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Performance Evaluation of 50HP Three Phase Induction Motor Drive using Vector Control

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Abstract

This paper introduces a novel technique for performance evaluation of three phase induction motor drive. A suitable value of DC supply is applied to three phase inverter, which provides controlled three phase ac supply to induction motor. Performance of this 50HP drive is considers for three cases; (a) no load condition (b) half load condition (c) Full load condition. Performance evaluation is also done for dynamic condition. Results obtained from simulation model are satisfactory and shows good dynamic performance of drive.

Keywords*: Induction motor drive, Vector Control, Performance Evaluation, Induction Motor.*

INTRODUCTION

over the last decades DC machines have been used drastically for variable speed packages due to the decoupled manipulate of torque and flux that can be carried out via armature and field cutting-edge manage respectively. DC drives are high quality in lots of components as in turning in high starting torque, ease of control and nonlinear overall performance. but because of the most important drawbacks of DC machine inclusive of presence of mechanical commutator and brush meeting, DC device drives hardly ever used in nowadays commercial applications [3].

The robustness, low value, the better performance and the convenience of maintenance make the asynchronous motor tremendous in lots of commercial programs. Squirrel cage induction automobiles (SCIM) are extra broadly used than all the rest of the electric motor as they have all the advantages of AC automobiles and are less expensive in price compared to slip ring induction cars. Because of the absence of slip earrings, brushes renovation period and value related to the wear and tear and tear of brushes are minimized. Because of those blessings, the induction vehicles were the execution element of maximum of the electric drive machine for all related components: starting, braking, speed change and velocity reversal and so on [21]. Variable pace IM drives makes use of specially PWM strategies to generate a poly section supply of a given frequency. maximum of these induction motor drives are primarily based on keeping a steady voltage/frequency (V/f) ratio for you to keep a regular flux in the device. despite the fact that the manipulate of V/f drives is highly easy, the torque and flux dynamic performance is extraordinarily poor. as a consequence, great quantities of industrial applications that require good torque, speed or position control still use DC machines [11].

The another technique of variable speed IM drives is field oriented control (FOC), The principle behind field oriented control is that the machine flux and torque are controlled independently, in a similar fashion to a separately exited DC machine. Instantaneous stator currents are transformed to a rotating reference frame aligned with the rotor, stator or air-gap flux vectors, to produce a *d* axis component of current (flux producing) and a *q* axis component of current (torque producing). In recent years, a commercial application of the vector control led induction motor drives has been applied rapidly, in machine tool, steel and paper machine, and many different industrial fields, mostly in Japan [3, 1].

INDUCTION MOTOR MODELLING

Induction refers to the fact that the field within the rotor is precipitated by the stator currents, and asynchronous refers back to the reality that the rotor velocity isn't equal to the stator frequency. No sliding contacts and permanent magnets are had to make an induction motor work, which makes it very simple and cheap to fabricate. As cars, they rugged and require very little maintenance. However, their speeds are not as easily controlled as with DC motors. They draw large starting currents, and operate with a poor lagging factor when lightly loaded [9, 21, 29]..

A. Three-Phase Transformations

The most commonly used transformation is the poly phase to orthogonal two phase (or two-axis) transformation. For the n-phase to two-phase case, it can be expressed in the form:

$$[f_{XY}]=[T(\theta)][f_{1,2,\ldots,n}] \quad (1)$$

$$[T(\theta)]=\sqrt{\frac{2}{n}}\begin{bmatrix}\cos\frac{p}{2}\theta & \cos\left(\frac{p}{2}\theta-\alpha\right) & \cos\left(\frac{p}{n}\theta-(n-1)\alpha\right)\\ \sin\frac{p}{2}\theta & \sin\left(\frac{p}{2}\theta-\alpha\right) & \sin\left(\frac{p}{n}\theta-(n-1)\alpha\right)\end{bmatrix} \quad (2)$$

The coefficient $2/n$ is introduced to make the transformation power invariant.

