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Simulation and Analysis of Closed loop Control of Multilevel Inverter fed AC Drives

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ABSTRACT

Background: Performance of Multilevel inverter. Objective: The simulation results effectively controls the motor speed and enhances the drive performance.. Results: Closed-loop control scheme not only prevents further unbalancing of capacitor voltages but also takes corrective actions to bring back the capacitor voltages in the balanced state. Conclusion: The effectiveness of the proposed system is verified through simulation using MATLAB Simulink. This paper presents the simulation of three phase multilevel inverter fed induction motor using Simulink. Due to the presence of harmonics there is significant level of energy losses and poor quality of voltage and current. Generally the inverters with higher level can generate high quality voltage waveforms. The operating limitation of open-loop control scheme takes corrective action toward the existing unbalance in the dc-link-capacitor voltages. Similarly a simple closed-loop control scheme is based on the switching-state redundancy. Closed-loop control scheme not only prevents further unbalancing of capacitor voltages but also takes corrective actions to bring back the capacitor voltages in the balanced state. The simulation results effectively controls the motor speed and enhances the drive performance. The effectiveness of the proposed system is verified through simulation using MATLAB Simulink.

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INTRODUCTION

Nowadays power electronic devices contribute with an important role in all part of harmonics, such as power rectifiers, thyristor converters and static var compensators. This results in the torque and speed control of AC motor drive. Variable speed induction motor drives are replacing the conventional DC Drives in industrial environment. Multilevel converters are considered for high- medium power drive applications. This is because the power structure can be realized with devices of lower voltage ratings. Multilevel inverters are also used in solving problems with high-frequency adjustable speed drives. A multilevel inverter has several advantages over conventional methods. . In many industrial applications it is very essential to control the output voltage of inverters. There are mainly three types of multilevel inverters; they are 01) diode- clamped, 02) flying capacitor and 03) cascade multilevel inverter (CMLI). Out of which CMLI has wide range of application (Fang Zheng Peng, Jih-Sheng Lai, *et al*., 1996; Jih-Sheng Lai, Fang Zheng Peng, 1996). In (Peng, F.Z., J.W. McKeever, 1997; Tolbert, L.M., F.Z. Peng, 1999), iterative numerical analysis have been implemented to solve the SHE equations. By using the proposed topology the number of switches will reduced and hence the efficiency will improve as in (Yan Deng, Hongyan Wang, 2005). In high power applications, the harmonic content of the output waveforms has to be reduced as much as possible in order to avoid distortion in the grid and to reach the maximum energy efficiency (Alan Joseph, *et al*., 2005). The phase shifted technique is best suitable for CMLI and it is used in this paper for generation of triggering pulses to CMLI (Erdman, J., R. Kerkman, 1996; Kailath, T., 1980). Multilevel sinusoidal PWM can be classified as in (Klabunde, Y., Zhao, 1996). In this paper the multilevel inverters fed AC drive is used and an analysis of open & closed loop Control system is designed using PI controller in order to maintain load voltage constant during voltage sag. The diagram of a multilevel inverter is shown in Fig.01.

Multilevel Inverter fed Drive:

According to research, the first multilevel inverter was designed in the year 1975 and it was a cascade inverter with diodes blocking the source of the circuit. This inverter was later derived into the Diode Clamped

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Multilevel Inverter, also called Neutral-Point Clamped Inverter. In the NPCMLI topology the voltage clamping diodes is used which is an essential one. The main function of this multilevel inverter is to synthesize a desired voltage from several dc sources. The connection of AC terminal voltages of each bridge are in series. Unlike the other methods of inverter, the cascaded inverter does not require any voltage clamping diodes or voltage balancing capacitors. Here one important characteristic of multilevel converters is using a voltage escalation that is electric power distribution and switching frequency. This type of configuration is useful for constant frequency applications. This analysis makes an overview to find the various induction motor drive configurations used in industry where control strategies used to improve drive efficiency and the motor speed. The block diagram of the system is shown in Fig.02.

