International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031(Online)
www.ijlret.com ‖ Volume 1 Issue 2‖ July 2015 ‖ PP.01-08

Control of induction machine connected through long cable and Isolation Transformer

Dr. Uma Shankar S
Asso. Prof.
Power Electronics and Drives
SELECT,
Vellore India

Prem Sai
Power Electronics and Drives
SELECT,
Vellore, India

Dhanesh Choudhary
Power Electronics and Drives
SELECT,
Vellore, India

Mayank Varshney
Power Electronics and Drives
SELECT,
Vellore, India

Abstract- It is always a general wondering that which method is better for the controlling of speed of induction motor. This paper deals with the control of induction machine connected through a 2Km long cable and isolation transformer using different control strategies and then comparing the simulation results and various other factors that affect the working of induction motor. This paper deals with V/Hz control and Field oriented control. It uses SVPWM to produce the gating signal and the above controls vary the reference voltage of the SVPWM to produce the desired output voltage. MATLAB/SIMULINK is used to perform the simulation in this paper and the results of that are presented to show the effectiveness of the control strategies.

I. INTRODUCTION

It is often compared amongst the various method of speed control of an induction motor to decide which method is the best. The most conventional method of speed control is Volts/Hz control. In this control the flux in the machine is kept constant by varying voltage and the frequency in equal proportions. But since this method takes only magnitude into considerations there are distortion in the output and also superior control over the speed is not attained. Therefore a better Control technique had to be implemented which takes phase along with the magnitude and frequency into consideration. This led to the study of vector control of induction motor. The vector control is further classifiedinto two categories. If voltage and current measurement along with speed or hall sensors are employed then it is called direct vector control [12]. If only machine parameters are used then it comes under indirect vector control [12]. Field oriented control is one of the methods which are used forcontrol of speed as well as torque. In this method the current is resolved into two components, both in quadrature to each other and independent of each other. The first current is responsible for the production of flux and the other one in the production of torque. Therefore an independent control over flux and thereby speed, and torque is attained. In this paper the control of an induction motor using both of the above methods is shown along with their simulation results. The induction motor is connected to the inverter through a 2Km long ∏-section line and an isolation transformer along with the AC filter and series reactor. The gating signals are generated using SVPWM technique and are given to the neutral point clamped inverter (NPC). The NPC inverter used produces a three level output voltage. The Fig.1.1 shows the block diagram and the power flow in the circuitry. A 3-Φ diode rectifier along with an output LC filter to convert the input AC supply to DC is connected so that it can be fed to the Adjustable speed drive (Inverter).

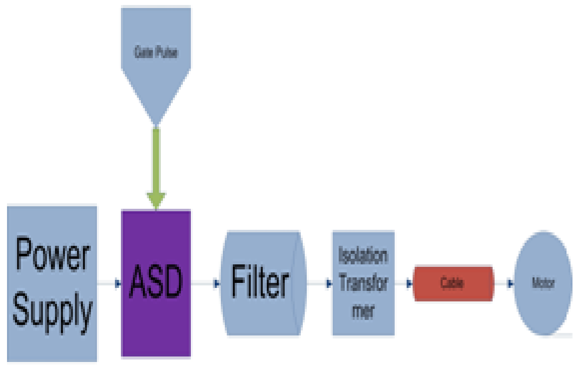


Fig 1.1 Block Diagram representing the power flow

II.NPC INVERTER AND SVPWM

The NPC inverter, as mentioned above, is a 3 level inverter. Fig.2.1 shows the circuit diagram of a three level NPC inverter. For a three level NPC inverter 27 switching states are required. If both of the top switches are ON then the switching state is said to be +1. If both of the bottom switches are ON then it is -1. If the middle two switches are ON then it is 0 [4]. If the switching state of all the three phases is same, like (-1,-1,-1), (+1,+1,+1),

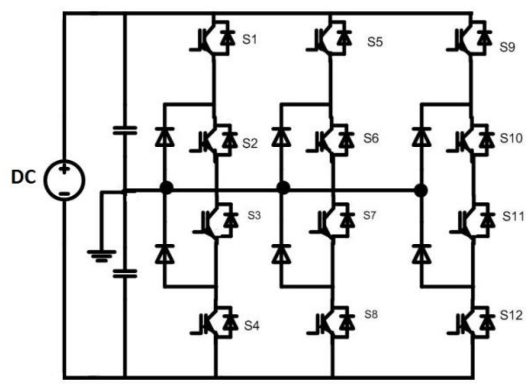


Fig. 2.1 3 level NPC Inverter

(0,0,0),then the vector obtained is called Zero Vector [5]. The Fig.2.2 shows all the 27 states in the form of a hexagon with the three zero vectors at the center. Each triangle in the hexagon is a sector. To determine in which sector the reference rotating vector is the following steps are followed.

