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Difference between Three Phase and Five Phase Induction Motor

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ABSTRACT
Multiphase variable speed drives today are major competitors for a variety of applications. Multilevel (especially three-level) voltage source inverters (VSIs) and transformers have become industry-accepted technologies in three-phase systems. In recent times, efforts have been made to integrate VSIs with advanced converters with multiphase drive technology. Our paper provides an update on the latest developments in this area. The standard configuration of the converter is considered and the differences regarding the control of standard converters of three to three phases are drawn. Next, the two different topology of multiphase multilevel offerings are discussed and emphasized in the appropriate pulse-wide alternating pulse (PWM) techniques that can be used in conjunction with the given conversion structure. The first topology uses multi-level (three levels) VSI and the stator multiphase winding machine is connected to a star. In the second topology the winding is open and each side of the winding is connected to a two-level VSI. PWM company-based network and space vector strategies are considered and performance is demonstrated using test results.

Key words: Carrier-based PWM, converter, modulation strategy, multilevel inverter, multiphase drive, open-end winding, space vector PWM

INTRODUCTION

The use of power converters has resulted in the number of categories considered as an additional Design parameter. Multiphase (more than three stages) Equipment has certain advantages over three categories: Improved error tolerance, reduced torque reduction, lower power requirements for each phase, improved modeling and improved audio features. Despite its remarkable advantages, the widespread availability of three-phase machines prevents the use of multi-phase equipment in specialized systems, where three-phase drives are not readily available or unsatisfactory for specification. The input machine is used in a variety of applications as a means of converting electrical energy into mechanical power. Pump metal mill, hoist drives, indoor applications are just a few applications of import equipment. Induction motors are widely used as they offer better performance than other ac motors. In this chapter, the development of a three-phase induction motor model is tested first on how an induction motor works. Flexible statistical detection, which describes the engine is explained. The theory of evolution, which makes it easier to analyze an induction motor, is discussed. Steering engine status statistics are available. The basic principles of three-phase inverter operation are explained, following which the operation of a three-phase inverter feeding an induction machine is explained

The voltage and torque equations that define the variable behavior of an induction motor vary with time. It is used successfully to solve such various scales and may involve some complexity. Flexible variables can be used to reduce the complexity of these calculations by subtracting all the inductances that change over time, due to electrical circuits in related movements, from the electrical energy calculations of the machine. In this way, the rotation of the poly phase can be reduced to a set of two-phase windings (q-d) with their magnetic axes built into the quadrature. In other words, the stator and rotor variables (voltages, currents and dynamic connections) of the input device are transmitted to the reference frame, which can rotate at any angular speed or remain constant. Such a framework for reference is often referred to in general machine analysis as an unofficial reference framework.

BASIC PRINCIPLE OF OPERATION OF THREE-PHASE INDUCTION MOTOR

The principle of operation of an input engine can be summarized by the fact that, when three rated phase voltages are removed from each other at an angular frequency of 120 applied to a three-phase vertical stator propelled by 120electrical, a rotating magnetic field is generated. This 45 rotating magnet has the same power and revolves around the supply frequency; the rotor which was thought to have stood still, has a magnetic field that is introduced into it. As the rotor windings rotate slightly, currents begin to rotate in them, producing reactions. As is known in Lenz law, the reaction is against the source of rotor currents. These currents can be zero when the rotor begins to rotate in the same direction as that of a rotating magnetic field, and with the same force. So the rotor starts to rotate in an attempt to capture the rotating magnetic field. When the speed of separation between the two becomes zero then the rotor currents will be zero, there will be no emf leading to the production of zero torque. Depending on the shaft load the rotor will remain r nest, which is less than the frequency supply eω. This unique speed is called the slide speed of soω. The relationship between ωe and ωso is provided as follows:

THREE-PHASE INDUCTION MACHINE EQUATIONS

The winding arrangement of a two-pole, three-phase wye-connected induction machine is shown in Figure 1. The stator windings of which are identical, sinusoidal distributed in space with a phase displacement of 120, with equivalent turns and resistance. Two-pole three-phase symmetrical induction machine. The rotor is assumed to symmetrical with three phase windings displaced in space by an angle of 120, with effective turns and a resistance of the voltage equations for the stator and the rotor are as given in Equations:

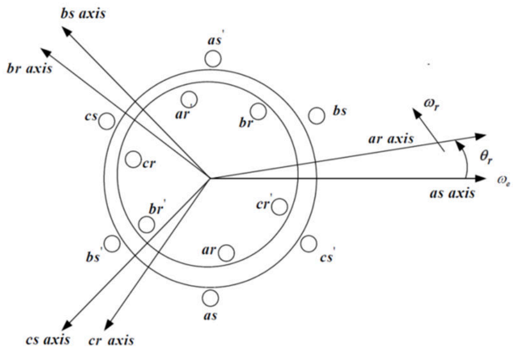

Fig. 1 Three phase Induction Machine

VOLTAGE EQUATION OF INDUCTION MOTOR

$$V_{as} = r_s I_{as} + p\lambda_{as}$$

$$V_{bs} = r_s I_{bs} + p\lambda_{bs}$$

$$V_{cs} = r_s I_{cs} + p\lambda_{cs}$$

Where Vas, Vbs, and Vcs are the three phase balanced voltages which rotate at the supply frequency. For the rotor the flux linkages rotate at the speed of the rotor, which is rω:

The above equations can be written in short as

$$V_{abcs} = r_s I_{abcs} + p\lambda_{abcs}$$

$$V_{abcr} = r_r I_{abcr} + p\lambda_{abcr}$$

In the above two equations 's' subscript denoted variables and parameters associated with the stator circuits and the subscript 'r' denotes variables and parameters associated with the rotor circuits. Both and are diagonal matrices each with equal nonzero elements. For a magnetically linear system, the flux linkages may be expressed as:

WINDING INDUCTANCES

$$L_s = \begin{bmatrix} L_{ls}+L_m & -\frac{1}{2}L_m & -\frac{1}{2}L_m \\ -\frac{1}{2}L_m & L_{ls}+L_m & -\frac{1}{2}L_m \\ -\frac{1}{2}L_m & -\frac{1}{2}L_m & L_{ls}+L_m \end{bmatrix}$$

$$L_r = \begin{bmatrix} L_{lr}+L_m & -\frac{1}{2}L_m & -\frac{1}{2}L_m \\ -\frac{1}{2}L_m & L_{lr}+L_m & -\frac{1}{2}L_m \\ -\frac{1}{2}L_m & -\frac{1}{2}L_m & L_{lr}+L_m \end{bmatrix}$$

$$L_{sr} = L_{sr}\begin{vmatrix} \cos\theta_r & \cos(\theta_r+\frac{2\pi}{3}) & \cos(\theta_r-\frac{2\pi}{3}) \\ \cos(\theta_r-\frac{2\pi}{3}) & \cos\theta_r & \cos(\theta_r+\frac{2\pi}{3}) \\ \cos(\theta_r+\frac{2\pi}{3}) & \cos(\theta_r-\frac{2\pi}{3}) & \cos\theta_r \end{vmatrix}.$$

In the above inductance equations, and are the leakage and magnetizing inductances of the stator windings; and are for the rotor windings. The inductance is the amplitude of the mutual inductances between stator and rotor windings.

