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Investigation of Various Levels of Cascade Multi-Level Inverter DVR for Improve Power Quality of Induction Motor

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Abstract: This paper presents a direct torque control (DTC) of induction motor drive (IMD) using Different levels of Cascade Multilevel DVR. The DTC is one of the most excellent strategies of flux ripples control and torque of IMD. The main drawback of the DTC of IMD using conventional PI controller based SR is high torque, stator flux ripples and speed of IMD is decreasing under transient and steady state operating conditions. This drawback was eliminated using In front of DTC IM drive connected Different levels of Cascade Multilevel DVR. The main objective of this paper is to present an approach capable of performing fast torque response and harmonics reduction in DTC drive. Because of that, an efficient control strategy is applied, is needed to reduce the voltage fluctuations like sag and swell conditions and also to reduce current and voltage harmonics in the DTC drive system. In this paper, the work proposed is aimed at obtaining results exhibiting improved THD contents of 5, 7 and 9 level cascade multilevel inverters at the ac mains and reduced the Torque ripples of the DTC IMD Drive.

Keywords: Direct torque control; induction motor; DVR; Cascade Multilevel Inverter;THD.

Introduction

Induction motors, the most widely used motors in industry, are usually traditionally operated in open loop deal with functions, for purposes of expense, dimensions, durability, toughness, suppleness, effectiveness, much less maintenance, ease of manufacture and their functionality to operate in dirty or maybe profitable circumstances[1]. In spite of this, because the induction motor necessitates much more complicated control procedures, the dc motor possesses dominated in excellent performance adjustable speed drive applications [2]. With advancements in microprocessors/digital signal processor (DSP), power electronics and also control theory, the induction motor can be positively utilized in excellent performance adjustable -speed and cost-sensitive functions, for example heating system, air circulation, as well as air conditioning (HVAC) methods, waste water treatment plants, blowers, fans, textile mills, rolling mills etc. as a consequence of their benefits similar to energy conservation and also elimination of inrush current drawn, etc.

The utilization of variable frequency induction motor drives (VFIMDs) possesses additional improved on account of their functionality to accomplish good dynamic overall performance making use of vector control (or field oriented control-FOC) and direct torque and flux control (DTC)[3]. With these control techniques, induction motor drives may attain equivalent as well as much better performance as compared with dc motor drives. It can be renowned that the FOC requirements complex co-ordinate transformations to decouple the conversation between the flux as well as torque components of stator currents.

It can be depending on the decoupled and also impartial charge of stator flux and torque offering a speedy as well as powerful response. However, the traditional DTC technique utilizing swapping table of a six pulse voltage source inverter (VSI) offers significant torque, flux, current and speed ripple. In DTC, stator voltage vectors are chosen based on the variations between the reference and also exact torque and stator flux linkage. The DTC based induction motor drive (IMD) [4] makes use of a single-phase or maybe three-phase unrestrained ac-dc converter (for rectification of ac mains voltage), an electric power storage component (capacitor filter for smoothening the dc link voltage), and a three-phase voltage source inverter (VSI) for supplying a three-phase squirrel cage induction motor[5]. These kind of electricity interface is affected with difficulties associated with power quality for instance inadequate power factor, injection of current harmonics into the ac mains, variation in dc link voltage with alternations in the voltage of input ac supply, apparatus overheating because of harmonic current assimilation, voltage distortion at the point of common coupling (PCC) on account of the voltage decrease attributable to harmonics currents flowing through system impedance together with diminished rectifier efficiency[6].

Different active and passive filtering techniques [7] are used to mitigate distortions in the input line current. The strategy of dynamic power factor correction can attain unity power factor and also lower total harmonic distortion (THD) of ac mains current in addition to an excellent regulation of the dc link voltage. However the drawbacks are high cost (cost is nearly doubled), improved complication responsible for all (particularly if optimum performance is desired under pre existing supply voltage distortions), and higher dc-link voltage due to enhance operation. Early DVR generally employed the zigzag transformer commonly circuit topology as voltage source inverter. However, the zigzag transformer has certain difficulties that could be difficult to conquer regarding cost, transformer loss in addition to manage [8]. When the cascaded multilevel inverter is employed as the primary circuit topology, DVR possesses a little ground area, an easy task to split-phase restrain, substantial reliability, as well as effortless development of capability, etc. Additionally, as it has little or no make use of for the zigzag transformer, it creates the pre-existing DVR free from the majority of significant difficulties for example gadget over-voltage a result of the magnetic saturation and nonlinearity in the transformer excitation circuit[9]. So the cascaded multilevel inverter structure for massive capability DVR is concerned by numerous mechanism creative designers increasingly more.

