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CERTAIN INVESTIGATION ON INDUCTION MOTOR PERFORMANCE WITH VARIABLE FREQUENCY DRIVE

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Abstract - *Induction Motor (IM) plays an important role due to its low cost and simplicity which are widely used to control the speed of pumps, blowers, machine tools, conveyor systems and others applications that require variable speed with variable torque. Variable Frequency Drive (VFD) is a technique used to control the speed and frequency of AC Induction motors thus it is also called as adjustable speed drive or variable speed drive. VFD provides flexibility in starting, speed control and improves performance of induction motors. In this phenomenon, motor voltage and frequency is controlled using a Pulse Width Modulation (PWM) technique. The speed of the motor is compared with the speed of reference voltage and if any changes can be corrected by the generation of PWM pulses corresponding to the desired speed. These PWM pulses are then fed to a pulse modulated inverter whose AC output given to the motor controls the speed and runs the motor at the desired speed with reduction of harmonics, high starting torque and smooth speed control. The system was investigated, tested and simulation results are discussed. Simulation results are obtained using MATLAB /Simulink environment for effectiveness of the study.*

Key Words: **Pulse Width Modulation, Diode rectifier, Insulated Gate Bipolar Transistor, Induction Motor, Voltage Source Inverter, Variable Frequency Drive.**

1. INTRODUCTION

Induction Motor are widely used in many industries all over the world due to their robustness, reliability, high efficiency and its ability to operate in wide torque and velocity ranges as compared to DC motor.

In past, DC motor had been used extensively for its high starting torque and speed control in wide range. But due to the presence of commutators and brushes it is not suitable for high speed applications, as it requires continuous maintenance. It is not suitable in corrosive and explosive environment. Therefore it has limited applications.

Induction motor has dominated over the fixed application because of its low maintenance. Its variable speed application can be achieved by using frequency converters i.e. power converter control technique using between the main supply and motor, which means that motor, is not directly connected to the supply [1]. Figure 1 shows the construction of Induction motor.

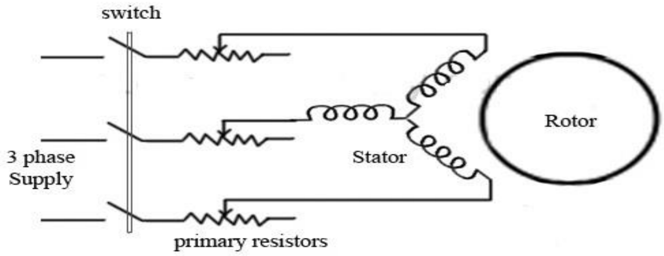

Fig -1: Construction of Induction motor

The Speed of Induction Motor is given by,

$$N_s = (120\ F) / P$$

Where,

Ns = Synchronous speed of the stator magnetic field

P = Number of poles on the stator

F = Supply frequency in Hertz

2. VARIABLE FREQUENCY DRIVE

VFD is used in industries due to its starting, flexible speed control and operating characteristics of Induction motor. A Variable Frequency Drive (VFD) also termed as Adjustable Frequency Drive, Variable Voltage Variable Frequency (VVVF) Drive. By varying the motor input frequency and voltage, we can control the speed and torque [2-5].

A variable-frequency drive consists of AC motor, main drive controller assembly and operator interface [3-5]. The block diagram of VFD is shown in figure 2.

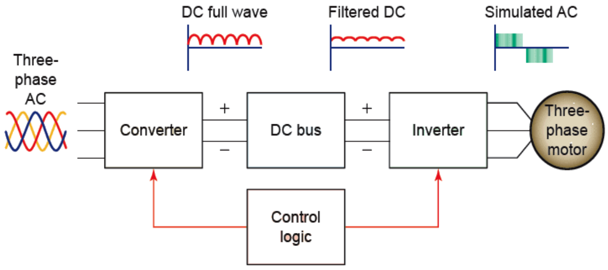

Fig -2: Block diagram of VFD

There are various application of variable frequency drive in different appliances like fans [6-7], pumps [7], tower cooling systems [8], micro wave ovens [9], air conditioners and ship propulsion systems [10]. Figure 3 shows the equivalent circuit of VFD controller.

