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Flying Clamped Capacitor Multilevel Inverter In Variable Frequency Drive

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Abstract: This paper presents Performance of VFD (Variable Frequency Drive) using FCCMLI (Flying Clamped Capacitor Multilevel Inverter). A conventional voltage source inverter-fed induction motor drive is modeled and simulated using matlab simulink and the results are presented. VFD using multilevel inverter is also simulated and the corresponding results are presented. The results obtained are compared. Using FCCMLI in VFD, Harmonics are reduced. Switching loss and EMI are also reduced.

Keywords: VFD, Problems of VFD, Multilevel Inverter, Modulation Technique, Simulation Circuits & Their results of VFD w ith Conventional Inverter & 3 level Inverter respectively, Analysis of THD.

I. INTRODUCTION

Induction Motor's speed is directly proportional to the supply frequency. So by changing the frequency, the synchronous speed and the motor speed can be controlled below and above the normal full load speed. The voltage induced in the stator, E is proportional to the product of slip frequency and air gap flux. The motor terminal voltage can be considered proportional to the product of the frequency and flux, if the stator voltage is neglected. The variable frequency control below the rated frequency is generally carried out by reducing the machine phase voltage, V, along with the frequency in such a manner that the flux is maintained constant. Above the rated frequency, the motor is operated at a constant voltage because of the limitation imposed by stator insulation or by supply voltage limitations. Motor damage and failure has been reported by industry as a result of adjustable speed drive inverters' high frequency PWM switching. Another drawback of conventional adjustable speed drives is efficiency. Because the inverter must switch at supersonic frequency, the associated switching losses (turn on and turn-off losses) are normally much higher than the device conduction loss, which results in low efficiency power Conversion from dc to ac. The problems associated with conventional adjustable speed drive inverters are as follows:

- Due to High switching frequency, switching losses increases, efficiency decreases.
- Rate of change of voltage is high due to switching causes motor bearing failure and stator winding insulation Breakdown.
- Electromagnetic interference (EMI) to nearby communication or other electronic equipment due to High frequency switching generates broadband.

II. CONTROL STRATEGIES OF MULTILEVEL INVERTER

Multilevel inverter solves problems with present high frequency PWM adjustable speed drives (VFD's). The multilevel voltage source inverters' unique structure allows them to reach high voltages with low harmonics without the use of transformers. Multilevel voltage source inverter allows reaching high voltages with low harmonics without use of series connected synchronized switching devices or transformers. As the number of voltage levels increases, the harmonic content of output voltage waveform decreases significantly. The advantages of multilevel inverter are good power quality [1], low switching losses, reduced output dv/dt and high voltage capability. Increasing the number of voltage levels in the inverter increases the power rating. This paragraph has the aim to introduce to the general principle of multilevel behavior. Figure 1 helps to understand how multilevel inverters work. The leg of a 2-level inverter is shown, in which the semiconductor switches have been substituted with an ideal switch. The voltage output can assume only two values: 0 or E. The voltage output of a 3-level inverter leg can assume three values: 0, E or 2E. A generalized n-level inverter leg is also presented. Even in this circuit, the semiconductor switches have been substituted with an ideal switch which can provide n different voltage levels to the output [2].

A) Topologies of Multilevel Inverter:

- Neutral Point Inverter
- Flying Capacitor Inverter
- Cascaded H-bridge

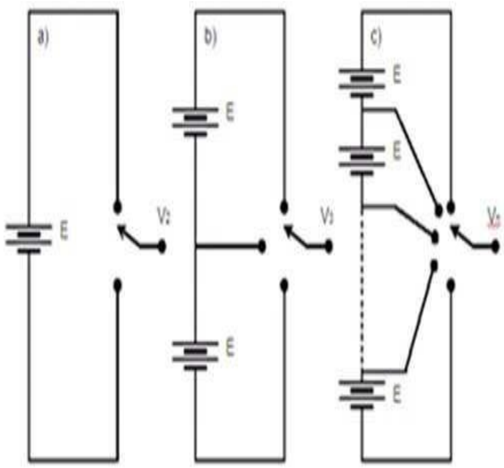

Fig. 1. Concept of Multilevel Inverter.

