its standard deviation will be used to discover faults.

3.4.3. Anomaly detection and model testing

In this section, testing cases I and II with proven gearbox failures in T17 and T16 are used to demonstrate the standard NSET model's detection capacity. Figure 3.7(a) depicts T17's testing results across a month's worth of data, from the beginning of April through the end of the month's last failure. This graph reveals a gearbox cooling oil temperature peak of 61.0, lower than the top limit of 62.0 specified by the state memory matrix's maximal vector. This maximal vector improves the model accuracy and overall performance, as indicated in Section 4.3 and demonstrated in Section 3.4.5. In addition, this figure shows significant differences between model estimations and observations, which also correspond to the substantial and protracted residual displayed in Figure 3.7(b). This gives an early indicator of gearbox overheating due to impending gearbox failure, and Welch's hypoResearch Paper test, as described in Section 3.2.3, is used to find the defect.

Remember the low pass filter in Equation (3-12), where the recursive term represents contributions from past outputs, thus applying a time-weighted averaging process to the data. To reduce the contribution from prior outputs to less than 1%, 90-time steps (equal to 15 hours) are required, resulting in a 90-minute effective window length.

This low pass filter is applied to both the validation and test residuals, resulting in significantly smoother residual time series, as seen in Figures 3.6(b) and 3.7(b), respectively. Welch's t-test is used to compare the filtered test residuals (Xtest) and their corresponding standard deviation to the maximum of the filtered validation residuals (Xre) and their associated standard deviation (Sre). The test uses a 90-second effective window length and a significance threshold of 0.005 to achieve robust detection and minimize false alarms. The data are logged using a binary recorder, with the high level indicating abnormal turbine gearbox behavior and the low level indicating normal or acceptable functioning. Wind turbine operators would have access to these recordings, and anomalies would be noted if alarms occurred for an unusually long or frequent period.

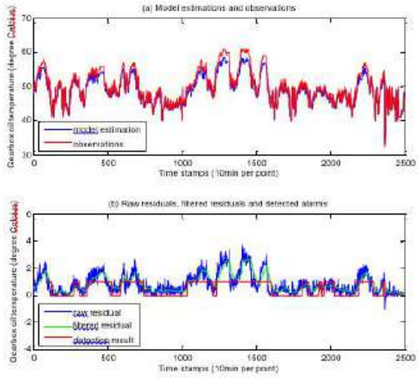


Fig.3.7: T17 testing results and anomaly identification for standard NSET

The red line in Figure 3.7(b) depicts a series of alerts that began at the start of the assessment period, exposing aberrant behavior and proving consistency between the method created here and residual observations. The alerts are reported immediately following each steep increment in the testing residuals, as shown in the exact figure. That demonstrates the NSET model's capacity to reliably detect incipient abnormalities in a wind turbine gearbox before they become catastrophic problems.

The detection method should have been compared against simple threshold-based fault detection in the ideal case. High temperatures did occur on a few occasions while turbines functioned regularly, but these data points had to be used as part of the training set and could not be used for testing. Among the data points were: temperatures of 62°C, which would be higher than any essential barrier. As a result, false alarms would have occurred with such a threshold. Setting higher criteria to reduce false alarms would have failed to detect actual defects.

The data from turbine T16 is used in testing case II. The model's anomaly detection capacity is confirmed using operational data from half a year before the turbine's breakdown, from August 2005 to January 2006. The failure of the gearbox occurred shortly after the completion of the testing session.

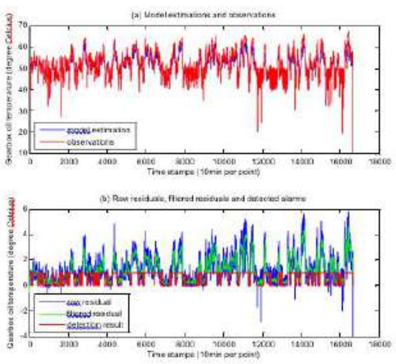


Fig.3.8: T16 testing results and anomaly identification for conventional NSET

In this example, anomaly identification follows the same techniques for turbine T17, and the hypoResearch Paper testing is based on the same validation result from turbine T1. Figures 3.8(a) and (b) show successful anomaly detection findings, which give the turbine operator up to half a year to make decisions about shut down and maintenance schedule, demonstrating the system's robustness. However, in Figure 3.8(b), the test residuals show an increasing trend over the six months, indicating the turbine gearbox's progressive degradation.

The maximum oil temperature measurement is 67.0, higher than the upper limit of 62.0 introduced by the maximal vector, as shown in Table 3.4 and Figure 3.8(a). The maximum modeled temperature for this peak is 62.6 degrees, suggesting that the NSET can extrapolate beyond the memory matrix maximum values, albeit to a limited extent and with questionable accuracy. However, the addition of the maximal vector significantly improves model correctness and overall performance.

3.4.4. Neural Network model's comparison

A performance comparison with a Neural Network (NN) model comparable to that effectively applied to wind turbine gearbox condition monitoring. NN models are designed to capture data interrelationships between input parameters and outputs utilizing weight and bias parameters for individual neurons instead of the NSET model, which generates weights based on the similarity between state vectors encompassing the whole input parameters. These weights are determined by a training process that frequently uses the backpropagation method [98]. Because it is believed to be the fastest approach for training small and medium-sized networks [99], the Levenberg-Marquardt algorithm is used here.

Because the NSET model used in the case study, an auto-associative model as described in Section 2, has four inputs and four outputs, a four-input four-output NN model is employed for a fair comparison with comparable validation data turbine T1 and testing data from turbines T16 and T17. The "tansig" transfer function is used for the neurons in both the hidden and output layers (see Table 2.1). And a hidden layer with three neurons, as described in reference [44], is used here since it performs best in terms of model correctness when compared to other layouts, such as those with two hidden layers.

The memory matrix's state vectors, which have a size of 989 in this case, are normalized before being utilized for NN model training, and the same defect detection algorithms as described in Section 3.2.3 are applied based on NN model estimation.

Figures 3.9, 3.10, and 3.11 depict the outcomes of validation and testing. When comparing these figures to those from the NSET model (Figure 3.6 for validation results; Figure 3.7 and Figure 3.8 for testing results and associated fault detection), it can be seen that the NSET model is more accurate than the NN model in terms of producing smaller validation residuals, as well as more capable of timely fault detection for the testing cases, especially in case I for turbine T17 (Figure 3.10), which fails to pick up any signatures for the anomaly. This comparison of the NSET model to the NN model demonstrates its resilience.

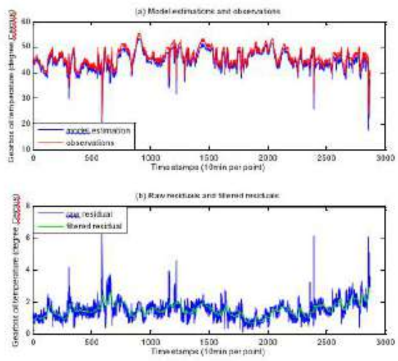


Fig.3.9: T1 validation results for the NN model

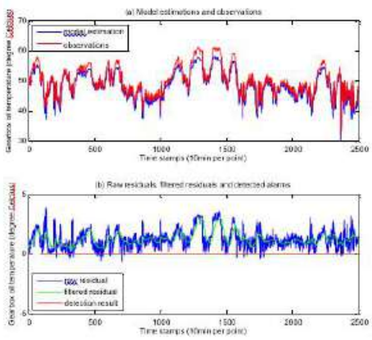


Fig.3.10: T17 testing results and anomaly identification for NN model

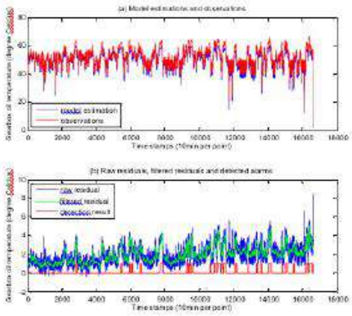


Fig.3.11: T16 for NN model testing results and anomaly identification

3.4.5. Justification for using the enhanced state memory matrix

In this part, the effects of including the null and maximal vectors on model performance are studied using both validating and testing data in both testing scenarios.

The null vector was added primarily to increase model correctness, particularly in the case of missing/null data values. It also aids in the improvement of gearbox oil temperature modeling after a turbine shutdown, which results in a progressive decrease in temperature. However, it should be observed that the crude filtration has removed the missing/invalid data and the entries related to the times of shutdown, making the null vector slightly redundant.

[582.2, 69.0, 62.0, 24.4] is the observation state vector with the maximum oil temperature to be included in the augmented memory matrix. This vector was chosen because it contains the highest oil temperature reached by any healthy turbine from the wind farm throughout the data collection period. In the case of high temperatures, this vector is added to the memory matrix to improve model accuracy. Of course, if the temperature surpasses this number, as it did in testing case II for T16, the model's performance will suffer. One problem is that because anomaly identification is predicated on residuals, better model performance may make it more difficult to detect anomalies. The case studies in the previous section, on the other hand, illustrate successful fault detection. Therefore, improved models are expected to result in fewer false alarms.

Table 3.5 shows the influence of additional vectors on model validation and testing performance, using four memory matrix formats to choose from: no augmentation, only null vector, only maximal vector, and both vectors. In each scenario, model performance is measured using the average and RMS values of the validation and testing residuals for gearbox cooling oil temperature, with smaller RMS values for validation residuals indicating better model accuracy. A Residual Ratio (RR) is a calculation that determines the RMS ratio of testing residuals to validation residuals is utilized to show the degree of variance in the testing data and the capability for defect identification to some level. For the testing data, the Detection Ratio (DR) concept presents the proportion of testing occurrences discovered out of the entire testing set. For example, in the expanded NSET model, 8164 alarms are triggered out of 16559 testing instances for turbine T16, resulting in a DR value of 8164/16559=49.3 percent, as shown in Table 3.5. According to this, greater DR values for abnormal data suggest stronger anomaly detection sensitivity.

Table 3.5: A comparison of model efficacy to justify the addition of null and maximum vectors

	Validation: T1		Testing I: T17				Testing II: T16			
	Mean (°C)	RMS (°C)	Mean (°C)	RMS (°C)	RR	DR (%)	Mean (°C)	RMS (°C)	RR	DR (%)
No augmentation	0.199	0.418	0.922	1.246	2.98	37.3	1.313	1.877	4.49	50.7
With null vector only	0.216	0.327	0.906	1.226	3.75	35.0	1.316	1.882	5.76	46.0
With maximal vector only	0.195	0.419	0.880	1.161	2.77	50.2	1.181	1.604	3.83	62.0
With both vectors	0.212	0.321	0.862	1.139	3.55	49.3	1.181	1.591	4.96	61.2

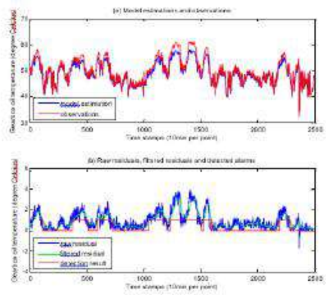


Fig.3.12: T17 testing results and anomaly identification for standard NSET with a non-augmented state memory matrix

The addition of the maximal vector improves model correctness in both testing situations by reducing the RMS value of the related residual, as shown in Table 3.5. Surprisingly, the maximal vector present model has the highest DR values in both testing scenarios, even though the related RR values are the lowest, proving the maximal vector's increased model detectability. However, because the variable's value in this scenario remains within the usual range, the maximal vector has little effect on the validation accuracy. Furthermore, the null vector has no bearing here because of the data filtration discussed earlier. Table 3.5 shows a similar comparison between the non-augmented and null vector present models. Overall, the model with both vectors displays the lowest residuals RMS in all validation and testing instances, even though the DR values are slightly worse than the model solely with the existence of the vectors.