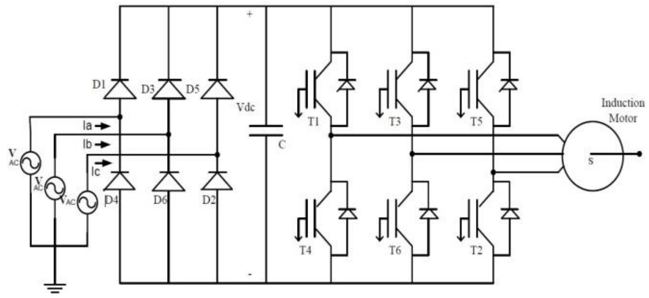

Fig- 3: Equivalent circuit of Variable Frequency Drive

The VFD controller consists of bridge rectifier, DC link and an inverter. The common solution engaged for ASDs is the Voltage Source Inverter (VSI) fed Induction motor. The inverter generates a Pulse Width Modulation (PWM) output voltage which makes multiple advantages such as efficiency up to 98%, low sensitivity to line transients, constant high input power factor, small in size, wide speed range and excellent speed regulation. In order to decrease the switching losses, fast switching devices like Insulated Gate Bipolar Transistors (IGBTs) are used.

The output current of inverter is regulated by a sine wave reference, created by PWM, the IGBTs are triggered at constant delay angle. In most of the drives, AC-AC that is, AC line input to AC inverter output is used. But, in a common DC bus or solar applications, drives are configured as DC-AC drives.

The rectifier converter for VSI drive is three phase, six-pulse, full wave diode bridge type. The DC link capacitor smoothen the DC output ripple and gives a solid input to the inverter circuit. This filtered DC voltage is converted into quasi-sinusoidal AC output voltage by switching mechanism. VSI drive provides high power factor and lower harmonic distortion when compared to CSI and LCI drives. The drive controller can be configured as a phase converter of single-phase converter input and three-phase inverter output.

2.1 Rectifier Stage

It converts Single or three phase AC input supply to fixed DC voltage. Rectifier used here is 3 phase full wave diode bridge rectifier which consist of 6 diodes connected as shown in figure 4. It includes transformer of high voltage system [15]. This rectifier section also called AC to DC converter [11]. In three phase full wave rectifier, six diodes are used. It is also called 6-diode half wave rectifier. In this type, each diode conducts for 1/6th part of the AC cycle.

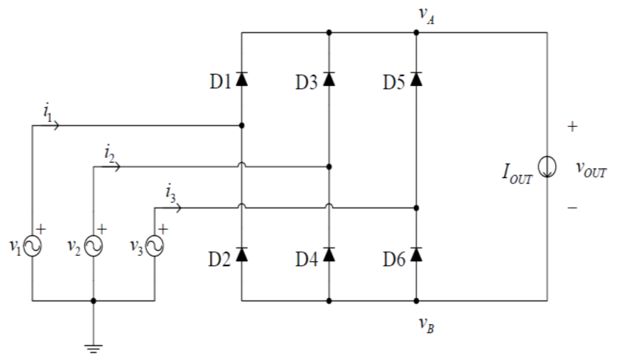

Fig -4: Three phase full wave diode bridge rectifier [16]

2.2 DC Link Bus

After rectification process, small amount of ripples (Harmonics) is detected along with dc voltage. It causes harmonic distortion. These ripples cause distortion and prevent smooth working of electrical appliances so they must be removed using a filter. So, a large capacitor is connected parallel with between rectifier and inverter which remove the ripples from dc voltage as shown in figure 5. It prevents the inverter from getting damage.

