IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 09, Issue 5 (May. 2019), ||S (V) || PP 48-54

Operation of Asymmetrical Two Phase Induction Motor by Using Three-Leg Voltage Source Inverter

Mr. Abhishek M. Junghare, Dr. Pankaj B. Thote
Department of Electrical Engineering,S. B. Jain Institute of Engineering and Research,Nagpur, India.

Abstract: *Single phase induction motor is widely used for low power applications and domestic purpose, but it consists with its own losses and low starting torque. Single phase Induction motor can be used as asymmetrical two phase Induction motor which will run with two phase supply with more efficient results. Two phase supply can be obtained from Scott-T transformer for which three phase supply is needed. This method have its own disadvantage, the supply leads to unbalance in the system. The efficient technique is to generate two phase supply is by using two phase inverter by using sine pulse width modulation (SPWM) technique. The 16 bit Microcontroller and Digital signal controller dsPIC33EP256MC202 is used for SPWM signal generation.*
Keywords: *Two phase motor, two phase supply, Scott-T transformer, Sine PWM, 3-Leg voltage source Inveter (VSI).*

I. Introduction

Single phase Induction motor is most widely used in industrial and commercial applications. This motor is also used in domestic applications because single phase induction motor is supplied by single phase AC source with constant frequency. In domestic application it is used with greater advantage but their performance is menial compared to poly phase induction motor due to low rated power, zero starting torque, low harmonics, and high torque harmonics. Two phase motor is developed in the core of single phase induction motor to improve the performance of two phase drive [1]. Two phase supply can be generated with the help of 3 phase supply and Scott-T transformer. But for the domestic applications and household single phase supply is used. So either conversion of supply is needed or any other suitable setup is required. This complexity can be reduced with the help of microcontroller. This paper presents the method for two phase supply using the 3-leg voltage source inverter (VSI) which is used to supply asymmetrical two phase induction motor. A dsPIC33EP256MC202 microcontroller is used to generate Sine Pulse Width Modulation (SPWM) switching signal for running the two phase Induction motor and controlling the speed of motor. The control is performed by SPWM technique with voltage source inverter and tested by open loop control.

II. Two Phase Supply

The simple method to obtain two phase supply is to by using the Scott-T transformer and conventional three-phase supply. The Scott-T is made by two different single phase transformer with different tapping ratios. The connections are made in such manner that Scott-T transformer gives two single phase output which are called as Main output and Teaser output. The Main and Teaser output are 90^0 out of phase [2]. Connections consist of 1:1 centre-tapped ratio of Main transformer T1, and 86.6% ratio of Teaser transformer T2. The centre-tapped side of T1 transformer is connected between two of the phases in the three phase side. Centre tap then connected to one end of higher turn side of T2, the other ends to remaining phases [3]. The remaining side of transformer T1 and T2 are the side at which two phase output is obtained and at which two phase motor can be connected.

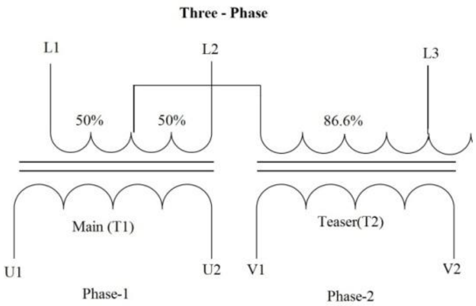

Fig. 1. Scott-T Transformer Connections

Two phase induction motor is connected between phase-1 and phase-2. But these type of supply causes imbalance in the system side due to which power quality issue arises. The devices sensitive to the power quality connected in the system can cause mal- operation. Also in the household applications the Three-phase supply is not available as per requirement of above circuitry. As per industrial application concern the cost of Scott-T transformer goes high. Thus more efficient and low cost technique to obtain Two-phase supply is by using micro-controller.

III. Proposed System

The block diagram of proposed system is shown in figure 2. The single-phase AC supply can converted to DC by simply using bridge rectifier and using filter circuitry the pure DC can be obtained. The three leg voltage source inverter is used to convert DC to Two phase AC supply. The 3-leg voltage source inverter consists of 6 IGBT switches. The switching pulses for the IGBT are obtained by Micro-controller dsPIC33EP256MC202. The SPWM technique is used as modulation technique.