The full vector. Figures 3.12 and 3.13 depict the testing results of T17 and T16, respectively, using the non-augmented model, which may be compared to Figures 3.7 and 3.8, which illustrate the results of the wholly augmented model.

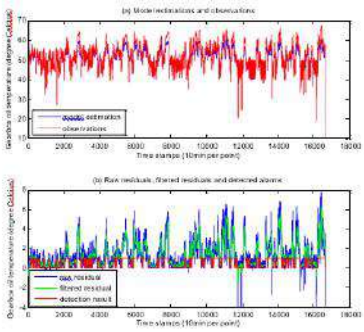


Fig.3.13: T16 testing results and anomaly identification for standard NSET with a non-augmented state memory matrix

3.4.6. The comparison of improved NSET model

Remember the modified NSET model given in Section 3.2.4, where the weight vector calculation is done without the indicative variable in the state memory matrix and the observation vector. Because the results are based solely on readings from legitimate sensors, this model version is thought to generate more accurate results than the standard model. In this section, the effectiveness of the modified model is examined, and the results are compared to those of the standard model using the same gearbox case studies as in earlier sections.

In the updated NSET model, the gearbox cooling oil temperature is omitted from the memory matrix for weight vector calculation, leaving the gearbox bearing temperature, nacelle temperature, and turbine power output as the only variables involved. 4 989 was chosen as the memory matrix size for the base model. The amended model retains the same amount of state vectors as the original model for a fair comparison, including those two additional vectors. And all of the validation and testing data is identical to that utilized in the standard model.

The model validation results in Figure 3.14 are significantly worse than those displayed in Figure 3.6 for the basic model. Table 3.6 summarizes the validation residuals statistics and shows that the updated model's accuracy has degraded. The testing statistics in Table 4.6 and the comparison between Figure 3.15 and Figure 3.7 for turbine T17 and Figure 3.16 and Figure 3.8 for turbine T16 reveal similar findings for the testing situations. Another observation is the significant decrease in detected alarms compared to the standard.

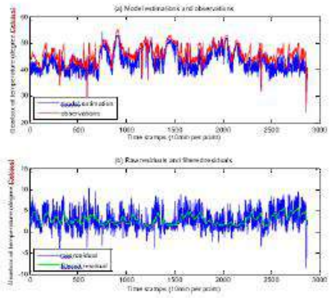


Fig.3.14: T1 validation findings for updated NSET

T17, as illustrated in Figure 3.15(b), where only a few isolated and inconsistent alerts are recorded, is an excellent example of this approach. Unfortunately, the residual and detection ratio values in Table 3.6 also indicate that the updated model is less successful.

The lack of model input variables is most likely to blame for the model's poor accuracy and detection sensitivity. Unlike the reference [57], which relies on more than 20 highly model-relevant parameters for successful implementation of the modified NSET model, just three variables are accessible in this situation. The improved version of the model is projected to improve with gearbox oil-related variables. The rotor/generator rotational speed (in this case, a fixed speed stall regulated turbine) is, for example, closely related to the gearbox loading, and hence is thought to increase model accuracy. This variable is present in the input sets of the gearbox-related model created in reference [94] but not in the SCADA data for the case studies provided. Therefore, the modified NSET model will not be employed in the remaining studies in this Section for the reasons stated above, and instead, the conventional NSET model will be used.

Table 3.6: Comparison of the effectiveness of conventional and modified models

	Validation: T1		Testing I: T17				Testing II: T16			
	Mean (°C)	RMS (°C)	Mean (°C)	RMS (°C)	RR	DR (%)	Mean (°C)	RMS (°C)	RR	DR (%)
Standard NSET	0.212	0.321	0.862	1.139	3.55	49.3	1.181	1.591	4.96	61.2
Modified NSET	2.968	3.644	4.577	5.145	1.41	0.12	5.172	5.747	1.58	20.7

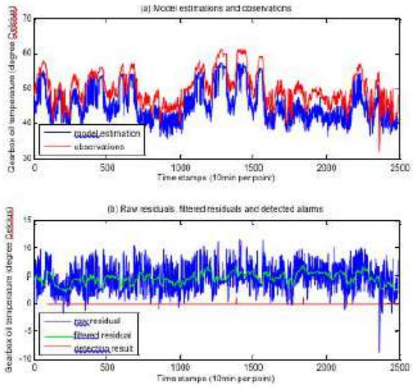


Fig.3.15: T17 testing results and anomaly identification for modified NSET

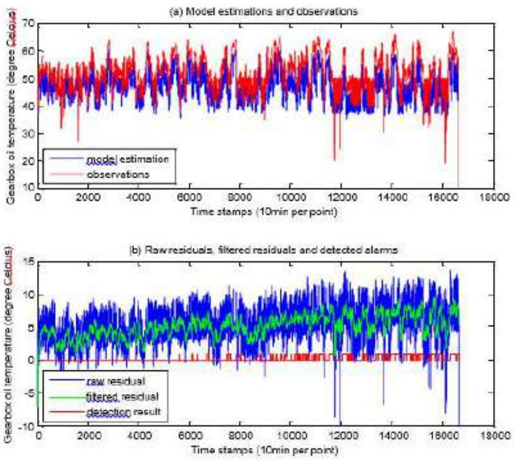


Fig.3.16: T16 testing results and anomaly identification for modified NSET

3.4.7. Memory matrix normalization's effect on model performance

When generating the estimate of the variable of interest, the conventional NSET model preserves the original value of variables in the state memory matrix to calculate the weight vector applied to the different states. The weight vector estimation was explained in Section 3.4.1 using a Euclidean distance operator. A Euclidean distance determined from the raw values of the individual variables, on the other hand, is dominated by the variable with the most extensive range of values. In this scenario, the turbine power output is 102 kW. In contrast, the rest of the temperature-related variables in the usual model are on the order of 101, implying that the power output makes the most significant contribution, which may not be ideal. Therefore, it is desirable to normalize all variables individually concerning their respective ranges, as implemented in reference [60], to eliminate this bias. The impact of normalizing variables on model performance is investigated in the following way.

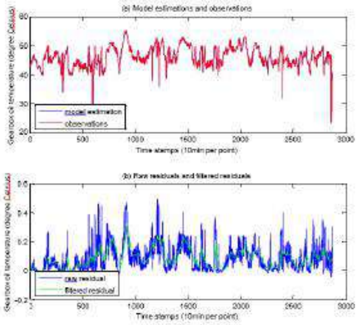


Fig.3.17: T1 validation findings for normalized NSET

The same validation and testing data are used in these studies, and the results are shown in Figures 3.17, 3.18, and 3.19, respectively, with residual statistics summarized in Table 3.7.

The general model accuracy has been dramatically improved in all validation and testing situations once normalized variables. The disadvantage of the normalized NSET model is that it reduces detection sensitivity, as shown by the DR value in Table 4.7 and the anomaly detection findings in Figures 3.18(b) and 3.17(b) for testing cases I and II, respectively. Compared to the data in Figure 3.7, Figure 3.18(b) demonstrates a substantially slower and less frequent detection of T17 (b).

A month of healthy operational data from July 2006 for turbine T16 after its gearbox was replaced following the known failure is chosen as an additional period of testing data. This additional scenario, known as testing case III, is used to assess the model's resilience to false alarms, and the results are shown in Figures 3.20 and 3.21 and Table 3.7. The model's resistance to false alarms should ideally be investigated using data from healthy turbines operating with high gearbox oil temperatures. Still, these instances are scarce, and the only data points available had to be used as part of the training set and thus could not be used for testing.

The findings of the standard and normalized NSET models for testing case III are shown in Figures 3.20 and 3.21. Even though it was July, the statistics reveal a reasonably low level of cooling oil temperature, proving a healthy gearbox as previously stated, in which case the detection ratio should be zero, as shown in Figure 3.21. Figure 3.20, on the other hand, shows that the traditional NSET model is less successful than the normalized model due to false alarms.

Regarding model accuracy and resistance to false alarms, the normalized NSET model outperforms the standard model with lower detection sensitivity. As one might assume, Greater detection sensitivity leads to more false alarms. This trade-off must be taken into account when selecting the best model. The impact of weighted variables on the performance of a normalized model will be explored further in the following section.

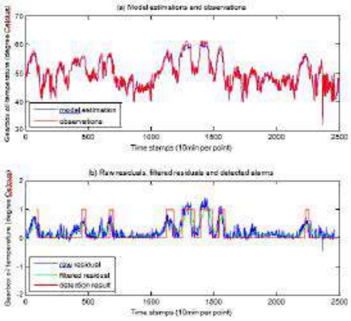


Fig.3.18: T17 testing results and anomaly detection for normalized NSET

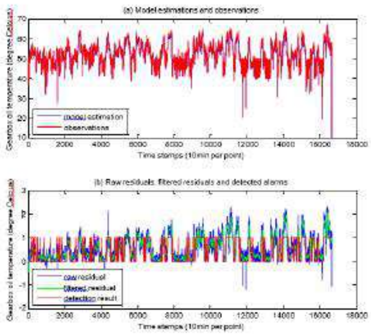


Fig.3.19: T16 testing findings and anomaly detection for normalized NSET

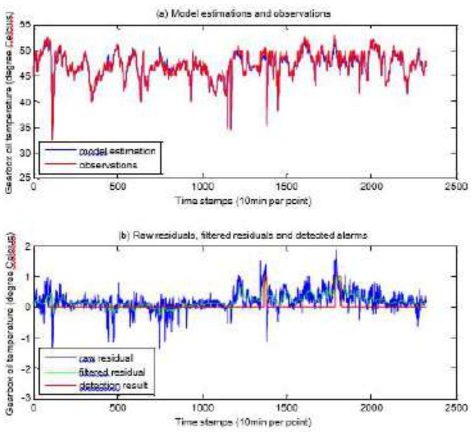


Fig.3.20: Standard NSET testing findings for healthy T16 in case III

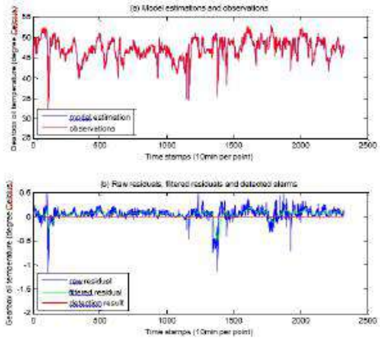


Fig.3.21: Normalised NSET testing results for healthy T16 in case III

Table 3.7: A comparison of model efficacy in various conditions for the gearbox case study

	Validation: T1		Testing I: T17				Testing II: T16				Testing III: T16			
	Mean (°C)	RMS (°C)	Mean (°C)	RMS (°C)	RR	DR (%)	Mean (°C)	RMS (°C)	RR	DR (%)	Mean (°C)	RMS (°C)	RR	DR (%)
Standard NSET	0.212	0.321	0.861	1.139	3.55	49.3	1.181	1.591	4.96	61.2	0.119	0.166	1.14	2.55
Normalised NSET	0.086	0.125	0.229	0.367	2.94	16.5	0.526	0.720	5.76	48.5	0.049	0.146	1.17	0
Normalised NSET with weighted variables	0.059	0.091	0.142	0.254	2.79	12.1	0.396	0.547	6.01	47.2	0.031	0.100	1.10	0
Reduced parameter NSET	0.002	0.025	0.110	0.176	7.04	39.9	0.153	0.220	8.80	56.5	-0.055	0.155	62	0
Time lagged NSET	0.003	0.027	0.127	0.196	7.26	40.1	0.166	0.240	8.89	54.1	-0.096	0.227	8.41	0

3.4.8. The effect of weighted variables in the distance norm on model performance

The contribution of various variables to the computation of the Euclidean distance was explored in the previous section, which led to refining the distance calculation with weighted variables. In this scenario, the nonlinear operator Y utilized in Equation (3-7) for weighting vector calculation is replaced by Equation (3-17), in which the weighting parameter, ki, is assigned to the associated correlation coefficients for the variables with the cooling oil temperature, as shown in Table 3.3.