- Consider the outermost hexagon as a 2 level hexagon and determine the sector in which the Reference vector is [3].
- Then sub divide each sector into four equal sectors as shown in the Fig. 2.3 and calculate the exact position of the reference vector [3].

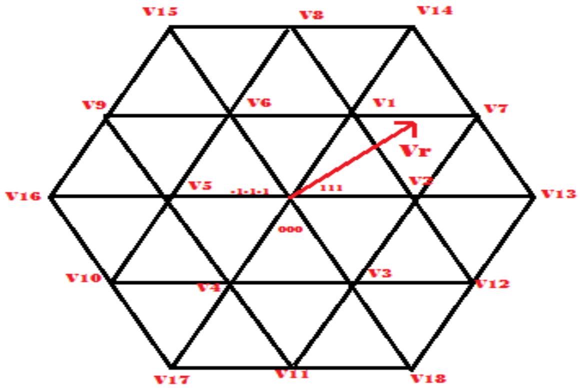


Fig. 2.2 State Diagram

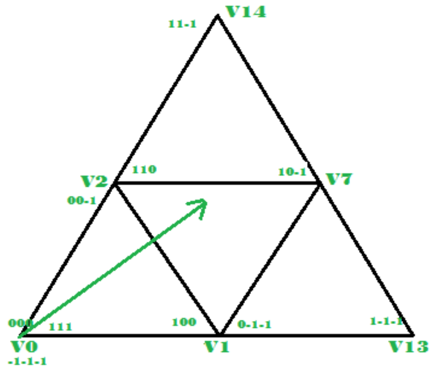


Fig. 2.3 Selected Sector

The selection of the sector is shown in the following flow chart in the Fig. 2.4. The selection of inter sector is also similar to the process employed in the flow chart. After selecting the sector the ting signal are generated [1].

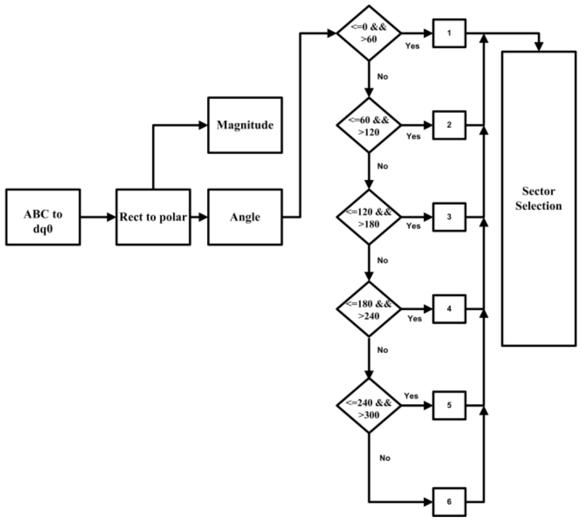


Fig. 2.4 Flow Chart showing sector selection

III. VOLTS PER HERTZ CONTROL

It is nothing but a scalar control which takes only magnitude into consideration. The speed variation is achieved by varying the input voltage as speed is directly proportional to the square of the voltage [13]. But along with the change in voltage the frequency is also varied so that the ratio of the voltage to frequency is kept constant (hence the name V/Hz control) and thereby keeping the flux constant. The flux is not allowed to vary because with the increase in flux iron losses increases and also the core might get saturated resulting in the increase in magnetizing current [12].

In this paper an open loop control of an induction motor connected through a 2Km long cable and isolation transformer using V/Hz control and SVPWM technique is presented. The Fig. 3.1 shows the block diagram of the proposed V/Hz control.

A desired value of speed is given as the reference speed input. Using this speed the value of the frequency is calculated, assuming a 4 pole induction machine, and thenthe peak value of the phase RMS voltage is calculated in the Voltage and flux calculator block. From this the reference voltages are calculated and converted to αβ0 plane and then the gating signals are generated using SVPWM technique. These pulses are given to the inverter and the output voltage is provided to the IM through the cable and isolation transformer.