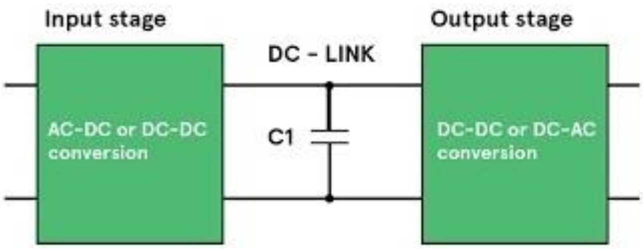

Fig -5: DC Link Bus

2.3 Inverter Section

It converts fix or variable dc voltage to variable ac voltage. Figure 6 shows three phase inverter having IGBT as the switching device. Now days, IGBT is a common choice for the selection of switching device for VFD. As it can switch ON and OFF several thousand times per seconds and control the power deliver to the induction motor. To generate the sine wave pulses or to trigger the switches, IGBT uses Pulse Width Modulation technique at desired frequency [17]. It is also called as PWM Inverter.

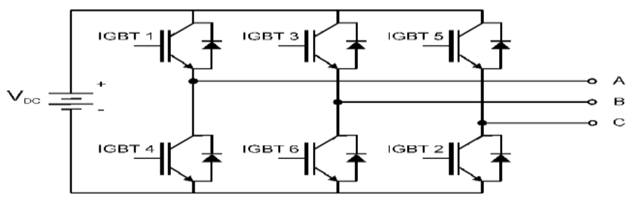

Fig -6: Three phase Inverter using IGBT

3. PULSE WIDTH MODULATION

Pulse width modulation is the basic technique used very widely for controlling motor speed and frequency [12]. Figure 7 shows the block diagram of PWM.

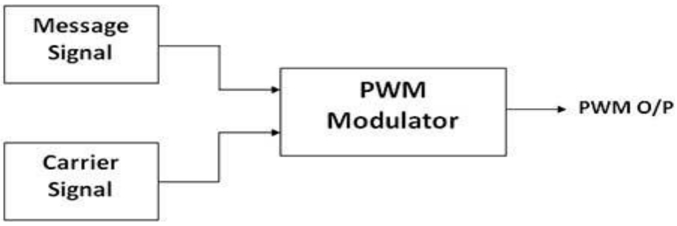

Fig -7: Block diagram of PWM

Here, two signals i.e. Carrier signal and Message signal are compared together with comparator. It compares both the waveforms and gives output as per requirement. The basic principle of PWM is a sine wave is generated in the microcontroller which is super imposed on a triangular wave [13]. This results in a square wave which is then fed to inverter section. The width of this square wave can be controlled by changing the duty cycles of the pulse. Basically duty cycles describes the time for which pulse waveform turned on and off thus by switching the waveform between two discrete levels the square wave is approximated with a sine wave of desired duty cycles. A PWM representation is shown in figure 8.

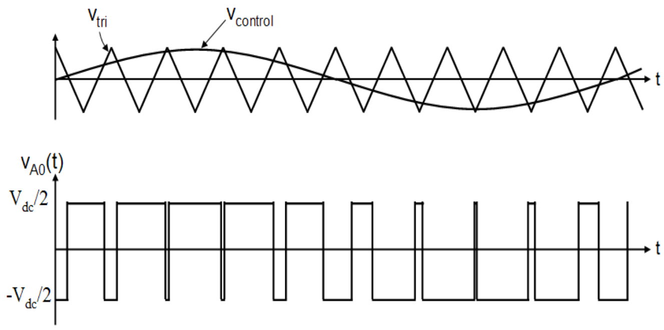

Fig -8: PWM Representation [14]

Combining a triangle wave and a sine wave produces the output voltage waveform. In which the triangular signal is the carrier/switching frequency of inverter. The modulation generator makes a sine wave that determines the pulse width as well as the RMS voltage output of the inverter.

4. SIMULATION ANALYSIS AND RESULTS

In this paper, a DC-AC inverter fed induction motor in Simulink/Matlab with PWM inverter controlling both the frequency and output voltage is developed. For generating PWM pulses, the sinusoidal control voltage is compared at the preferred output frequency with a chosen switching frequency triangular waveform. The harmonics present in the output voltage multiples in a PWM inverter. So, a high switching frequency results in an effectively sinusoidal current with a superimposed high frequency ripple in the motor.