2.DTC based induction motor drive

DTC uses |a basic switching table to determine the most Opportune inverter condition to achieve a desired output torque. Through current and voltage measurements, it is possible to calculate approximately the instantaneous stator flux and output motor torque. The control algorithm depending on flux as well as torque hysteresis controllers establishes the voltage needed to drive the flux as well as torque to the desired values within a fixed time period. The fundamental functional blocks used to implement the DTC scheme are represented in figure. 1.

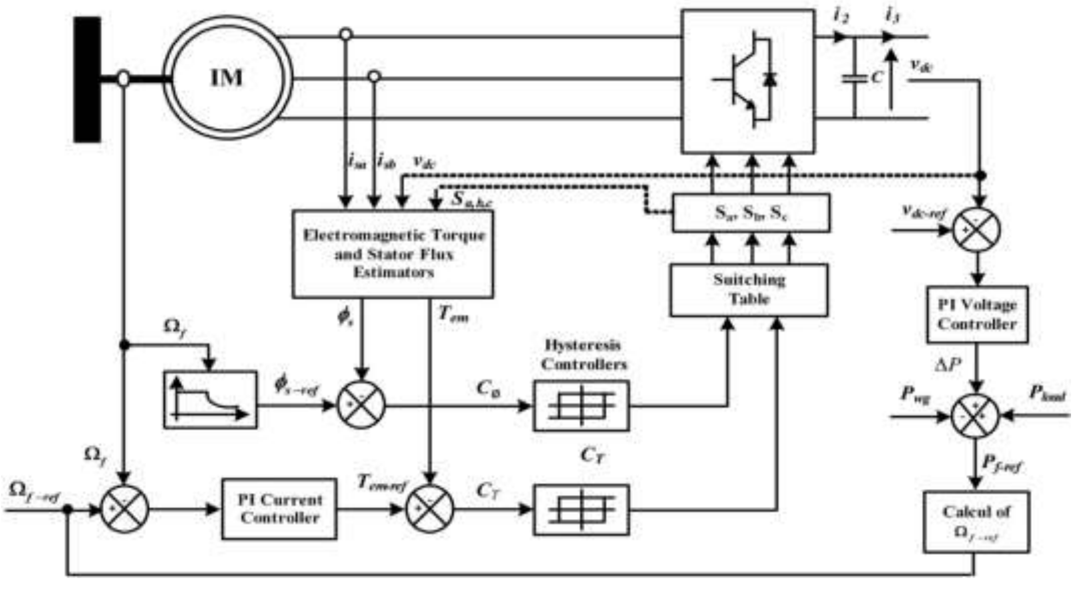
The stator flux vector and the torque produced by the motor, Gem, can be estimated respectively. These equations only require the knowledge of the previously applied voltage vector V_s, measured stator current I_s, stator resistance R_s, and the motor poles P

$$\overline{\emptyset_S} = \int (V_S - R_S I_S) dt \tag{1}$$

$$\Gamma_{em} = Y_Z \;\; with\bar{y} = \frac{3}{2} P\left(\overline{\emptyset_S} X \overline{I_S}\right) \tag{2}$$

Once the electromagnetic torque and stator flux magnitude are estimated, a hysteresis control is done and the voltage vectors to be applied are obtained from a switching table. The stator voltage polar components ($V_{s\alpha}$, $V_{s\beta}$)on perpendicular (α, ß) reference frame result from measured dc-link voltage U_{dc} and the switching controls logical states S_α, S_b, and S_c is given as

Figure 1. DTC Induction Motor scheme.



$$V_{S\alpha} = \sqrt{\frac{2}{3}U_{dc}(S_{\alpha} - \frac{1}{2(S_{\alpha} + S_c)})} \tag{3}$$

$$V_{S\beta} = \frac{1}{\sqrt{2}}U_{dc}(S_{\alpha} - S_c) \tag{4}$$

and stator current components (I_{α},I_{β}). The stator resistance can be assumed constant. During a switching period, the voltage vector applied to the motor is constant. By integrating the back electromotive force (EMF), the stator flux can be estimated using (5).