It is thought to improve model accuracy because the more relevant, i.e., highly correlated, variables, such as gearbox bearing temperature, can make a more significant contribution through distance metric weighting than the less relevant variables, such as nacelle temperature.

Table 3.7 shows the statistics of the corresponding residuals for the validation and testing instances compared to the results from the normalized NSET model, which is currently the preferred model. The model accuracy is increased by assigning weighting to different variables in the distance norm calculation, as evidenced by the RMS values for validation residuals. In this situation, the resistance to false alarms is kept, but the detection sensitivity is slightly worse. Nevertheless, the overall model performance is outstanding, notwithstanding a minor reduction in the capacity to detect anomalies. Based on the normalized NSET model with weighted variables, the impact of lowered parameters on model performance is investigated in the following section.

3.4.9. Model performance without the parameter of Gearbox bearing temperature

Table 3.4 shows that both the maximum gearbox cooling oil temperature and the bearing temperature are higher than in the control cases in the testing circumstances.

Set for training and validation. Figures 3.22 and 3.23, which plot cooling oil and bearing temperatures versus turbine power output for T16 in testing case I and T17 in testing case II, respectively, show more evident connections. In both graphs, the pattern created by the cooling oil temperature of anomalous turbines and their power production differs significantly from that of healthy turbines. This highlights the sensitivity of the gearbox cooling oil temperature to impending failure and, as a result, the value of this variable as a condition indicator. In these two figures, the relationship between anomalous gearbox bearing temperature and corresponding power production shows differences from the standard conditions (increasing trend similar to the cooling oil temperature case), though with a lesser degree of a discrepancy than the cooling oil temperature case. This is comprehensible, given that the bearing temperature is influenced by the gearbox's continuous degradation and the resulting increase in temperature due to heat conduction between the two. It should also be emphasized that neither test event featured a primary bearing failure, which has been confirmed. However, including such a variable in the model could reduce the model's effectiveness in fault detection because higher bearing temperatures would result in higher model estimates of oil temperature than if the bearing temperature was not included in the model, resulting in smaller testing residuals and a potential failure in anomaly detection.

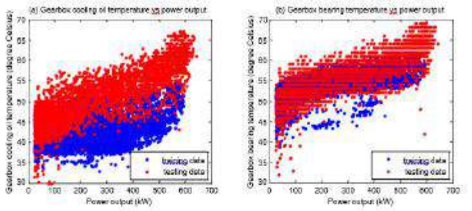


Fig.3.22: For T16 in testing case I, gearbox temperature vs. power output

This section investigates the impact of omitting the gearbox bearing temperature on model performance using the normalized NSET model with weighted variables, which is more effective than the standard and basic normalized models, particularly model accuracy. The reduced parameter model is the model that is being investigated here. The same validation and testing data as in the previous section are used. The results are shown in Figure 3.24, Figure 3.25, Figure 3.26, Figure 3.27, and Table 3.7, which can be compared to results under other conditions in Table 3.7 and figures from previous sections to see how the reduced parameter model affects the results.

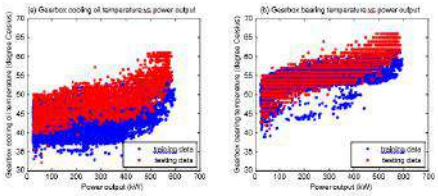


Fig.3.23: For T17 in testing case II, gearbox temperature vs. power output

With a few exceptions, such as testing case III in Table 3.7, where the comparatively large RR value for the reduced parameter model does not contribute to alarm detection, the RR value is consistent with the DR value for most of the analyses. This is due to the significant negative residuals (as seen in Figure 3.27), which raise the associated residual RMS and RR value but unrelated to anomaly detection. Furthermore, it can be demonstrated that using the lower parameter NSET model improves both model accuracy and detection sensitivity. The reduced parameter model's residuals for both testing instances I and II are smaller than in the normalized model with weighted parameters, which is unexpected. Here, too, the resistance to false alarms is preserved.

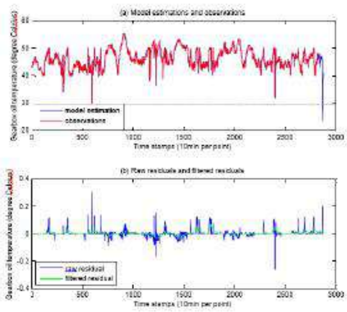


Fig.3.24: T1 validation results for normalized NSET with reduced parameter and weighted variables

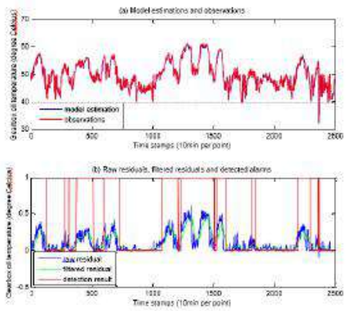


Fig.3.25: T17 testing results and anomaly identification for normalized NSET with reduced parameter and weighted variables

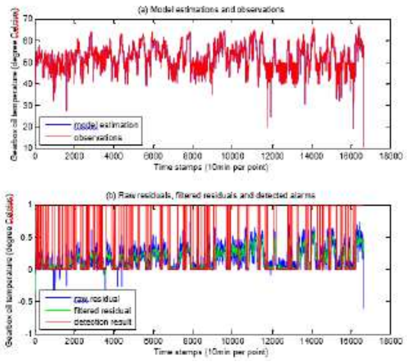


Fig.3.26: T16 testing results and anomaly identification for normalized NSET with reduced parameter and weighted variables

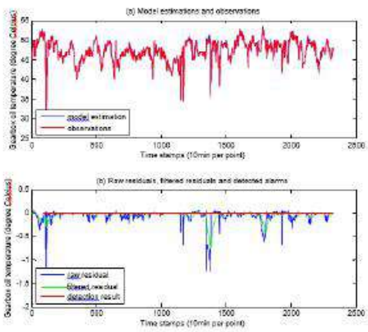


Fig.3.27: Normalised NSET with lowered parameter and weighted factors testing results of healthy T16 in case III

3.4.10. Discussions of the impact of time-lag variables on model performance

The heat generated in the gearbox due to power output will cause a rise in gearbox cooling oil temperature. However, there will be a time delay due to the gearbox's inherent thermal mass. As a result, it's expected that time-lag power will be more closely tied to gearbox oil temperature than contemporary readings. Therefore, it's worth investigating whether utilizing appropriately time-lagged power values in the memory matrix can improve NSET models and improve fault detection. The impact of time delay in power output on model performance is investigated using the best-performing model to date, namely the normalized model with weighted distance norm and decreased parameters, as reported in the preceding section.

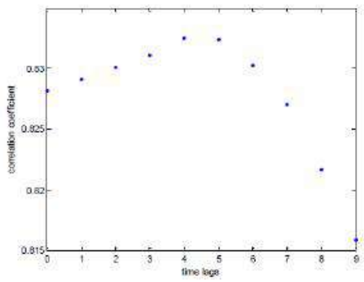


Fig.3.28: Time-delayed correlation coefficients between cooling oil temperature and turbine power output.

Figure 3.28 depicts the correlation coefficients between cooling oil temperature and power production for various time delays, revealing that the highest correlation, 0.8325, occurs at power output with a four-step delay.

As seen in Table 4.3, the coefficient without delay is slightly lower at 0.8282, indicating a 40-minute lag (and Figure 3.28). So, in the last step, the reduced variable model with three inputs is updated by replacing the concurrent power output with its value at (t-4), resulting in the time-lagged model. Table 3.7 summarizes the associated outcomes.

The time-lagged model, contrary to expectations, has somewhat lower model accuracy than the reduced parameter model, and the detection sensitivity has not improved. The quality of the data and subsequent data filtering to exclude incorrect measurements could be one explanation for this, resulting in an incomplete time series. As a result, the time-lag power output could sometimes be further back in time, resulting in decreased model effectiveness. As indicated in Table 3.4, the percentage of values deleted by filtration for the testing instances from turbines T16 and T17 is 36 percent and 42 percent, respectively, showing somewhat low data quality and thus corroborating the proposed interpretation. It's plausible that using lagged power values with high-quality data might be beneficial, but more research is needed to confirm this. Therefore, the time-lag model is not taken into account anymore, and the reduced parameter NSET model is kept for its superior performance.

3.4.11. Discussions of various model performance metrics

The model accuracy and detection ratios have been used to illustrate a model's ability to correctly predict a variable's value and successfully detect the performance deviation caused by an approaching system breakdown. Based on these criteria, the reduced parameter model has shown to be the most effective. In this section, two additional metrics, auto-sensitivity, and cross-sensitivity, are introduced and used to evaluate the performance of the preferred NSET model as an auto-associative model, as described in Section 2.

The ability of an auto-associative model to make proper estimations of variables when they are distorted owing to a malfunctioning sensor or degradations in the monitored system is measured by auto-sensitivity. The change in auto-sensitivity, SA i, is defined as estimating a specific variable induced by drift in the related sensor data [100], as shown in Equation (3-18).

$$S_{Ai} = \frac{1}{N}\sum_{k=1}^{N}\left|\frac{\hat{x}_{ki}^{drift} - \hat{x}_{ki}}{x_{ki}^{drift} - x_{ki}}\right| \quad (3\text{-}18)$$

The denominator represents the drifted values of a particular variable, the numerator is the corresponding change in variable estimation, and N represents the number of samples used in the prediction. A robust auto-associative model would cause small or no changes in the variable prediction for tiny drifts in the fault-free variable values. The optimal auto-sensitivity value is 0, indicating that the model can produce reliable predictions even when sensor measurements are drifting. An extreme situation with an auto-sensitivity value of 1 suggests that a model will not detect anomalies since the model prediction will follow the input drift, resulting in zero residuals. In most circumstances, the auto-sensitivity parameter of the model is between 0 and 1, implying that the residuals will underestimate sensor reading drifts, i.e., the failure signature [58].

Equation (4-19) below defines cross-sensitivity for each variable in the model, S_{Ci}.

$$S_{Ci} = \frac{1}{N}\sum_{k=1}^{N}\left|\frac{\hat{x}_{ki}^{drift} - \hat{x}_{ki}}{x_{kj}^{drift} - x_{kj}}\right| \quad (3\text{-}19)$$

Except for $i \neq j$, which indicates the consideration of the effect of a problematic sensor on the prediction of other variables [100], the numerator and denominator retain the same meaning as in the auto-sensitivity expression.

