Abstract

The paper emphasis the importance of DTC for an induction motor with multi level inverter in order to reduce the frequency of switching for the IGBT’S for same hysteresis bands of torque and flux. The simulations were completed in SIMULINK software. Simulation results from conventional NPC-DTC and modified NPC- DTC are presented and compared. Results shows that torque, flux linkage and stator current ripples are decreased with proposed NPC-DTC strategy. Evaluation was made based on the motor performance, which are like reduction of switching cycles and improvement in flux responses.

Keywords - Direct Torque Control (DTC), Multi-level Inverter (MLI).

I. Introduction

With the advancements in power electronics field there were many speed control techniques were evolved. Out of these direct control is special. And for the efficient control of the motor we go for multi level inverse along with direct torque control. With the conventional MLI-DTC there is a stress on the devices because of faster switching. Proposed MLI-DTC uses the optimized switching vectors according to the speed of induction motor. Which results a drive with faster torque response and reduced switching frequency of the device[V,VIII]. The features of the direct torque control are

1. Stator magnetic flux and torque developed by motor are controlled directly.
2. Without control of stator voltage and current
3. Unfixed switching frequencies and
4. No decoupling operations.
To keep motor fluxes and torques within a constant width of a hysteresis, one adopts a selection strategy of switched vectors to adjust magnitudes of flux and torque vectors.

In the ideal DTC method, the stator flux control is determined by the hysteresis comparator, which helps to select an appropriate voltage vector to make flux vector inside the circle with a constant radius.
The stator electro magnetic flux vector is located at the sector on the plane. The output with is to increase the flux vector magnitude; thus one selects the voltage vector. If, it means to decrease flux vector magnitude, then the voltage vector is chosen (counter clockwise direction). In general, if the flux vector is located in the vector, voltage vectors and move the flux in the forward direction. Also they will increase the torque due to the increment of torque angle. On the contrary, that vectors and decrease will reduce the torque.

Fig. 4 Stator flux vector movement relative to rotor flux vector and zero voltage vectors.

After comparing the actual flux and torque with the reference values the error signal in the form of digital outputs will be generated. These digital output signals i.e. and are used in the selection of inverter switching state from look up table.

Fig. 5 Sectors in the classical DTC method

II. Proposed mli-DTC( with a diode clamped inverter)

In the proposed MLI-DTC strategy the selection space voltage vectors will be from the same switching table only but during low speed operations instead of small magnitude voltage vectors large magnitude voltage vectors are selected. By this strategy we can reduce the faster switching of the device due to higher torque ripple.
The DTC with two level inverter has only six voltage space vectors other than zero voltage vectors, and it does not able to make any difference between large and small error in the torque. And coming to MLI-DTC has eighteen voltage space vectors which are of small magnitude and large magnitude but with normal strategy it does not able to make differentiate between the error during low speeds and high speeds. That is why this proposed strategy is better compared to the conventional one[I,III].

Fig.6 Three-Level neutral point clamped Inverter

The digital outputs of the flux hysteresis and torque hysteresis comparators are used for selecting voltage space vector from the switching table, whereas during this selection process the speed of induction motor should be taken care of. For this to happen we have to track the angular position of the motor. And the proposed strategy includes the selecting the switching state for the inverter from the available voltage vectors for low switching frequency. So that lookup table is known as optimum switching vector selection table.
III. Simulation Results of Conventional MLI-DTC of Induction Motor.

The system built in simulink for the IM drive has been tested for closed loop operation using DTC scheme. The simulation step size of 0.1e-3(max) has been considered to carry out simulation results. The IM drive is made to run at step changes in reference speed and torque. Response of the torque developed by the motor at different load torques is shown in fig.9.
Fig. 9 Response of torque developed by motor for step changes in load torque.

Fig. 10 shows how the stator flux linkages maintained at constant reference value of 0.9 Wb. The response of flux till t=1.5 s has more dips because instead of active voltage vectors (V_1 - V_18) zero voltage vectors are selected due to limited availability of active voltage vectors in each sector when stator flux linkage changes from one sector to other sector under low speed operation.

Fig. 11 shows the speed response of IM drive achieving the steady state values of 200 rpm, 800 rpm and 1430 rpm. Here we can observe one thing from speed and torque wave forms during increase in load torque there is a sudden dip in the speed wave and vice versa. Fig. 12 shows the variation of armature currents I_{abc} for different load torque conditions.

Fig 10. Response of flux linkage with reference flux of 0.9 wb
Fig. 11 Speed response for step changes in speed.

Fig. 12 Armature currents $i_{abc}$ for different load conditions.

FFT analysis of the line current waveform shown in fig. 13 and the value of THD is 2.40. If we want to reduce this value (THD) further, we should reduce the torque and flux hysteresis band level. With this approach, we may have to switch the IGBT’s at a faster rate, but it increases the switching losses and the cost of the device.

Fig. 13 FFT analysis of line current.

Fig. 14 shows the voltage across IGBT which is used in the inverter, the main purpose of taking a device voltage into consideration is that to observe it’s switching frequency.
IV. Simulation Results of Proposed MLI-DTC Induction Motor Drive.

Fig.15 shows how the stator flux linkages maintained at constant reference value of 0.9 Wb. Hence, the response of flux till $t=1.5s$ have dips but compared with fig.10 the dips got reduced because in proposed MLI-DTC during low speeds separate switching strategy is followed.

Fig.15 Magnitude of stator flux linkage response with reference as 0.9Wb.
Fig. 16 shows the variation of armature currents $I_{abc}$ for different load torque conditions. Hence the currents $I_{abc}$ got improved especially during low speeds. Figures 17 & 18 shows speed and torque of the motor at different load torques and speeds.

Fig. 17 Speed response for step changes in reference speed.
Fig. 18 Response of torque for step changes in reference torque.

Fig. 19 FFT analysis of line current.

Fig 20. Voltage across IGBT switch (enlarged)
FFT analysis of the line current with the new implemented strategy which shows that the THD value of the drive got reduced with the proposed strategy. Mainly if we observe the figures 14 & 20 the switching frequency of the IGBT is drastically reduced.

I. Conclusion

Conventional NPC-DTC gives a reduced torque ripple and better speed response over other speed control techniques. However the main need to going for a new strategy is control is that the drawbacks contained by conventional switching strategy which is like voltage vectors applied to the machine are independent of it’s speed, so undesirable switching of IGBT’S and harmonic distortion in both stator currents and voltages. A simple way to avoid this is to reduce the value of torque hysteresis band. However it leads to more switching of IGBT’S which results more switching losses and so expensive switching devices. By using propsed NPC-DTC strategy the classical NPC-DTC drawbacks will be overcoming and consequently improve the performance. With the availability of eighteen voltage vectors and twenty seven states the voltage and current waveforms have been improved and so the THD value got reduced. The conventional NPC-DTC shows frequent switching, high THD value, torque and flux ripples while this method reduces all these significantly.

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