$$\emptyset_{S\alpha} = \int (V_{s\alpha} - I_{S\alpha}R_{S\alpha})dt \tag{5}$$

$$\emptyset_{S\beta} = \int \left(V_{s\beta}I_{S\beta} - R_{S\beta}\right)dt$$

During the switching period, each voltage vector is constant and (5) is then rewritten as

$$\emptyset_{S\alpha} = \emptyset_{S\alpha} + (V_{S\alpha} - I_{S\alpha}R_{S\alpha})T_{S\alpha} \tag{6}$$

$$\emptyset_{S\alpha} = \emptyset_{S\beta} + \left(V_{S\beta} - I_{S\beta}R_{S\beta}\right)T_{S\beta}$$

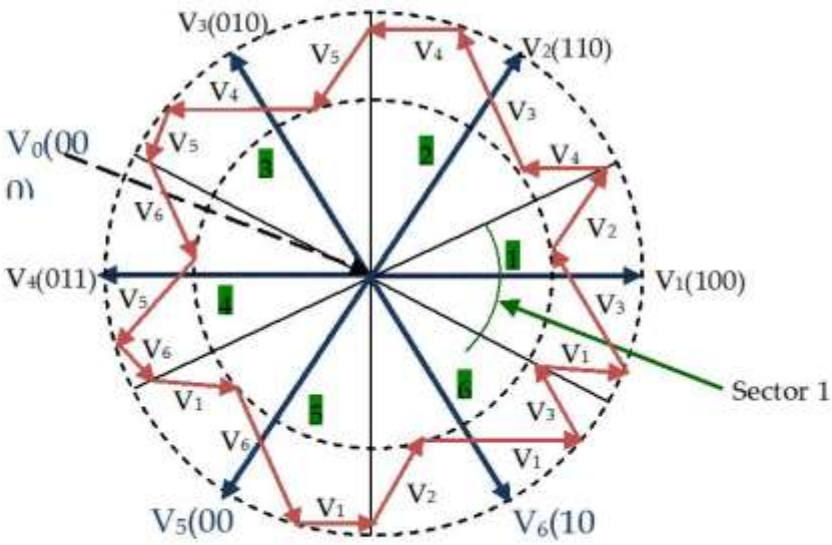
The magnitude of the stator flux can be estimated by

$$\emptyset_S = \sqrt{\emptyset S\alpha^2 + \emptyset S\beta^2} \tag{7}$$

We can find the flux vector zone using the stator flux components ($f_{s\alpha}$,$f_{s\beta}$). By using the flux components, current components and IM number of poles, the electromagnetic torque can be calculated by

$$\Gamma_{em} = \frac{3}{2}P\left(\emptyset_{S\alpha} - \emptyset_{S\beta}\right) \tag{8}$$

Figure 2. DTC sectors and inverter voltage vectors.



As shown in figure 2, six equally spaced voltage vectors having the same amplitude and two zero-voltage vectors are the only switching combinations, which can be chosen for an inverter operation. The selection of a voltage vector is made to preserve the torque and the stator flux inside the hysteresis bands limits.

3.Working of DVR

DVR is a primary series device of the FACTS household which makes use of power electronics to control power flow and also develop transient durability on power grids. The DVR controls voltage at its terminals by regulating the quantity of reactive power injected into |or perhaps assimilated from the power system. For purely reactive power flow the three phase voltages of the DVR must be maintained in phase with the system voltages. The difference of reactive power is performed by way of a VSC attached through a coupling transformer.