B. Clark's Transformations

The two-phase variables in stationary reference frame are sometimes denoted as α and β.

$$[f_{\alpha\beta 0}]=[T_{\alpha\beta 0}][f_{abc}] \quad (3)$$

Where the Transformation Matrix, $[T_{\alpha\beta 0}]$, is given by:

$$[T_{\alpha\beta o}]=\frac{2}{3}\begin{bmatrix}1 & -\frac{1}{2} & -\frac{1}{2}\\ 0 & \sqrt{\frac{3}{2}} & -\sqrt{\frac{3}{2}}\\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2}\end{bmatrix} \quad (4)$$

The inverse transformation is:

$$[T_{\alpha\beta 0}]^{-1}=\frac{2}{3}\begin{bmatrix}1 & 0 & 1\\ -\frac{1}{2} & \sqrt{\frac{3}{2}} & 1\\ -\frac{1}{2} & -\sqrt{\frac{3}{2}} & 1\end{bmatrix} \quad (5)$$

C. Park's Transformations

The Park's transformation is a well-known transformation that converts the quantities to two-phase synchronously rotating frame. The transformation is in the form of:

$$[f_{dq0}]=[T_{dq0}(\theta_d)][f_{abc}] \quad (6)$$

Where the dq_0 transformation matrix is defined as:

CIRCUIT MODEL OF THREE PHASE INDUCTION MOTOR

Using the coupled circuit approach and motor notation, the voltage equations of the magnetically coupled stator a rotor circuit can be written as follows:

Stator Voltage Equations:

$$V_{as}=i_{as}r_{as}+\frac{d\psi_{as}}{dt}V$$

$$V_{bs}=i_{bs}r_{bs}+\frac{d\psi_{bs}}{dt}V$$

$$V_{cs}=i_{cs}r_{cs}+\frac{d\psi_{cs}}{dt}V \quad (7)$$

Rotor voltage equations:

$$V_{ar}=i_{ar}r_{ar}+\frac{d\psi_{ar}}{dt}V$$

$$V_{br}=i_{br}r_{br}+\frac{d\psi_{br}}{dt}V$$

$$V_{cr}=i_{cr}r_{cr}+\frac{d\psi_{cr}}{dt}V \quad (8)$$

Using the flux linkage relationships, one can show that

$$T_{em} = \frac{3}{2}\frac{p}{2}\left(\psi'_{qr} i'_{dr} - \psi'_{dr} i'_{qr}\right) \quad \text{Nm}$$

$$T_{em} = \frac{3}{2}\frac{p}{2}\left(\psi'_{qs} i'_{ds} - \psi'_{ds} i'_{qs}\right) \quad \text{Nm}$$

$$T_{em} = \frac{3}{2}\frac{p}{2} L_m \left(i'_{dr} i_{qs} - i'_{qr} i_{ds}\right) \quad \text{Nm} \qquad (9)$$

VECTOR CONTROL

due to dc gadget like performance, vector manage is likewise referred to as decoupling, orthogonal, or trans vector manage. Vector manipulate will oust the scalar control, and widespread because the enterprise-trendy manipulate for ac drives