The simulation model of VFD based Induction Motor Drive using PSIM is shown in figure 9. Results for SPWM inverter for connected resistive load are shown using MATLAB and PSIM. A constant 400 V DC supply is given to the inverter circuit. A 3 phase, 1 HP, 415 V, 50 Hz, 1400 RPM Induction motor is used. For triggering of the switches, SPWM is taken with modulation index less one. Various voltage, speed and torque waveforms are shown which are measured and compared. When changing in load occurs, the voltage and frequency are changed, but voltage upon frequency ratio is constant so speed is remaining constant.

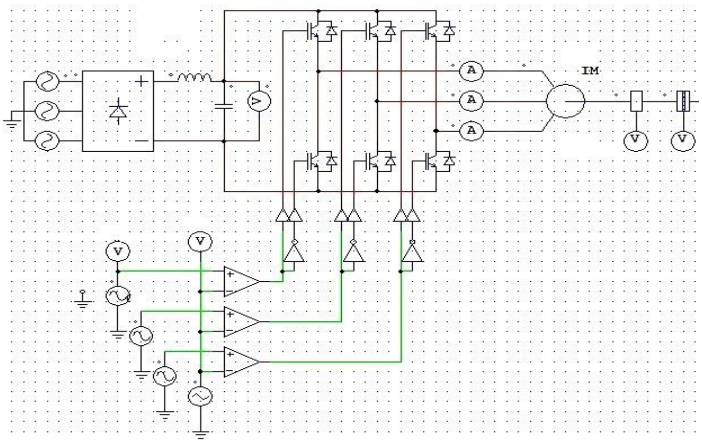

Fig -9: Simulation of VFD based induction motor drive

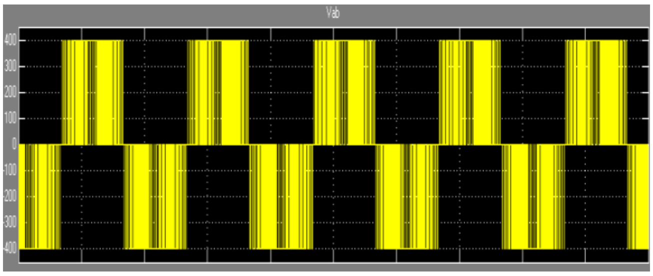

Fig -10: Waveform of line Voltage of 3-phase SPWM

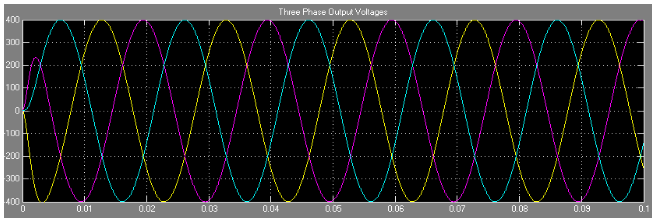

Fig -11: Waveform of Output Voltage of 3-phase SPWM

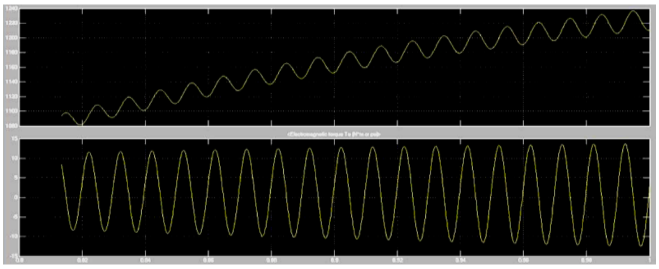

Fig -12: Motor speed and Torque developed

3. CONCLUSIONS

This paper has presented variable frequency drive in an induction motor. By the variable frequency drive, starting current and speed can be efficiently controlled by varying the supply voltage and frequency. Adding a variable frequency drive (VFD) to a motor-driven scheme may suggest potential energy savings in which the loads vary with time. It also provides less distortion, lower switching frequencies and high efficiency. The experimental results are also presented which shows that it has good performance, rapid dynamic response and has wide range of applications. VFD can be used for the number of applications of Induction motor and speed can be controlled as per the load. Hence, energy consumption gets reduced, more reliable and economically beneficial.