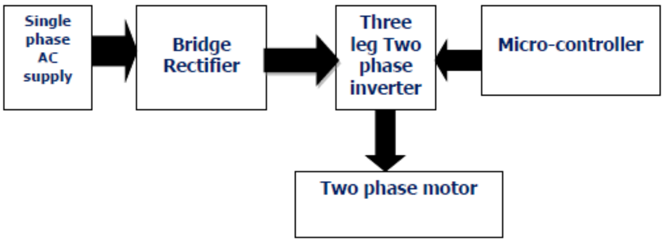

Fig. 2. Block Diagram

IV. Induction Motor Model

The single phase Induction motor dynamic model is given. The constant distance of air gap, linearity of magnetic circuit and current flow in the winding results to sinusoidal magnetic field distribution in the air gap. The Dynamic equations of single phase Induction motor are more complex than three phase Induction motor [1].

$$V_{sd}^{s} = r_{sd}\, i_{sd}^{s} + \frac{d\lambda_{sd}^{s}}{dt} \qquad (1)$$

$$V_{sq}^{s} = r_{sq}\, i_{sq}^{s} + \frac{d\lambda_{sq}^{s}}{dt} \qquad (2)$$

$$0 = r_{rd}\, i_{rd}^{s} + \frac{d\lambda_{rd}^{s}}{dt} + \omega_r \lambda_{rq}^{s} \qquad (3)$$

$$0 = r_{rq}\, i_{rq}^{s} + \frac{d\lambda_{sd}^{s}}{dt} - \omega_r \lambda_{rd}^{s} \qquad (4)$$

$$\lambda_{sd}^{s} = l_{sd}\, i_{sd}^{s} + M_{srd}\, i_{rd}^{s} \qquad (5)$$

$$\lambda_{sq}^{s} = l_{sq}\, i_{sd}^{s} + M_{srq}\, i_{rq}^{s} \qquad (6)$$

$$\lambda_{rd}^{s} = l_{rd}\, i_{rd}^{s} + M_{srd}\, i_{sd}^{s} \qquad (7)$$

$$\lambda_{rq}^{s} = l_{rq}\, i_{rq}^{s} + M_{srq}\, i_{sq}^{s} \qquad (8)$$

V_{sd}^{s} and V_{sq}^{s} are the stator dq voltages, i_{sd}^{s} and i_{sq}^{s} are the dq currents, λ_{sd}^{s} and λ_{sq}^{s} are the stator flux, λ_{rd}^{s} and λ_{rq}^{s} are the rotor flux. $r_{sd}, r_{sq}, r_{rd}, r_{rq}$ are the dq stator resistance and rotor resistance. The $l_{sd}, l_{sq}, l_{rd}, l_{rq}$ denotes the dp stator and rotor self inductances and M_{srd}, M_{srq} denotes their mutual inductances.

The dynamic model equations derived are similar to the equation derived from dynamic model of three-phase induction motor. However there is asymmetry between auxiliary and main winding of single phase induction motor. This could be considered as asymmetrical two phase induction motor having number of turns of auxiliary winding more than main winding. Hence the voltage of main winding is lower than the auxiliary winding voltage [5]. Turns ratio of auxiliary and main winding can be given as,

$$a = \frac{N_{aux}}{N_{main}} \qquad (9)$$

Where

a: turns ratio

N_{aux} : Number of turns in auxiliary winding

N_{main} : Number of turns in main winding

Hence the induction voltage in rotor of main winding can be multiplied by factor 1/a. And induction voltage in auxiliary winding due to rotating magnetic field of the main winding will be multiplied by a [1]. Therefore equation (3) and (4) can be modified as below,

$V_{rd} = 0 = r_{rd}\, i^s_{rd} + \frac{d\lambda^s_{rd}}{dt} + a^* \omega_r \lambda^s_{rq}$ (10)

$V_{rq} = 0 = r_{rq}\, i^s_{rq} + \frac{d\lambda^s_{sd}}{dt} - (1/a)^* \omega_r \lambda^s_{rd}$ (11)

V_{rd} and V_{rq} are the rotor dq voltages.