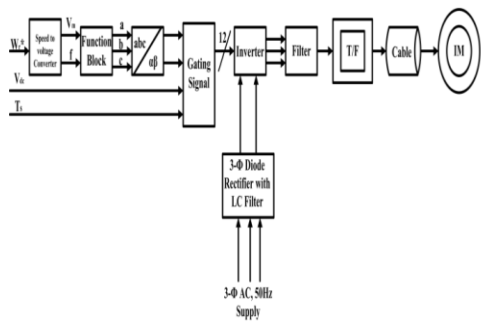


Fig. 3.1 Blok Diagram for V/Hz Control

IV. FOC CONTROL

FOC is a closed loop control technique which takes even phase into consideration along with magnitude and frequency. As explained above after resolving the current into two components the magnitude and angle is calculated. This is again, along with the speed is given back as feedback.

The FOC control used in this paper is RFOC. Hence all the calculations are using rotor reference frame and rotor parameters. The Fig. 4.1 shows the block diagram of FOC Control [12]. A speed reference signal (ω_r*) is given which is compared with the actual speed and the error is given to the speed controller which calculates the reference torque (T_e*). From this torque reference i_q* is calculated. The blocks flux converter, magnitude and angle resolver (MAR), torque and current estimator are based on simple mathematical relations between currents, flux linkage, speed and torque [8].

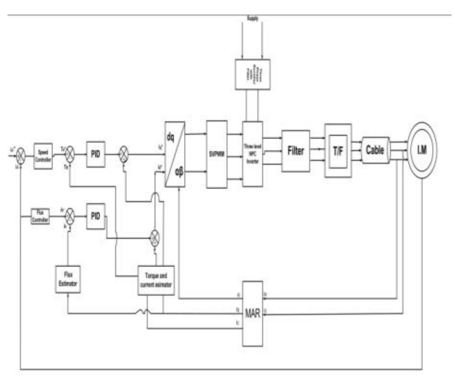


Fig. 3.1 Block Diagram for FOC Control

The timing signals generated is then fed to SVPWM block which then will produce the gating signal. The simulation results of FOC are presented in the next segment.

V. SIMULATION RESULTS

This section of the paper shows the final output results. The data assumed for the simulation is shown below in the Table 5.1.

S.No.	Parameters	Value
1	V_{dc}	450V
2	Sampling Frequency	1KHz
3	Reference Speed (ω_r*)	150rad/s to 110rad/s
4	Cable	R = 0.0754Ω/Km L= $5.04*10^{-4}$ H/Km C=0.84μF/Km
5	Torque	2N-m
6	Induction Motor	4KW,400V,50Hz,4 pole, 1430rpm

Table 5.1 Assumed Data for the simulation

V (A). VOLTS PER HERTZ CONTROL

In this segment the simulation results for V/Hz method with and without cable and isolation transformer are shown. The THD analysis and dv/dt, di/dt stress for the switch are also presented. Fig. 5.1.1 shows the change in speed and torque as the reference speed decreases from 150rad/s to 110rad/s. Fig 5.1.2 shows the change in voltage magnitude and its frequency once the reference speed is changed, thereby keeping the V/Hz ratio constant. The above mentioned figures are for the circuit without cable and isolation transformer. Fig. 5.1.3 and Fig. 5.1.4 show the same for the circuit with cable and isolation transformer.

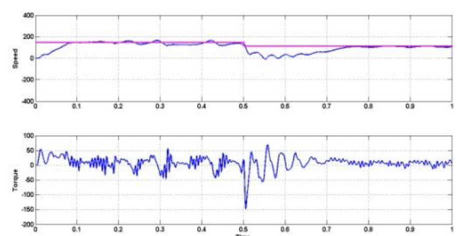


Fig. 5.1.1 Speed and torque of induction motor without cable and isolation transformer

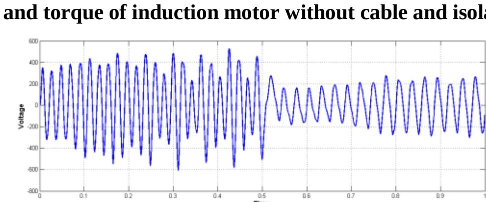
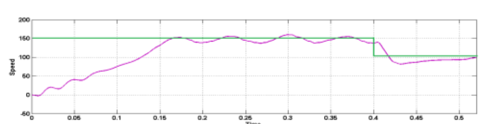