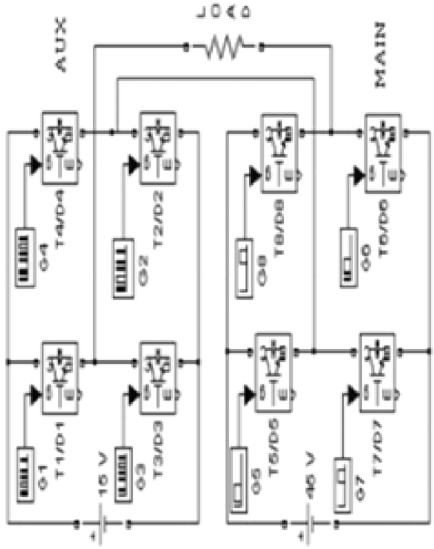

Fig. 1: Multilevel Inverter (Nine Level).

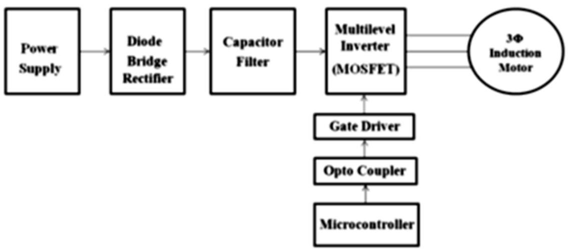

Fig. 2: Block Diagram of Multilevel Inverter fed Drive.

Selective Harmonic Elimination (SHE) technique for one phase inverters is one of the options for inverters to reduce some harmonics and set the cut frequency of a low- pass filter with a higher value to reduce the size of inductances and capacitances of the filter. Even some harmonics can be eliminated, the total harmonic distortion could increase. Multilevel inverters provide a less THD than other inverters and it can improve with more levels added. One of the drawbacks is the calculation of the switching angles since the more levels are needed, more angles must be calculated and more time is spent in calculation. The RMS voltage for (2p+1) levels is,

$$V_{o,RMS} = \sqrt{p^2 - \frac{2}{\pi}\sum_{i=0}^{p-1}(2i+1)\alpha_{i+1}} \quad ---- \qquad (1)$$

Where p is the number of switching angles in half cycle.

The Fourier coefficients are,

$$b_n = \sum_{i=1}^{p}\frac{2}{\pi}\int_{\alpha_i}^{\pi-\alpha_i} E\, sin(n\theta)d\theta$$

$$b_n = \frac{4E}{n\pi}\sum_{i=1,3,5,\ldots}^{p} cos(n\alpha_i) \quad ----- \qquad (2)$$

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One of the most used techniques for finding the switching angles is to use the Fourier coefficients to eliminate some harmonics. The number of harmonics to be eliminated is equal to the number of switching angles to be calculated minus one, with this technique.

RESULTS AND DISCUSSIONS:

The analysis of multilevel inverter fed induction motor model was done using MATLAB Simulink. Using tool box of MATLAB, the inverter is modeled using the "Universal Bridge" block and the motor by the "Asynchronous Machine" block. The inverter is fed to induction motor with a three phase PWM inverter controlling both the frequency and magnitude of the voltage output. In this paper, Fig.02 shows the simulation of new multilevel inverter.

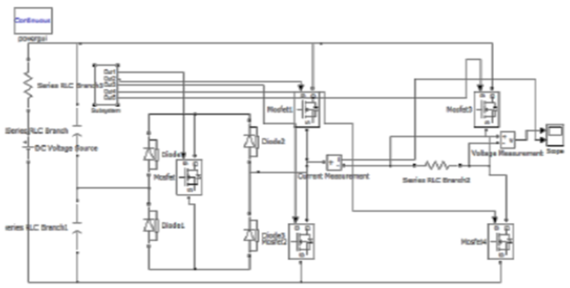

Fig. 2: Simulation of Multilevel inverter.

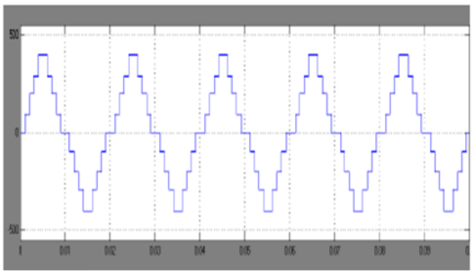

Fig. 3: Inverter output Voltages measures 440 Volts.