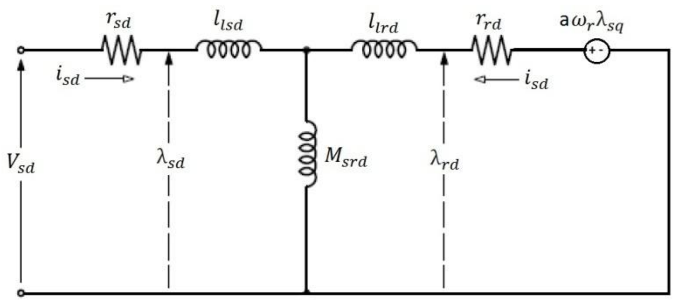

Fig. 3 (a) Equivalent circuit of d- axis

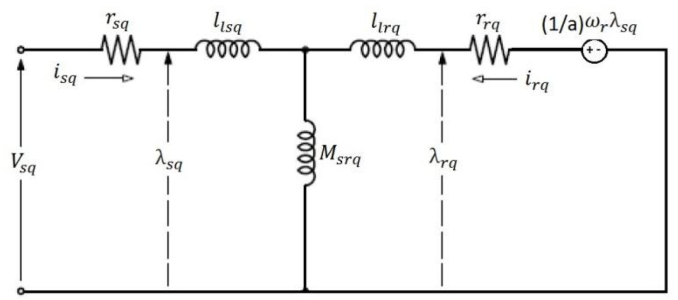

Fig. 3 (b) Equivalent circuit of q – axis

Fig. 3 Equivalent circuit based on stationary reference frame of asymmetrical two phase induction motor

The torque equation in terms of stator and rotor currents can be written as,

$T_e = \frac{P}{2}\,(M_{srq}\, i^s_{sq}\, i^s_{rd} - M_{srd}\, i^s_{sd}\, i^s_{rq})$ (12)

$(T_e - T_m) = J \frac{d}{dt}\omega_m + B\,\omega_m$ (13)

Electrical angular velocity of rotor (ω_r) is (P/2) times the mechanical angular velocity of rotor (ω_m). Electrical angular velocity of rotor is measured in rad/sec.

$\omega_r = \frac{P}{2}\omega_m$ (14)

Hence the mechanical dynamic equation in terms of electrical angular velocity of rotor is given as,

$\frac{d}{dt}\omega_r = \frac{P}{2J}(T_e - T_m) - B\,\omega_r$ (15)

Where,

P: number of poles of motor

T_e: Electromagnetic torque

T_m: Load torque

J: Moment of inertia

B: Friction of coefficient

Motor speed can be calculated by

$n_r = \frac{60 * \omega_r}{\pi P}$ (16)

n_r represents the rotor speed of induction motor.

V. 3- Leg Voltage Source Inverter

3-leg voltage source inverter is constructed as shown in figure 4. The inverter consists of 6 switches.

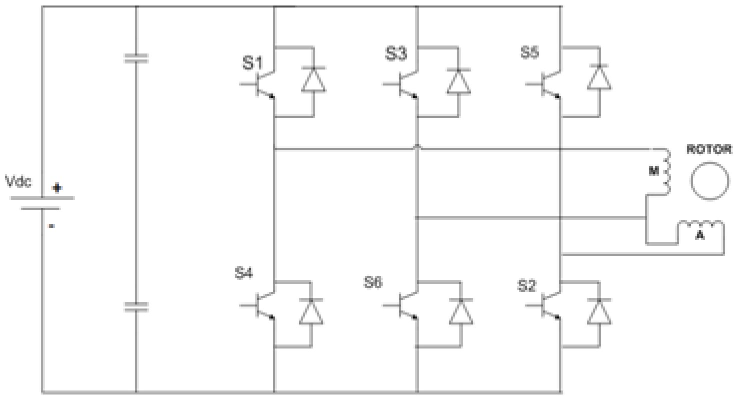

Fig. 4 Three leg voltage source inverter

The voltages V_{a0}, V_{b0} and V_{c0} are defined by following equations,

V_{a0} = m.sin $(w_s t)$

V_{b0} = m.sin $(w_s t - \frac{\pi}{2})$

V_{c0} = m.sin $(w_s t - \pi)$

Where, w_s is the angular electrical speed and m is the modulation index at 0<m<1. The asymmetrical two phase voltage can be given as,