III. CONTROL STRATEGIES OF MULTILEVEL INVERTER

The capacitor clamped inverter alternatively known as flying capacitor was proposed by Meynard and Foch. This is one of the alternative topology for the diode clamped inverter. The flying capacitor involves series connection of capacitor clamped switching cells . Figure 2 shows the three-level flying capacitor inverter. The general concept of operation is that each flying capacitor is charged to one-half of the dc voltage and can be connected in series with the phase to add or to subtract this voltage. In the operation of the converter, each phase node (a, b, or c) can be connected to any node in the capacitor bank (V3, V2, V1). Connection of the a-phase to positive node V3 occurs when S1ap and S2ap are turned on and to the neutral point voltage when S2ap and S1an are turned and the negative node V1 is connected when S1an and S2an are turned on. The clamped capacitor C1 is charged when S1ap and S1an are turned on and is discharged when S2ap and S2an are turned on. The charge of the capacitor can be balanced by proper selection of the zero states. In comparison to the three-level diode-clamped inverter, an extra switching state is possible. In particular, there are two transistor states, which make up the level V3. Considering the direction of the a-phase flying capacitor current Ia for the redundant states, a decision can be made to charge or discharge the capacitor and therefore, the capacitor voltage can be regulated to its desired value by switching within the phase. As with the three-level flying capacitor inverter, the highest and lowest switching states do not change the charge of the capacitors. The two intermediate voltage levels contain enough redundant states so that both capacitors can be regulated to their ideal voltages.

Of course, with a higher number of voltage levels the complexity of the inverter increase and also, as earlier mentioned, the number of components needed. To achieve the different voltage levels in the output a setup of switching state combinations are used [3].

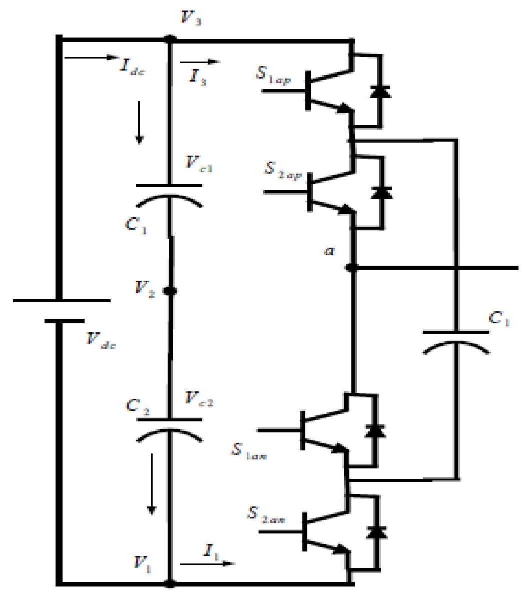

Fig. 2. One Leg of 3 level FCC Inverter.

A. LEVEL SHIFTED PWM

- Phase Disposition (PD).
- Phase Opposition Disposition (POD)
- Alternative Phase Opposition Disposition (APOD)

1) Phase Disposition: The most evident method, Depicted in Figure 3, is called Phase Disposition (PD). The interval of possible voltage reference values is subdivided into one zone for each carrier which modulates the output only when the reference belongs to its zone. When the reference does not belong to a zone, associated carrier comparison output is fixed to high or low level: it is high when the reference is above the carrier; vice versa it is low when the reference is under the carrier. The comparison output, obtained in this way, and its negation can directly drive a couple of switches in diode-clamped. The sum of all the comparison outputs, shown in Figure 3, is a signal proportional to the instantaneous required output level.

2) Phase Opposition Disposition: In this carriers above the zero reference are in phase, but shifted by 180 from those carriers bellow zero reference.

3) Alternative Phase Opposition Disposition: In this each

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carrier band is shifted by 180 from the adjacent carrier.

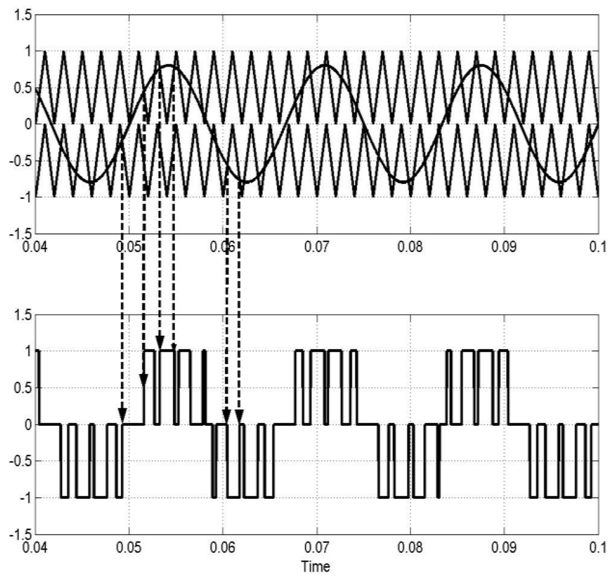

Fig. 3. Phase Disposition.

