Performance Evaluation of Direct Torque Control of Induction Motor Drives

S. Krishnan and R. Karthika

Abstract--- In work we developed Direct torque control (DTC) is an emerging technique for controlling PWM inverter-fed induction motor (IM) drives. It allows the precise and quick inspection of the IM flux and torque without calling for complex control algorithms. In principle, moreover, it requires only the knowledge of the stator resistance. The application by reviewing the basic operation of an IM and a PWM inverter using the space vector theory. The field-oriented (FO) control of an IM drive is also discussed. Then the concept of direct self-control (DCS), space vector modulation (SVIM) are described. The ST strategy is dealt with in detail, discussing the results which can be obtained with different choices of the switching table. Problems associated with the selection of the amplitude of the hysteresis bands of the flux and torque controllers are illustrated using experimental data. Modulation technique can be used in both open and closed-loop motor control applications. A device which consist of Single Phase Induction Motor and it has single phase winding which is winding on the stator of the motor and a winding placed on the rotor. A pulsating magnetic field is produced, when a phase supply energizes the stator winding of the single-phase induction motor shown below. The developed control technique is based on the comparison of the high-frequency output signal with the input source, similar to the one used in voltage source inverter although the pulsing single is widely employed for control of voltage source inverter

I. INTRODUCTION

The main area of work is the industrial motor, an induction motor has a fixed outer portion, the stator and a rotor that inside with a carefully winding air gap between the two. Virtually all electrical engines use magnetic field rotation to spin their rotors. A single-phase induction motor is the type where the rotating magnetic field is created usually in the stator because of the input source. DC motors depend getting on mechanical or electronic commutation to generate rotating magnetic fields.

There is no direct approach to have controlled outputs from the commanded inputs. So it is necessary to generate equivalents of the data for the output control. This is achieved by three-phase to a two-phase transformation where the output equivalent currents for flux and torque respectively are obtained. The equivalent phase circuit of the machine is valid only in steady state condition. In adjustable speed drives, the device usually constituted an element within a feedback loop, and therefore its transient behavior has to be taken into consideration. Besides, high performance over control, such as space vector control is based on the dynamic d- q model of the machine. Therefore, we go for d- q model for understanding space vector control principle. Differential equations can describe the machine model with time, requires mutual inductance: but such a model tends to be very complicated.

SVM compares a high-frequency triangular waveform with a modified waveform to generate pulses. The following steps can implement mathematical modeling.

S. Krishnan, M.E., Assistant Professor, Department of Electrical and Electronics Engineering, Mahendra Engineering College, [Autonomous], Mahendhirapuri, Mallasamudram, Namakkal.

R. Karthika, PG Scholar, M.E – Control System Engineering, Department of Electrical and Electronics Engineering, Mahendra Engineering College, [Autonomous], Mahendhirapuri, Mallasamudram, Namakkal.

The method of the symmetrical pulse pattern for two consecutive intervals are switching frequency the sampling time. Note that the full time has been conveniently distributed between and vectors to describe the symmetrical pulse width.

In this work a induction motor is a material type motor where power is supplied to the rotating device using electromagnetic induction. Another commonly used name is squirrel cage motor because the rotor bars with short circuit resemble a squirrel cage (hamster wheel). A device which converts electrical power to mechanical power in its rotor for general application. There are several way to validity the rotating machine unlike the transformer previous model in static machine approximately sinusoidal distributed over the performance of the rotor the winding motor phase circumference when n is the number of voltage is existing voltage approximately distributed of motor If this magnetic field is produced stator current rotate the clock speed the motor rotates the clock speed the need of supplying parallel capacitive resistance

II. LITERATURE SURVEY

Still, the country faces a large gap between energy generation and demand. About two-third of the villages have been electrified due to geographical and economic factors. Solar PV technology is a great invention through, which energy can be generated at the workplace eliminating the installation costs and losses due to [2].In order to overcome these power quality problems, an alternative drive system has been proposed in this paper for exercising constant volts/hertz control in induction motors by means of Matrix Converters.