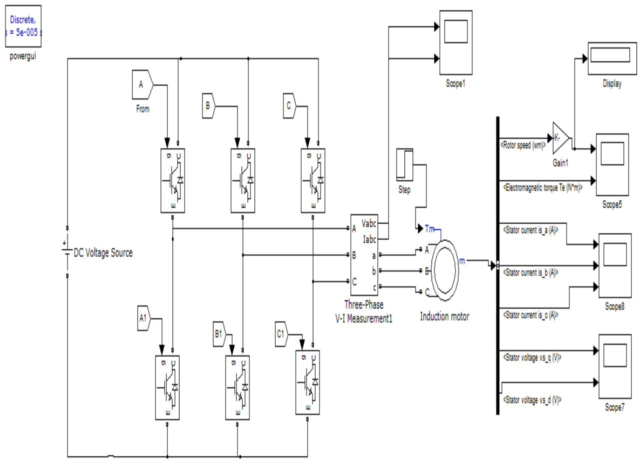

Fig. 2 Matlab model of 3 phase induction motor

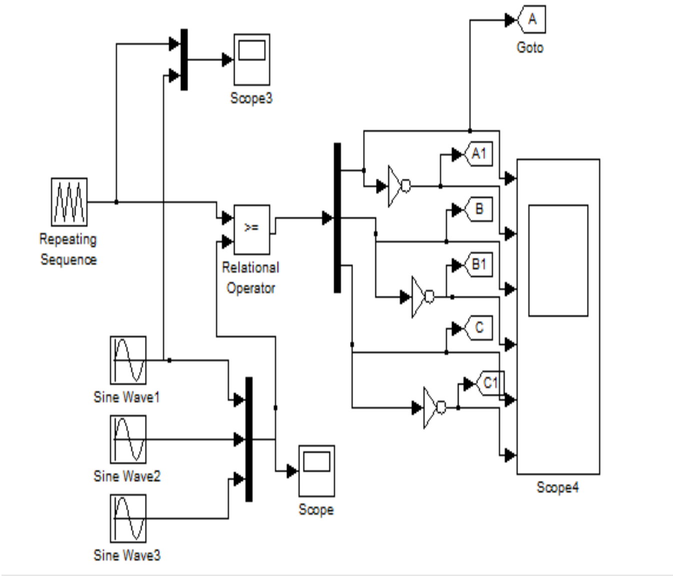

Fig.3 Control Circuit of 3 phase induction motor

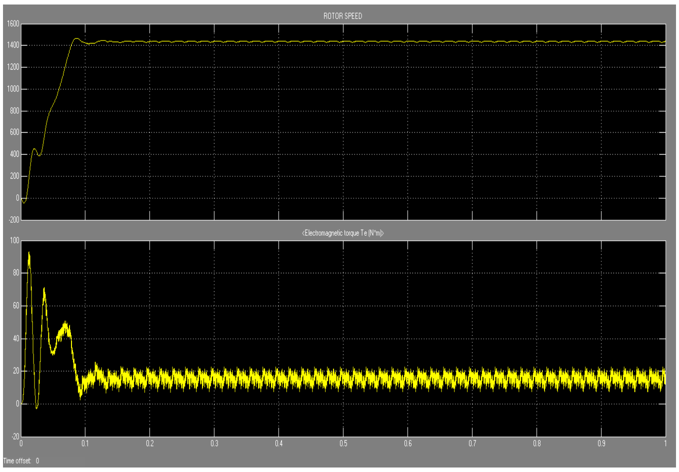

Fig. 4 Three phase induction motor

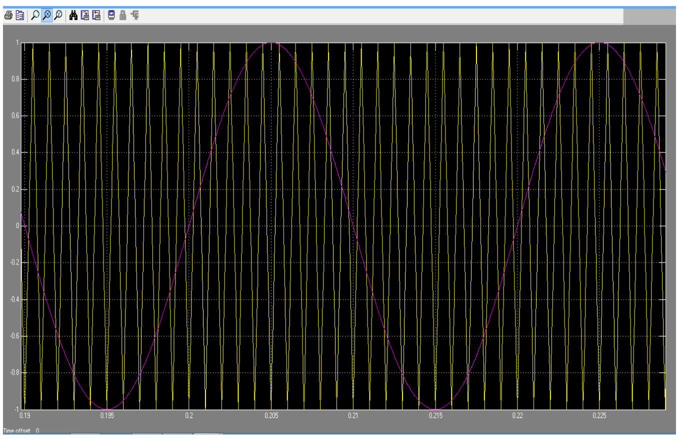

Fig. 5 Three phase Inverter

MULTIPHASE

Multiphase induction motor (more than three phases) drives possess several advantages over conventional three-phase drives, such as lower torque pulsation, higher torque density, fault tolerance, stability, high efficiency and lower current ripple. To increase the motor's power per phase and to decrease its weight a multi-phase motors was used. Probably the first application of a multi-phase motor dates back to 1969, a five-phase motor, followed by a nine-phase motor (triple star), that was practically a cascade connection of some three-phase motors. The advantages of the multi-phase motor over the correspondent three-phase one, much improved in reliability, and reduction of the power per inverter leg.

Other advantages of the multi-phase motors are: the improvement of the noise, a possibility of reduction in the copper stator loss leading to an improvement in the efficiency and, also, the improvement of the torque-speed characteristics by increasing the low-speed torque more than 5 times than the three-phase induction motors. Multiphase motors have various advantages such as lower torque pulsation, reduced current per phase without increasing the voltage per phase, reduction in harmonic current, greater reliability, fault tolerance and minimal de-rating at occurrence of fault. Five-phase is the smallest phase number of multiphase motor which is commonly used. A five-phase machine can continue to operate if one or even two phases of the supply are lost. Various advantages of multiphase drives over conventional three phase drives, such as increase in frequency of pulsating torque, reduced torque pulsations. Reduction in harmonic currents, increase in current per phase without the need to increase the phase voltage, increase in torque/ampere relation for the same volume of the machine.

