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Low Cost Direct Torque Control Algorithm for Induction Motor without Using AC Phase Current Sensor

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ABSTRACT: Direct torque control (DTC) of induction motors has gained popularity in industrial applications mainly due to its simple control structure from its first introduction. An electric motor drive controlled with the DTC technique exhibits performance similar to a field-oriented drive despite a simpler structure. In fact, a DTC scheme achieves the closed-loop control of the motor stator flux and the electromagnetic torque without using any current loop or shaft sensor. Many researchers are interested in this control technique because of its wide area applications used with various ac machine types as induction motor, PMSM, PM Brushless, and reluctance motor. The DTC scheme requires information about the stator currents and the dc-link voltage, which is used with the inverter, switches states, to estimate the values of stator flux and electromagnetic torque. The current feedback for the closed-loop control is usually obtained by sensing instantaneous phase currents by current sensors. In general, galvanic ally isolated current sensors such as Hall-effect sensors and current transducers are widely used in many applications,. Recently, single current sensor operation has been proposed to reconstruct phase currents from the dc-link current sensor. This proposed project aims to design a low-cost and simple phase-current reconstruction algorithm for induction motor (IM) under direct torque control (DTC) using the information obtained from only one shunt resistor (in series with low-side switches in a conventional inverter).The aim is to develop a low-cost high-performance IM drive. The proposed algorithm is robust and very simple. It uses the dc current to reconstruct the stator currents needed to estimate the motor flux and the electromagnetic torque. A theoretical concept is developed, the modified look-up table is presented, and current-access tables are designed and used in the phase-current reconstruction. The DTC technique will be developed using PIC16F877A microcontroller and the firmware will be developed using MPLABIDE.

KEYWORDS:Rectifier, Inverter, Dc-link, switching signals of MOSFET, Look -Up Table

I.INTRODUCTION

DIRECT torque control (DTC) of induction motors has gained Popularity in industrial applications mainly due to its simple control structure from its first introduction in 1986 . An electric motor drive controlled with the DTC technique exhibits performance similar to a field-oriented drive despite a simpler structure . In fact, a DTC scheme achieves the closed-loop control of the motor stator flux and the electromagnetic torque without using any current loop or shaft sensor.Many researchers are interested in this control technique because of its wide area applications used with various ac machine types as induction motor, PMSM, PM Brushless , and reluctance motor . The DTCscheme requiresinformation about the stator currents and the dc-link voltage, which is used with the inverter, switches states, to estimate the values of stator flux and electromagnetic torque. The current feedback for the closed-loop control isusuallyobtained by sensing instantaneous phase currents by current sensors. In general, galvanic ally isolated current sensors such as Hall-effect sensors and current transducers are widely used in many applications. Recently, single current sensor operation has been proposed to reconstruct phase currents from the dc-link current sensor In this way, various approaches have been proposed in the literature. Some methods adjust the pulse-width modulation (PWM) signals to ensure that two-phase currents can be sampled in each control period .Other strategies introduce modifications of the modulation algorithm in order to guarantee the reliability of the measurements from the dc-link current sensors under all the operating conditions .Other interesting approaches are based on the estimation of the motor phase currents using prediction-correction algorithms, thus introducing additional computational burden to the drive system . Only a few papers deal with the DTC technique for induction

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motor and PMSM .The algorithm used in these works operates in two stages. First, it predicts the stator currents from a model of the motor and then adjusts the prediction on the basis of the sensed dc-link current. This algorithm requires an additional computation burden and the knowledge of the stator transient inductance. Inthis project we propose a low-cost single shunt current sensor induction motor (IM) DTC. The stator flux vector and the electromagnetic torque are directly calculated from the voltage and thecurrent derivedfrom a single dc-link voltage sensor (simple voltage divider) and a single dc-link current sensor (simple shunt resistor).Thephase currents are estimated by twodc-linkcurrent measurement processes. This algorithm does not require additional computation burden or other motor parameter knowledge.

