"VARIOUS SPEED CONTROL TECHNIQUES OF THREE PHASE INDUCTION MOTOR"

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Abstract— This paper presents Space Vector Modulation of Inverter fed with three phase Induction Motor using MatLab Simulation. Induction motors are the most widely used electrical motors due to their reliability, low cost and robustness. However, induction motors do not inherently have the capability of variable speed operation. Due to this reason, earlier dc motors were applied in most of the electrical drives. But the recent developments in speed control methods of the induction motor have led to their large scale use in almost all electrical drives. Voltage control is required to meet the variation in the input voltage and to regulate the output of the inverter and it is an algorithm for the control of Pulse Width Modulation technique. SVM gives better harmonic response and higher efficiency compared to pulse width modulation techniques.

Keywords- SVM Technique, PI Control, Speed control method, VSI bridge inverter, MatLab.

I. INTRODUCTION

Pulse Width Modulated (PWM) inverter systems are used in a wide variety of applications as a front-end power conditioning unit in Electric drives, Uninterruptible power supplies, High Voltage DC transmission, Active power filters, reactive power compensators in power systems, Electric vehicles, Alternate energy systems and Industrial processes. The inverters realize dc-to-ac power conversion and in the most commonly used voltage source inverter configuration. The dc-input voltage can be obtained from a diode rectifier or from another dc source such as a battery. A typical voltage source PWM inverter system consists of rectifier, DC-link, PWM inverter along with associated control circuit and the load. Most modern voltage source inverters are controlled using a wide variety of pulse width modulation schemes, to obtain output ac voltages of the desired magnitude and frequency shaped as closely as possible to a since wave. Analysis of PWM inverter system is required to determine the input-output characteristics for an application specific design, which is used in the development and implementation of the appropriate control algorithm. In addition to time domain analysis, harmonic assessment is an integral part of analysis and simulation of any power conversion system.00

II. THREE PHASE INDUCTION MOTOR AND TRANSIENT MODEL

Based on the construction of the rotor, a 3-induction motor can be categorized into two types:

1.Squirrel Cage Induction Motor

2.Slip Ring Induction Motor

The stator of both types of motors consists of a three phase balanced distributed winding with each phase mechanically separated in space by 120 degrees from the other two phase windings. This gives rise to a rotating magnetic field when current flows through the stator. In squirrel cage IM, the rotor consists of longitudinal conductor bars which are shorted at ends by circular conducting rings. Whereas, the wound rotor IM has a 3-balanced distributed winding even on the rotor side with as many number of poles as in the stator winding A model of a 3-ϕ induction motor was setup in matlab simulink and the rotor and stator currents, speed, electromagnetic torque and the Torque-Speed characteristics were observed with different values of rotor and stator resistances and impedances.