The auto- and cross-sensitivity are determined using the validation data with artificial alteration of the time series data for the parameters of interest for the best performing model so far, i.e., the reduced parameter model. Finally, the performance indicators are computed.

Equations (3-18) and (3-19) are utilized to calculate the gearbox oil temperature, which is the condition indicator for the gearbox case study.

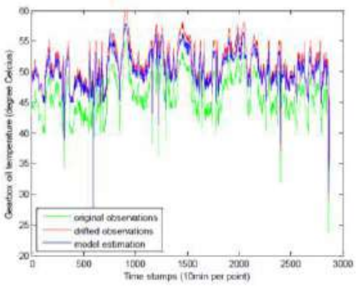


Fig.3.29: Validation data used to illustrate the auto-sensitivity performance

The auto-sensitivity findings are shown in Figure 3.29, where a constant drift of +5 is added to the initial oil temperature observation of the validation data, as shown by the green line. The red and blue curves in the same picture represent the changed observation and the associated prediction, respectively. The model prediction is affected by the erroneous inputs, as can be seen by the auto-sensitivity value of 0.82. The corresponding residual would likewise underestimate actual sensor drift, reducing the model's detectability to some extent. The tension between NSET model accuracy and detection sensitivity reflects the auto-associative NSET model's essential character. However, the preceding section's successful anomaly identification revealed the model's robustness, implying that even a high auto-sensitivity number isn't a concern. The cross-sensitivity values due to artificial drift in power output and nacelle temperature, respectively, are 0.02 and 0.07. As a result, the average cross-sensitivity value is around 0.05.

This is a low value, indicating that the model's oil temperature estimate is unaffected by other variables' erroneous inputs.

3.5. APPLICATION OF NSET TO A CASE STUDY OF A WIND TURBINE GENERATOR

In previous sections, successful NSET application to gearbox condition monitoring was demonstrated. A generator case study is used to demonstrate the usefulness of the NSET concept. Based on the domain knowledge in Section 3.2, three available variables are chosen for the condition monitoring purpose for the generator: turbine power output, generator winding temperature, and nacelle temperature, with the generator winding temperature serving as the condition indicator for the generator.

Table 3.8: Pearson's correlation coefficients between generator model input and output parameters

Output parameters / Input parameters	Generator winding temperature
Generator winding temperature (°C)	1
Power output (kW)	0.9066
Nacelle temperature (°C)	0.3008

Table 3.8 shows the relationship between the generator winding temperature and the other variables. The power output is required because of the significant correlation between the winding temperature and the nacelle temperature, as described in the gearbox study.

As previously stated, the generator failure for turbine T8 happened in November of 2006. Therefore, the testing data is taken two months before the final failure. The gearbox case study used a generic model that used averaged values from healthy turbines as training data and then validated and tested the model on different turbines. The generator study here employs a specific model, with training, validation, and testing data derived from the same turbine, in this case, T8. This is because other factors set the maximum temperature of the generator windings.

During the testing time, the winding temperature range of healthy turbines does not approach that of turbine T8. The data from T8 shows a far broader winding temperature range throughout the available period.

To eliminate the concern of the model's inability to extrapolate, data from turbine T8 is used as training data, and the first three months (April to June 2005) of the available period are chosen to avoid deteriorating performance in the training set and thus to eliminate false negatives in the detection results. The following month (July 2005), validation is done using operational data. Finally, the model's resistance to false alarms is investigated using new testing data from August 2005, which reflect a healthy generator. Table 4.9 shows the value ranges for several data sets and the crude data filtration used in the same way as the gearbox case study. The maximum training generator winding temperature is 154, the highest available, even though it is still 2 less than the testing limit.

The same procedure employed in Section 3.4.1 for the gearbox analyses is utilized to choose a memory matrix size of 3818. The findings of validating and testing three alternative NSET models, including the conventional model, the normalized model, and the normalized model with weighted parameters, are summarized in Table 3.10. However, the results are not presented here because of the consideration of space occupation and because they are identical in character to those already presented.

These three models all exhibit successful defect identification and a lack of false positives. In addition, the model accuracy is greatly improved by normalizing the memory matrix and adding weighting to the parameters, as shown in Table 3.10. On the other hand, the detection sensitivity displays an inverse relationship with model accuracy, which is consistent with the results of the gearbox application in Table 4.7 for the three models. In the gearbox case study, the NSET model performance was further enhanced by deleting a redundant variable, but all variables are considered highly relevant to the generator analysis. So there you have it that there are no easy guidelines to follow for model selection and that compromises between model correctness and detection sensitivity are necessary.

Table 3.9: The filtering criteria for the selected variables in the generator case study, as well as the findings

Data usage	Variables	Filtration criteria	Value range after filtration		Percentage of values being removed (%)
			min	max	
Training set (April – June 2005)	Active power (kW)	> 25	30.09	634.59	70
	Generator winding temperature (°C)	> 0	13.00	154.00	
	Nacelle temperature (°C)	> 0	5.00	28.62	
Validation set (July 2005)	Active power (kW)	> 25	30.29	611.04	25
	Generator winding temperature (°C)	> 0	23.00	131.00	
	Nacelle temperature (°C)	> 0	9.00	29.09	
Testing set I (anomalous; October – November 2006)	Active power (kW)	> 25	30.02	626.10	49
	Generator winding temperature (°C)	> 0	11.00	156.00	
	Nacelle temperature (°C)	> 0	5.82	22.92	
Testing set II (healthy; August 2005)	Active power (kW)	> 25	30.10	546.22	46
	Generator winding temperature (°C)	> 0	23.00	116.00	
	Nacelle temperature (°C)	> 0	10.00	25.29	

Table 3.10: A comparison of model efficacy in various conditions for the generator case

	Validation		Testing I (anomalous)				Testing II (healthy)			
	Mean (°C)	RMS (°C)	Mean (°C)	RMS (°C)	RR	DR (%)	Mean (°C)	RMS (°C)	RR	DR (%)
Standard NSET	-0.011	0.757	3.530	5.928	7.83	66.3	-0.012	0.263	0.35	0
Normalised NSET	0.052	0.460	1.653	2.844	6.18	38.6	0.026	0.167	0.36	0
Normalised NSET with weighted variables	0.035	0.390	1.350	2.575	6.99	31.8	0.024	0.149	0.38	0

IV. RESULTS AND DISCUSSION

4.1. SPATIAL APPLICATION OF THE NSET MODEL FOR DEFECT DETECTION IN WIND TURBINE GEARBOXES

Individual turbine-based anomaly detection across the wind farm will necessitate several data analyses, which will be impossible to complete by hand. The development of spatial data-mining algorithms that can analyze SCADA data from parts of or entire wind farms with vast numbers of identical make-of-turbines will significantly minimize the time and effort required to build models for each turbine.

Following its successful application to individual turbine gearbox condition monitoring in Section 3.4., the NSET method captures relationships among wind turbines across the wind farm by applying it to multiple turbines in a spatial context using the same gearbox examples from turbines T16 and T17. The state vectors in the memory matrix in this scenario contain recordings of gearbox oil temperature and other relevant variables from a group of turbines that are near together inside the wind farm and hence experience similar wind conditions and operating status. Compared to developing individual turbine models, the model outputs are estimates of the indicator variables for all turbine members within the group, saving time and effort. Aside from the memory matrix's state vector composition, all of the algorithms, including weighting vector calculation, memory matrix building, and hypoResearch Paper test-based fault detection, are implemented in the same way as in Section 4.1 of the previous Section. In addition, the correlation coefficients of wind speed between the turbine of interest and its surrounding turbines are used to identify the turbine group for model creation.

In the following parts, the implementation will be detailed. First, the ideal input parameter combination for model performance will be investigated, and the impact of normalizing the memory matrix and weighting the parameters on model performance. Finally, the improved model's effectiveness, which was unsatisfactory in the case of the individual turbine model, will be tested.

This Section delves into the subject. First, the model's extension and generalization capabilities will be studied, and the NSET model's geographical applicability constraints. Then, at the end of this Section, there will be a brief comparison of the spatial and individual NSET models.

4.2. MODEL TRAINING, VALIDATION, AND TESTING WITH DATA

The spatial NSET model's data selection for training, validation, and testing purposes must consider data availability across the entire wind farm or selected group, rather than just the turbine of interest, as in individual turbine analyses. For the training and validation sets, the operational status of the sub-group members should be ensured to be expected, and the testing data from turbines T16 and T17 are utilized to illustrate the model's effectiveness.

The wind farm configuration and details about gearbox failure for T16 and T17 were introduced in Section 3.2 of the previous Section. In addition, T16 and T17 are placed near each other in Figure 3.2, demonstrating a strong link between these two turbines. As a result, these two turbines will likely be grouped in a sub-group for spatial NSET modeling. Unfortunately, the training data will need to be reselected because the confirmed failure for turbine T17 occurred in April of 2005, which falls inside the training period (April to June of the same year) for the individual turbine gearbox example.

The fact that the data supplied only goes back to April of 2005 eliminates picking the training set earlier. Using training data from T17 and T16 failures would be inappropriate because T17's downtime ended in August of 2005. By that time, indicators of degradation for T16 had already appeared, as seen in the testing findings from the previous Section. After the reported failure at the end of January 2006, Turbine T16 was taken offline for gearbox repair and returned to production in March 2006. Because of the factors above, the training period was chosen to be from April to June 2006, when both T16 and T17 were operational and no documented concerns with the remaining turbines.

They are considered for sub-group membership. The model will be validated the next month. The testing duration for these two turbines is the same as the individual turbine analysis, i.e., April 2005 for T17 testing case I and August 2005 to January 2006 for T16 testing case II. The model's susceptibility to false alarms is assessed during the validation phase based on the healthy turbines in the specified sub-group.

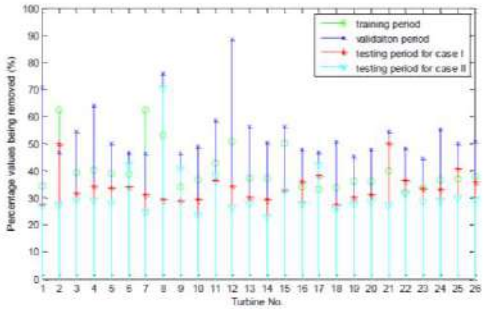


Fig.4.1: For each turbine, the percentage of invalid data entries in various data usages

Unlike in the individual NSET model, where data is filtered based solely on the turbine of interest, data filtration in this scenario must consider the entire wind farm or sub-group, i.e., simultaneous readings for the group of turbines would be invalidated if any of them had an invalid entry. For turbines T16 and T17, Figure 4.1 depicts the proportion of invalid data inputs in each turbine for various data usages, including the training, validation, and testing phases. The filtering is based on three variables: the temperature of the gearbox cooling oil, the power output, and the temperature of the nacelle. The temperature of the gearbox bearings is excluded from the filtration foundation since it is known from the previous Section that it should be avoided owing to the risk of false negatives. The validation data in this figure demonstrates that a substantial number of incorrect entries are deleted, with a peak of over 90% for turbine T12, followed by T1 and T8, and then T1 and T8. In such instances, excessive filtration will not only result in significantly less legitimate data, but it is also likely that the anomalous data from the testing sets will be partially or deleted as a result of inaccurate data from other turbines within the same period. For the sake of validation data, turbines with an excessive elimination rate, such as T1, T8, and T12, are deleted. Due to the examination of training and testing cases, T2, T4, T6, T7, T9, and T22 are also removed for the following analyses.