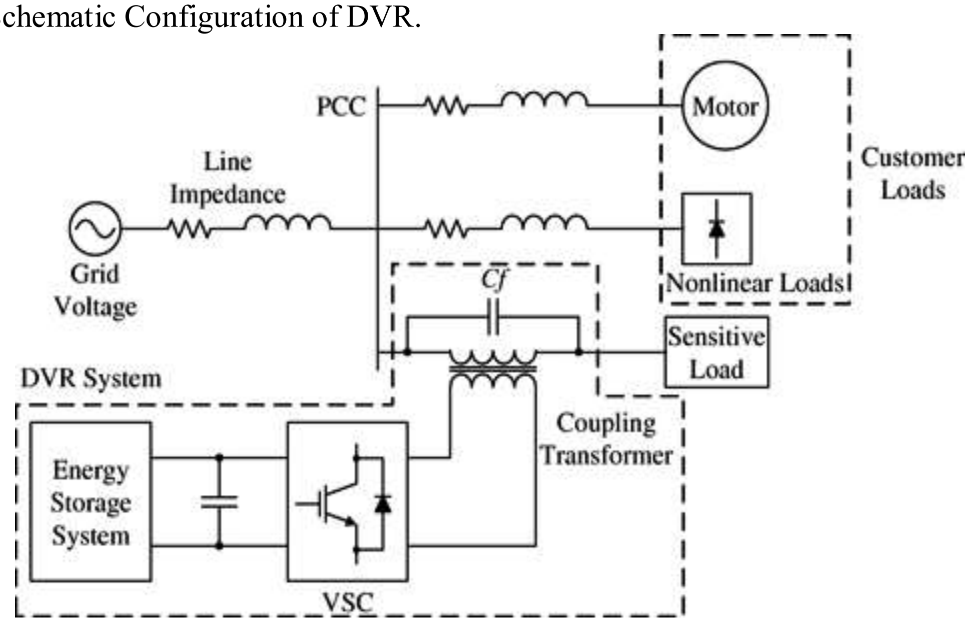
The VSC makes use of forced commutated power electronics devices (GTO's or IGBT's) to synthesize the voltage from a dc voltage source. The operating principle of DVR is described in figure 3. It may be seen that if $V_2 > V_1$ and then the reactive current I_q streams from the converter to the ac system by means of the coupling transformer by injecting reactive power to the ac system. Alternatively, if $V_2 < V_1$ then current I_q flows from ac system to the converter by consuming reactive power from the system.

Finally, if $V_2 = V_1$ in that case it does not have any substitute of reactive power. The quantity of reactive power exchange is provided by,

$$Q = \frac{V_1(V_1 - V_2)}{X_S} \tag{9}$$

Where, V_1: Magnitude ofsystem Voltage. V_2: Magnitude of DVR output voltage. X_s: Equivalent impedance between DVR and the system.

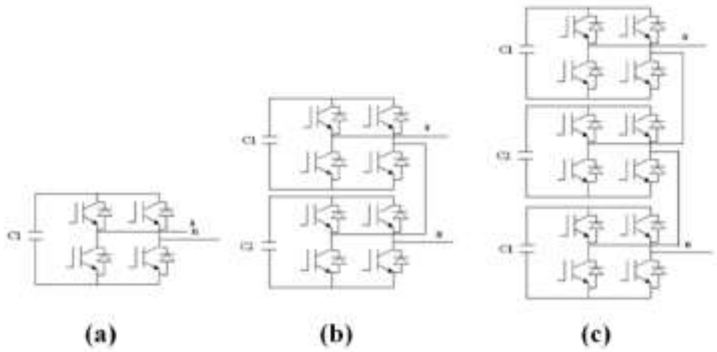
Figure 3. Schematic Configuration of DVR.



4. Cascaded multilevel circuit

One more alternative for a multilevel inverter is the cascaded multilevel inverter or series H-bridge inverter. The series H-bridge inverter appeared in 1975. Cascaded multilevel inverter was not fully realized until two researchers, Lai and Peng. They patented it and presented its various advantages in 1997. Since then, the CMI has been utilized in a wide range of applications. With its modularity and flexibility, the CMI shows superiority in high-power applications, especially shunt and series connected FACTS controllers. The CMI synthesizes its output nearly sinusoidal voltage waveforms by combining many isolated voltage levels. By adding more H-bridge converters, the amount of VAR can simply increased without redesign the power stage, and build-in redundancy against individual H-bridge converter failure can be realized.

Figure 4. Single phase structures of Cascaded inverter (a) 3-level, (b)5-level, (c) 7-level