Matrix Converters are a relatively new breed of AC voltage controllers that offer a controllable output voltage at unrestricted frequency while maintaining desirable power quality at the input as well as output[3]. Besides serving as an improved power quality drive, a matrix converter based induction motor drive offers single stage AC to AC conversion, hence eliminating the need for a heavy D.C link capacitor that is otherwise required in a conventional drive system [4]. An alternative Matrix Converter (MC) based drive system has been proposed in this paper so as to overcome the power quality problems that are associated with conventional VSDs [5]. Matrix Converter based induction motor drives besides improving the source side power quality, also exhibits added advantages such as single stage AC to AC conversion, nearly eliminated need for energy storage elements, directionality and a reduced size [6]. The dynamic response of MC based drive systems is very much at par with that offered by conventional PWM VSI based drives, however the range of speed control is often compromised in MC based drives owing to inherent limitations in most modulation algorithrns used for matrix converters [7]. The PLLC estimates the frequency and amplitude of the respective voltage/current waveform of the IM [8]. The other two voltages/currents are estimated by providing proper delay using a transport delay. In addition, the IM speed is estimated from the frequency command of PLLC. The PIDTC provides a considerable distortion in current, flux, torque, and speed due to the poor performance of PI-controllers [9].

Direct Torque and Flux Control (DTFC) method for induction motors using a novel form of Model Predictive Control (MPC) [11].

This MPC strategy is novel from the point of view of the power supply (a three phase inverter) since, instead of using a single voltage vector as the control action during a complete sampling period of the controller, as is done in standard DTFC strategies, we propose to use an

III. PROJECT DESCRIPTION

Mostly induction motors have common range of application in many industries and tractions. Thus, the control of induction motor gains popularity and seeks attention of researchers in recent years.

Direct torque control (DTC) is one of the methods for the control action of induction motor efficiently. This work presents DTC of three phase squirrel cage induction motor by using space vector modulation. A Robust control strategy for decoupling the speed and torque characteristics of the motor.

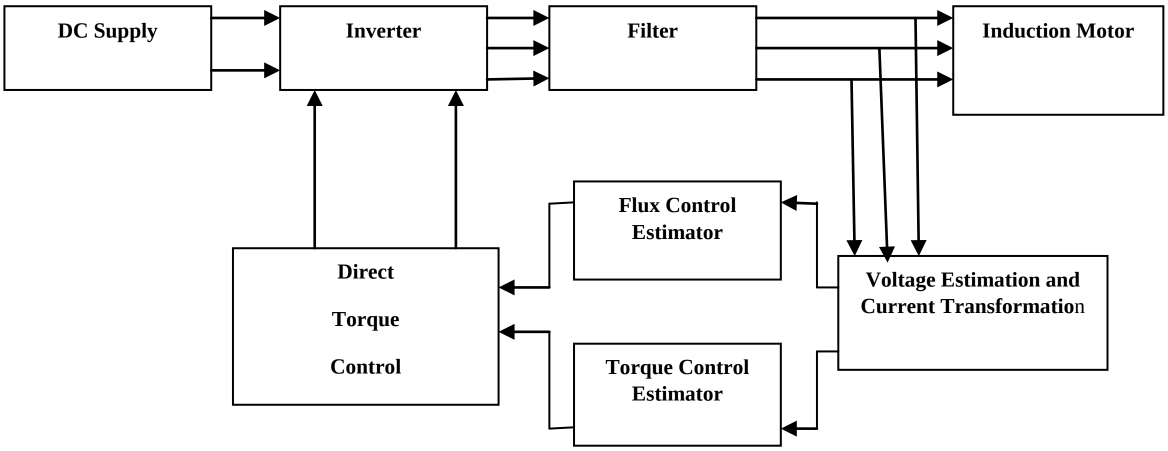

Figure 1: Proposed Block Diagram

The induction motors are also called as asynchronous motors, which are the most commonly used a type of engine in industrial applications. In particular, the winding induction motors are widely used electric motor in the physical application, because these machines are very less power consumption, user-friendly and reliable. They are available in the ranges of several Horse Power to multi-output capacity. The source Horse Power motors are available in single-phase as well as poly-phase (three-phase). The phase drive is used most often in variable-speed drives where the torque requirement controller is high.