II. RELATED WORK

Direct Torque Control with Multilevel Inverter (DTC-MLI) has emerged recently in high dynamics AC drives fields for induction machines or permanent magnet machines application. Direct Torque Control (DTC) has the characters such as combined simplicity and robustness with excellent performance of torque control for the drive system. In this paper, DTC technique for drive system fed on three-level inverter and induction motor is presented, which means to select and compose right voltage vectors varying from speed working in constant torque area. The simulation results confirm that the control method is very effective with greater number of levels in the output voltage waveforms, lower dv/dt, less harmonic distortion and lower switching frequencies Induction machines have several advantages over DC machines. They are robust, require less maintenance, cheaper, and operate at higher speed. Basically, induction machines control methods can be classified into scalar and vector control. In scalar control, only magnitude and frequency of voltage, current, and flux linkage space vectors are controlled. Whereas, in vector control, the instantaneous positions as well as the magnitude and frequency of voltage, current, and flux linkage space vectors are controlled. Constant volt per hertz is a well-known scalar control method while Field Oriented Control (FOC) and Direct Torque Control (DTC) are the two most popular vector control methods. DTC performs separate control of the stator flux and torque, which is also known as decouple control. The core of this control method is to minimize the torque and flux errors to zero by using a pair of hysteresis comparators. The hysteresis comparators lie at the heart of DTC scheme not only to determine the appropriate voltage vector selection but also the period of the voltage vector selected. The performance of the system is directly dependent on the estimation of stator flux and torque. Inaccurate estimations will result in an incorrect voltage vector selection.

III. INDUCTION MOTOR

One of the most common electrical motor used in most applications which is known as **induction motor**. This motor is also called as asynchronous motor. Synchronous speed is the speed of rotation of the magnetic field in a rotary machine and it depends upon the frequency and number poles of the machine.An **induction motor** always runs at a speed less than synchronous speed because the rotating magnetic field which is produced in the rotor with flux current in the stator, the rotor will never reach to its rotating magnetic field speed. Stator will generate flux in the rotor which will make the rotor to rotate, but due to the lagging of flux current in the rotor with flux current in the stator, the rotor will never reach to its rotating magnetic field speed.

Synchronous speed

An AC motor's synchronous speed, n_s, is the rotation rate of the stator's magnetic field, which is expressed in revolutions per minute as

$$n_s = \frac{120 \times f}{p} \quad \text{(RPM)},$$

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where f is the motor supply's frequency in Hertz and p is the number of magnetic poles. That is, for a six-pole three-phase motor with three pole-pairs set 120° apart, p equals 6 and n_s equals 1,000 RPM and 1,200 RPM respectively for 50 Hz and 60 Hz supply systems.

Slip

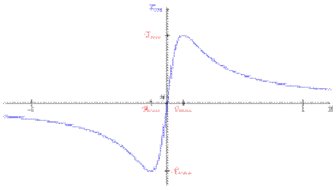

Fig 1.Torque V/S Slip

Typical torque curve as a function of slip, represented as 'g' here.

Slip, s, is defined as the difference between synchronous speed and operating speed, at the same frequency, expressed in rpm or in percent or ratio of synchronous speed. Thus

$$s = \frac{n_s - n_r}{n_s}$$

where n_s is stator electrical speed, n_r is rotor mechanical speed. Slip, which varies from zero at synchronous speed and 1 when the rotor is at rest, determines the motor's torque. Since the short-circuited rotor windings have small resistance, a small slip induces a large current in the rotor and produces large torque. At full rated load, slip varies from more than 5% for small or special purpose motors to less than 1% for large motors. These speed variations can cause load-sharing problems when differently sized motors are mechanically connected. Various methods are available to reduce slip, VFDs often offering the best solution.

Principle of operation :

When three phase supply is given to the three phase stator winding of the induction motor, a rotating magnetic field is developed around the stator which rotates at synchronous speed. This rotating magnetic field passes through the air gap and cuts the rotor conductors which were stationary. Due to the relative speed between the stationary rotor conductors and the rotating magnetic field, an emf is induced in the rotor conductors.As the rotor conductors are short circuited, current starts flowing through it. And as these current carrying rotor conductors are placed in the magnetic field produced by the stator, they experiences a mechanical force i.e. torque which moves the rotor in the same direction as that of the rotating magnetic field.
the induction motor can't run at the synchronous speed because at synchronous speed the induction motor can not develop any torque to move the rotor from its stationary position.

Applications of Induction Motors:

Around 90 per cent of the electrical motors used in industry and domestic appliances are either three-phase induction motors or single-phase induction motors. This is because induction motors are rugged in construction requiring hardly any maintenance, that they are comparatively cheap, and require supply only to the stator. No supply is required to be given to the rotor. The rotor gets excited by virtue of electromagnetic induction. Further, there is no requirement of brush, slip rings, or commutator. However, slip-ring-type induction motors where extra resistance is added to the rotor

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circuit are used in applications where high starting torque is required. Three-phase induction motors are used as drive motors in pumps, lifts, cranes, hoists, lifts, compressors, large capacity exhaust fans, driving lathe machines, crushers, in oil extracting mills, textile and paper mills, etc.