Fig. 5.1.2 Voltage waveform of induction trnsformer without cable and isolation transformer



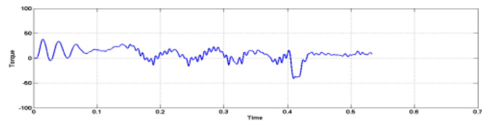


Fig. 5.1.1 Speed and torque of induction motor with cable and isolation transformer

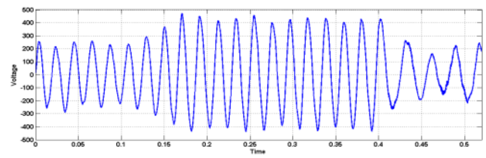


Fig. 5.1.2 Voltage waveform of induction trnsformer with cable and isolation transformer

The variations in the voltage waveform and speed and torque waveforms are clearly visible n waveforms. The voltage is made more sinusoidal using a LC filter. The ripples in the torque are reduced by using a series reactor.Further important parameters relating the switch and the induction motor are presented below in the Table 5.2 for both the cases including and excluding the isolation transformer and cable.

Parameters	**With cable and Isolation Transformer**	**Without cable and Isolation Transformer**
dv/dt stress on switch	140KV/μs	75KV/μs
di/dt stress on switch	65KA/μs	220KA/μs
Voltage THD	5.34%	6.18%
CurrentTHD	33.89%	22.45%

Table 5.2 Results for V/Hz control

V (B). FOC CONTROL

The simulation results for FOC control are presented in this segment for both the cases including and excluding the cable and isolation transformer. Fig. 5.2.1 and Fig. 5.2.2 show the speed and torque and voltage waveforms of induction motor without cable and isolation transformer and Fig. 5.2.3 and Fig. 5.2.4 show the same including them.

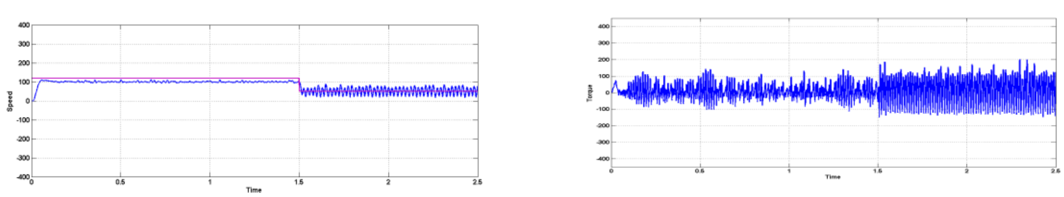


Fig. 5.2.1 Speed and Torque Waveforms without Cable and Isolation Transformer

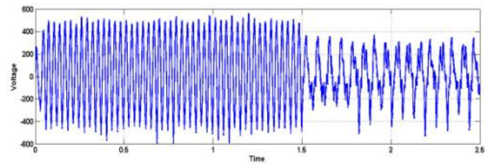


Fig. 5.2.4 Voltage Waveforms without Cable and Isolation Transformer

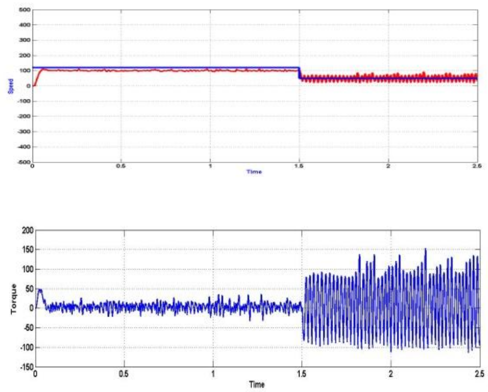


Fig. 5.2.3 Speed and Torque Waveforms with Cable and Isolation Transformer.

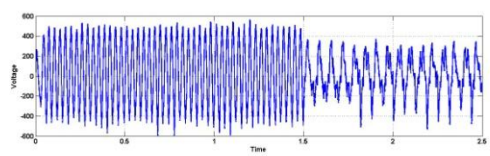


Fig. 5.2.4 Voltage Waveforms with Cable and Isolation Transformer

The ripples in the torque are increasing as the speed is decreasing resulting in the increase of Torque mean value. The error between the reference speed and the actual speed is reduced with the use of a PID controller. The change in frequency and magnitude is clearly visible from the voltage waveforms.