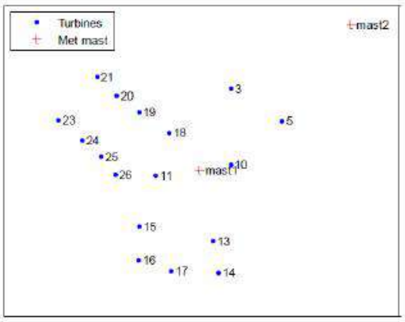


Fig.4.2: Disqualified turbines have been removed from the new wind farm plan

This eliminates 9 turbines from the initial group, leaving 17 turbines for this Section's examination. Figure 4.2 depicts the revised layout of a wind farm that only contains valid turbines. Table 4.1 shows the results of filtering operational data from this selected group concerning each candidate using the same criteria for the individual model. Because each turbine is unique, the percentage of values deleted in this situation is typically significantly higher than in individual turbine evaluations.

Filtration takes place within the sub-group. The high elimination rate in this table indicates poor data quality, but fortunately, the gearbox cooling oil temperature values for the training and testing sets are preserved. The validation set's maximum cooling oil temperature of 57.36 comes from turbine T14, and the related data is used for testing case III, the false alarm investigation.

Table 4.1: The results of data filtration based on wind farms (for 17 qualifying turbines)

Data usage	Variables	Filtration criteria	Value range after filtration		Percentage of values being removed (%)
			min	max	
Training set (April – June 2006)	Active power (kW)	> 25	25.01	657.66	67
	Gearbox cooling oil temperature (°C)	> 0	6.61	62.00	
	Nacelle temperature (°C)	> 0	2.24	28.43	
Validation set/false alarm testing (July 2006)	Active power (kW)	> 25	25.02	596.16	80
	Gearbox cooling oil temperature (°C)	> 0	15.03	57.36	
	Nacelle temperature (°C)	> 0	11.00	31.62	
Testing set in case I (April 2005)	Active power (kW)	> 25	25.28	640.71	61
	Gearbox cooling oil temperature (°C)	> 0	13.49	61.00	
	Nacelle temperature (°C)	> 0	2.65	21.28	
Testing set in case II (August 2005 – January 2006)	Active power (kW)	> 25	25.03	658.61	78
	Gearbox cooling oil temperature (°C)	> 0	6.62	67.00	
	Nacelle temperature (°C)	> 0	0.58	28.05	

4.3. IMPLEMENTATION OF THE MODEL WITHIN A SUB-GROUP

Due to their high correlation, the two turbines of interest, T16 and T17, are always included in the sub-group for the following studies in this Section. Section 4.3 will present the geographical model, which includes sub-groups of various sizes or even the entire wind farm. To begin, the model candidates are chosen based on the wind speed correlation. Turbines T10, T11, T13, T14, and T17 all have a nacelle anemometer correlation of greater than 0.96 with T16, hence they are included in the sub-group, resulting in a sub-group size of 6. The selected turbines are geographically close to each other, as shown in Figure 4.2, since the correlation of wind speed, which was utilized as the selection basis, is in general inversely related to the distance between measurement locations.

The 3-inputs model, which included oil temperature, power output, and nacelle temperature, produced the best results, as indicated in the previous Section. Given that among the standard, normalised, and weighted-variable NSET models, trade-offs between model accuracy and detection sensitivity are always required, the spatial NSET model with the three mentioned inputs is investigated first in this section based on the standard model within the selected sub-group, followed by discussions of the necessity of nacelle temperature and the role played by gearbox bearing temperature.

The state vectors in the memory matrix, symbolised by (m) in Equation (3-1) from the previous Section, represent records of the gearbox cooling oil temperature and other associated variables from the sub-group of turbines for geographic application of the NSET model. For example, in the three inputs model with the determined sub-group here, each state vector has 18 variables for each of the 6 sub-group members, including oil temperature, generated power, and nacelle temperature.

The various models to be investigated have varied memory matrix compositions, resulting in a different ideal matrix size, with the model with more variables requiring more historical state vectors to cover the entire operating range. The size of the matrix

Figure 4.3 depicts a decision with all three variables present. Based on the balance between model correctness and computational complexity outlined in Section 4.3.1, a good state number of roughly 1000 can be observed in this figure, resulting in a matrix D of size 1810 00. To conduct fair comparisons while maintaining model correctness, all subsequent studies within the specified sub-group employ a memory matrix size of 1017 state vectors.

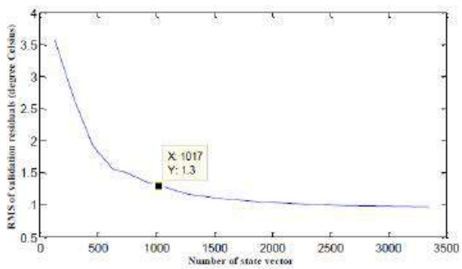


Fig.4.3: Determining the size of the memory matrix

The algorithms for the spatial NSET model and the related hypoResearch Paper test based fault detection are the same as in the previous Section for the individual turbine model. The matrix is built using 1017 historical states, and the model is then evaluated on turbine T16, with the results shown in Figure 4.4, demonstrating adequate model accuracy. For further defect detection, the maximum of the smoothed validating residual is employed as a reference. As demonstrated in Figures 4.5 and 4.6, the anomalies of turbines T17 and T16 are successfully recognized from the start of the testing period, confirming the model's anomaly detection effectiveness. Figure 4.7 also depicts the model's resilience to false alarms using healthy operational data from turbine T14, which contribute to the highest gearbox cooling oil temperature throughout the selected period. This demonstrates that a completely healthy turbine can achieve high temperatures.

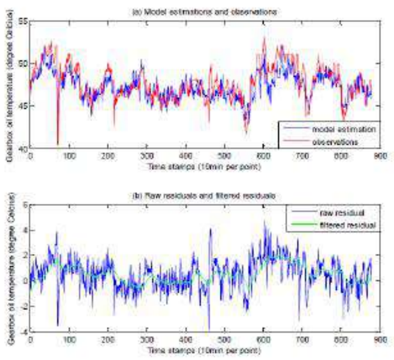


Fig.4.4: T16 validation findings for typical spatial NSET

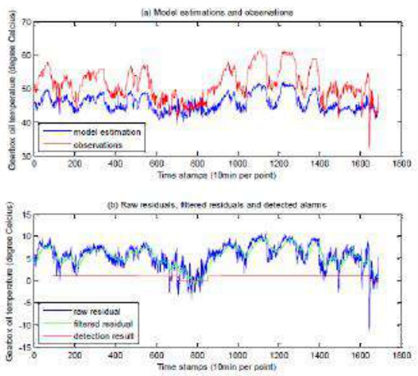


Fig.4.5: T17 testing results and anomaly identification for typical spatial NSET

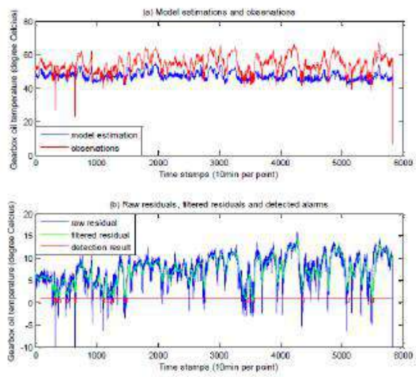


Fig.4.6: T16 testing results and anomaly detection for conventional spatial NSET

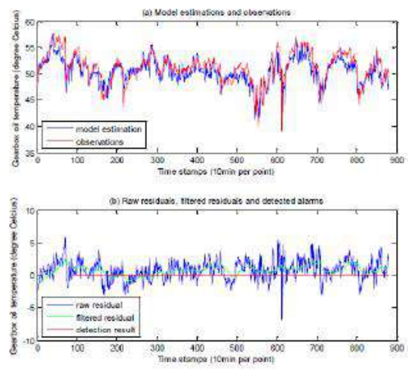


Fig.4.7: False alarm testing results of healthy T14 using typical spatial NSET

4.3.1. Discussions on the importance of maintaining nacelle temperature

Both the ambient temperature and the gearbox temperature have an effect on the temperature of the turbine nacelle. The impact of nacelle temperature in the modeling may be reduced since the selected turbine can be assumed to have a common ambient temperature with the other turbines. Using the same data as before, the effectiveness of an NSET model without nacelle temperature, i.e. only containing power output and cooling oil temperature, is explored.

Figure 4.8 shows the validation time series of oil temperature, power output, and nacelle temperature for the six selected turbines within the sub-group, and it can be seen that the oil temperature peaks about time instance 600, which corresponds to the nacelle temperature peaks. These are known to be caused by the high ambient temperature, and the accompanying power production is quite minimal in this case.

It is evident that the high ambient temperature drives the oil temperature peaks in this scenario, highlighting the impact of ambient temperature (which is not accessible in this

SCADA data set) and thus nacelle temperature on the model result.

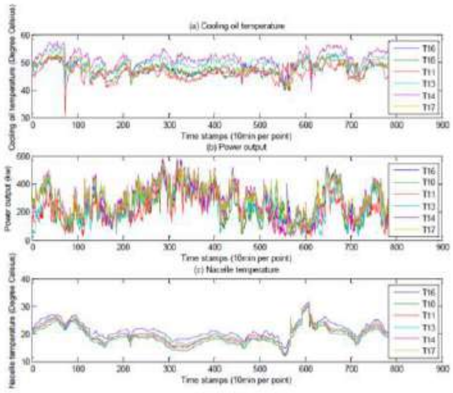


Fig.4.8: Validation data for all sub-group candidates as a time series

Figure 4.9 shows the validation findings for the 2-input NSET model, with the exact oil temperature measurement peak of 53 for the verified turbine T16 seen at time occurrence 602. The associated estimations from the 2-inputs and 3-inputs models, as shown in Figure 4.4, are 49.81 and 51.07, respectively, indicating that the 3-inputs model has a better degree of accuracy and therefore proving the need for nacelle temperature to be included in the spatial NSET model.

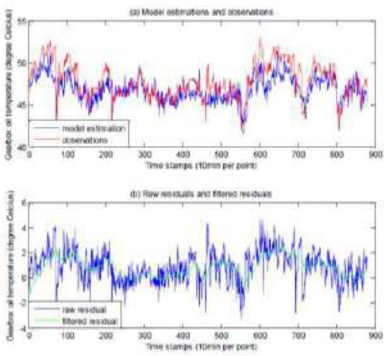


Fig.4.9: T16 validation findings for 2-input standard spatial NSET

Table 4.2 summarizes the validation and testing statistics for the 2-inputs model and compares them to those reported in the preceding section for the 3-inputs model. The 3-inputs model performs well, as shown in the table by displaying higher validation accuracy and a larger detection ratio for the testing data than the 2-inputs model.

4.3.2. The effect of gearbox bearing temperature on model performance

The gearbox bearing temperature, which was previously discussed as something to avoid in order to improve detectability, is analyzed individually in this section to highlight the potential performance damage that can occur. An extreme instance is used in which the model only includes the cooling oil temperature and the bearing temperature, and data filtration is only done for these two variables, which is different from what has previously been done. In this scenario, the refinement is based on the turbines operational data from the sub-group rather than the entire wind farm, and the filters picks up entries with positive oil temperature and bearing temperature.