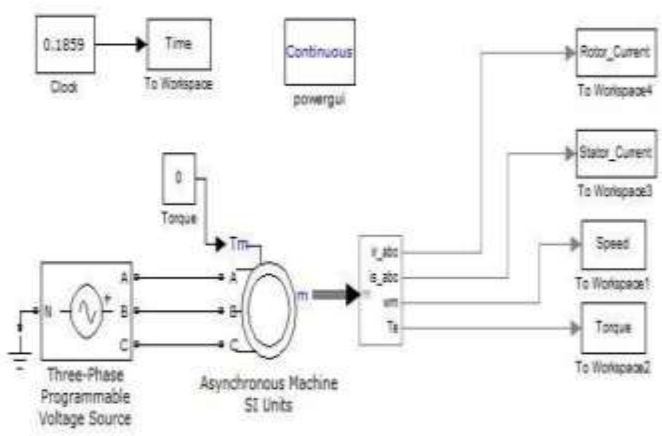


Fig.1 Transient model of Induction Motor

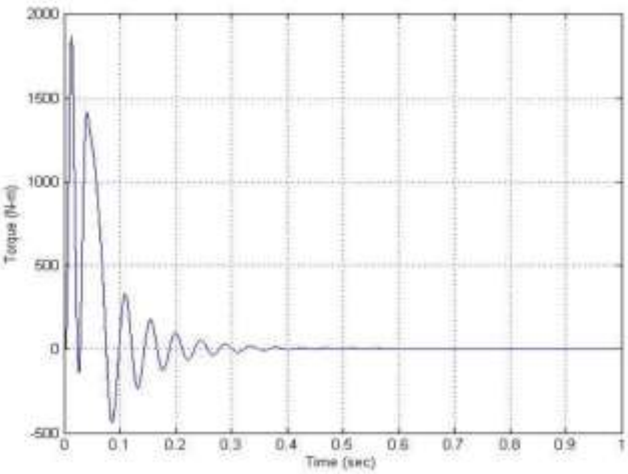


Fig. 2 Speed Vs Time

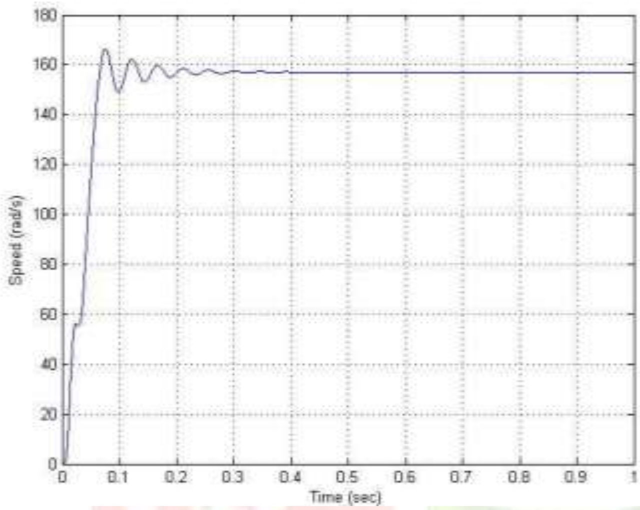


Fig. 3 Torque Vs Time

III. ANALYSIS OF VARIOUS METHODS FOR SPEED CONTROL OF INDUCTION MOTOR

The various methods of speed control of 3-ϕ Induction motor are as under

1. Variable rotor resistance control
2. Variable supply voltage control
3. Constant V/f control
4. Vector Control

3.1 Variable Rotor Resistance control

This method is applicable only to the wound rotor motor as external resistance can be added to it through the slip rings. A MATLAB code was developed to observe the variation in Torque-Speed characteristics of a 3-ϕ induction motor with variable rotor resistance and the output Torque-Speed characteristics are shown in Figure 3.1. External resistances can be connected in the rotor circuit during starting. This increases the starting torque and reduces the starting current. By making use of appropriate value of resistors, the maximum torque can be made to appear during starting. This can be used in applications requiring high starting torque. Once the motor is started, the external resistance can be cut out to obtain high torque throughout the accelerating range.

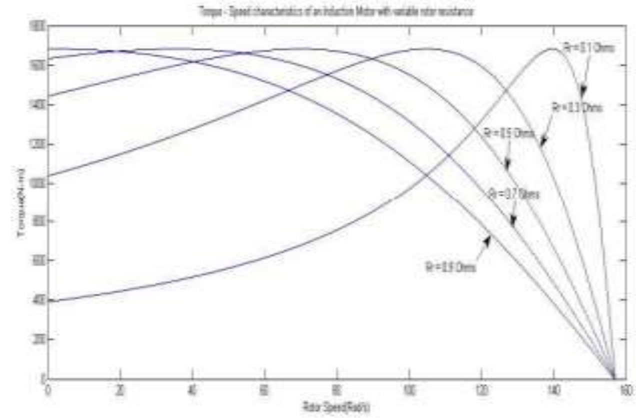


Fig.4 Torque Vs Rotor Speed

3.2 Variable supply voltage control

The torque developed by an induction motor varies as square of the voltage applied to its stator terminals. Thus by varying the applied voltage, the electromagnetic torque developed by the motor can be varied. This method is generally used for small squirrel-cage motors where cost is an important criterion and efficiency is not. However, this method has rather limited range of speed control. As the supply voltage is decreased, the value of maximum torque also decreases. However it still occurs at the same slip as earlier. Even the starting torque and the overall torque reduce. Thus the machine is highly underutilized. Thus this method of speed control has very limited applications.