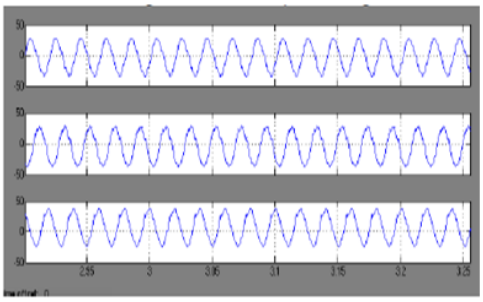

Fig. 4: Inverter output Current measures 46 amps.

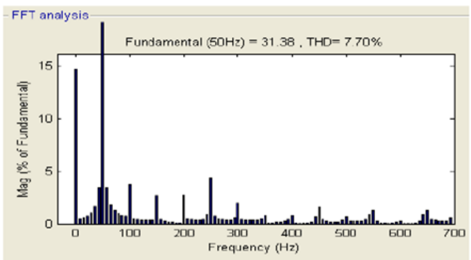

Fig. 5: FFT analysis of Multilevel Inverter.

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The Inverter output voltage and current are shown in Fig.03 and Fig.04 which measures 440 volts and 46 amps. The harmonics level in the output voltage appears as sidebands of the switching frequency and the level of harmonic is lesser when compare to the other methods. The threshold level measures using FFT analysis which is seen in the fig.05. The frequency of reference signal in the inverter determines the output frequency; and its peak amplitude controls the modulation index. The variation in modulation index changes the rms output voltage of the multilevel inverter.

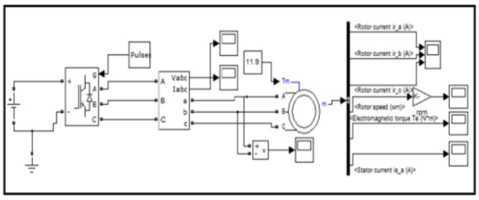

Fig. 6: Open loop analysis of Inverter fed Induction Motor.

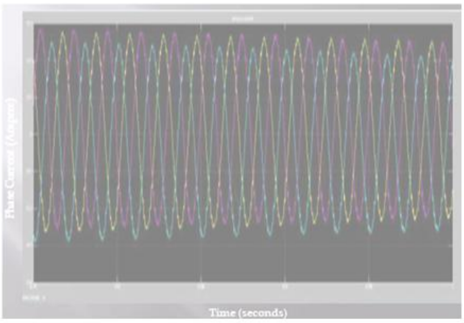

Fig. 7: Open loop phase Current.

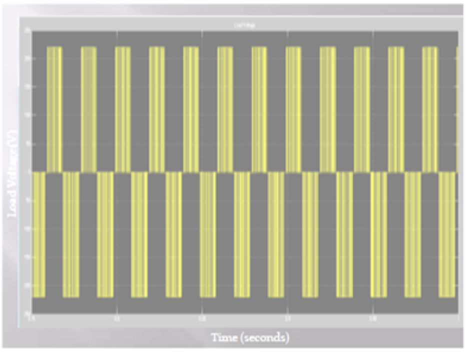

Fig. 8: Open loop load voltage.

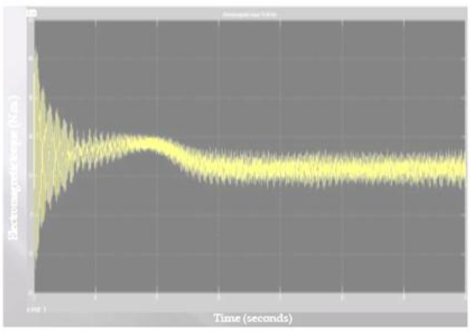

Fig. 9: Open loop Electromechanical Torque.

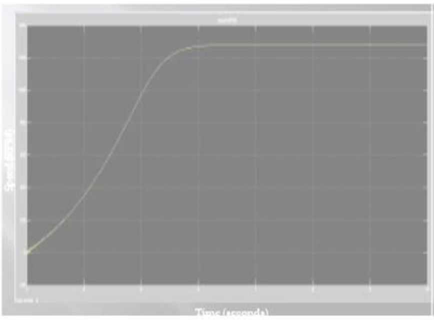

Fig.10: Open loop Speed measurement.