Figure 4.10 shows the validation results, which show that the model is extremely accurate. However, as shown in Figure 4.11(a), the testing results for turbine T17 indicate good agreement between model calculations and observations even when the temperature peaks with apparent fault signals, resulting in anomaly detection failure (b). This is because, as discussed in the previous Section, the gearbox bearing temperature has a common causal link with the oil temperature in terms of gearbox failure, and hence would convey some comparable fault information, resulting in anomaly detection ineffectiveness. As a result, the temperature of the gearbox bearings should be removed from the model inputs.

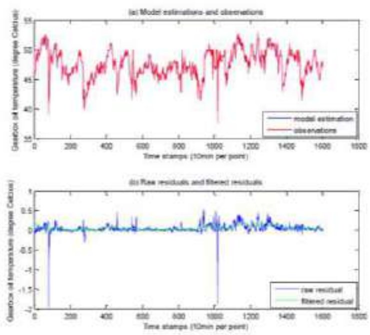


Fig.4.10: T16 validation findings for conventional spatial NSET with bearing temperature

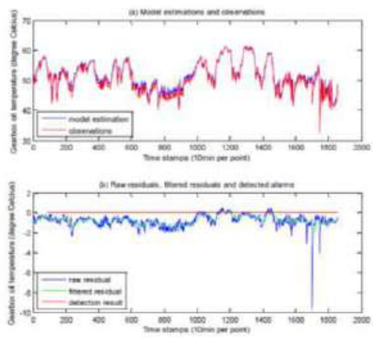


Fig.4.11: T17 testing results and anomaly identification for standard spatial NSET

4.3.3. The effect of a normalized memory matrix and weighted parameters on model performance

In this part, the performance of a model with memory matrix normalization and variable weighting is explored using the same data as in Section 4.2. Because the representations of the validation and testing findings are identical in character to those already shown earlier in this Section, they are included in Appendix II instead of being presented here, and the accompanying statistics of results can be found in Table 4.2. Despite the decreased detection ratio, the normalised and weighted model is substantially more accurate than the conventional model in the table, and it is also capable of identifying the anomaly with ample time before the final failure.

4.3.4. Discussion of the updated model in the context of spatial NSET

The modified NSET model is thought to produce more reliable results than the standard model because the indicative variable of the turbine of interest, in this case the gearbox cooling oil temperature, is omitted from the weighting vector estimation process, and the results are solely based on measurements from valid sensors. It was not chosen for the individual turbine studies in the previous Section due to poor performance caused by insufficient input variables. The associated variables from the neighboring turbines greatly increase the model's input size, hence the updated model is explored here.

The modified model is implemented using the same normalized and weighted model as in the previous section, with the same data. Because the oil temperature for the turbine of interest is missing from the input sets, 17 variables are included in the model inputs, and an optimal state number of 1017 is preserved, resulting in a memory matrix size of 171017. The modified model's validation and testing results are shown in Figures 4.12, 4.13, 4.14, and 4.15, and the accompanying data are summarized in Table 4.2, along with those from other models under examination.

The residual RMSs for the modified model are often bigger than the normalised matrix and weighted parameter model, as can be observed in both these figures and the table, especially for the T16 and T17 testing scenarios. This could be due to a number of factors.

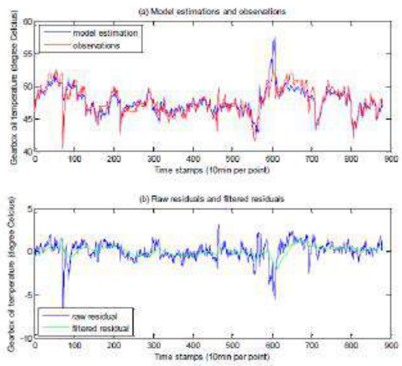


Fig.4.12: T16 validation findings for redesigned spatial NSET

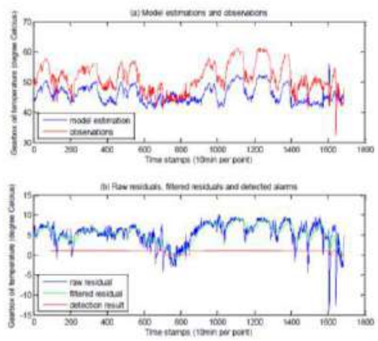


Fig.4.13: T17 testing results and anomaly identification for modified spatial NSET

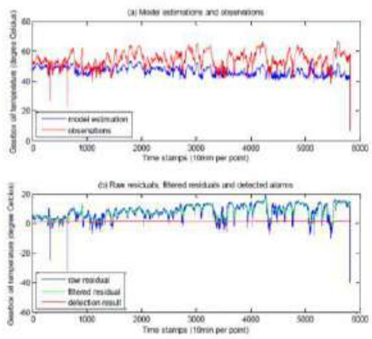


Fig.4.14: T16 testing results and anomaly identification for modified spatial NSET

The model auto-sensitivity for the normalised matrix and weighted parameter model is 0.88, suggesting that the related predicating residuals are often underestimated by 88 percent, resulting in lesser residual RMS values. The modified model, on the other hand, has an auto-sensitivity value of 0 for oil temperature because this variable is not present in the model input sets, which is the ideal scenario according to the associated metric definition presented in Section 3.4.11 of the previous Section. As a result, for further studies, the modified spatial model with normalized memory matrix and weighted parameters, also known as the modified model, is utilized.

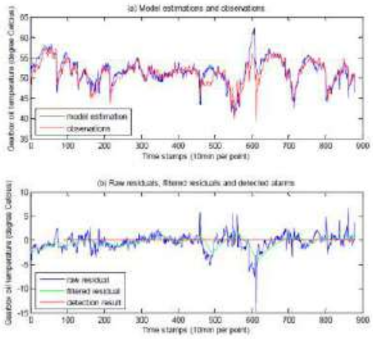


Fig.4.15: False alarm testing results of healthy T14 using modified spatial NSET

It's also worth noting that the training data originates from a time when the T16 and T17 turbines' aberrant gearboxes were changed, implying that the training and testing are based on separate operational systems. As a result, the model will generate predictions based on the training patterns learned from the new system, which may or may not be identical to the original. This will obviously reduce the model's accuracy and effectiveness, and hence should be avoided if at all possible, however it was not practicable due to the reasons stated in Section 3.2.

Table 4.2: Comparison of the effectiveness of spatial models with various input combinations in both conventional and modified settings

		Validation: T16		Testing I: T17				Testing II: T16				Testing III: T14			
		Mean (°C)	RMS (°C)	Mean (°C)	RMS (°C)	RR	DR (%)	Mean (°C)	RMS (°C)	RR	DR (%)	Mean (°C)	RMS (°C)	RR	DR (%)
Oil temp – Power	Standard	0.866	1.551	4.636	5.439	3.51	75.1	7.007	7.855	5.06	87.1	1.415	2.067	1.33	0
Oil temp – Power + Nacelle temp	Standard	0.503	1.300	5.546	6.210	4.78	88.0	7.182	8.032	6.18	90.8	0.740	1.680	1.29	0
	Normalized & weighted parameters	-0.092	0.724	0.715	1.052	1.45	38.8	0.567	1.263	1.74	38.9	-0.248	0.926	1.28	0
	Modified	0.106	1.040	5.344	6.094	5.86	88.0	7.652	9.100	8.75	87.9	-0.424	1.725	1.66	0

4.4. THE IMPACT OF SUB-GROUP SIZE ON MODEL PERFORMANCE

With six turbines in the sub-group, the spatial modified NSET model performs well. In this part, the influence of sub-group size on model performance is explored using the modified NSET model and turbine T16 as the foundation for sub-group selection once again. Table 4.3 lists the wind speed correlation coefficients between turbine T16 and the 17 available turbines in the wind farm in descending order. Changing the correlation threshold level changes the sub-group size.

Table 4.3: Wind speed correlation coefficients between T16 and the wind farm's available turbines

Turbine No.	Correlation coefficient with T16	Turbine No.	Correlation coefficient with T16	Turbine No.	Correlation coefficient with T16
16	1.000	26	0.958	18	0.934
17	0.987	3	0.954	21	0.930
13	0.973	25	0.954	19	0.914
14	0.968	24	0.953	20	0.899
11	0.967	23	0.949	15	0.824
10	0.967	5	0.938		

The relationship between the correlation coefficients and the related (rescaled) geographical distance from turbine T16 is depicted in Figure 4.16. With a few exceptions, such as turbine T15, it can be seen that the correlation level decreases as the geographical distance grows. The individual terrain roughness, land topology connected with the turbine, and wake effects from neighboring turbines are all possible reasons for this [46].

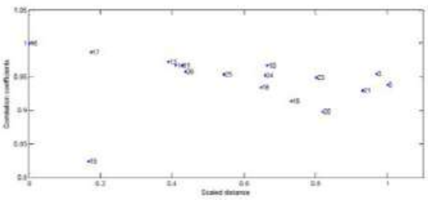


Fig.4.16: The spatial relationship between the available turbines in the wind farm and turbine T16

The data used for model validation and testing is the same as in Section 4.1, where the operational data is filtered based on the 17 turbines in the wind farm. The model described in the previous part, as well as models with sub-group sizes of 10, 15, and 17, are explored and compared here, including the one presented in the previous section and models with sub-group sizes of 10, 15, and 17 that cover all the turbines available in the wind farm. For a fair comparison, the equivalent matrix sizes of these models are kept around 1000.

Since of space constraints and because they are identical in nature to those already presented, the results are not reported here. Instead, they can be found in Appendix III, and the statistics related with them are summarized in Table 4.4. In this scenario, both the graphics and the corresponding data reveal that the sub-group size has no impact on model performance, implying that there is a lot of room to expand the spatial model to even larger wind farms and save modeling time without sacrificing model dependability. However, more data must be examined for the potential of the spatial NSET model to be extended before any definitive conclusions can be drawn, as the lowest correlation coefficient provided in Table 4.3 is 0.82, which is still a reasonably high correlation level. Larger wind farms are likely to have weaker correlations, which would lead to less accurate modeling.

Table 4.4: Comparison of the effectiveness of the 3-input modified spatial model with various sub-group sizes

Correlation Coefficient threshold	Sub-group size	Validation: T16		Testing I: T17				Testing II: T16				Testing III: T14			
		Mean (°C)	RMS (°C)	Mean (°C)	RMS (°C)	RR	DR (%)	Mean (°C)	RMS (°C)	RR	DR (%)	Mean (°C)	RMS (°C)	RR	DR (%)
0.96	6	0.106	1.040	5.344	6.094	5.86	88.0	7.652	9.100	8.75	87.9	-0.424	1.725	1.66	0
0.95	10	0.073	1.114	5.542	6.260	5.62	88.6	7.772	9.147	8.21	89.3	-0.430	1.765	1.58	0
0.90	15	0.079	1.129	5.372	6.197	5.49	88.1	7.870	9.190	8.14	89.9	-0.444	1.743	1.54	0
0.80	17	-0.053	1.185	5.667	6.554	5.53	88.2	7.997	9.266	7.82	91.1	-0.448	1.779	1.50	0

4.5. A DISCUSSION OF THE MODEL'S GENERALIZATION ABILITY

For the reasons described in Section 4.2, the preceding results are based on models built on turbine T16. This section investigates the model's generalisation capabilities utilizing other validating turbines within the largest accessible sub-group (comprising 17 turbines), which has been shown to be as effective as models with any sub-group size.