IV. SIMULATION CIRCUITS AND THEIR RESULTS

Simulation of VFD of 30 Kw motor [4] is done with Conventional Inverter [5] and also with Multilevel Inverter [6], [7]. Simulation of switching sequence is also done for 3 level inverter.

A. 3 Level Inverter

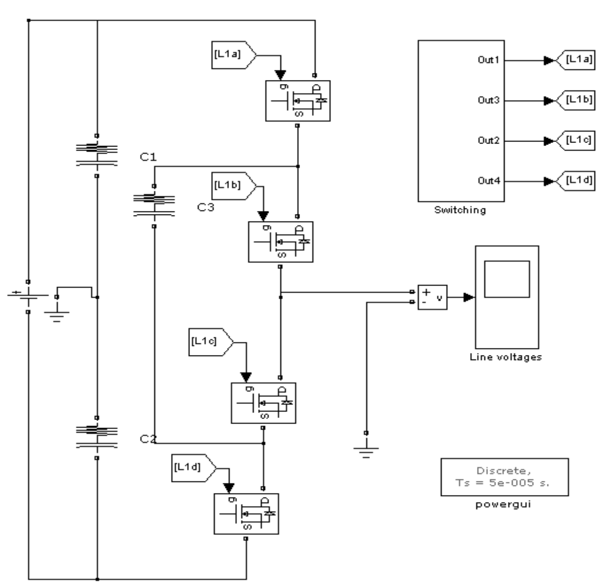

Fig. 4. 3 Level Flying Clamped Capacitor Inverter Model.

B. Switching Sequence for 3 Level Inverter

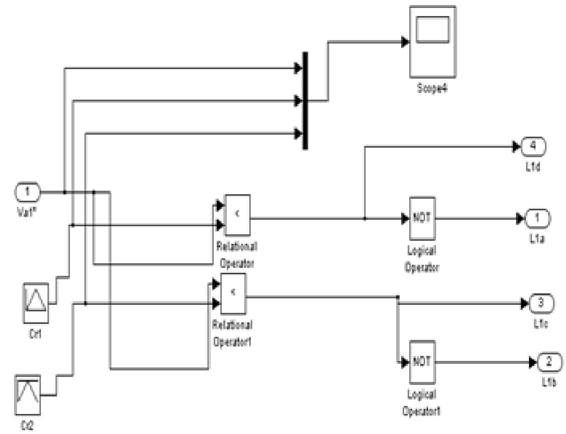

Fig. 5. Switching Sequence of 3 Level FCCMLI.

B. Output Voltage of 3 Level Inverter

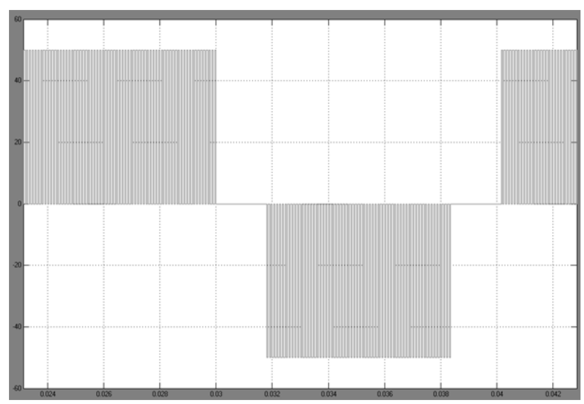

Fig. 6. Output Volt of FCCMLI.

D. VFD with Conventional Inverter

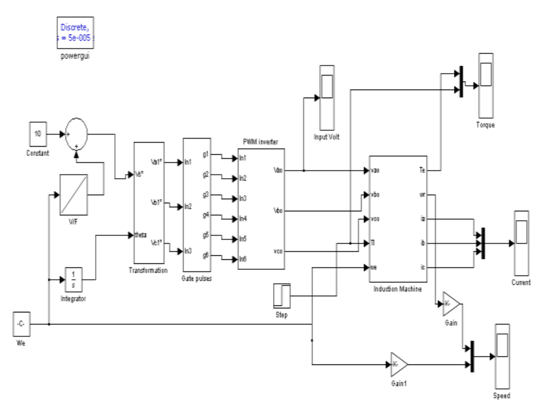

Fig. 7. VFD with Conventional 3 Level Inverter.