An asynchronous technique motor is a type of alternating current motor where power is supplied to the rotor using electromagnetic induction. An electric motor rotates because of the magnetic force exerted between an electromagnet winding called the stator and rotating filed called the rotor. The source in the stator side creates an electromagnetic field which interacts with the secondary to produce a resultant output, transforming electrical energy into mechanical energy.

$$Ns = 120f/p \ldots\ldots (1)$$

P is the number of poles

Equivalent Circuit

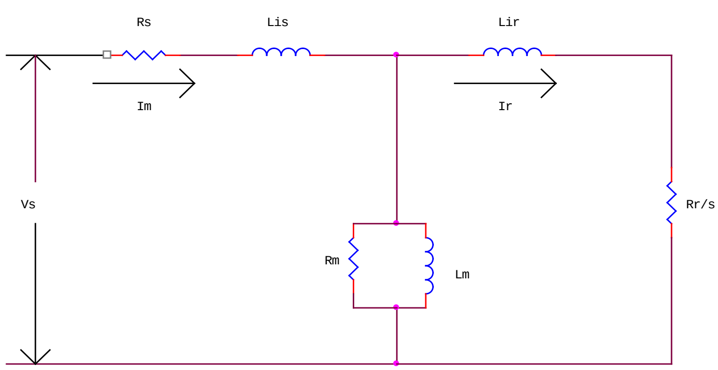

Figure 2: Phase Equivalent Circuit of Induction Motor

From the equivalent circuit diagram the various power expressions can be written as follows:

Input power $=3V_sI_sCOS\emptyset$.

Core loss$=\frac{3Vm^2}{R_m}$.

Rotor copper loss $P_k = 3I^2{}_r$.

Output power Po $=P_g - Pl_r$.

$$\frac{R_r}{S}I^2{}_r \ldots (2)$$

Since the output power is the product of developed torque T_e and speed ω_m, T_e can be expressed as

$$T_s = \frac{P_0}{w_m} \ldots. (3)$$

$$T_e = \frac{3}{w_m}I^2{}_rR_r\left(\frac{1-s}{s}\right) = 3(\frac{P}{2})I^2{}_r\frac{R_r}{sw_e} \ldots (4)$$

From the equivalent circuit, the approximate equivalent circuit can be obtained as shown in Fig 4, where the core loss resistor R_m has been dropped and the magnetizing inductance L_m has been shifted to the input. This approximation is easily justified for an integral horsepower machine, where

$$(R_s + j\, w_eL_{is}) \ll w_eL_m \ldots (5)$$

The performance prediction by the simplified circuit typically varies within 5 percent

From that of the actual machine

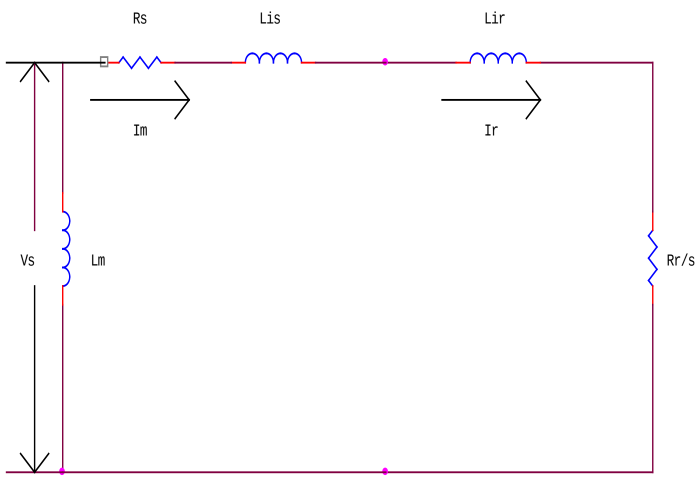

Figure 3: Approximate Per Phase Equivalent Circuit of IM

In Figure 4, the current I_r is figured

$$I=\frac{V_s}{\sqrt{(R_s+\frac{R_r}{s})^2+w_e2(L_{ls}+L_{Lr})^2}} \ldots.. (6)$$

Substituting Equation yields

$$T_e = 3\left(\frac{P}{2}\right)\frac{R_r}{sw_e}\frac{V^2{}_s}{(R_s+\frac{R_r}{s})^2+w_e2(L_{ls}+L_{Lr})^2} \ldots(7)$$

A further simplification of the equivalent circuit of can be made by neglecting the stator parameters R_s and L_{ls}. This assumption is not unreasonable for an integral horsepower machine, particularly if the speed is typically above 10 percent.

