Performance Analysis of Flying Capacitor Multilevel Inverter

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Abstract— This paper presents a simulation study of phase-disposition (PD-PWM) pulse width modulation strategies in 3 phases, seven level flying capacitor multilevel inverter (FCI) performed in MATLAB Simulink. Here we have used a new approach of modular-cell inverter with a reduced number of flying capacitors (RFCI). The propose RFCI will reduce significantly the component counts, cost, and size of the converter. The overall performance of RFCI will greatly enhance as compared with the classical multilevel flying capacitor inverter (FCI). Hence, a comparative analysis of the propose RFCI will made against the modified FCI based on seven-level output phase voltages.

Keywords— Flying capacitor multilevel inverter (FCI), PD-PWM, Third harmonic distortion (THD).

I. INTRODUCTION

Nowadays Multilevel inverters are proven technology in the industry and have been extensively researched over the past decades. A multilevel inverter (MLI) is an electrical device that converts a dc power supply into an ac power supply. MLI are capable of handling high voltage with minimum voltage stress on switching devices, generate output voltage with minimum harmonic content, and generate low dv/dt and have a lower common mode voltage, which result in reduced stress on motor bearing in drive applications. In recent years, the need for high power apparatus has been derived by numerous industrial applications. Medium voltage motor drives and utility applications are some examples, since they require medium voltage and megawatt power level. There are three types of multilevel inverter

1. Diode-clamped multilevel inverter.
2. Flying-capacitor multilevel inverter.
3. Cascaded-multi level inverters [1].

Flying-capacitor-multilevel inverter was intro-duced by Meynard and Foch in 1992. The structure of multi level inverter is similar as of diode-clamped inverter only the difference is instead of using clamping diodes, the inverter uses capacitors at same place.

II. FLYING CAPACITOR MULTILEVEL INVERTER

2.2 OPERATING PRINCIPLES OF 7L FCI

In the given circuit, each phase leg requires minimum 12 switches (Sx1 to Sx6 and Sx1’ to Sx6’) and 5 capacitors (Cx1 to Cx3) which are clamped between the modular cells depending on the device voltage ratings considered during the design of the converter. When the converter is designed for three-phase systems, the difference would be even obvious. In the proposed SIX-cell 7L-MFCI since 6 pairs of active switches are used. For zero output level two redundant states are produced and for each ±Vdc/2, ±Vdc/3 and ±Vdc/6 output levels three redundant states are produced [1]. It should be noted that when Sx1 conducts all positive output levels are achieved, whereas all when Sx1’conducts negative output levels are obtained. Therefore, the two switches Sx1 and Sx1’ in Cell 1 are always performing at fundamental frequency of 50 Hz. During steady-state operation, the flying capacitor voltages VCx1, VCx2, VCx3, VCx4 and VCx5 of SIX-cell 7L-RFCI are maintained at Vdc/6, Vdc/3, and Vdc/2, respectively.
2.2 Output voltage waveform for single phase MFCI

In fig. 2 for gate signals given to the 1 ph 7 levels FCI circuit 2 PD-PWM switching method are used. In subsystem 1 to trigger the switches switching logic circuit is designed [4].

III. 3 PH MFCI CIRCUIT

3.1 Discussion about the selection of carrier frequency and value of capacitor

The value of carrier frequency should be chosen in such a way that the sinusoidal signal which is reconstructed from dc source should be even in nature means if the frequency is less than the reconstructed signal will be a sinusoidal signal and also at output side it has more percentage of square wave so it will be called as modified sine wave inverter [2]. However, the value of carrier frequency should be selected in such a way that, at output pure sinusoidal waveform should be available using low pass filter.

Also the value of capacitor should selected in such a way that during the switch off period of MOSFET the capacitor should not discharge and in each switching instant the magnitude of voltage level should be maintained.

Because during switching off instance of time $t_0$, discharging rate of the capacitor is given by

$$V_c = V_{\text{max}} e^{(t_0/R_c)}$$

Where $R =$ load resistance and $C =$ capacitor.

So for $V_c = V_{\text{max}}$

The value of $t_0/R_c$ should be approximately zero. Either it should have less value of numerator or high value of denominator [3]. We cannot increase the value of $R$, if we do so, the efficiency of the system will determinate and we get sine $I^2R$ loss. So increase the value of $C$ and reduce the value of $t_0$, means reduction of capacitance value will result the more discharging of capacitor so, then we get same results as that of modified wave [2]. So, select higher value of capacitance and less time period of carrier frequency (more than 10K_HZ) but
due to this switching losses will increase and further efficiency will get decrease [6]. So the optimized value for carrier frequency should be in range of 3KHZ to 10KHZ and value for capacitor should be in the range of 2200uf to 4700uf because if you further increase the value of capacitor than it will be heavy on packets.

3.2 OUTPUT VOLTAGE VA, VB, VC

![Figure:5 Waveform of Va](image)

3.3 OUTPUT VOLTAGE Vab, Vbc, Vca

![Figure:6 waveform Vb](image)

![Figure:7 waveform Vc](image)

![Figure:8 Waveform of Vab](image)

![Figure:9 Waveform of Vbc](image)
IV. INVERTER VOLTAGE, CURRENT

A. INVERTER VOLTAGE

Figure: 10 Waveform of Vca

B. FFT ANALYSIS OF INVERTER VOLTAGE

Figure: 11 waveform of inverter voltage

Figure: 12 FFT voltage

C. INVERTER CURRENT

Figure: 13 Waveform of inverter current

D. FFT analysis of inverter current

Figure: 14 FFT current

V. MOTOR CIRCUIT

Figure: 14 3-ph. flying capacitor multilevel inverter

Connected motor circuit
VI. CONCLUSION

The work presented here focuses on simulation and implementation of 1-phase and 3-phase flying capacitor MLI. A brief view of the operating principles of 1-phase and 3-phase flying are discussed and experimental modules are shown. The 1-phase and the 3-phase flying capacitor MLI configurations were individually designed by MATLAB. Waveforms for the voltage-source inverters, either Single phase or three phase configurations were also figured out in off time by MATLAB.

REFERENCES