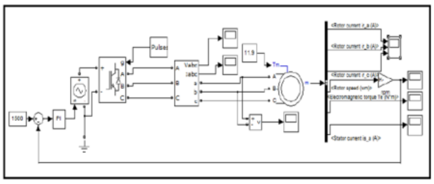

Fig.11: Closed loop analysis of Inverter fed Induction Motor.

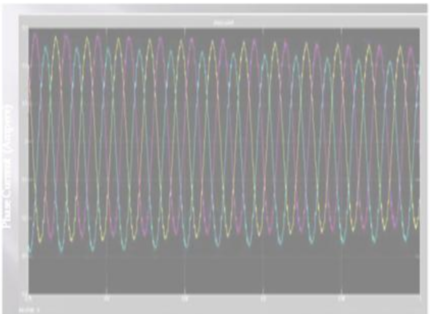

Fig.12: Closed loop phase Current.

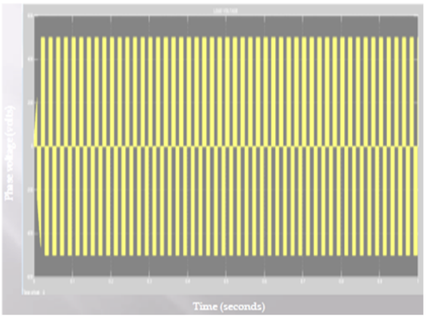

Fig.13: Closed loop load voltage.

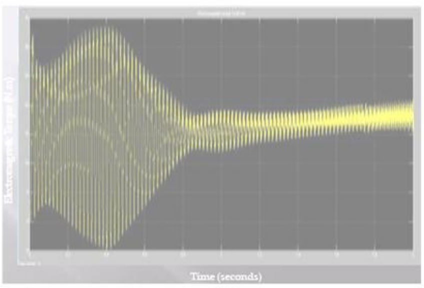

Fig.14: Closed loop Electromechanical Torque.

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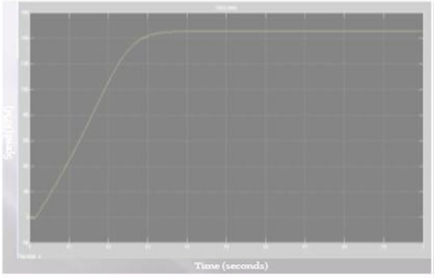

Fig.15: Closed loop Speed measurement.

Open loop controlled multilevel inverter circuit is shown in Fig.06. Step rise in output current and voltage waveform is shown in Fig.07. & Fig.08. The frequency of the modulating signal is several orders lower than the frequency of the carrier signal. The gate signal of inverter produced controlled output voltage that supplied to the three phase induction motor. The proposed multilevel inverter fed induction motor drive using field orientation control technique has given high quality output signal with lower total harmonics distortion which provide better speed and torque regulation which is observed from Fig.09. & Fig.10. Closed loop system is shown in Fig.11. Output voltage is sensed and it is compared with a reference voltage. The error is processed through a PI controller. Step rise in output current and voltage waveform of closed loop system is shown in Fig.12. & Fig.13. The corresponding speed and torque regulation which is observed from Fig.14. & Fig.15. We first simulated and analyzed the open loop system and obtain the THD of phase current and voltage through FFT analysis of MATLAB Simulink block. Then secondly we simulated the close loop system and obtain the index. The main aim of this paper was to reduce THD of phase currents and voltages. The frequency of the inverter output frequency; and its peak amplitude controls the modulation index. The variation in modulation index changes the rms output voltage of the multilevel inverter.

Conclusion:

The analysis of multilevel inverter fed induction motor drive was done and simulated using Simulink. The results of voltage waveforms, current waveforms, and motor speed are analyzed. An Open loop and closed loop models are developed and they are used successfully for simulation. The simulation results show that the proposed system effectively controls the motor speed and enhances the drive performance through reduction in total harmonic distortion. From the results, the author can conclude that the speed torque characteristics of drive are having very good transient and steady state characteristics. The simulation results are in line with the predictions. The hardware implementation will be done in future.

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