Then, the equation can be simplified as

$$T_e\ 3(\frac{P}{2})(\frac{V_s}{w_e})^2(\frac{w_s l R_r}{R_{r^2+w_{sl}2+L_{lr}2}}$$

$$\psi m = \frac{V_s}{w_e} \ldots. (8)$$

In a low-slip region, equation can be approximated as,

$$T_e\ = 3\ (\frac{p}{2})\frac{1}{R_r}(\psi m)^2\omega_{sl}\ \ldots (9)$$

Where, $R_{r^2} \ll w_{sl^2+L_{lr}2}$ is important because it indicated that at constant flux Ψm, the torque T_e is proportional to slip frequency ω_{sl}, or at constant slip frequency ω_{sl}, torque T_e is proportional to Ψ^2.

The slip can be defined as the difference between the synchronous speed and actual speed of the machine. It can be expressed in the percentage. Based on this slip speed, the voltage induced in the rotor winding changes, which in turn changes the rotor current and also the torque. As slip increases, the rotor current and the torque also increases. The rotor moves in the same direction as that of the rotating magnetic field to reduce the induced current (Lenz's law). The slip can be expressed as given below:

$$\text{Slip s} = \frac{N_s - N_s}{N_r} \ldots. (10)$$

Or

$$\text{Slip s} = \frac{w_s - w_s}{w_r} = \frac{w_s l}{w_e} \ldots (11)$$

$$N_r = Ns(1\text{-}S) \ldots (12)$$

Synchronous speed is given by

$$N_s = \frac{120f}{p} \ldots (13)$$

Where P represents the number of poles and f is stator frequency

$$\text{Rotor speed} N_s = \frac{120f}{p}(1\text{-}S) \ldots (14)$$

Thus, the speed of an induction motor depends on slip 'S', stator frequency 'f' and the number of poles 'P' for which the windings are wound.

Different Speed Control Methods

From equation, the speed of IM can be varied by varying the slip 'S' or number of poles 'p' or frequency of supply. The different methods of speed control of induction motor can be broadly classified in to scalar and vector control methods. In this work, scalar control methods are used. Hence only details of scalar methods are discussed here. The explanation of vector control method is beyond the scope of this thesis. The scalar methods of speed control can be classifieds

Stator Voltage Control Method

A very simple and economical method of speed control is to vary the stator voltage at constant supply frequency. The three-phase stator voltage at line frequency can be controlled by controlling the switches in the inverter. As seen from the equation the developed torque is proportional to the square.

IV. Result and Discussion

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment. A proprietary programming language developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and Interfacing with programs written in other languages, including C, C++, and they create Simulink model for power system and power electronics based models.

