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Nine Level Diode Clamped Inverter Fed Direct Torque Controlled Induction Motor Drive

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ABSTRACT

This paper presents the performance of Direct Torque Controlled (DTC) induction motor fed from nine level diode clamped Multi Level Inverter (MLI). The distortion in line voltages is less in nine level diode clamped inverter compared to five level and seven level inverter. The increase in number of levels will minimize the torque ripple and the ripple in the stator flux. Therefore nine level inverter improves the torque and flux quality in the induction motor drive. The proposed nine level inverter uses less number of switches and does not experience neutral-point fluctuations. The DC link capacitor carry only the ripple current since isolated DC supplies are used for the DC links. The simulation results for DTC induction motor drive fed from nine level diode clamped inverter are presented in this paper.

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INTRODUCTION

The DTC of an induction motor offers good dynamic performance and is commercially available for conventional inverters (I. Takahashi and T. Noguchi, 1986) (M. Depenbrock, 1988). Multilevel voltage-source inverter topologies, including flying capacitor, diode-clamped and cascaded H- bridge structures, are widely used for high-power applications (L. G. Franquelo, J. Rodriguez, J. I. Leon, S. Kouro, R. Portillo, and M. A. M. Prats Jun. 2008) (J. Rodriguez, J. S. Lai, and F. Z. Zeng, Aug. 2002). The standard drives are commercially available for medium voltage industrial applications (M. F. Escalante, J. C. Vannier, and A. Arzande 2002), (T. Ishida, K. Matsuse, T. Miyamoto, K. Sasagawa, and L. Huang 2002). Solutions with a higher number of output voltage levels have the ability to synthesize waveforms with a better harmonic spectrum and to limit the motor-winding insulation stress. However, their increasing number of devices tends to reduce the overall reliability and efficiency of the power converter. A three level diode clamped multilevel inverter fed direct torque control of induction motor was proposed in (R.Dharmaprakash and Joseph Henry 2014). This multilevel inverter has the advantages of fewer harmonic in the output and low torque ripples. A 15 level hybrid multilevel inverter for DTC IM drive was proposed in (H.G.Zaini, M.K. Metwally and Mahrous Ahmed, 2014). In this paper the control method uses the torque and speed estimation to control the load angle and to obtain the appropriate flux vector trajectory from which the voltage vector is directly derived based on direct torque control method. The voltage vector is then generated by a hybrid multilevel inverter with lower power electronic components. The inverter high quality output voltage which leads to a high quality IM performances. Besides, the MLI switching losses is very low due to most of the power cell switches are operating at nearly fundamental frequency.

Application of cascaded H-bridge multilevel inverter in DTC-SVM based induction motor drive was proposed in (Gholinezhad J. and Noroozian R. 2012). Each H-bridge was implemented using a dc source, which would be available from fuel cell, batteries or ultra-capacitors. The control strategy was based on DTC-SVM Five-level and nine-level inverter were employed to investigate the considered motor drive performance. A new switching table for DTC of a nine-level Multi Point Clamped VSI fed induction motor drive was proposed in (O. Chandra sekhar and K. Chandra sekhar, 2012). In this topology nine level inverter has 729 switching states and there are 217 effective vectors are possible. The proposed multi level inverter drive scheme is capable for enough degrees of freedom to control both electromagnetic torque and stator flux with very low ripple and high

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dynamic speed response. A nine level diode clamped inverter with reduced number of switches is proposed in this paper to investigate the performance of DTC IM drive.

Proposed DTC system:

The operation of the proposed closed loop system is can be explained by the following general block diagram as shown in the Figure 1. Nine level diode clamped inverter generates the required voltage vectors, V_a, V_b, V_c, for the Induction Motor in each of its legs. The corresponding individual voltage vectors, along with the corresponding Line currents I_a, and I_b, are measured by the Torque and Flux Estimator. The third current vector, I_c, is internally generated by the vector difference of these two current vectors. Meanwhile, the speed controller generates the reference torque, T^*_e, and reference flux, λ^*_S, vectors by comparing the electrical rotor speed, ω_r, with the set reference speed, ω^*_r, input given to the controller. As already discussed, the rotor flux linkages reference λ^*_r is derived from the rotor speed via an absolute-value function generator. λ^*_r is kept at 1 p.u. for from the 0- to 1- p.u. rotor speed; beyond 1-p.u speed. The reference torque value, T^*_e, is generated by a suitable PI Controller.