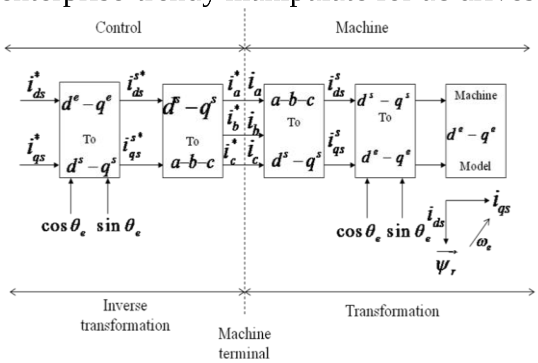

Fig.1. *Principle of Vector Control*

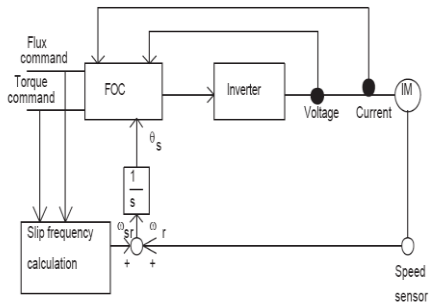

Fig.2. *Indirect Vector Control*

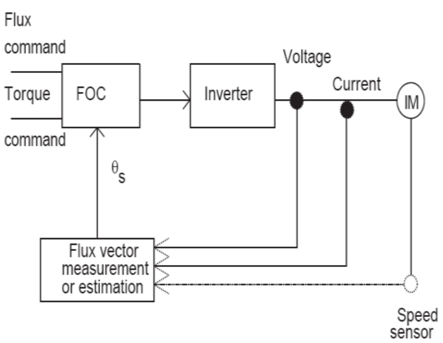

Fig.3. *Direct vector Control*

VOLTAGE SOURCE INVERTER

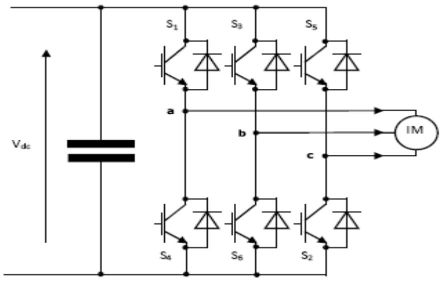

Fig.4. *Three Phase VSI using IGBTs*

A basic 3 phase VSI is a six step bridge inverter, inclusive of minimal six energy electronics switches (i.e. IGBTs, Thyristors) and six remarks diodes. A step can be described because the exchange in firing from one transfer to the following transfer in proper sequence. For a six step inverter each step is of 60º c programming language for one cycle of 360º. meaning the switches could be gated at ordinary intervals of 60º in proper sequence to get a three section ac output voltage on the output terminal of VSI [8, 13].

VOLTAGE SPACE VECTOR

area vector modulation for 3 leg VSI is based at the illustration of the 3 segment quantities as vectors in -dimensional (α-β) plane. Fig.five indicates the first switching kingdom, and line-to-line voltages are given via

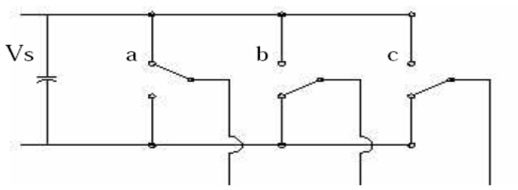

Fig.5. *First Switching State of VSI*

$$V_{ab} = V_s$$
$$V_{bc} = 0$$
$$V_{ca} = -V_s$$

This can be represented as shown in fig.6, where V_{ab}, V_{bc} and V_{ca} are the three line voltage vectors displaced by 120^0 in space.

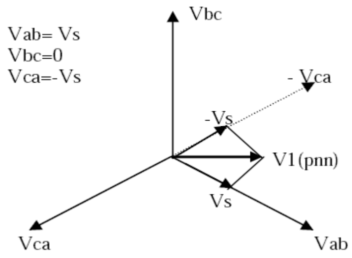

Fig.6. *Representation of First Switching state*

The effective voltage vector generated by this topology is represented as V1 (pnn) in fig.6. Here (pnn) refers to the three leg /phases a, b, c being either connected to the positive dc rail (p) or to the negative dc rail (n).

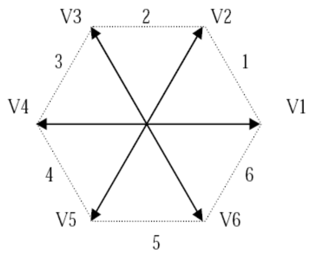

Fig.7. *Non Zero Voltage Vector*

SIMULATION MODEL OF IM DRIVE

The three phase induction motor version is simulated via using the MATLAB / SIMULINK. . on this SIMULINK model PWM approach primarily based voltage supply inverter fed 3 section induction motor pressure has been implemented. Fig.eight depicts the entire SIMULINK version of IM force.

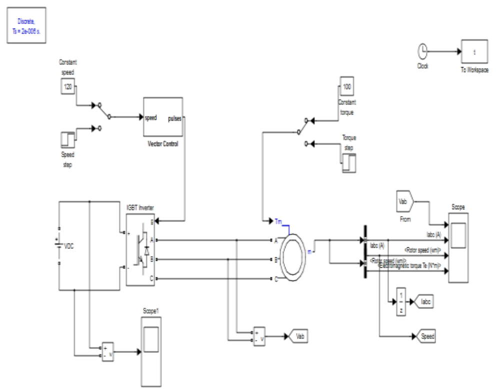

Fig.8 *Simulation Model*

Table1 includes the parameter and specification of IM, used in this SIMULATION model. Specification of Induction Motor: Three phase AC supply, squirrel cage induction motor, 50HP (37kW), 50Hz, 4 pole, 415V, 1480rpm.

Table :1 *Parameters of Induction Motor*

SNo.	Nominal per phase parameters	Values in SI units
1	Stator resistance (R_s)	0.08 Ω
2	Rotor resistance (R_r)	0.228 Ω
3	Mutual inductance (L_m)	34.7 H
4	Stator self inductance(L_s)	0.0058 H
5	Rotor self inductance (L_r)	0.0058 H
6	Moment of inertia (J)	0.0131 Kg-m^2
7	Damping co-efficient (B)	0.0029 N-m-s/rad.