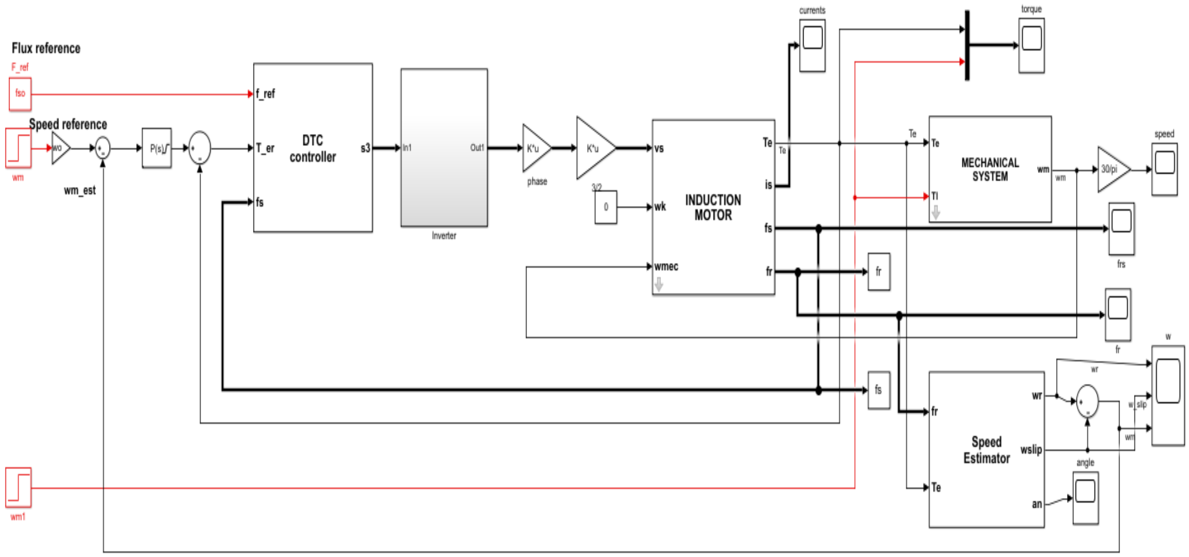

Figure 4: Simulink Model for Direct Torque based Induction Motor

Figure 4 shows the Simulink model for the carrier wavemodulation strategy based induction motor which is strategy is effectively control speed /torque characteristics of the Induction motor.

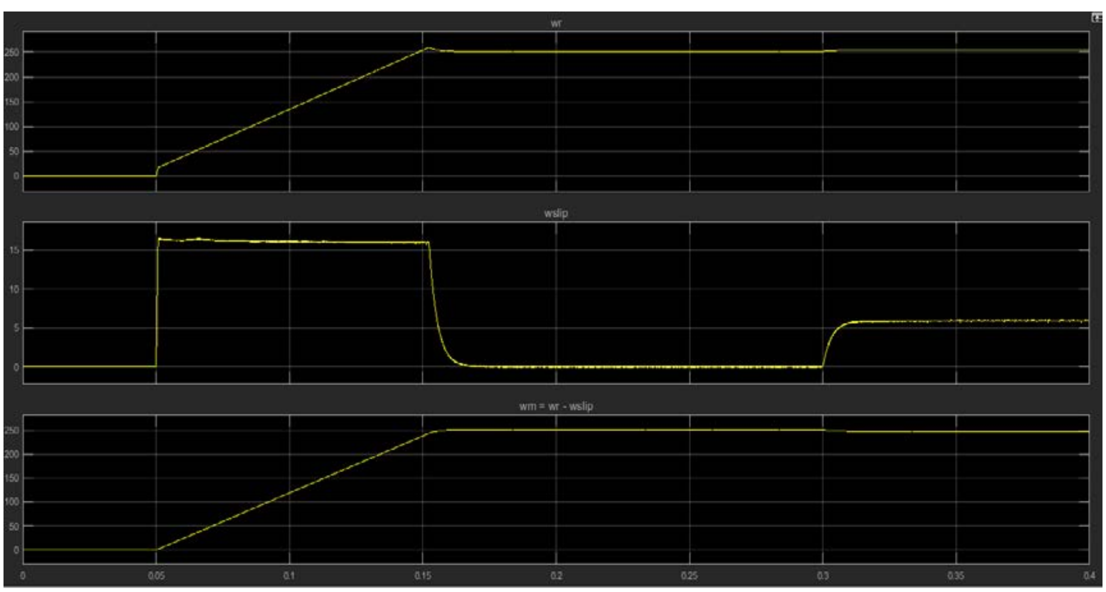

Figure 5: Output Source of Induction Motor

The frequency **wr*** is the required variable (electrical rotor angular speed where mechanical speed is **wm** = **wr**/Pole pairs) because it is approximately equal to speed we neglecting the small **slip** frequency WSL, of the **machine**.