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E. VFD with 3 Level Inverter

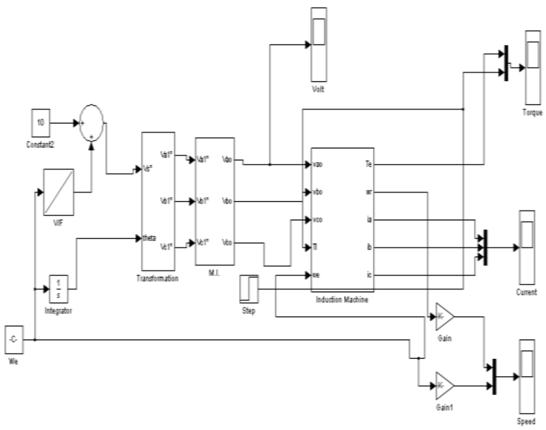

Fig. 8. VFD With 3 Level FCCMLI.

F. Comparison of Output Waveform of VFD without and with 3 Level Inverter

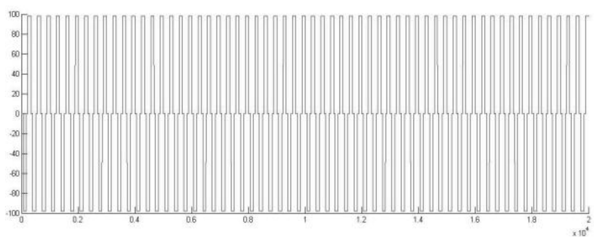

Fig. 9. Output Volt Vs Time Without FCCMLI.

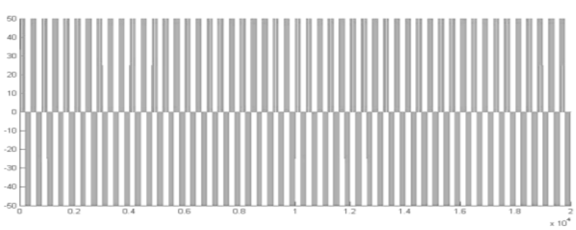

Fig. 10. Output Volt Vs Time With FCCMLI.

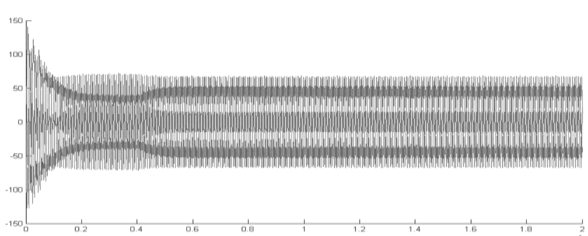

Fig. 11. Current Vs Time Without FCCMLI.

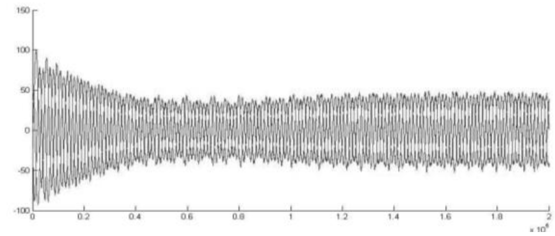

Fig. 12. Current Vs Time With FCCMLI.

With multilevel inverter harmonics in voltage waveform reduces. Ripples in current are also reduce when multilevel inverter is used.Losses are reduced.

- *Abbreviations and Acronyms*

M.I. : Multilevel Inverter
VFD : Variable Frequency Drive
FCCMLI : Flying Clamped Capacitor Multilevel Level Inverter

- *Units*

Time : Second
Voltage : Volt
Current : Ampere
Torque : N/M
Speed (N) : R.P.M.
Angular Speed (We) :

V. CONCLUSION

Multilevel inverter fed induction motor drive is simulated using the blocks of Simulink. The results of multilevel inverter system are compared with the results of VSI based drive system. It is observed that the total harmonic distortion produced by the multilevel inverter system is less than that of VSI fed drive system. Therefore the heating due to multilevel inverter system is less than that VSI fed drive system. The simulation results of voltage, current, speed and torque are presented. This drive system can be used in industries where adjustable speed drives are required to produce output with reduced harmonic content.

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