The other important parameters relating the switch and the induction motor are listed below in Table 4.2

Parameters	With cable and Isolation Transformer	Without cable and Isolation Transformer
dv/dt stress on switch	90KV/ns	23.39KV/μs
di/dt stress on switch	2.19KA/ps	7.5KA/μs
Voltage THD	19%	8.24%
CurrentTHD	30%	32%

Table 5.2 Results for FOC Control

VI. CONCLUSION

V/Hz control is an optimum control technique where cost and space is an important criterion. The efficiency of the system and the stability of the system is less as it is an open loop system. Moreover the proposed control had no controller to reduce the settling time and the steady state error.

In FOC control a proper closed control along with various controllers is implemented reducing both the settling time and steady state error. The decoupling is effectively achieved and a good control over the machine is achieved. Hence with respect to the stability and efficiency this method is better than V/Hz method. However the THD of both voltage and current waveforms is less in V/Hz control when compared to FOC Control.

The Isolation transformer provides a separation between the inverter and cable which reduced the stress on the switches but still the stress on the switches is increased when the cable is connected and which forces to use a switch of higher rating. However that results in the increase in cost of the system. This control along with cable finds its applications in the oil industries.

REFERENCES

[1]. P. M. Meshram, Dipesh Hanote, M. M. Renge. "A Simplified Space -Vector PWM for Three Level Inverters Applied to Passive and Motor Load" 978-1-4244-2800-7/09/$25.00 ©2009 IEEE.

[2]. Chalasani Hari Krishna ,J. Amarnath, and S Kamakshiah. "A Simplified SVPWM Algorithm for Multi-Level Inverter fed DTC of Induction Motor Drive"International Journal of Engineering and Innovative Technology (IJEIT) Volume 1, Issue 4, April 2012.

[3]. P.Satish Kumar,J.Amarnath and V.L.narasimham "An Effective Space-Vector PWM Method for Multi-level Inverter Based on Two-level Inverter" International Journal of Computer and Electrical Engineering, Vol. 2, No.2, April, 2010 1793-8163

[4]. Ning-Yi Dai, Man-Chung Wong,Ying-Duo Han. "Application of a Three-level NPC Inverter as aThree-Phase Four-Wire Power QualityCompensator by Generalized 3DSVM",ieee transactions on power electronics, vol. 21, no. 2, march 2006.

[5]. Youngroc kim, hanju cha, Byeong-mun song, Kwang y. Lee," Design and Control of a Grid-Connected Three-Phase 3-Level NPC Inverter for Building Integrated Photovoltaic Systems" 978-1-4577-2159-5/12/$31.00 ©2011 ieee

[6]. Amit Kumar Gupta, Ashwin M. Khambadkone, ieee"A General Space Vector PWM Algorithm forMultilevel Inverters, Including Operation in Over modulation Range" ieee transactions on power electronics, vol. 22, no. 2, march 2007.

[7]. Hengameh kojooyan jafari, ahmad radan," Improved Design of Three-Level NPC Inverters in Comparison to Two-Level Inverters", wseas transactions on circuits and systems.

[8]. "Field Orientated Control of 3-Phase AC-Motors", Literature Number: BPRA073Texas Instruments Europe, February.

[9]. Kwon, H.-J., Kim, B.-W.: Design of Long Distance Cable and Filter Considering the Subsea Environment, Journal of the Korea Academia-Industrial cooperation Society. 14, No.10, pp. 5105--5114 (2013)

[10]. Kil, G.-S., Ryu, K.-S., Park, D.-W., Cho, Y.-J., Cheon, S.-G., Choi, S.-Y.: Measurement and Analysis of Transient Voltage for an Inverter-fed Induction Motor, The Korean Society for Railway. 10, Issue 6, pp. 650--654 (2007)

[11]. Han, H.-S., Song, J.-H., Ahn, H.-S.: The Correlation Study of Factors which Effect on Insulation Reliability of Inverter Motor, EESRI (Electrical Engineering and Science Research Institute), pp. 18--20 (2008).

[12]. Electric Motor Drives: Modeling, Analysis and Control, by R.Krishnan.

[13]. Walid Emar, Hussein Sarhan, Rateb Al-Issa, Issam TTrad, "V/F Control of Squirrel Cage Induction Motor Drives Without Flux or Torque Measurement Dependency", International Journal of Robotics and Automation (IJRA), Volume (2) : Issue (2) : 2011.

[14]. Math Works, 2010, SimPowerSystems, User□ s Guide.