V_{sd} = V_{a0} - V_{b0}

V_{sq} = V_{c0} - V_{b0}

V_{dc} = V_{sd} + jV_{sq}

The switching signal pattern is derived from equation (17) to equation (19) of the three phase reference voltage are compared with the triangular carrier signal. If the reference voltage is lower than the triangular carrier then status of switching is off. Otherwise if reference voltage is higher than or equal to the triangular reference voltage status of switch is on. This modulation technique is called as Sine pulse width modulation (SPWM).

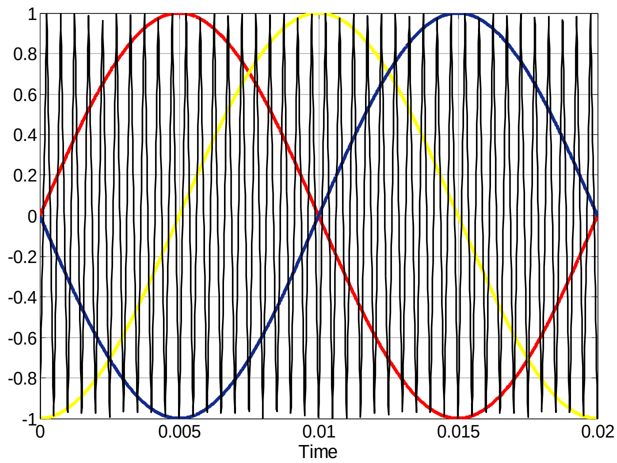

Fig. 5 Three phase reference voltage and Triangular carrier signal

The reference voltage can be adjusted by varying values of modulation index m from 0 to 1, while the magnitude of triangular carrier voltage (V_{tri}) is to be 1. The frequency of testing signal ie kept 50 Hz, as per Indian standard.

VI. Gate Driver Circuit Design

The block diagram of Gate driver circuit for operation of IGBT is given as below in figure 6.

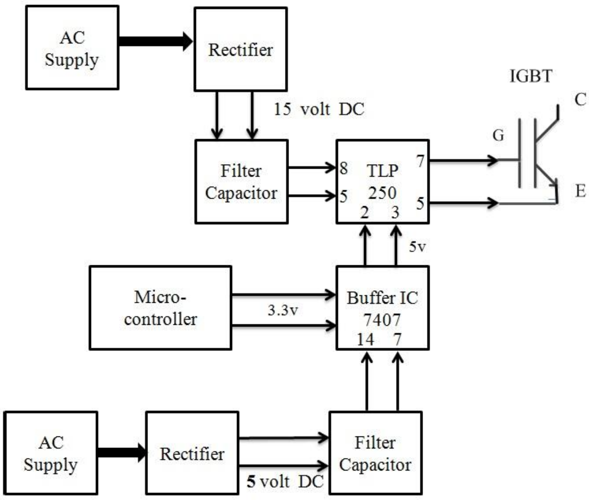

Fig. 6.a. Gate Driver Circuit

The Gate driver circuit consists of main parts
1. AC supply
2. Rectifier
3. Filter Capacitor
4. Microcontroller dsPIC33EP256MC202
5. Buffer IC 7407
6. Driver IC TLP250

The rectifier circuit is used to covert AC to DC as per requirement. The microcontroller dsPIC33EP256MC202 works on the 3.3 DC volts and its output voltage is also a 3.3 DC Volt. The buffer IC 7407 works on 5 volt DC while optocoupler IC TLP 250 needs 15 volt DC. In this way the Gate pulse with voltage nearly equal to 14.5 volt is given to IGBT for its operation. The figure 6.b shows the hardware setup of gate driver circuit

Fig. 6.b. Gate Driver Circuit

The grounding of 15 volt supply for optocoupler IC TLP250 for switches S1 and S4, S3 and S6, S5 and S2 should not be same otherwise it would result in short-circuit.
The grounding for switch S4, S2 and S6 can be made common for 15 volt DC.