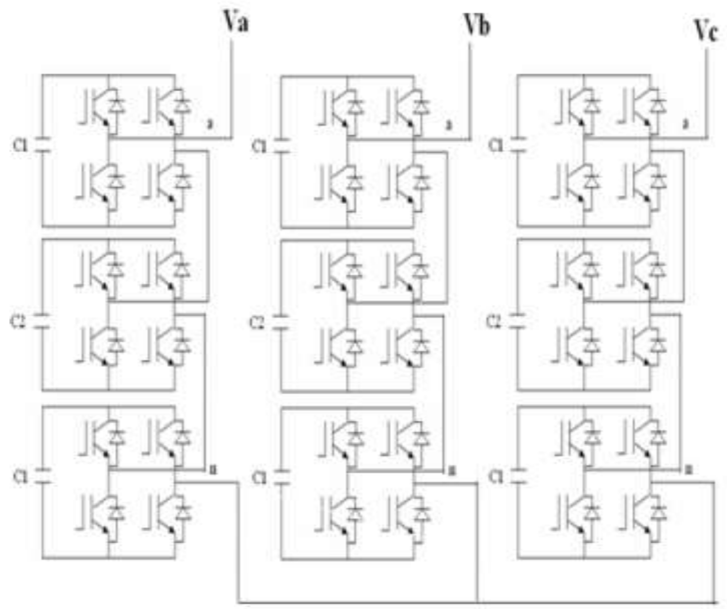


A series of single-phase full bridges makes up a phase for the inverter. A three-phase CMI topology is essentially composed of three identical phase legs of the series-chain of H-bridge converters, which can possibly generate different output voltage waveforms and offers the potential for AC system phase-balancing. This feature is impossible in other VSC topologies utilizing a common DC link. Since this topology consists of series power conversion cells, the voltage and power level may be easily scaled. The dc link supply for each full bridge converter is provided separately, and this is typically achieved using diode rectifiers fed from isolated secondary windings of a three-phase transformer. Phase-shifted transformers can supply the cells in medium-voltage systems in order to provide high power quality at the utility connection.

4.1. Operation of CMLI

The converter topology is based on the series connection of single-phase inverters with separate dc sources. figure 4 shows the power circuit for single phase leg of a three-level, five-level and seven-level cascaded inverter. The resulting phase voltage is synthesized by the addition of the voltages generated by the different cells. In a 3-level cascaded inverter each single-phase full-bridge inverter generates three voltages at the output: $+V_{dc}$, 0, $-V_{dc}$ (zero, positive dc voltage, and negative dc voltage). This is made possible by connecting the capacitors sequentially to the ac side via the power switches. The resulting output ac voltage swings from $-V_{dc}$ to $+V_{dc}$ with three levels, $-2V_{dc}$ to $+2V_{dc}$ with five-level and $-3V_{dc}$ to $+3V_{dc}$ with seven-level inverter. The staircase waveform is nearly sinusoidal, even without filtering. For a three-phase system, the output voltage of the three cascaded converters can be connected in either wye (Y) or delta (Δ) configurations. For example, a wye-configured 7-level converter using a Cascaded Multilevel Converter (CMC) with separated capacitors is illustrated in the figure 5.

Figure 5. Three-phase 7-level cascaded multilevel inverter (Y-configuration).



4.2. Features of CMLI

For real power conversions, (ac to dc and dc to ac), the cascaded-inverter needs separate dc sources. The structure of separate dc sources is well suited for various renewable energy sources such as fuel cell, photovoltaic, and biomass, etc. Connecting separated dc sources between two converters in a back -to-back fashion is not possible because a short circuit will be introduced when two back -to-back converters are not switching synchronously.

5. Results and Discussions

The proposed type of multilevel DVR associated in series configuration to a three phase source supplying powerful motor loads is established utilizing Simulink of MATLAB software. Simulated results establish that multi-level DVR will be considered as a multipurpose option for resolving such this kind of voltage dip problems. This paper work is designed at developing a multilevel DVR for induction machines with voltage drop. Direct torque control (DTC) is a widely known control method of induction motor drives that delivers rapid as well as strong management of the induction principle.

This paper deals with the design and implementation of a multi-level voltage source converter based dynamic voltage restorer (DVR) employing an effective modulation based on three phase induction motor under direct torque control(DTC) technique in a MATLAB/ Simulink. So large starting current and objectionable voltage drop during the starting of an induction motor could be critical for the entire system. This large voltage dip is encountered at the starting of induction motor. However, the voltage dip is now within limits as the motor is already started and is drawing normal full rated current, shows the stator current, rotor current, load voltage, speed, electromagnetic torque with respect to time. The advantages of CHB inverter are low harmonic distortion, reduced number of switches and suppression of switching losses. The multi level DVR helps to improve the power factor and eliminate the Total Harmonics Distortion (THD).