SIMULATION MODEL OF VECTOR CONTROL

By using vector control principle fig.9 has been implemented. In this simulation model hysteresis current controller is used for generation of switching pulses of inverter.

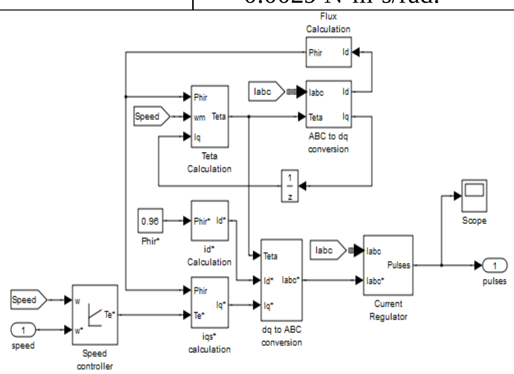

Fig.9 *Simulation Model of Vector Control*

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SIMULATION RESULTS

Fig.10 exhibits the waveform of dc voltage supplied to IGBT based inverter. The value of applied dc voltage is 415V and the below figure clearly depicts the same value.

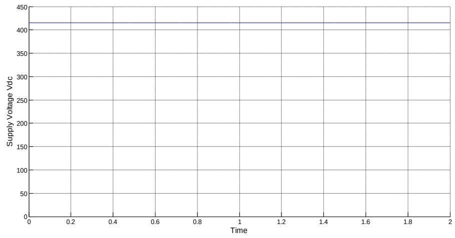


Fig.10 *DC Voltage*

Fig.11 depicts the waveform of output voltage (V_{ab}) between phase a and b, of three phase inverter. Simulation result included the result obtained from vector control implemented induction motor drive.

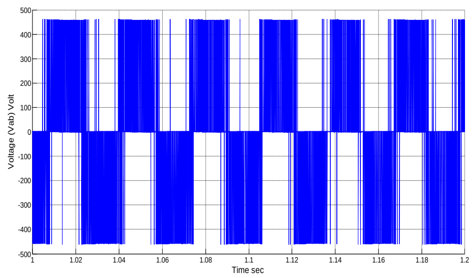
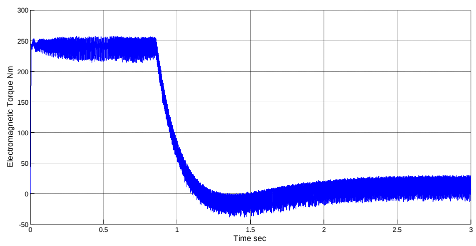
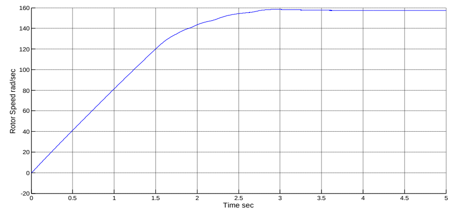


Fig.11 *Output Voltage of VSI (V_{ab})*





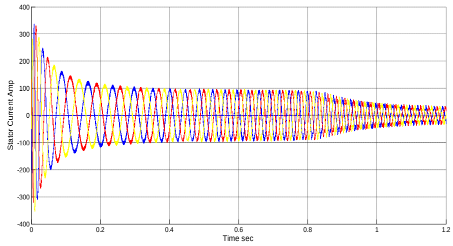
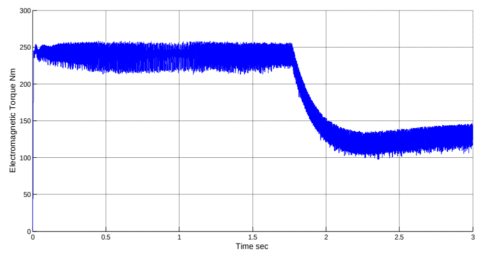


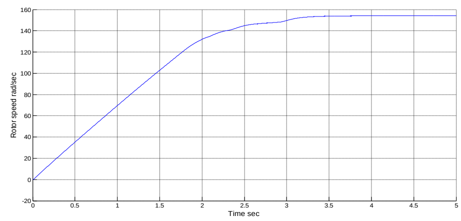
Fig.12 *Performance of Drive in No Load Condition*

Fig.12 dipicts the results obtained from developed simulation model. In this waveform drive is operated in no load condition. The first diagram shows the waveform of electromagnetic torque versus time graph.