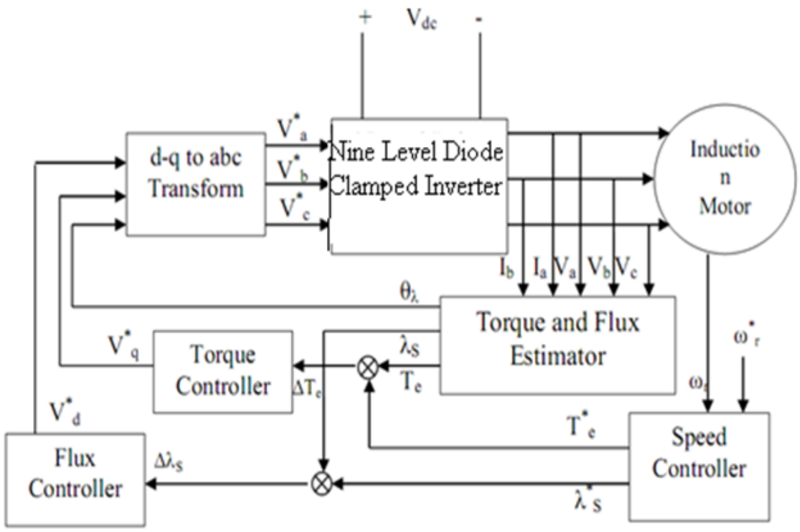

Fig. 1: The proposed Nine Level Diode Clamped Inverter FED DTC IM.

The Torque and flux estimator includes the 'abc' to 'd-q ' transformation and then generates the corresponding actual torque, T_e, actual flux, λ_s by the following equations:

$$\lambda_{ds} = \int (V_d - R_s i_{ds}) dt$$

$$\lambda_{ds} = \int (V_d - R_s i_{ds}) dt$$

$$\lambda_s = \sqrt{[(\lambda_{qs})^2 + (\lambda_{ds})^2]}$$

$$\theta_f = \tan^{-1}\left(\frac{\lambda_{qs}}{\lambda_{ds}}\right)$$

$$T_e = \frac{3}{2}\frac{p}{2}(i_{qs}\lambda_{ds} - i_{ds}\lambda_{qs}) \quad (1)$$

Computation steps and dependence on many motor parameters could be very much reduced by using the stator flux linkages and calculating the electro-magnetic torque, using only the stator flux linkages and stator currents. Then only stator resistance is employed in the computation of the stator flux-linkages, thereby removing the dependencies of mutual and rotor inductances of the machine for this calculation. This approximation is suitable only in case of high or medium voltage drives as considered here.

The Torque and Flux errors, ΔT_e and $\Delta\lambda_s$ respectively, thus computed by comparing the reference values and the actual measured values are given to the Torque and Flux controllers respectively. These incorporate suitable PI Controllers to generate the corresponding reference voltage vectors in 'd-q' plane, V^*_d and V^*_q respectively. In order, to obtain the actual three phase voltage reference vectors they are transformed from 'd-q' stationary plane to 'abc' synchronous plane. Then these reference voltage vectors, V^*_a, V^*_b, and V^*_c are compared with the suitable carrier signal to generate appropriate PWM pulses for the switching of the multilevel inverter switches in each leg at corresponding phase differences respectively. The proposed inverter topology is shown in Figure 2. Thus the Inverter outputs the required voltage vectors and current vectors of suitable magnitudes and phases in order to meet the required load values at reduced harmonics due to higher level inverter and reduced torque ripple content with the implementation of the closed loop DTC technique.