$$W_{r=W_m - W_{slip}} \ \ \ldots\ldots (15)$$

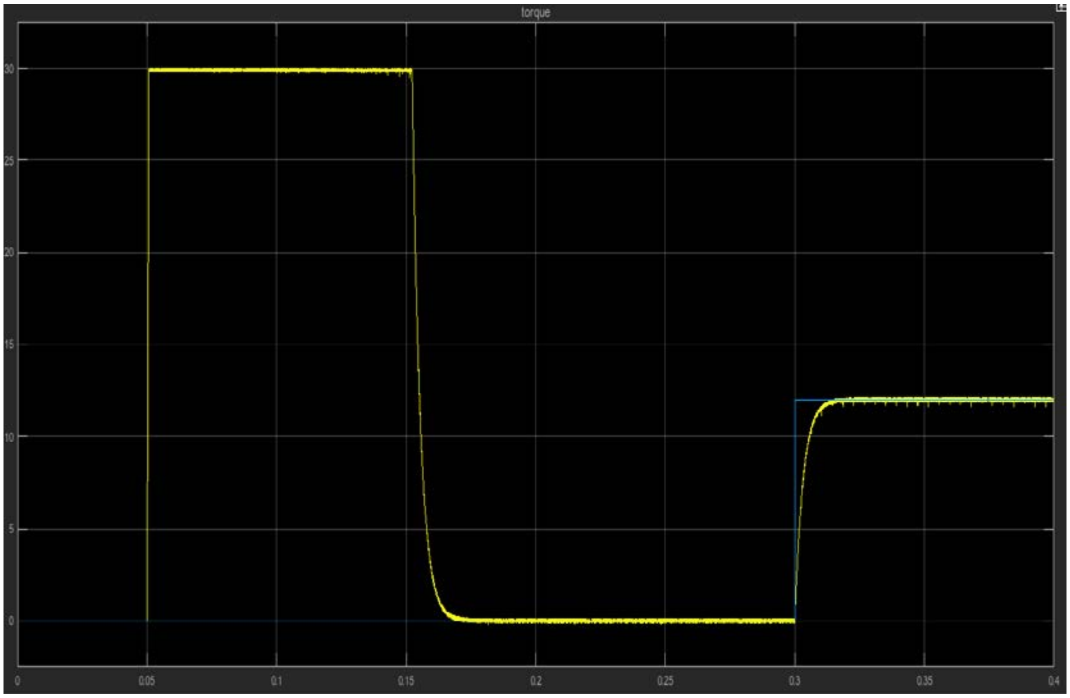

Figure 6: Torque/Speed Characteristics of Induction Motor

The Torque /speed characteristics of induction motor the waveform describes the electromagnetic torque= 30 N-m, rotor angle = 3 theta (rad).