Second diagram dipicts the waveform of rated speed versus time graph. In this condition drive is operated in rated speed of 157rd/sec.

Third diagram shows the waveform of current drawn induction motor, it is clearly dipicts that as the drive got its rated speed, current drawn by induction motor is reduced.





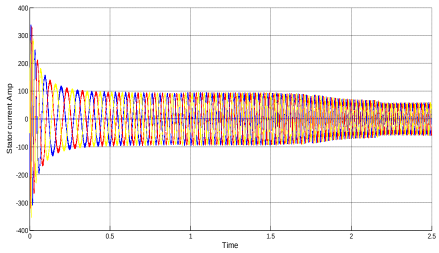


Fig.13 *Performance of drive In Half Load condition*

Fig. 13 shows the three different waveforms obtained from developed model, when the drive is operated in half load condition and rated speed.

First diagram shows the electromagnetic torque versus time graph, and drive got settle in 2.2sec.

The second waveform shows the rated speed versus time graph.

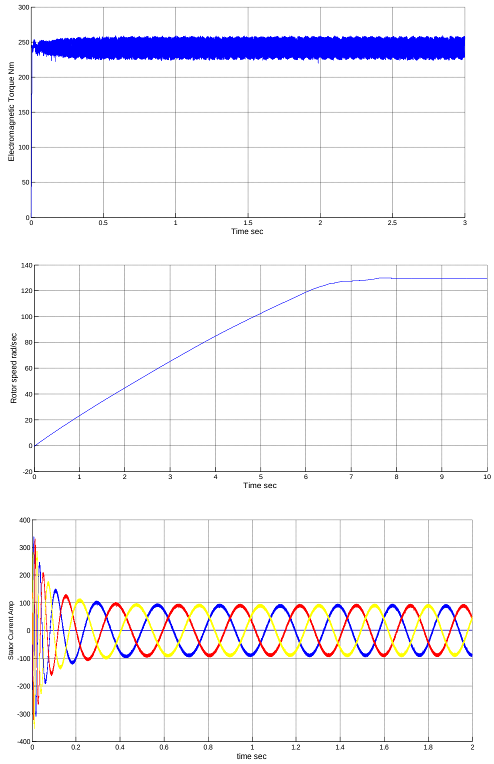


Fig.14 *Performance of Drive in Full Load Condition*

Fig.14 shows the waveform obtained from developed model of induction motor drive, when drive is operated in full load condition. In this condition the settling time of drive is about 7sec.

Table-2 perceives the settling time vector induction motor drive for different values of load torque. As shown in above table settling time increases as the value of load torque decreases.

Table-2 *settling time*

S No.	Torque (Nm)	Settling Time (Sec)
1.	237	7
2.	120	2.2
3.	0	1.5

CONCLUSION

The vector control of induction motor using controllers is discussed for an inverter fed induction motor drive. For any IM drives, vector control technique is one of the best control methods so far. From the analysis it has proven that this PWM based VSI fed IM drives are easy to implement, as SIMULINK model, and the results are also satisfactory. As over the past decades the DC machine drives are mainly used in industry, now mostly AC machines drives took over the these drives.

The performance of drive done for three conditions (a) no load (b) half load (c) full load

Settling time is calculated for all three conditions and performance of drive satisfactory.

REFERENCE

1. M. P. Kazmierkouski and H-Kopcke, “A simple control system for current source induction motor drives,” IEEE Trans. Ind. Appl., voI.21, no.4, pp.617-623. May/June, l985.
2. Habetler, T. G. Profumo, F. Pastorelli, M. and Tolbert, “Direct Torque Control of Induction Machines Using Space Vector Modulation”, IEEE Transactions on Industry Applications, 1992, Vol.28, No. 5, pp. 1045-1053.
3. Blaschke, F., “The Principle of Field Orientation as Applied to the New Trans vector Closed Loop Control for Rotating Machines”, Siemens Rev., 1993, Vol.39, No. 5, pp. 217-220.