IV. CIRCUIT DIAGRAM FOR DTC

The coil to which alternating voltage is supplied is called as primary winding and the coil to which load is connected is called as secondary winding. When the primary winding is given an alternating supply, the alternating flux established in it also links the secondary winding. According to Faraday's law of electromagnetic induction, an emf is induced in the secondary winding that is called as mutually induced emf. The induced emfs are proportional to number of turns. In any transformer, the primary ampere-turn equals the secondary ampere-turn. $N1I1=N2I2$ Thus, we have $I1/I2=E2/E1=V2/V1=N2/N1=K$.

Whenever any load is put on the transformer, it should be connected to the secondary winding and the primary winding of the transformer draws the required amount of current in order to keep the working flux constant. Thus, the transformer works with a perfect static balance.

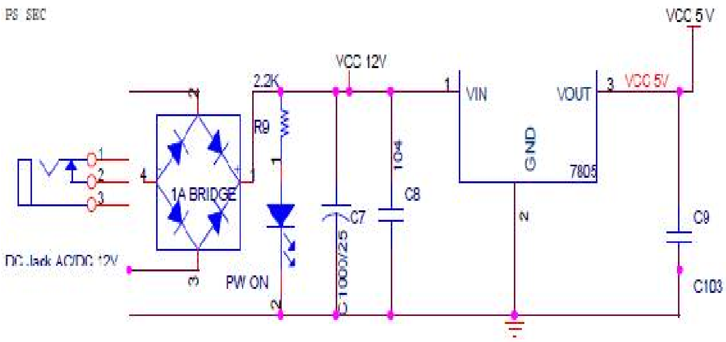

Fig 1.Circuit diagram of power supply unit

Fig a.The stator voltage measurements should have as low offset error as possible in order to keep the flux estimation error down. For this reason the stator voltages are usually estimated from the measured DC intermediate circuit voltage and the transistor control signals.

V. BLOCK DIAGRAM FOR DTC

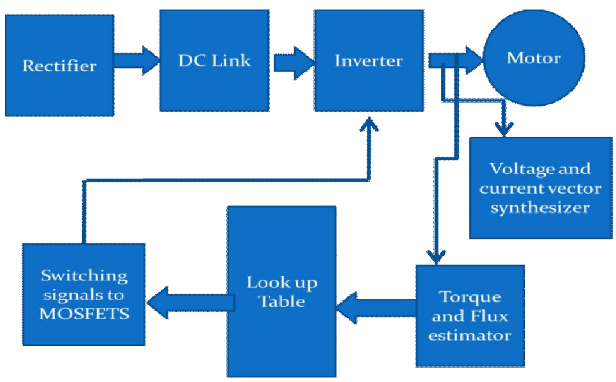

Fig 1.Block Diagram for Direct Torque Control

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In Fig a. AC supply is the input supplied to the rectifier circuit. The rectifier circuit convert the AC supply to the DC supply and given to the filter circuit which filter the pulsating DC supply in to the smooth supply and supply the output to the inverter circuit. The inverter circuit consists of many switches it is drive by the driver circuit. The driver circuit has two functions one is to isolation and another for amplification. It can be used to amplify the 5V pulses to 12V for using transistor technology and provided isolation by using up to coupler. The pulse generator produces the pulses for the transistor by using PIC microcontroller. The PIC microcontroller produces a switching signal. The output of inverter is AC which is used to drive the Induction Motors. A low-cost single shunt current sensor induction motor (IM) DTC. The stator flux vector and the electromagnetic torque are directly calculated from the voltage and the current derived from a single dc -link voltage sensor (simple voltage divider) and a single dc -link current sensor (simple shunt resistor). The phase currents are estimated by two dc-link current measurement processes. This algorithm does not require additional computation burden or other motor parameter knowledge. The transformer used here is a step –down transformer and it is used to step-down. The rectifier used here is a bridge rectifier that converts an ac voltage into pulsating dc voltage using both half cycles of applied ac voltage. The filter used here is a capacitive filter, which is used to filter out the rectified output, which has some ac components. From the filter, the output will be 12v D.C. Then the 12v D.C is given to voltage regulator that regulates the constant DC voltage in-spite of variations in input and load. The Voltage Regulator used here is 7805 Voltage Regulator.