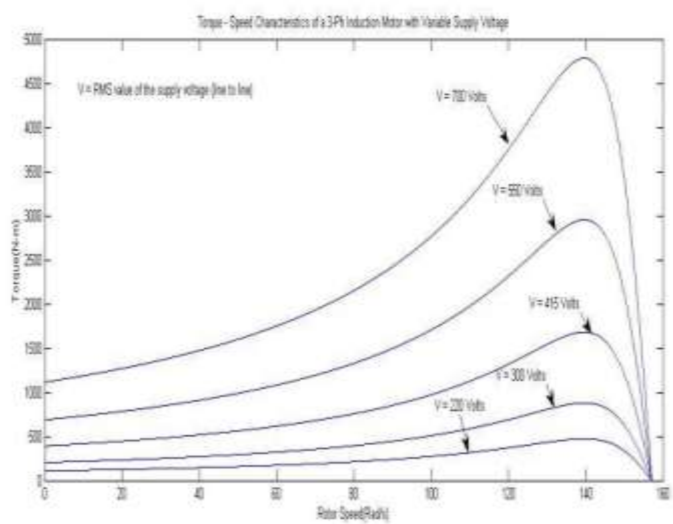


Fig. 4 Torque Vs Rotor Speed

3.3 Constant V/f Control

We vary the stator voltage in such a way that the flux remains constant by simultaneously varying the supply frequency such that the ratio V/f remains constant. The AC supply is rectified and then applied to a PWM inverter to obtain a variable frequency, variable magnitude 3-ϕ AC supply. The electromagnetic torque developed by the motor is directly the stator and the flux produced by the stator is proportional to the ratio of applied voltage and frequency of supply. Therefore, by varying the voltage and frequency by the same ratio, flux and hence, the torque can be kept constant throughout the speed range. This makes constant V/f method the most common speed control method of an induction motor

3.3.1 Closed Loop V/f speed control method

The basis of constant V/f speed control of induction motor is to apply a variable magnitude and variable frequency voltage to the motor. Both the voltage source inverter and current source inverters are used in adjustable speed ac drives. The following block diagram shows the closed loop V/f control using a VSI.A speed sensor or a shaft position encoder is used to obtain the actual speed of the motor. It is then compared to a reference speed. The difference between the two generates an error and the error so obtained is processed in a Proportional controller and its output sets the inverter frequency. The synchronous speed, obtained by adding actual speed ωf and the slip speed ωsl, determines the inverter frequency. The reference signal for the closed-loop control of the machine terminal voltage Vs is generated from frequency.

3.4 Vector Control Method

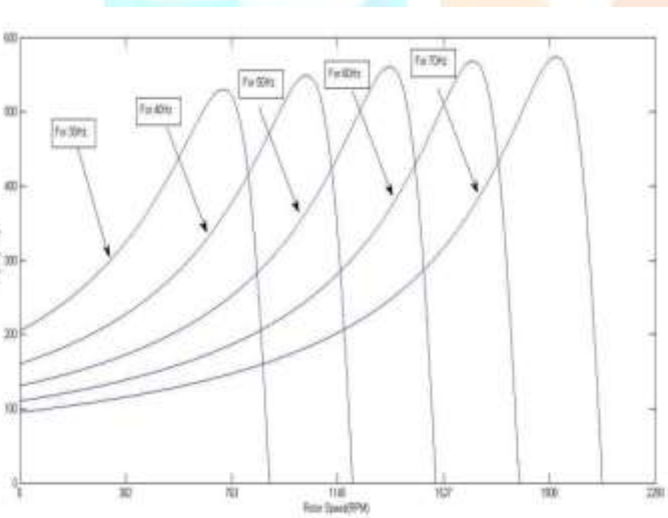
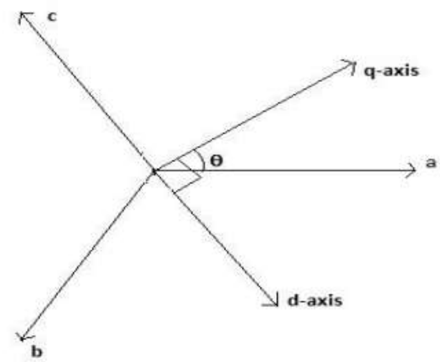


Fig.5 Speed Vs Torque

The induction motor is the most widely used electrical motor due to its rugged structure, low cost and reliability. However, the nonlinearity in the Torque-Voltage relationship of an IM makes its analysis difficult. Also it is a fifth order system making its dynamic response poor. Development of Vector Control analysis has enabled us to get as good dynamic performance from an IM as a dc motor. The torque and the flux components can be controlled independently using vector control just like in a dc motor. In order to analyses vector control, we need to develop a dynamic model of the IM. This is done by converting the 3-ϕ quantities into 2-axes system called the d-axis and the q-axis. Such a conversion is called axes transformation. The d-q axes can be chosen to be stationary or rotating. Further, the rotating frame can either be the rotor oriented or magnetizing flux oriented. However, synchronous reference frame in which the d-axis is aligned with the rotor flux is found to be the most convenient from analysis point of view. A major disadvantage of the per phase equivalent circuit analysis is that it is valid only if the three-phase system is balanced. Any imbalance in the system leads to erroneous analysis. Even this problem is eradicated if we use the d-q model.