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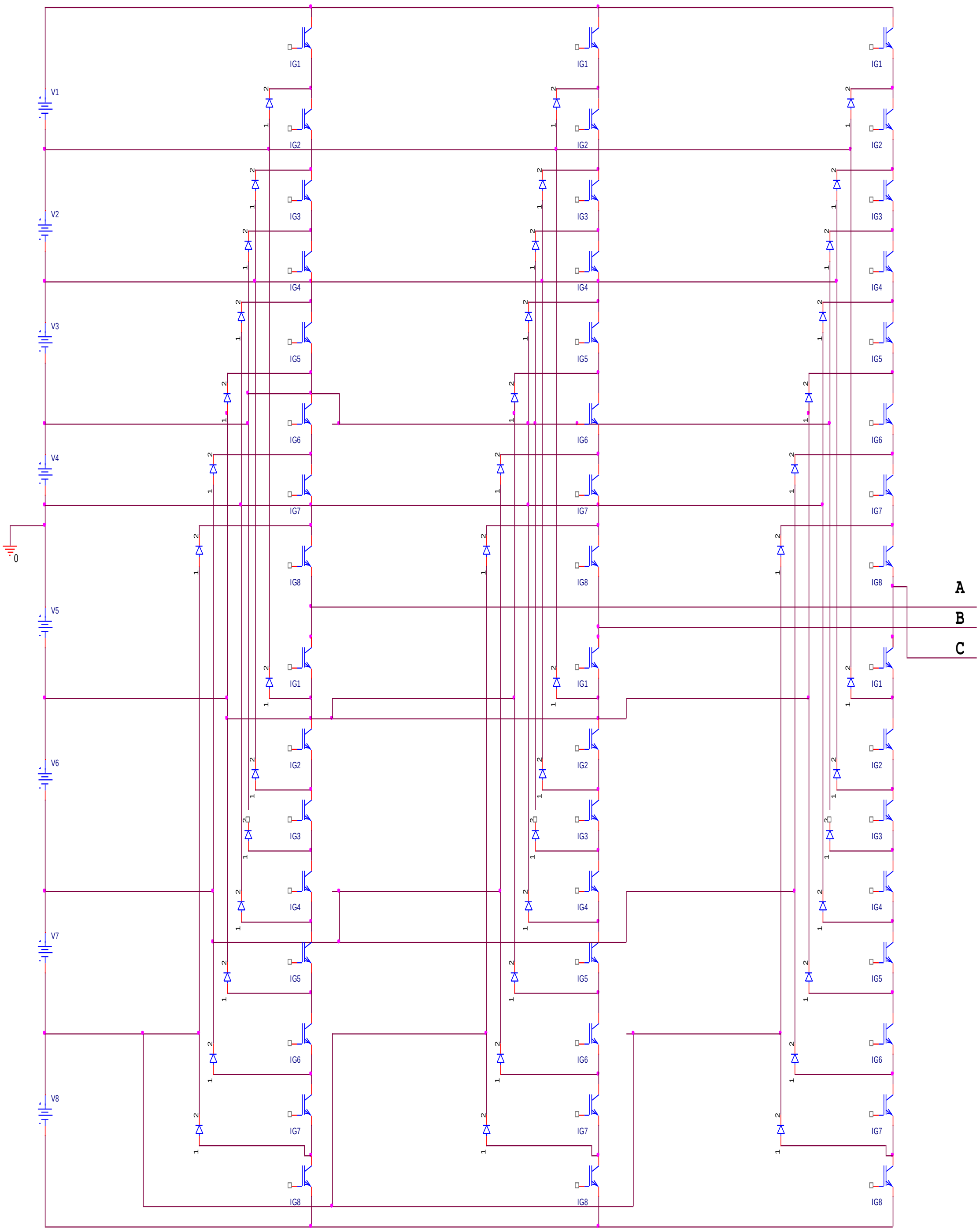

Fig. 2: Nine level diode clamped inverter.

Simulation Results:

The simulation is carried out using Matlab/Simulink. For Simulation Purpose, A 4 kW, 500V, 50 Hz, 2 pole Induction Motor is considered. The machine parameters are : Stator and Rotor Resistances, R_s= R_r =1.5Ω. The Stator and Rotor inductances, L_s= L_r= 5.8mH. While the Mutual Inductance, L_m=0.210mH and Moment of Inertia, J= 0.013Kg.m2 with friction Co-efficient, F = .003 Nms.

The simulation circuit is shown in Figure 3. The inverter per phase output voltage is shown in Figure 4. The three phase nine level diode clamped inverter output voltage is shown in Figure 5. The no load current and no load speed are shown in Figure 6 and Figure 7 respectively. Load torque of 10 N-m is applied and the motor torque is shown in Figure 8.