MATHEMATICAL MODELING OF MULTIPHASE INDUCTION MOTOR

$$v_a = \sqrt{2}V\cos(\omega t)$$
$$v_b = \sqrt{2}V\cos(\omega t - 2\pi/5)$$
$$v_c = \sqrt{2}V\cos(\omega t - 4\pi/5)$$
$$v_d = \sqrt{2}V\cos(\omega t + 4\pi/5)$$
$$v_e = \sqrt{2}V\cos(\omega t + 2\pi/5)$$

$$\underline{A}_s = \sqrt{\frac{2}{5}}\begin{bmatrix} \cos\theta_s & \cos(\theta_s - \alpha) & \cos(\theta_s - 2\alpha) & \cos(\theta_s + 2\alpha) & \cos(\theta_s + \alpha) \\ -\sin\theta_s & -\sin(\theta_s - \alpha) & -\sin(\theta_s - 2\alpha) & -\sin(\theta_s + 2\alpha) & -\sin(\theta_s + \alpha) \\ 1 & \cos(2\alpha) & \cos(4\alpha) & \cos(4\alpha) & \cos(2\alpha) \\ 0 & \sin(2\alpha) & \sin(4\alpha) & -\sin(4\alpha) & -\sin(2\alpha) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}$$

Transformation Equation

Transformation of the rotor variables is performed using the same transformation expression,

Except that θs is replaced with β, where β = θ   s−θ.

Here θs is the instantaneous angular

Position of the d-axis of the common reference frame with respect to the phase 'a' magnetic axis of the stator, while β is the instantaneous angular position of the d-axis of the common reference frame with respect to the phase 'a' magnetic axis of the rotor.

$$\underline{A}_r = \sqrt{\frac{2}{5}}\begin{bmatrix} \cos\beta & \cos(\beta - \alpha) & \cos(\beta - 2\alpha) & \cos(\beta + 2\alpha) & \cos(\beta + \alpha) \\ -\sin\beta & -\sin(\beta - \alpha) & -\sin(\beta - 2\alpha) & -\sin(\beta + 2\alpha) & -\sin(\beta + \alpha) \\ 1 & \cos(2\alpha) & \cos(4\alpha) & \cos(4\alpha) & \cos(2\alpha) \\ 0 & \sin(2\alpha) & \sin(4\alpha) & -\sin(4\alpha) & -\sin(2\alpha) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}$$

Multi-phase induction motor parameters

No. of Phases(n)	5	6	7	9	12
Power	2Kw	1hp	5hp	1hp	3Kw
V in volts	100	220	260	230	127
I in Amps	7.5	2.5	7.5	3	6
N_r in RPM	1440	1440	1440	1440	1440
T in N-m	13.26	10	45	15	20
F in Hz	50	50	50	50	50
Poles	4	4	4	4	4
R_s in Ω	1.26	10	2.238	1.98	7
R_r in Ω	1.03	6.3	0.855	1.85	2.4
L_{ls} in H	0.00476	0.04	0.012	0.0091	0.01
L_{lr} in H	0.0017	0.04	0.012	0.0091	0.01
M in H	0.1515	0.42	0.297	0.1986	0.3914
J in Kgm^2	0.015	0.003	0.03	0.003	0.025
B in Nms	0.0015	0.0015	0.0015	0.0015	0.004