4. Cristian Lascu, Ion Boldea and Frede Blaabjerg, "A Modified Direct Torque Control for Induction Motor Sensor less Drive" IEEE Transaction on Power Electronics, vol. 36, no. 1, February 2000.
5. Mineo Tsuji, Shuo Chen, Katsuhiro Izumi, and Eiji Yamada, "Vector Control System for Induction Motors Using q-Axis Flux with Stator Resistance Identification" IEEE Transaction on Power Electronics, vol. 48, no. 1, February 2001.
6. Zsolt Beres and Peter Vranka, "FOC of Induction Motor With Current Regulators in Current Reference Frame" IEEE Transaction on Power Electronics, vol. 47, no. 4, august 2001.
7. Domenico Casadei, Francesco Profumo and Giovanni Serra, "FOC and DTC: Two Viable Schemes for Induction Motors Torque Control" IEEE Transaction on Power Electronics, vol. 17, no. 5, September 2002.
8. Adnan Derdiyok, Mustafa K. Guven, Habib-ur Rehman, Nihat Inanc, and Longya Xu, "Design and Implementation of a New Sliding-Mode Observer for Speed-Sensor less Control of Induction Machine" IEEE Transaction on Power Electronics, vol. 49, no. 5, October 2002.
9. Adnan Derdiyok, Habib-ur Rehman, "A New Current Model Flux Observer for Wide Speed Range Sensor less Control of an Induction Machine" IEEE Transaction on Power Electronics, vol. 17, no. 6, November 2002.
10. Makouf, M. E. H. Benbouzid, "A Practical Scheme for Induction Motor Speed Sensor Field-Oriented Control" IEEE Transaction on Power Electronics, vol. 19, no. 1, March 2004.
11. Roberto Cardenas and Ruben Pena, "Sensor less Vector Control of Induction Machines for Variable-Speed Wind Energy Applications" IEEE Transaction on Power Electronics, vol. 19, no. 3, March 2004.
12. Young Ahn Kwon, "A New Scheme for Speed-Sensor less Control of Induction Motor" IEEE Transaction on Power Electronics, vol. 51, no. 3, June 2004
13. Janne Salomaki, Marko Hinkkanen, and Jorma Luomi, "Sensor less Control of Induction Motor Drives Equipped With Inverter Output Filter" IEEE Transaction on Power Electronics, vol. 53, no. 4, August 2006.
14. Heising, V. Staudt, A. Steimel, "Speed-sensor less stator-flux-oriented control of induction motor drives in traction", IEEE Symposium on Sensor less Control for Electrical Drives, 2010, pp.100-106.
15. Soufyane Chekroun and Abdelkader Mechernene, "A Robust MRAS-Sensor less Scheme Based Rotor and Stator Resistances Estimation of a Direct Vector Controlled Induction Motor Drive" IEEE Transaction on Power Electronics, vol. 53, no. 4, July 2011.
16. T. Raghu, J. Srinivas Rao, and S. Chandra Sekhar, "Simulation of Sensor less Speed Control of Induction Motor Using APFO Technique" International Journal of Computer and Electrical Engineering, Vol. 4, No. 4, August 2012.
17. D. Stando and M. P. Kazmierkowski, "Novel Speed Sensor less DTC-SVM Scheme for Induction Motor Drives" IEEE Transaction on Power Electronics, vol. 52, no. 4, August 2013.
18. Amir Dadashnialehi, Alireza Bab-Hadiashar, Zhenwei Cao, and Ajay Kapoor "Intelligent Sensor less ABS for In-Wheel Electric Vehicles" IEEE Transaction on Power Electronics, vol. 61, no. 4, April 2014.

19. J. M. Liu and Z. Q. Zhu, "Novel sensor less control strategy with injection of high-frequency pulsating carrier signal into stationary reference frame" IEEE Trans. Ind. Appl., vol. 50, no. 4, pp. 2574–2583, July /Aug. 2014.
20. G. R. Slemon and A. Straughen, Electrical machines, Addison-Wesley, reading, MA, 1980.
21. W. Leonard, control of electrical drives, Springer – Verlag, New York, 1985.
22. B. K. Bose, Power electronics and AC drives, prentice-hall, Englewood cliffs, NJ, 1986.
23. B. W. Williams, Power electronics, Devices, and applications, Wiley, New York, 1987.
24. M. H. Rashid, Power Electronics: circuits, devices, and applications, Prentice-Hall, Englewood cliffs, NJ, 1988.
25. P. Vas, Sensor less Vector and Direct Torque Control of AC Machine.
26. London, U.K.: Oxford Univ. Press, 1998.
27. R. K. Bansal, A. K. Goel, and M. K. Sharma MATLAB and its applications in engineering Delhi: Dorling Kindersley, 2009.
28. Dr. Shailendra Jain, modeling and simulation using MATLAB-SIMULINK, Wiley India, 2011.