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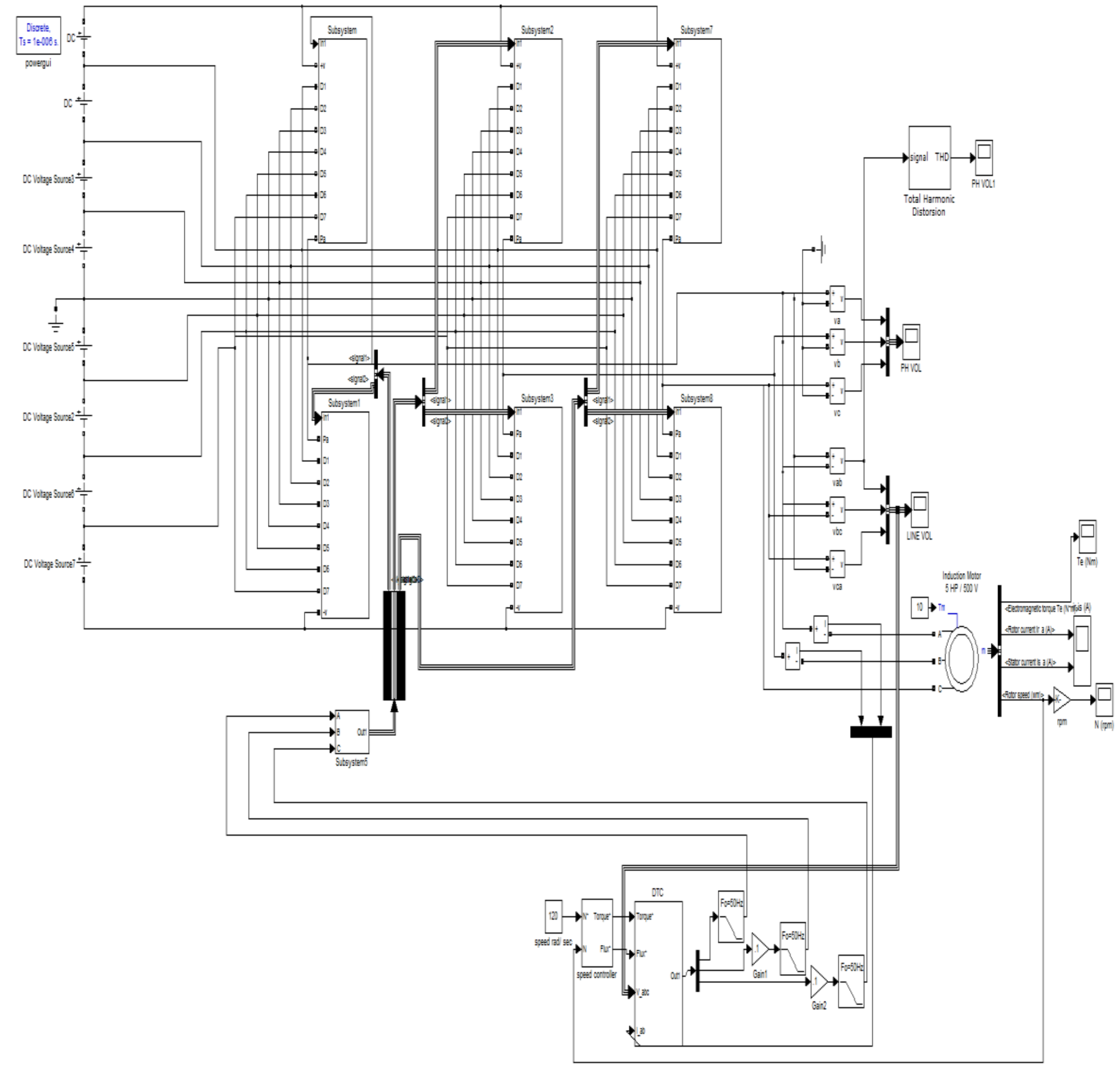

Fig. 3: Simulation Circuit.