$$v_{ds} = R_s i_{ds} - \omega_a \psi_{qs} + p\psi_{ds}$$

$$v_{qs} = R_s i_{qs} + \omega_a \psi_{ds} + p\psi_{qs}$$

$$v_{xs} = R_s i_{xs} + p\psi_{xs}$$

$$v_{ys} = R_s i_{ys} + p\psi_{ys}$$

$$v_{os} = R_s i_{os} + p\psi_{os}$$

Stator Side Voltage,

$$v_{dr} = R_r i_{dr} - (\omega_a - \omega)\psi_{qr} + p\psi_{dr}$$

$$v_{qr} = R_r i_{qr} + (\omega_a - \omega)\psi_{dr} + p\psi_{qr}$$

$$v_{xr} = R_r i_{xr} + p\psi_{xr}$$

$$v_{yr} = R_r i_{yr} + p\psi_{yr}$$

$$v_{or} = R_r i_{or} + p\psi_{or}$$

Electromagnetic Torque

$$T_e = \frac{5P}{2} M\left[i_{dr} i_{qs} - i_{ds} i_{qr}\right]$$

$$Wr = \int (P/2J)\,(T_e - T_L)$$

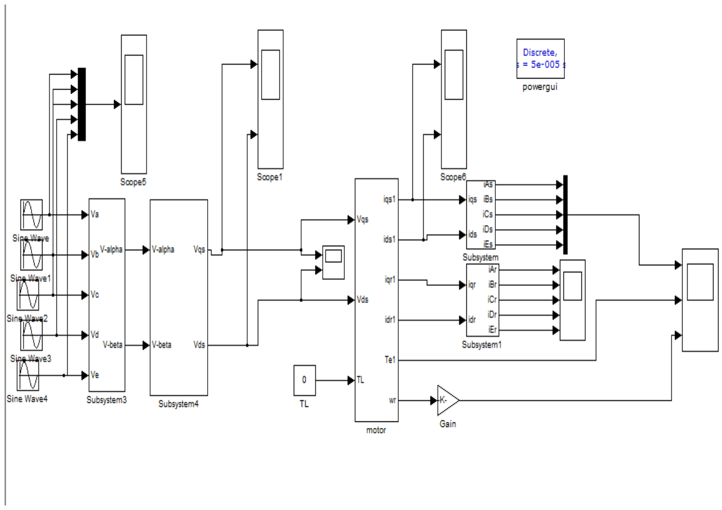

Fig. 6 Matlab Model of Five phase Induction Motor

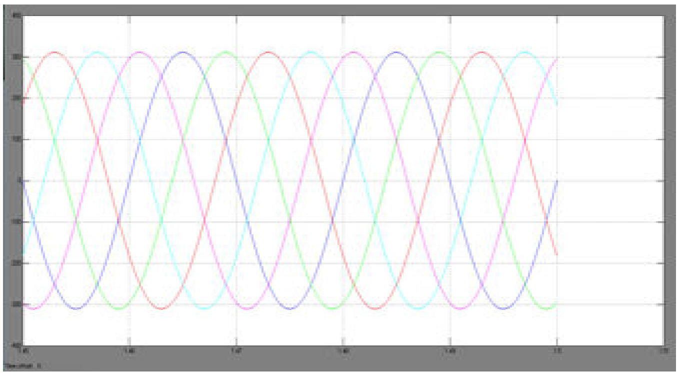

Fig. 7 Five phase Supply Voltage

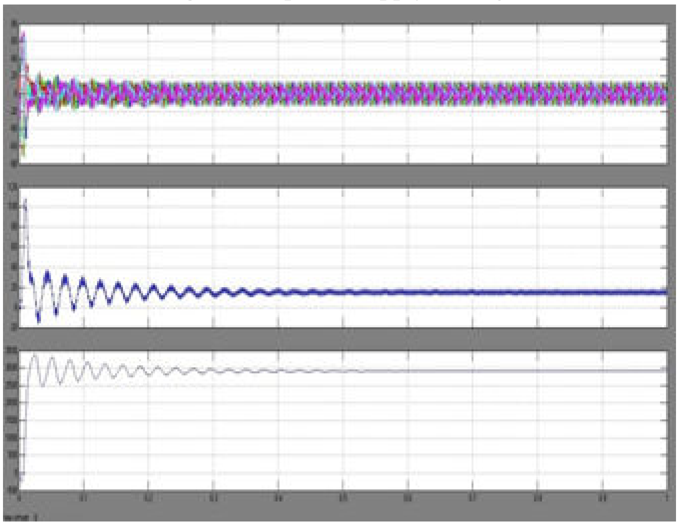

Fig. 8 Five phase induction motor

10 -STEP OPERATION OF A FIVE-PHASE VOLTAGE SOURCE INVERTER

Power circuit topology of a five-phase VSI which was used probably for the first time by Ward and Härer (1969). Each switch in the circuit consists of two power semiconductor devices, connected in anti-parallel. One of these is a fully controllable semiconductor, such as a bipolar transistor or IGBT, while the second one is a diode.

The input of the inverter is a dc voltage, which is regarded further on as being constant. Each switch is assumed to conduct for 180°, leading to the operation in the ten-step mode. Phase delay between firing of two switches in any subsequent two phases is equal to 360°/5 = 72°.