The testing data are identical to those used in the previous section for the 17-turbines sub-group, and the related testing residuals are also identical to those listed in Table 4.4 for the 17-turbines sub-group due to the identical memory matrix on which the model predictions are built. The sole difference in this scenario is the validation result, which affects the residual ratio, as well as the detection ratio, because the related hypoResearch Paper test is based on the validation result's maximum value.

Table 4.5: Comparison of effectiveness for geographical models built using different turbines with a sub-group size of 17

	Validation		Testing I: T17		Testing II: T16		Testing III: T14	
	Mean (°C)	RMS (°C)	RR	DR (%)	RR	DR (%)	RR	DR (%)
Sub-group based on T13	-0.716	2.366	2.77	80.6	3.92	83.5	0.75	0
Sub-group based on T10	-0.036	1.849	3.54	82.4	5.01	85.5	0.96	0
Sub-group based on T5	-1.166	2.259	2.90	87.1	4.10	89.0	0.79	0

T5, T10, and T13 are three random turbines chosen for model validation, and the relevant results of successful model application are reported in Table 4.5. Only the RR and DR numbers are shown because the Mean and RMS values are unchanged for the reasons stated above. When comparing the statistics in Table 4.5 with those in Table 4.4 for the 17-turbine sub-group, it can be seen that the impact of validating turbine selection on model performance for the same sub-group is negligible, implying the model's ability to generalize and the potential for effort savings for wind farm level condition monitoring.

4.6. LIMITATIONS OF THE NSET MODEL'S SPATIAL APPLICATION

The spatial NSET model has shown outstanding extension and generalization capacity in the previous two sections. However, because to the enormous number of turbines included in the model, there are several potential concerns that will be examined in this part.

To begin with, the data filtration is based on all candidates within the sub-group, which could lead to anomaly identification failure if the faulty data from the turbine of interest coincides with erroneous data from another turbine in the sub-group. Even if, as indicated in Section 4.1, a basic data refinement was used to remove the turbines with substantial numbers of incorrect records, the potential still exists, and the related chance grows as the sub-group grows.

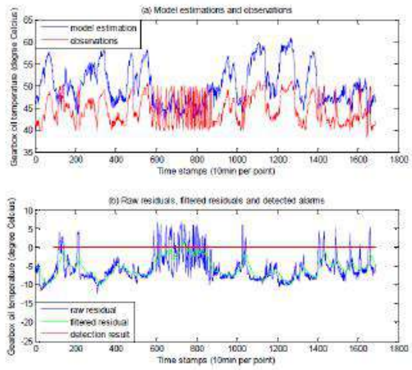


Fig.4.17: Modified spatial NSET results for healthy T14 using anomalous T17 in testing case I

Another source of concern is the impact of the erroneous data on model predictions for other healthy turbines. Figure 4.17 illustrates the testing results for the healthy turbine T14 based on the abnormal T17 using the same testing time (in testing case I) prior to its final gearbox failure, using the 6-turbines sub-group as mentioned in Section 4.2. The high model prediction values for T14 are due to the impact of anomalous data, which causes model accuracy to decline and testing residuals to decrease. When there are multiple anomalous turbines in the specified sub-group, this will become a severe problem. The aberrant data from other problematic turbines would affect the model estimation for the faulty turbine in a similar way, and the resulting lowered testing residuals would lead to erroneous results.

In the worst-case situation, there are disadvantages. In spatial NSET applications with a significant number of turbines in the specified sub-group, further caution is required.

4.7. SPATIAL AND INDIVIDUAL TURBINE NSET MODEL COMPARISON

Compare Table 4.2 with Table 4.7 from last Section to observe how much better the individual turbine NSET model outperforms the spatial model for different auto-associative forms (i.e. so called standard forms of the NSET model, including normalised and weighted). The spatial NSET solves the limitation of insufficient variables posed by the individual NSET modelling by efficiently utilising the variables from the surrounding turbines, therefore offering promising results. Moreover, the spatial NSET outperforms the effort-saving model However, for the reasons stated previously, the spatial model implementation viability is highly dependent on data quality. As a result, it is impossible to determine which model is preferable because they both have advantages and disadvantages, which allows for model selection based on data quality and availability.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUDING REMARKS AND FUTURE PROJECTS

This Research Paper presents promising SCADA data-based methods for robust fault identification, with a focus on the NSET technique for model estimate of both essential components of individual wind turbines and groups of wind turbines. In order to identify unusual behavior, this modeling is supplemented by a comparison of operational wind turbine power curves obtained in real time with a reference power curve. Comparisons, unlike earlier NSET implementations, involve a rigorous statistical comparison. To demonstrate the usefulness of the NSET algorithm and the suggested power curve based method, case studies of turbine gearbox and generator anomaly detection, as well as a turbine yaw misalignment example, are used. The following parts will show and discuss the Research Paper's primary scientific contributions as well as prospective future work to improve the approaches.

Conclusions

The following are the primary research contributions offered in this Research Paper:

a) For the comparison of power curves technique

i. The usage of a Copulas-based outlier rejection method to clean up the reference power curve is illustrated. This enhances the precision of the generated reference curve, increasing the sensitivity and reliability of later anomaly detection and so allowing for early defect diagnosis.

ii. A real-time power curve tracking approach is designed to identify any statistically significant variation from the reference power curve on a bin by bin basis, using an appropriate hypoResearch Paper test. This has been shown to be effective in detecting some defects in a timely manner.

b) For the NSET technique

i. The appropriate memory matrix size for the NSET approach is calculated as a tradeoff between model correctness and computational complexity.

ii. The use of extra null and maximal state vectors in the memory matrix is justified by the improved performance of the NSET model.

iii. The effect of re-scaling the memory matrix to normalize the parameter range of all variables to [0, 1] on model performance is examined and shown to improve model accuracy dramatically.

iv. Model accuracy is improved by adjusting variable weighting in the distance norm (traditionally the Euclidean norm) with NSET to reflect the relative relevance of the model variables.

v. The feasibility of extending the NSET model based on individual turbines to a multi-machine application is investigated, and the efficacy of such a spatially derived model is demonstrated. Model performance is found to be unaffected by sub-group size, and models validated with different turbines show no difference in performance, allowing this approach to be extended to entire wind farms, decreasing computational effort while maintaining model efficacy.

vi. The updated spatial NSET model improves the model's reliability by eliminating the indicative variable for the turbine of interest from the weighting vector estimation procedure, effectively resulting in a model with zero auto-sensitivity

The Welch hypoResearch Paper test has been used to execute both the power curve based fault detection and the NSET approach to anomaly detection in a statistically rigorous manner, reducing the likelihood of false alarm and increasing confidence in the condition monitoring systems.

Future Recommendations

The NSET technique's robustness in creating accurate and reliable model estimations enables for early detection of system incipient anomalies, enhancing the value of wind turbine status monitoring and increasing its cost-effectiveness. The applications given in this Research Paper, on the other hand, show the tension between NSET and NSET.

Because NSET models are auto-associated, they have high model accuracy and detection sensitivity.

The trade-off between the desired detection sensitivity and the false alarm rate is another key feature of condition monitoring algorithm development. False alarms can be costly in terms of wasteful downtime and maintenance measures that aren't required, especially for offshore wind turbines. Offshore turbine access is expensive, and visits may be squandered if they are the consequence of false alarms. The relationship between how far in advance an abnormality can be detected and the associated false alarm rates is not well understood, and gaining a better understanding of this relationship would aid in better decision-making for turbine repair and maintenance scheduling.

In the described gearbox case study, the autoregressive input (or time lagged input variable) has no effect on the NSET model's performance. One reason for this could be data filtration, which excludes invalid measurements, resulting in an incomplete time series with undesirable time changing changes in lag time, weakening the model. However, in circumstances where there are inherent time delays in the system, such as due to thermal mass, the introduction of a suitable time-lagged variable could be helpful, and this topic warrants additional investigation.

Furthermore, it has been determined that further research into the NSET model's resilience to false alarms should be conducted using typically operating turbines with high indicative variable values (such as the gearbox oil temperature in the condition monitoring of turbine gearbox). At the time of authoring this MS Research Paper, such information was not available.

The NSET method should be expanded to include data from new components and subsystems, as well as data from other sensors, such as vibration sensors and oil particle counts, in order to achieve the goal of a fully holistic status monitoring system. In addition, there is still a lot of work to be done to extend the framework of power curve-based anomaly detection to cover additional turbine sub-systems, or even individual component faults (including measurement instruments), allowing for the eventual development of a comprehensive fault logic that would provide a powerful tool to wind farm operators.

Finally, to improve algorithm performance and verify the capabilities of the NSET model and power curve tracking methods for condition monitoring, essential parameters such as the significance level in the Welch's t-test should be tuned using more extensive operational data from field testing. The economic value of such condition monitoring systems might be estimated using this data, which includes verified false alarm rates and successful defect identification performance statistics.

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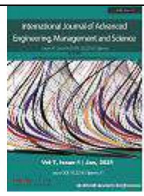

The Intellectual Capital and their Influence on the Financial Performance of Private Banks in the Province of Kurdistan

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Abstract**—** *Using value-added intellectual coefficient (VAIC) methodology, the present study was carried out in order to investigate intellectual capital (IC) performance of private banks located in Erbil and examine the influence of IC on the financial performance of those banks. In so doing, IC components affecting the traditional indices of bank success were specified. The study focused on 1 private bank operating in Erbil in 2017, and the results indicated that they had a low IC performance which was figured out to be positively associated with bank financial performance indicators. Nevertheless, the relationships between the components and financial performance indicators changed as a result of breaking value-added intellectual coefficient into its components.*

Keywords**— *Private Banks, VAIC methodology, intellectual capital.***

I. INTRODUCTION

The traditional sources of competitive advantage that once utilized tangible assets to create firm value and maintain competitive advantage started to fade away with the development of knowledge-based economy (Pablos, 2002). It is recognized that in the new economic period, intellectual capital (IC) resources like customer relations and human capital are considered as the most important business success factors in maintaining competitive advantage and creating value of firms (Maditinos, Chatzoudes, Tsairidis, & Theriou 2011; Andriessen, 2004). Likewise, the efficient management of IC, but not tangible assets, causes the potential for creating competitive advantage and long-term value. This is an obvious characteristic of knowledge-based and financial industries such as banks in which the main resources have a non-tangible and intellectual nature (Shih, Chang, & Lin, 2010). As pointed out by Ahuja and Ahuja (2012), if IC is efficiently used, success in banking can be achieved. Delivery of services with high quality by banks is reliant on their investment in IC-related items like brand building, human resources, processes, and systems. It is also stated that although banks require physical capital as an essential component to be able to operate, the quality of services provided to customers is determined by the intellectual capital (Goh, 2005). As a result, it is highly necessary that banks try to manage their IC efficiently.

In the present study, the value added intellectual coefficient (VAIC) developed by Pulic (1998) was utilized to assess IC performance of private banks located in Erbil. The effect of intellectual capital (IC) and its components on the banks' financial performance measures, i.e. return on assets (ROA) and return on equity (ROE), was also examined in the present study. Since the main resources of banks have an intellectual and intangible in nature, which play the most significant role in value creating process, efficiency of value creation and management of IC resources in the target banks were examined.