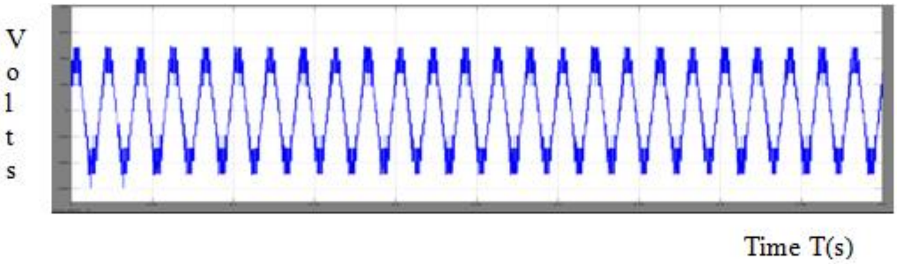

Fig. 4: Inverter Per Phase Output Voltage.

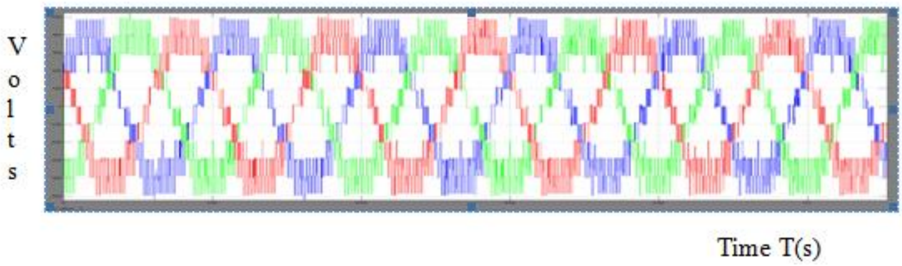

Fig. 5: Nine Level Inveter Output Voltage.

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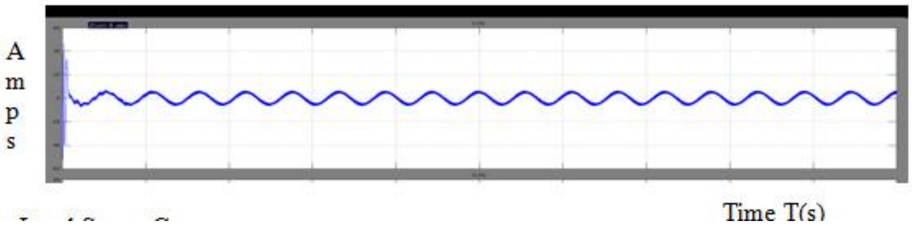

Fig. 6: No Load Stator Current.

Fig. 7: No Load Speed.

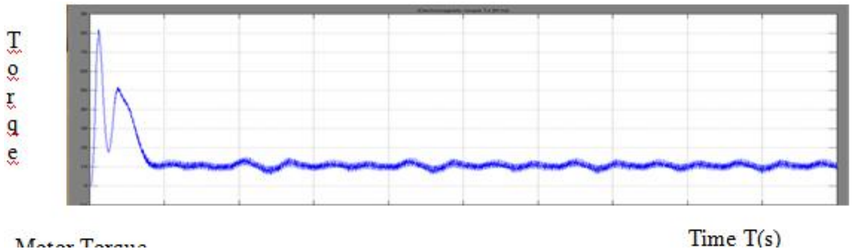

Fig. 8: Motor Torque

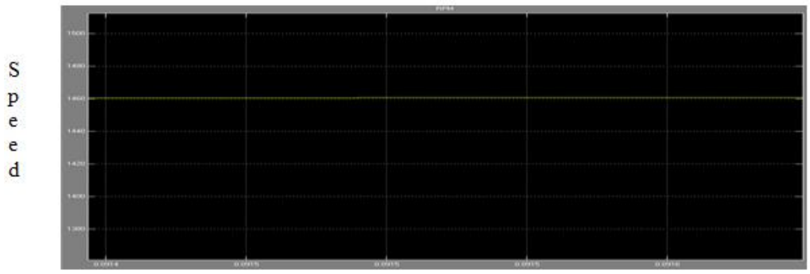

Fig. 9: Speed at 10 N-m Load Torque.