The Performance of DTC based IMD is studied for both the configurations namely, a six-pulse diode bridge rectifier and multi level DVR at the front end. figure 6 shows the dynamic performance of the drive fed from a six-pulse diode bridge rectifier for load conditions. Waveforms consist of source phase voltage (*vas*), source line current (*ias*), rotor speed (*Nr*), electromagnetic torque (T_e) for the rating of. P_n =1.1 kW, U_n =415 V, *f*=50 Hz, Ω*n* =1415 r/min, R_s=6.03 Ω, R_r = 6.085Ω, L_{ls} = 29.9 mH, L_{lr} = 29.9 mH, L_m =489.3 mH, J = 0.011787 $Kg.m^2$.

The ac mains current waveform and its harmonic spectra at load is shown in figure 7 which show that THD at full load. From these results it can be concluded that it is necessary to use improved power quality converters at front end of the DTC based IMD. As the next step, a Multi levelDVR is employed in place of the uncontrolled 6-pulse converter. The waveforms of a DTC based IMD for load conditions fed from a Multi level DVR at the front end are shown in figure 8**.** The ac mains current and its harmonic spectra for load as shown in Fig.9. It can be noted that the THD of ac mains current at load is 4.60%. A significant improvement as compared to the case fed from a simple diode bridge rectifier. The comparison of THD with load for DTC based.

Figure 6. DTC based IMD phase voltage (*Vas*), line current (*Ias*), rotor speed (*Nr*), electromagnetic torque (Te).

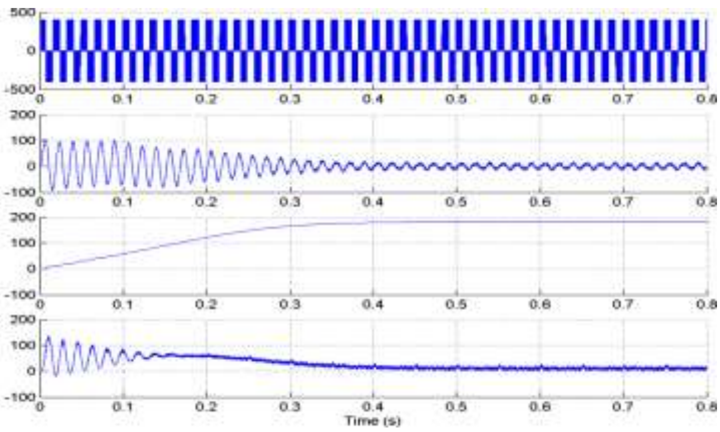


Figure 7. Source current and harmonic spectrum for DTC based IMD with a simple diode bridge rectifier at rated load.

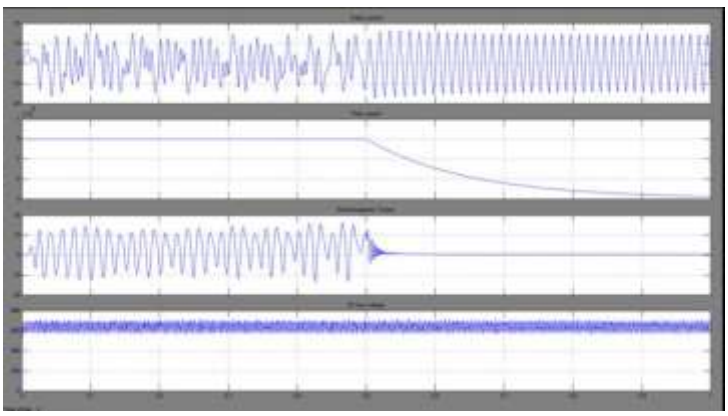


Figure 8. Dynamics of a DTC based IMD with a simple diode bridge rectifier and Multi-Level DVR at the front end.