VII. Results

In figure 7 the switching pulses for upper switch S1, S3 and S5 are given which is obtained with help of microcontroller dsPIC33EP256MC202. The complementary pulses are given to S4, S6, and S2 respectively. The phase shift of 90^0 is obtained between two windings.

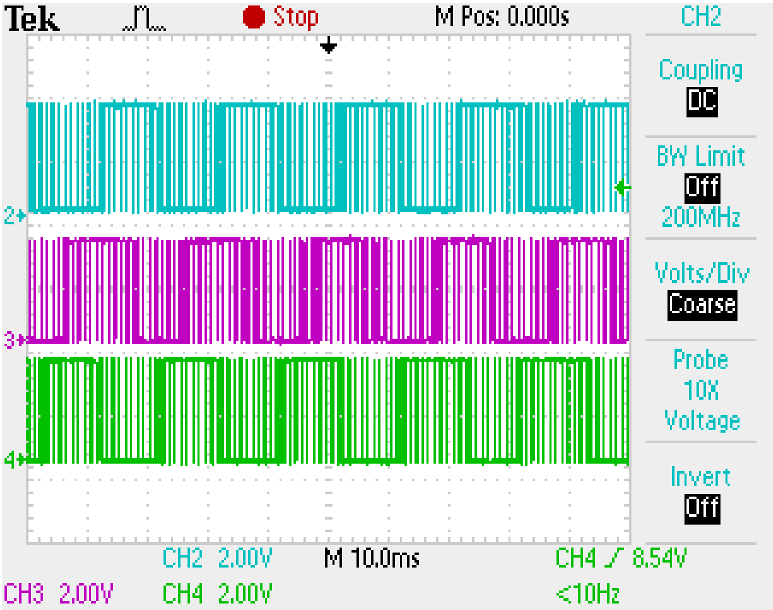

Fig. 7 Switching Signal for upper switches

In figure 8, shows the line voltage at the output terminal of inverter.

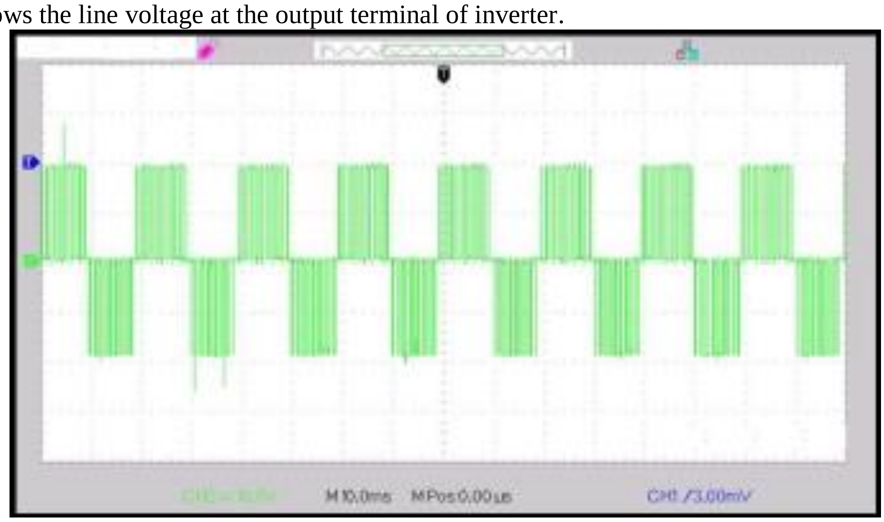

Fig. 8 Line Voltage

Figure 9, shows the phase voltage at the output terminal of inverter.