The present study was an attempt to provide private banks of Erbil with an easy method to figure out and asses their performance and promote IC management. Reviewing IC literature reveals the importance of IC efficiency role in the financial performance of banks; therefore, focusing on this issue in banks located in Erbil is of high significance.

II. BACKGROUND

Intellectual capital (IC) is defined by the Organization for Economic Co-operation and Development (OECD) (2000) as the "economic value of two categories of intangible assets of a firm: (1) organizational (structural) capital; and (2) human capital." This definition is in line with the VAIC methodology that was utilized in the present study to asses IC performance. Based on this definition, IC can be classified into two components of human capital (HC) and structural capital (SC). Edvinsson and Malone (1997) also proposed a similar classification for IC. IC has also been classified into three elements of structural capital, human capital, and relational capital (Ting & Lean, 2009). Human capital refers to the employees' knowledge, experiences, qualifications, and skills that they take with them when they quit the company (Zeghal & Maaloul, 2010). Structural capital is defined as the knowledge which maintains in the company after the employees leave it at night. This type of capital includes cultures and databases, customer relations and loyalty, firm brand and reputation, information technology, organizational routines, organizations' management processes, procedures, systems, production processes, and supplier relation. (Zeghal & Maaloul, 2010).

No measurement of IC exists that is accepted worldwide (Chan, 2009). By reviewing the current IC measurement methods, Sveiby (2010) figured out 34 methods among which value-added intellectual coefficient (VAIC) methodology is regarded by many researchers as a widely-used method to assess IC performance. Several studies have utilized this methodology to study the relationship between corporate performance and IC performance in both developed and developing economies, which led to different results in banking and non-banking sectors (see Chan (2009) in Hong Kong, Chu, Chan, and Wu (2011) in Hong Kong, Firer and Williams (2003) in South Africa Komnenic & Pokrajcic (2012) in Serbia, Ku Ismail and Abdul Karem (2011) in Bahrain, Kujansivu and Lonnqvist (2007) in Finland Maditinos et al. (2011) in Greece, Mehralian, Rajabzadeh, Sadeh, & Rasekh, (2012) in Iran, Ting and Lean (2009) in Malaysia, Wang (2011) in Taiwan, and Zeghal and Maaloul (2010) in the UK.

As defined by different sources, a firm is a set of tangible and intangible resources which can become the source of sustainable competitive advantage provided that they are rare, inimitable, valuable, and non-substitutable (Barney, 1991). According to resource-based theory, both human and structural intellectual capital and physical and financial capitals are regarded strategic resources because companies obtain competitive advantage and thus superior performance by acquiring, maintaining, and using these strategic resources efficiently (Zeghal & Maaloul, 2010). As argued by Reed, Lubatkin, and Srinivasan (2006), competitive advantage and value added are only created as a result of IC because imitating and replacing competitive advantage and value added are difficult, while physical capital can easily be imitated, substituted, purchased, and sold. The same point is referred to by Youndt, Subramaniam, and Snell (2004).

According to the IC-based theory proposed by Reed et al. (2006) which regards IC as the firms' only strategic asset playing an essential role in developing and retaining competitive advantage in firms, it is expected that IC and its elements to positively influence the organizational financial performance in the banks under study.

The study's hypotheses

In order to achieve the goals of the present study, the following hypotheses were raised.

Hypothesis 1: Higher IC performance in the banks under investigation leads to higher organizational performance.

Hypothesis 2: Higher human capital efficiency in the banks under investigation leads to higher organizational performance.

Hypothesis 3: Higher structural capital efficiency in the banks under investigation leads to higher organizational performance.

Hypothesis 3: Higher capital employed efficiency in the banks under investigation leads to higher organizational performance.

III. RESEARCH METHODS

The sample of the present study included 10 private banks located in Erbil. The required data were obtained from the annual reports of the banks during 2015-2017. Value added intellectual coefficient (VAIC) method proposed by Pulic (1998) was utilized to assess the banks' IC performance. This method was used by other studies like Abdulsalam et al. (2011); Al-Musali and Ku Ismail (2012); and Joshi, Cahill, and Sidhu (2010). VAIC is calculated using Equation 1:

$$VAIC = CEE + HCE + SCE \qquad \text{(Eq. 1)}$$

Where CEE stands for value added efficiency of the capital employed (CE) and CE for the book value of total tangible assets. CEE is the result of dividing the value added (VA) by CE. HCE stands for to efficiency of human capital in creating value, which is obtained by dividing VA by HC. HC represents personnel costs, SCE stands for value added efficiency of structural capital, obtained by dividing SC by VA, and SC for the difference between VA and HC. Total VA is calculated through Equation 2 below:

VA = OP + EC + D +A (Eq. 2)

Where OP stands for Operating Profits; EC for Total Employee Expenses; D for Depreciation, and A for Amortization.

Return on equity (ROE) and return on assets (ROA) are used to assess financial performance. ROE which is referred as returns on the shareholders' common stocks is regarded as a significant financial indicator by the stock owners. Return on equity (ROE) is measured as the annual net profit of an individual bank before tax is divided by average equity of shareholder. ROA which is an indication for effective utilization of available assets to create profits is calculated as the annual net profit of an individual bank before tax is divided by average total assets.

Bank size which was measured as the total assets was considered as a control variable in the regression model in order to be in agreement with previous studies such as Chan (2009) and Shiu (2006) and minimize its interference with the dependent variables. A dummy variable was also taken into account so as to control the global financial crisis (CRIS) which had a value of 1 in the period under study. The association between VAIC and the two financial performance measures (ROE and ROA) is examined in Models 1 and 2, while Models 3 and 4 substitute the aggregate IC measure with the three components of VAIC (see Table 2). All the linear regression assumptions were tested to make sure about the quality of the collected data and variable.

Table 1. Regression equations

Model	Regression equation
1	ROE= βi+β1VAIC+β2SIZE+β3CRISIS+e
2	ROA= βi+β1VAIC+β2SIZE+β3CRISIS+e
3	ROE= βi+β1HCE+β2SCE+β3CEE+β4SIZE+β5CRISIS+e
4	ROA= βi+β1HCE+β2SCE+β3CEE+β4SIZE+β5CRISIS+e

Findings

The banks' IC performance from 2015-2017 is indicated in Table 2. The overall mean IC performance of the Saudi banks is 3.646 which is lower than those found by Al-Musali and Ku Ismail (2011) for the Emirates banks (4.4), Abdul Salam et al. (2011) among Kuwaiti banks (4.45), El-Bannany (2008) for the British banks (10.80), Goh (2005) for banks in Malaysia (7.11) and Joshi et al. (2010) for Australian banks (3.80). Table 2 shows the trend of IC performance during the three years. Banks in Saudi Arabia experienced a decline in the value creation efficiency in 2009 reflecting probably the adverse impacts of global financial crisis on banking sectors in this Gulf country. However, IC performance of banks rose in 2010, reflecting probably the success of Saudi government`s policies to mitigate the negative impacts of the world financial crisis on the Saudi banking industry.

A comparison of VAIC components suggests that during 2008-2010, the banks in Saudi Arabia are generally more efficient in generating value from its HC rather than CE and SC.

Table 2. The banks' IC performance from 2015-2017

Year	Item	Coefficient
2015	HCE	2.985
	SCE	0.890
	CEE	0.046
	VAIC	3.978
2016	HCE	3.018
	SCE	0.452
	CEE	0.017
	VAIC	3.462
2017	HCE	2.843
	SCE	0.667
	CEE	0.037
	VAIC	3.897
2015-2017	HCE	2.948
	SCE	0.669
	CEE	0.033
	VAIC	3.779

The results of linear regression for Models 1 to 4are presented in Table 3. As seen in that table, all of the regression models possess high statistical significance and high explanatory power. Compared with the results of employing VAIC as an aggregate measurement (see Models 1 and 2); however, the explanatory power of the models using the three VAIC elements (Models 3 and 4) was significantly higher, which indicates different emphases of the stakeholders and managers on the three elements of VAIC (Chen et al., 2005).

According to the results obtained for Models 1 and 2 presented in Table 3, it can be concluded that there is a significant positive correlation between VAIC and both ROE and ROA as the financial performance indicators of the private banks over the study period. The results related to Models 1 and 2 showed VAIC as a predictor of the private banks' intellectual efficiency. This result shows that those banks that had greater IC performance had a better financial performance.

Table 3. Regression results

Independent variables	Model 1	Model 2	Model 3	Model 4
Intercept	-0.07***	-0.008**	-0.068**	-.011***
	(-3.487)	(-2.371)	(2.872)	(-3.575)
VAIC	0.826***	0.887***		
	(6.674)	(6.062)		
HCE			0.712***	0.464**
			(3.289)	(2.242)
SCE			0.026	0.142
			(0.098)	(0.874)
CEE			0.144	0.462***
			(1.498)	(4.795)
Size	0.103	-0.016	0.082	0.001
	(0.784)	(-0.086)	(0.432)	(0.012)
Crisis	0.088	0.064	0.086***	0.046
	(1.243)	(0.873)	(0.992)	(0.724)
Adjusted R^2	0.832	0.774	0.813	0.828
F value	58.328	38.672	28.749	34.034
Sig.	0.001	0.002	0.000	0.005
Notes: ***, **, and * denote statistical significance at the 1, 5, and 10 percent levels respectively. The figures in the parentheses are the t-statistics.				

The results presented in Table 3 indicate that there is a significant positive relationship between HCE and both financial performance indicators in private banks located in Erbil, Iraq. It was also concluded that SCE has no significant relationship with financial performance indicators. CEE was found to have a significant positive relationship financial performance indicators. Moreover, physical and financial CEE led to more profitability in the banks than HCE or SCE, which is in line with the results reported by Firer and Williams (2003), Ku Ismail and Abdul Karem (2011), and Mehralian et al. (2012). Furthermore, in terms of the control variables, the results showed that global financial crisis did not significantly affect the financial performance indicators of the private banks.

IV. CONCLUSION

The results of the present study showed that compared to their counterparts in developed and emerging economies, the private banks located in Erbil had a lower IC performance, which may be attributed to redundant and nonperforming resources. Therefore, these banks need to develop a system to increase their efficiency in value creation. Analyzing HCE, SCE, and CEE shows that the main factor that determines the capability of private banks in Erbil to create value is HCE, which is mainly because the banking sector is a service sector in which customer services depend heavily on human capital. It can be stated that banks that utilize their HC more efficiently are more likely to survive. Therefore, private banks of Erbil are recommended to spot key people and teach them to deliver high HCE because a continuous training program is an essential tool for the employees and managers' performance. The results of the present study also indicated that there was a dire need for developing value creation efficiency of SC. Mehralian et al. (2012) pointed out that realizing and maintaining the value of technological knowledge (know-how) is the best strategy whereby developing countries can empower SC.

In general, as the results of regression analysis (Models 1 and 2) showed, financial organizational performance of private banks in Erbil can be explained through VAIC. On the other hand, based on the results of the regression analysis of Models 3 and 4, it can be concluded that the private banks' managers failed to realize the full potential of human and structural capitals as the IC components in order to raise the stakeholders' benefit. The findings of the current study can be utilized by the managers of the private banks located in Erbil to adopt appropriate strategies and policies so as to obtain, utilize, develop, and retain intellectual capital. Policy makers in Erbil can utilize the findings of the present study in order to formulate and implement right policies in order to strengthen banking sector.

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