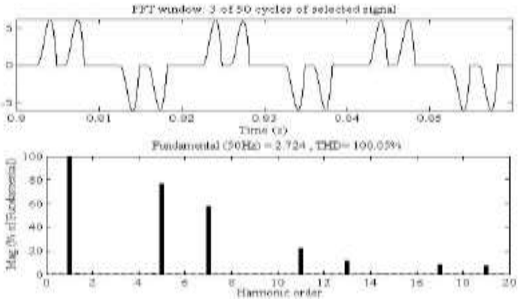
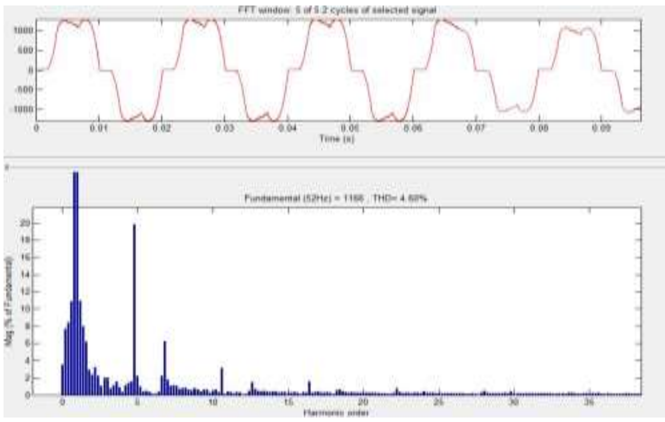


Figure 9. AC mains current and harmonic spectrum for DTC based IMD with Multi Level DVR at the front of DTC.



6. Conclusions

The main purpose of using DVR in industries is to maximize efficiency in production. This project has proposed an improved progressive phase changing scheme of post-fault voltage. For any fault situation of voltage sag this method is effective, in which it is proved from the analysis and MATLAB simulation results. The sag transients can be easily mitigated and pre-fault voltage can be established. For real time applications, this may necessitate the application of the microcontroller/processor with fast speed. The analysis done in this paper for voltage sag, swell, and harmonics affecting single phase and three phase supply. Similarly simulations can be carried for voltage sag, voltage swell, harmonics and three-phase fault. Hereby, the effectiveness of the proposed method is tested and is proven error free. The DVR handles both balanced and unbalanced situations without any difficulties and inject required voltage to compensate the sag in the supply voltage to keep the load voltage constant at the nominal value. The main advantages of the proposed DVR are simple control, fast response and low cost.

References

1. Takahashi and T. Noguchi, "A new quick-response and high-efficiency control strategy of an induction motor", *IEEE Trans. Ind. Appl.*, vol. 22, no. 5, pp. 820–827, Sep./Oct. 1986.
2. B. Singh, K. Al-Haddad, and A. Chandra, "A review of active filters for power quality improvement," *IEEE Trans. Ind. Electron.*, vol.46, no. 5, pp. 960–971, Oct. 1999.

3. S. A. Zaid, O. A. Mahgoub, and K. El-Metwally, "Implementation of a new fast direct torque control algorithm for induction motor drives", *IETElectr. Power Appl.*, vol. 4, no. 5, pp. 305–313, May 2010.
4 B. Singh, B. N. Singh, A. Chandra, K. Al-Haddad, A. Pandey and D. P.Kothari, "A review of three-phase improved power quality AC-DCconverters",*IEEE Trans. Industrial Electronics,* vol.51, no.3, June 2004.
5. BrahimMetidji,NabilTaib, LotfiBaghli, ToufikRekioua,andSeddikBacha, "Low-Cost Direct Torque Control Algorithm for Induction Motor Without AC Phase Current Sensors,"*IEEE Trans on Power Electron.,* vol. 27, no. 9, september 2012.
6. B.S.KrishnaVarma, G.Vineesha, J.Truptikumar, K.Sasank and P. Naga Yasasvi , "Simulated Control System Designof a Multilevel DVR for Reactive Power Compensation" *International Conference On Advances In Engineering, Science And Management(ICAESM -2012)* IEEE-2012,March 31, 2012.
7. Zhao Liu, Bangyin Liu, ShanxuDuan, and Yong Kang "A Novel DC Capacitor Voltage Balance Control Method for CascadeMultilevel DVR", *IEEETransactions on Power Electron*, vol. 27, no. 1, January 2012.
8. Chintan Patel, Rajeevan P. P., AnubrataDey, RijilRamchand, K. Gopakumar, and Marian P. Kazmierkowski, "Fast Direct Torque Control of an Open-End Induction Motor Drive Using 12-Sided Polygonal Voltage Space Vectors", *IEEE Trans on Power Electron,* vol. 27, no. 1, January 2012.
9. Tejavathu Ramesh, Anup Kumar Pandl, Y Suresh and Suresh Mikkili, "Direct Flux and Torque Control of Induction Motor Drive for Speed Regulator using PI and Fuzzy LogicControllers", *International Conference On Advances In Engineering, Science AndManagement (ICAESM - 2012)* IEEE- 2012,March 31, 2012.