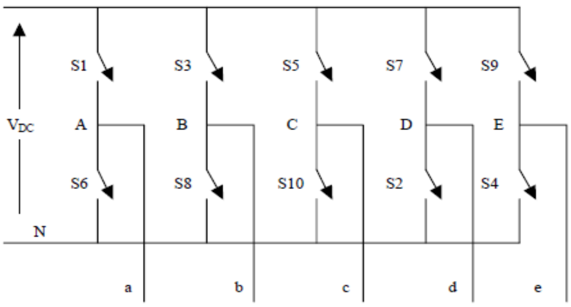

Fig. 9 Five-phase voltage source inverter

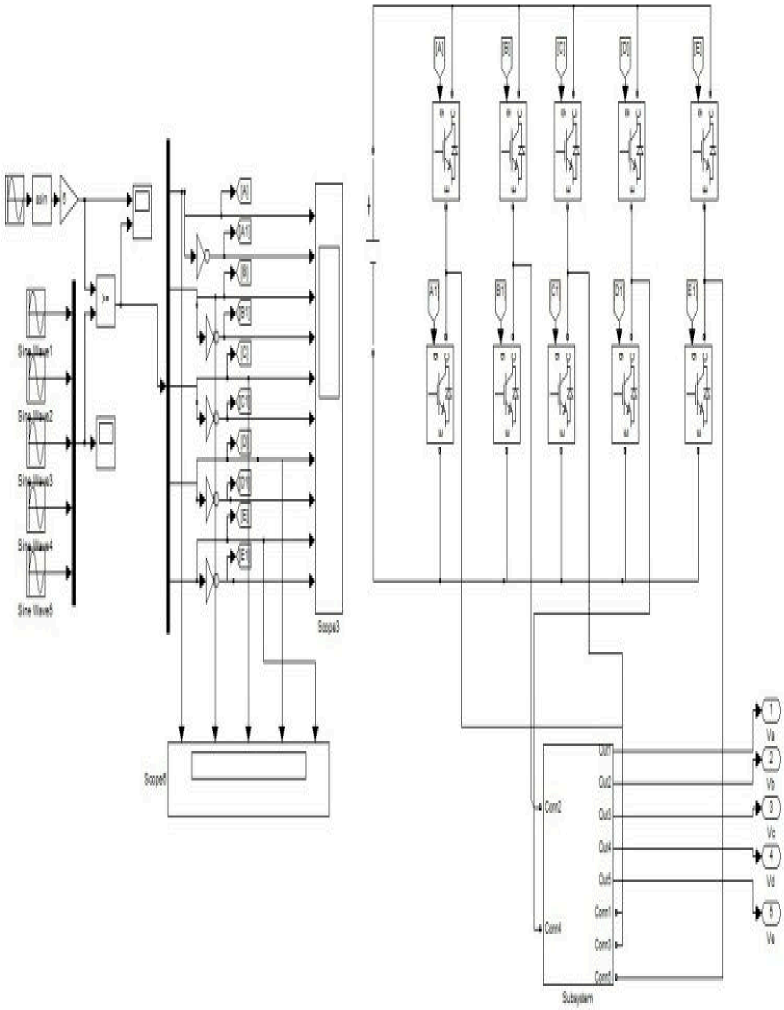

Fig. 10 Matlab Model of Inverter

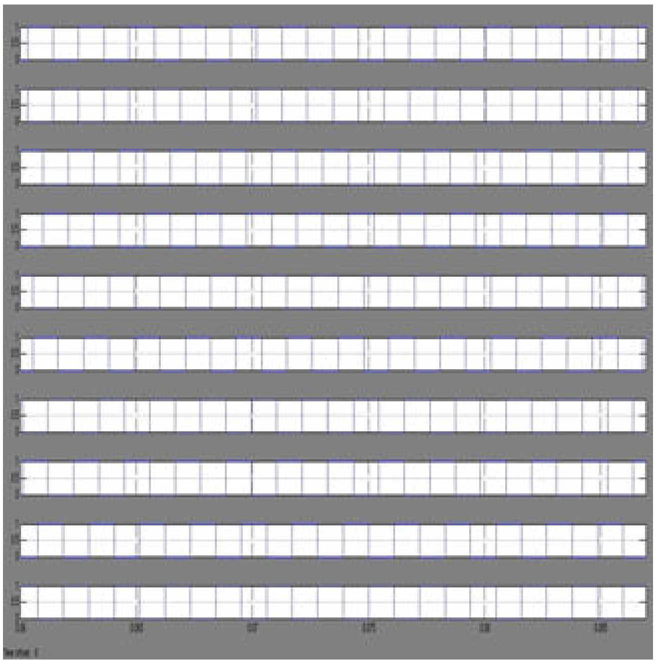

Fig.1 1 Five phase inverter

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