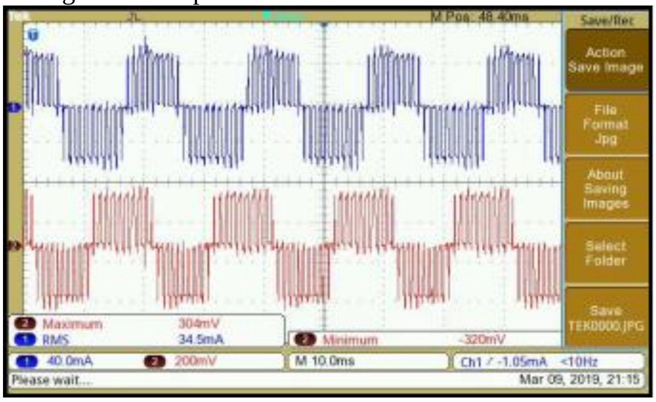

Fig. 9 Current waveform

The table 1 shows the speed of asymmetrical two phase induction motor with respect to input voltage to rectifier

Sr. No.	Input Voltage to rectifier (Single phase) (in Volt)	Speed (RPM)
1	110 V	1400
2	160 V	2034
3	200 V	2540
4	230 V	2600

Table no. 1. Induction motor reading with asymmetrical motor

VIII. Conclusion

Single phase induction motor is commonly used in household industries and irrigation for pumping purpose. If two phase induction motor is used in place of single phase motor then starting torque and high rated power can be archived, due to which supplying water at higher level can be achieved efficiently. The two phase mode of operation achieves increased rated torque causing more power in the same frame size and higher efficiency result in less running cost. By using 3-leg voltage source inverter for obtaining two phase supply the supply for motor is obtained in more economically and efficiently.

References

[1]. K.Kaenthong, V.Tipsuwanporn, A.Numsomran and A.Charean "Asymmetrical Two-Phase Induction Motor Speed Controlled with 3-Leg Voltage Source Inverter," IEEE International Conference on Industrial Technology (ICIT), pp. 640-645, 2015.

[2]. Jignesh Parmar. (2012, May 6). Scott-T Connection of Transformer [Online].Available: http://electricalnotes.wordpress.com/2012/05/06/scott-t-connection-of transformer

[3]. Md Ayubur Rahman Khan and Md Quamrul Ahsan "Development and Performance Analysis of a Two-Phase Induction Motor in the Frame and Core of a Single-Phase Induction Motor," *8th International Conference on Electrical and Computer Engineering*, pp. 469-472, Dhaka, Bangladesh, December. 2014

[4]. F.A.S. Neves,E.B.S. Filho,J.M.S. Cruz,R.P. Landim,Z.D.Lins and A.G.H. Accioly, "Single-Phase Induction Motor Drives with Direct Torque Control," in Industrial Electronics Society,2002.IECON 2002. 28th Annual Conference of IEEE, 2002, pp.241-246 vol.1

[5]. K.Kaenthong, V.Tipsuwanporn, A.Numsomran and W.Sawaengsinkasikit "Asymmetrical Two-Phase Induction Motor Speed Controlled with 4-Leg Voltage Source Inverter," IEEE 24th International Symposium on Industrial Electronics (ISIE), pp., 444 – 449, 2015.

[6]. Ekkawid Hayakwong, Vijit Kinnares "PV Powered Three-Leg VSI Fed Asymmetrical Parameter Type Two-Phase Induction Motor," 17th International Conference on Electrical Machines and Systems (ICEMS), Hangzhou, China, Octomber 2014.

[7]. Do-Hyun Jang "Problems Incurred in a Vector-Controlled Single-Phase Induction Motor, and a Proposal for a Vector-Controlled Two-Phase Induction Motor as replacement," IEEE Transaction on Power Electronics, Vol. 28, No. 1, January 2013

[8]. Younes Sangsefidi, Saleh Ziaeinejad, and Ali Mehrizi-Sani "A New Two-Motor Drive to Control a Two-Phase Induction Motor and a DC Motor," IEEE International Electric Machines and Drives Conference (IEMDC), DOI: 10.1109/IEMDC.2015.7409154, 2015

[9]. Microchip Technology " DS70000657H," 16-Bit Microcontrollers and Digital Signal Controllers with High-Speed PWM, Op Amps and Advanced Analog, 2013.