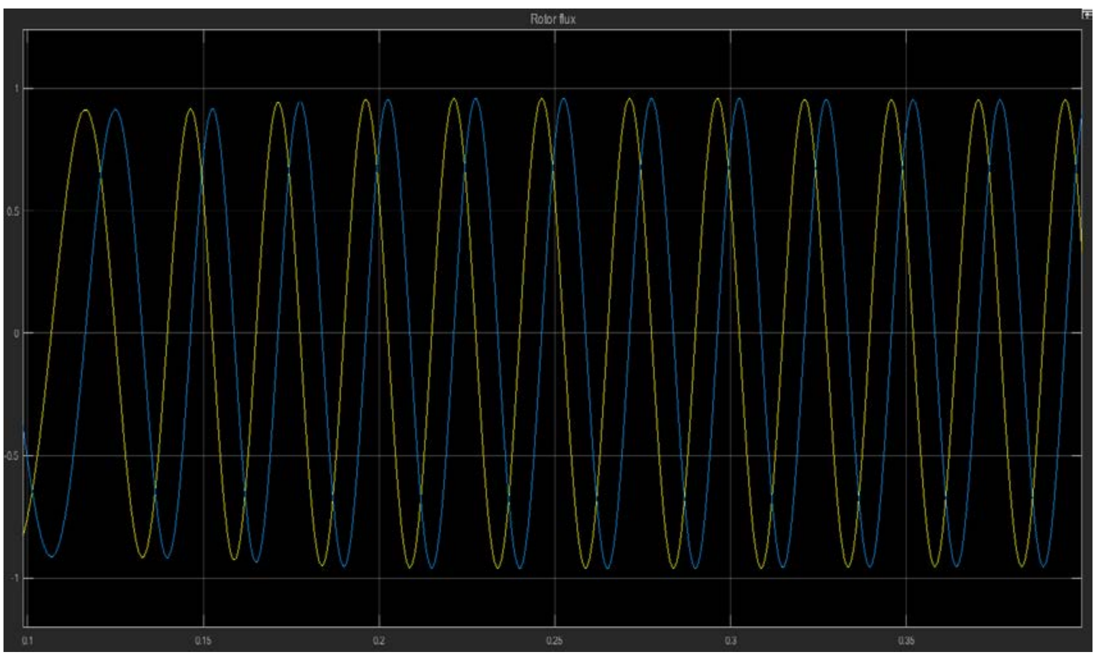

Figure 7: Output Wave Source of Stator

The stator revolves at very nearly the synchronous speed of the rotor field during the no-load operation. The difference in speed is just sufficient to produce enough current in the rotor to overcome the mechanical and electrical losses. Current waveform of the for no-load operation is given in Figure 7

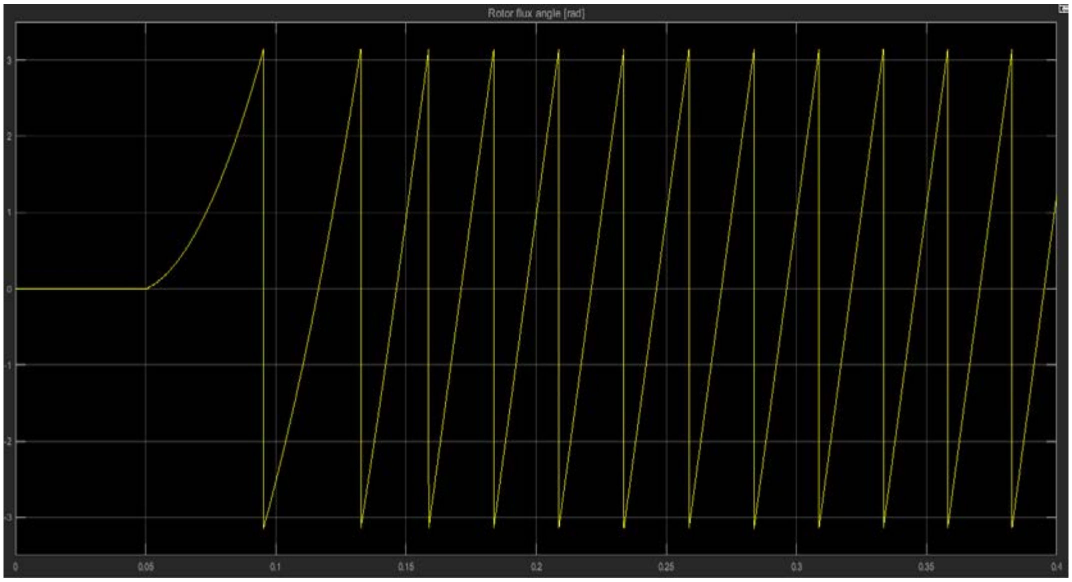

Figure 8: Output Wave Source of Stator

This causes increasing on the rotor current frequency. Rotor current frequency on the load operation is higher than the no-load operation. Harmonic spectrum of the rotor current waveform for load operation is shown in figure 8.

V. Conclusion

Induction motor drives, direct torque control is one of the best controllers proposed. It allows decoupled control of motor stator flux and electromagnetic torque. From the analysis it is proved that, this strategy of IM control is simpler to implement than other vector control methods as it does not require pulse width modulator and co-ordinate transformations. But it introduces undesired torque and current ripple. DTC scheme uses stationary d-q reference frame with d-axis aligned with the stator axis. Stator voltage space vector defined in this reference frame control the torque and flux. A simulation link is model has been fully developed. From the results it is apparent that control strategy is simpler to implement than the vector control method because voltage modulators and improved and switching frequency is maintained constant.

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