TORQUE AND FLUX ESTIMATOR:

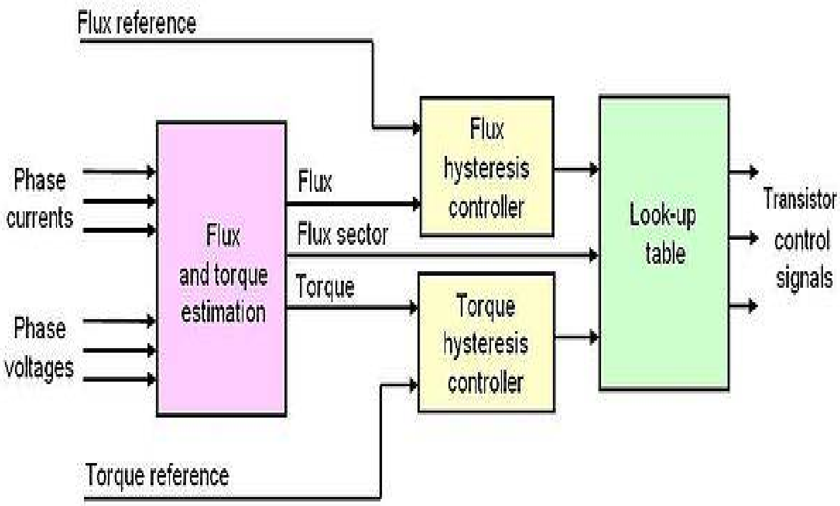

Fig1. concept of modification of a searching point by PSO

Torque and Flux EstimationStator flux linkage is estimated by integrating the stator voltages. Torque is estimated as a cross product of estimated stator flux linkage vector and measured motor current vector. The estimated flux magnitude and torque are then compared with their reference values. If either the estimated flux or torque deviates from the reference more than allowed tolerance, the transistors of the variable frequency drive are turned off and on in such a way that the flux and torque errors will return in their tolerant bands as fast as possible. Thus direct torque control is one form of the hysteresis control.

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VI. LOOK UP TABLE FOR DIRECT TORQUE CONTROL

S1	S2	S3	S4	TORQUE IN %	TORQUE IN KG/CM^2
0	0	0	0	0	0
0	0	1	0	12.5	.625
0	1	0	0	25	1.25
0	1	1	0	37.5	1.875
1	0	0	0	50	2.5
1	0	1	0	62.5	3.125
1	1	0	0	75	3.75
1	1	1	0	87.5	4.375
1	1	1	1	100	5

Fig1. Look up table

STEP1: Check the status of the switches S1, S2, S3, S4

STEP2: If S1, S2, S3, S4 switches are off (zero) torque value is zero from the look-up table.

STEP3: If S3 switch is ON (1) and other switches are off (zero) the corresponding torque value .625 kg/cm^2 is given from the look-up table.

STEP4: If S2 switch is ON (1) and other switches are off (zero) the corresponding torque value 1.25 kg/cm^2 is given from the look-up table.

STEP5: If S2 & S1 switches are ON (1) and other switches are off (zero) the corresponding torque value 1.875 kg/cm^2 is given from the look-up table.

STEP6: If S1 switch is ON (1) and other switches are off (zero) the corresponding torque value 3.125 kg/cm^2 is given from the look-up table.

STEP7: If S2 & S1 switches are ON (1) and other switches are off (zero) the corresponding torque value 3.75 kg/cm^2 is given from the look-up table.

STEP8: If S2 & S3 & S1 switches are ON (1) and other switch is off (zero) the corresponding torque value 4.375 kg/cm^2 is given from the look-up table.

STEP9: If S1 & S2 & S3 &S4 switches are on, the corresponding torque value 5 is given from the look-up table.

STEP10: Repeat the step1 for different torque values.

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VII.DISPLAY UNIT

Liquid crystal displays (LCDs) have materials which combine the properties of both liquids and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered form similar to a crystal. An LCD consists of two glass panels, with the liquid crystal material sand witched in between them. The inner surface of the glass plates are coated with transparent electrodes which define the character, symbols or patterns to be displayed polymeric layers are present in between the electrodes and the liquid crystal, which makes the liquid crystal molecules to maintain a defined orientation angle.One each polarisers are pasted outside the two glass panels. These polarisers would rotate the light rays passing through them to a definite angle, in a particular direction.When the LCD is in the off state, light rays are rotated by the two polarisers and the liquid crystal, such that the light rays come out of the LCD without any orientation, and hence the LCD appears transparent.When sufficient voltage is applied to the electrodes, the liquid crystal molecules would be aligned in a specific direction. The light rays passing through the LCD would be rotated by the polarisers, which would result in activating / highlighting the desired characters.The LCD's are lightweight with only a few millimeters thickness. Since the LCD's consume less power, they are compatible with low power electronic circuits, and can be powered for long durations.The LCD's don't generate light and so light is needed to read the display. By using backlighting, reading is possible in the dark. The LCD's have long life and a wide operating temperature range.Changing the display size or the layout size is relatively simple which makes the LCD's more customer friendly.The LCDs used exclusively in watches, calculators and measuring instruments are the simple seven-segment displays, having a limited amount of numeric data. The recent advances in technology have resulted in better legibility, more information displaying capability and a wider temperature range. These have resulted in the LCDs being extensively used in telecommunications and entertainment electronics. The LCDs have even started replacing the cathode ray tubes (CRTs) used for the display of text and graphics, and also in small TV applications.