REFERENCES

[1] Puja Talukder, Prashant Kumar Soori, and Benetta Aranjo, "Speed Control of Induction Motor Drive Using Universal Controller", IEEE International Power Engineering and Optimization Conference (PEOCO2012), Melaka, Malaysia: 6-7 June 2012.

[2] Campbell, Sylvester J,"Solid-State AC Motor Controls", New York: Marcel Dekker, Inc. pp.79–189, 1987.

[3] Jaeschke, Ralph L, "Controlling Power Transmission Systems", Cleveland, OH: Penton/IPC. pp. 210–215, 1978.

[4] Siskind, Charles S, "Electrical Control Systems in Industry". New York: McGraw-Hill, Inc. pp. 224, 1963.

[5] NEMA Standards Publication, "Application Guide for AC Adjustable Speed Drive Systems", Rosslyn, VA USA: National Electrical Manufacturers Association (now The Association of Electrical Equipment and Medical Imaging Manufacturers). pp. 4. Retrieved Mar 27, 2008.

[6] B.K. Bose, "Variable frequency drives-technology and applications," in Industrial Electronics, 1993. Conference Proceedings, ISIE'93-Budapest., IEEE International Symposium on, 1993, pp. 1–18.

[7] A. Y. Roba, "Technical and Financial Analysis of Using Variable Frequency Drive for Water Pumps Compared with Fixed Frequency," National University, 2014.

[8] C. Holmes and M. Stark, Refrigerant cooled variable frequency drive and method for using same. Google Patents, 2003.

[9] S. Bell, T. J. Cookson, S. A. Cope, R. A. Epperly, A. Fischer, D. W. Schlegel, and G. L. Skibinski, "Experience with variable-frequency drives and motor bearing reliability," Ind. Appl. IEEE Trans. On, vol. 37, no. 5, pp. 1438–1446, 2001.

[10] T. J. McCoy, "Trends in ship electric propulsion," in Power Engineering Society Summer Meeting, 2002 IEEE, 2002, vol. 1, pp. 343–346.

[11] M.et.al.Ikonen, "Two-Level and Three-Level Converter Comparison in Wind Power Application", Lappeenranta University of Technology, 2005.

[12] G.S. Buja and M.P. Kazmierkowski, "Direct torque control of PWM inverter-fed AC motors-a survey," Ind. Electron. IEEE Trans. On, vol. 51, no. 4, pp. 744–757, 2004.

[13] J. R. Rodríguez, L. W. Dixon, J. R. Espinoza, J. Pontt, and P. Lezana, "PWM regenerative rectifiers: state of the art," Ind. Electron. IEEE Trans. On, vol. 52, no. 1, pp. 5–22, 2005.

[14] Syed Usama Hassan, Hafiz Bilal Akram, "Speed and Frequency Control of AC Induction Motor Using Variable Frequency Drive," Student Research Paper Conference Vol. 2, no. 56, July 2015.

[15] Ashish B. Bala, Prashant P. Jagtap, "Investigation in Induction Motor Starting and Speed Control with Variable Frequency Drive," International Research Journal of Engineering and Technology (IRJET), Vol. 3, no. 2, Feb 2016.

[16] Pejovic. P, "Three phase diode rectifiers with low harmonics current injection methods," Springer, Vol. 8, pp. 318, 2007.

[17] C.S. Sharma, Tali Nagwani, "Simulation and Analysis of PWM Inverter Fed Induction Motor Drive," International Journal of Science, Engineering and Technology Research (IJSETR), Vol. 2, no. 2, Feb 2013.