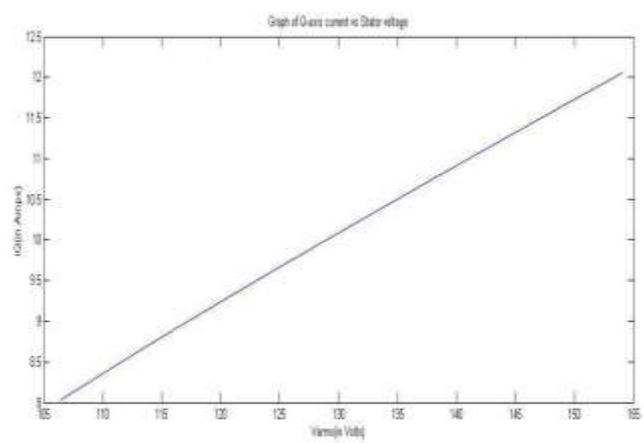


Fig.6 d-q transformation

Fig.7 Variation of q axis stator current with change in stator voltage

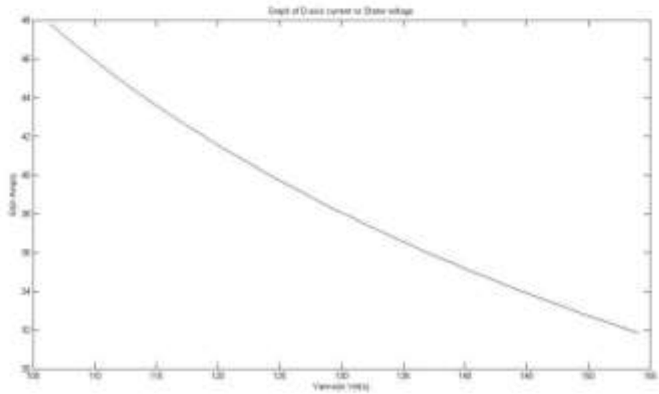


Fig.8 Variation of d axis stator current with change in stator voltage

IV. CONCLUSION

Torque-Speed characteristics for different methods of speed control of an IM were obtained and analyzed by developing MATLAB codes. In rotor resistance control method, the starting torque can be varied with the variation of rotor resistance. The maximum torque however, remains unaffected. Thus for operations requiring high starting torque, the rotor resistance can be varied to even obtain the maximum torque during starting. But simultaneously the copper losses will increase due to increase of resistance. So this method is highly inefficient and cannot be used throughout the operation. In variable supply voltage control method of speed control, the maximum torque decreases with the decrease of supply voltage and thus the motor remains underutilized. So even this method cannot be used for good performance. In constant control, by use of rectifier and PWM inverter, we can vary the supply voltage as well as the supply frequency such that the ratio remains constant so that the flux remains constant too. So we can get different operating zone for various speeds and torques and also we can get different synchronous speed with almost same maximum torque. Thus the motor is completely utilized and also we have a good range of speed control. Also from the SIMULINK model for the starting of an induction motor with varying parameters, it was deduced that the stator resistance must be kept as low as possible so as to reduce the steady state time during starting and also to obtain a smoother start. Increasing the rotor resistance leads to increase in the starting torque (maximum torque occurs at a lesser speed) however, it also leads to a jerky start. Decreasing the inductance (either rotor or stator) lets the machine achieve its steady state quicker with slightly lesser jerks. The traditional per phase equivalent circuit analysis of an induction motor has the disadvantage that it is valid only if the system is a balanced one. Any imbalance in the system leads to erroneous analysis. Also the dynamic response of the motor cannot be obtained from the per phase equivalent circuit. The vector control method or the d-q axes model leads to a simpler analysis of an induction motor. A d-q axes model with the d-axis aligned along the synchronously rotating rotor frame, leads to the decoupled analysis where the torque and the flux components can be independently controlled just like in case of a dc motor.

V. REFERENCES

[1] Gopal K. Dubey, “Fundamental Of Electrical Drives”, Narosa Publication House, Second Edition, 2011

[2] A. E. Fitzgerald, Charles Kingsley, Jr. And Stephan D. Umans, “Electrical Machinery”, McGraw-Hills Publications, Year 2002

[3] “IEEE Standard Test Procedure for Polyphase Induction Motors and Generators”, volume 112, issue 1996 of IEEE, by IEEE Power Engineering Society

[4] Scott Wade, Matthew W. Dunnigan, and Barry W. Williams, “Modelling and Simulation of Induction Machine Vector Control with Rotor Resistance Identification”, IEEE transactions on power electronics, vol. 12, no. 3, may 1997.

[5] D.W. Novotney, et al (editor), “Introduction to Field Orientation and High Performance AC drives”, IEEE IAS tutorial course, 1986.

[6] Ramon BlascoBlasco Gimenez, “High Performance Sensorless Vector Control of Induction Motor Drives”, The University of Nottingham, December 1995.