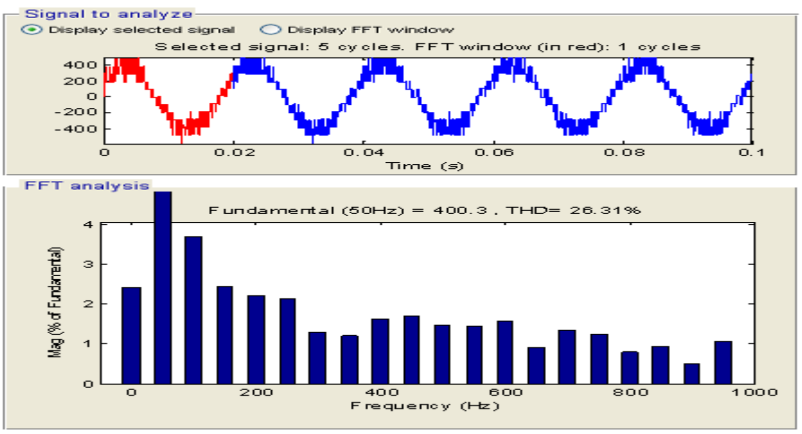

Fig. 10: FFT Analysis of Stator Voltage.

Conclusion:

A novel diode clamped nine level inverter for DTC of IM motor was proposed. It is observed from the simulation results that the torque oscillations are reduced and proposed inverters offers comparatively less THD. The proposed inverter is suitable for VSD.

REFERENCES

Takahashi, I. and T. Noguchi, 1986. “A New Quick-Response and High-Efficiency Control Strategy of an Induction Motor, *IEEE Transactions on* Industry Applications”, 1(22): 820-827.

Depenbrock, M., 1988. “Direct self-control (DSC) of inverter-fed induction machine”, *IEEE Transactions on Power Electronics,* 3: 420-429.

Franquelo, L.G., J. Rodriguez, J.I. Leon, S. Kouro, R. Portillo and M.A.M. Prats, 2008. “The age of multilevel converters arrives,” *IEEE Ind.Electron. Mag.*, 2(2): 28–39.

Rodriguez, J., J.S. Lai and F.Z. Zeng, 2002. “Multilevel inverters: A survey of topologies, controls and applications,” *IEEE Trans. Ind. Electron.*, 49(4): 724–738.

Das, A., K. Sivakumar, R. Ramchand, C. Patel and K. Gopakumar, 2009. “Acombination of hexagonal and 12-sided polygonal voltage space vector PWM control for IM drives using cascaded two-level inverters,” *IEEE Trans. Ind. Electron.*, 56(5): 1657–1664.

Yuan, X. and I. Barbi, 2000. “Fundamentals of a new diode clamping multilevel inverter,” *IEEE Trans. Power Electron.*, 15(4): 711–718.

Huang, J. and K.A. Corzine, 2006. “Extended operation of flying capacitor multilevel inverters,” *IEEE Trans. Power Electron.*, 21(1): 140–147.

Escalante, M.F., J.C. Vannier and A. Arzande, 2002. “Flying capacitor multilevel inverters and DTC motor drive applications,” *IEEE Trans. Ind.Electron.*, 49(4): 809–815.

Ishida, T., K. Matsuse, T. Miyamoto, K. Sasagawa and L. Huang, 2002. “Fundamental characteristics of five-level double converters with adjustable DC voltages for induction motor drives,” *IEEE Trans. Ind. Electron.*, 49(4): 775–782.

Dharmaprakash, R. and Joseph Henry, 2014. “Direct Torque Control of Induction Motor Using Multilevel Inverter”, International Journal of Latest Research in Science and Technology, 3(3): 70-75.

Zaini, H.G., M.K. Metwally and Mahrous Ahmed, “Direct Torque Control of Induction Motor Drive Fed from Hybrid Multilevel Inverter” International Journal of Electrical & Computer Sciences IJECS-IJENS, 14(03): 6-11.

Gholinezhad, J. and R. Noroozian, 2012. “Application of cascaded H-bridge multilevel inverter in DTC-SVM based induction motor drive”, Conference proceedings *IEEE Power Electronics and Drive Systems Technology (PEDSTC),* pp: 127-132.

Chandra sekhar, O. and K. Chandra sekhar, 2012. “Modulation and Control of Multilevel Inverter Fed DTC Induction Motor Drive” International Journal of Energy and Power, 1(1): 7-17.

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