INTERFACE WITH MICROCONTROLLER

The power supply should be of +5V, with maximum allowable transients of 10mv. To achieve a better / suitable contrast for the display, the voltage (VL) at pin 3 should be adjusted properly.A module should not be inserted or removed from a live circuit. The ground terminal of the power supply must be isolated properly so that no voltage is induced in it. The module should be isolated from the other circuits, so that stray voltages are not induced, which could cause a flickering display**.**

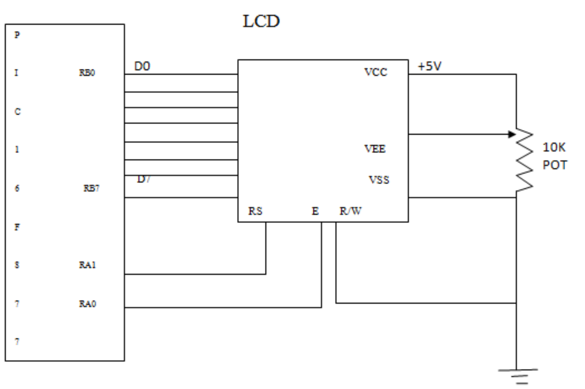

Fig1. Interface with microcontroller

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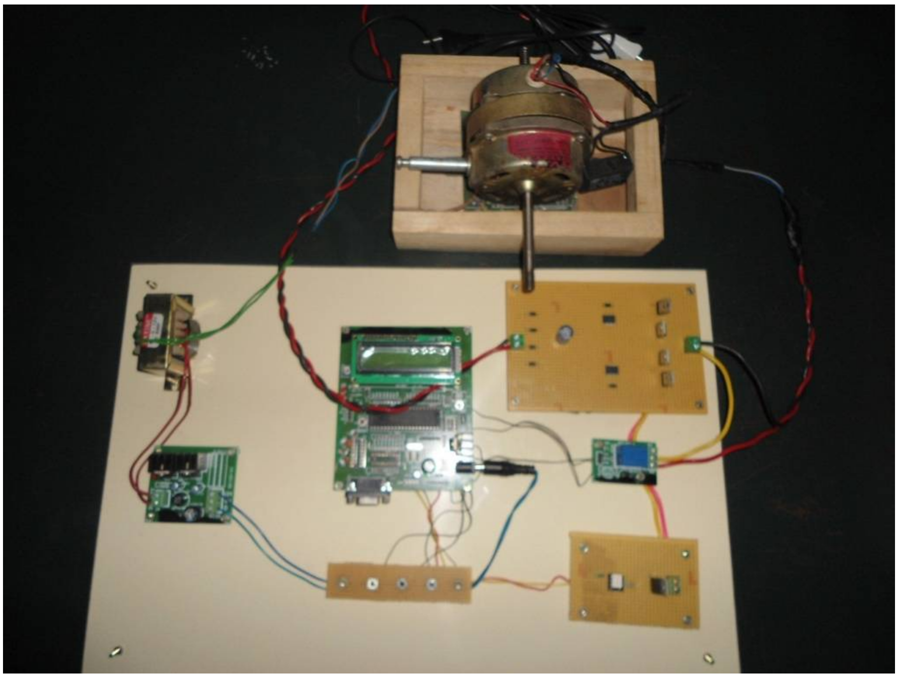
VIII.SNAPSHOT OF OUR PROJECT KIT



IX. CONCLUSION

This project presents a new direct torque and flux control strategy based on LOOK-UP table. DTC strategy realizes almost ripple-free operation for the entire speed range. Consequently, the flux, torque, and speed estimation is improved. The fast response and robustness merits of the basic DTC are entirely preserved. The switching frequency is constant and controllable. In fact, the better results are due to the increasing of the switching frequency. By using DTC the overall system performance is increased.

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