SVPWM Based Speed Control of Induction Motor with Three Level Inverter Using Proportional Integral Controller

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***Abstract* - In general speed control techniques are essential in flexible speed drive system. To achieve this it requires variable frequency and supply voltage. Even though there are numbers of pulse width modulations scheme is used to obtain variable frequency and voltage supply from an inverter. It is less used than the space vector pulse width modulation. In the space vector pulse modulation method with proportional integral control of induction motor drive is widely used in high performance drive system. It is due to its characteristics like good power factor and high efficiency. In this paper the voltage source inverter type space vector pulse width modulation with three level inverter using proportional integral control model design and implementation has been done through MATLAB / SIMULINK software for the speed control of induction motor and also parameters like stator current, rotor current, torque and speed are expressed graphically.**

***Keywords* - PI control, Induction motor, SVPWM.**

I. INTRODUCTION

In industries the motor control section is the dominant sector. Therefore speed control of induction motor is very important and also most essential one. The three main design aspects like low power consumption, improved power factor and cost reduction are to be achieved in order to meet these challenges. The conventional method has to be modified with advanced control techniques. In the speed control of three phase inductor there are several method like frequency control, stator voltage control, V/F control and rotor resistance control are used. At present three phase induction motors are most widely used electric motor. In addition to that eighty percentage of mechanical power used by industries are provided by three phase induction motors and also in many industrial applications the induction motor are used because of the merits like easy maintenance, low cost, robustness and better performance. [1] Has explained the complete analysis of electrical machinery drive system. Actually because independent control of torque and flux separately excited dc drives are simpler in control. Due to ruggedness, efficiency and simplicity the induction motors have been used in several applications for over a century. [2-3] has presented the analysis and simulation model development of induction motor in MATLAB / SIMULINK software.

In addition to that the induction motors involve a corresponding control of stator current magnitude and the phase, making it a complex control. The stator flux linkages can resolve along any frame of reference. For this action it requires position of flux linkage at every instant. In addition to this the control of the ac machine is very similar to that of separately excited direct current motor and also this type of control involves field coordination. So it is also called as field oriented control [vector control].The vector control is divided in to two types on the basis of method of measurement. They are indirect and direct vector control. Therefore in the case of direct vector control, the flux measurement is done by using the flux sensing coils or the Hall devices. But in case of indirect vector control the flux angle is not calculated directly, but it is predicted from the equivalent circuit model and from measurements of the stator current, voltage and rotor speed. The Main reasons for two level inverter topologies is to provide a three phase voltage source, where the phase, frequency of the voltage and amplitude, phase should always be controllable. SVPWM technique is widely used in rectifier and inverter controls. In SV pulse width modulation inverter the voltage utilization factor can be increased to 0.906, normalized to that of the six step operation. The SV Pulse Width Modulation can be obtained by suitably adding a zero-sequence voltage to the original modulation waveform. The motor-control issues are conventionally handled by fixed gain PI controller.

II. VOLTAGE SOURCE INVERTER AND SVPWM PRINCIPLE

The figure.1 shows the three phase voltage source inverter. The inverter consists of three leg and six switches. In every switch of the inverter two back to back connected semiconductors will be used. But in that two switches one will be a controllable device and the other will be a diode for protection. The voltage waveforms for all the three phases are shown in figure.2. At the same tine from figure.2 it is observed that the state of one inverter leg changes after an interval of sixty degree and then it state remains constant for sixty degree interval. Therefore the leg voltage will have six distinct and discrete values in one cycle of three sixty degree.

The space vector pulse width modulation technique is frequently used in direct torque control drive and vector control drive. In addition to this when current control is exercised in rotating reference frame. The reference voltage generation is used in particularly for vector control drives.

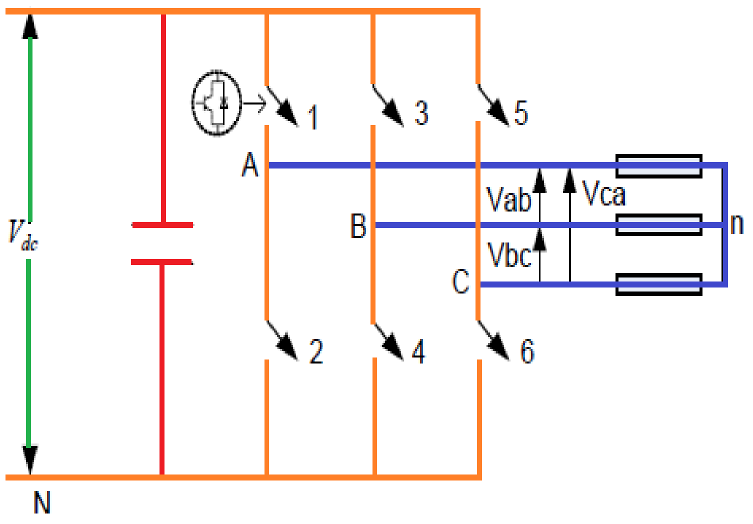

Figure.1. Circuit diagram of three phase voltage source inverter

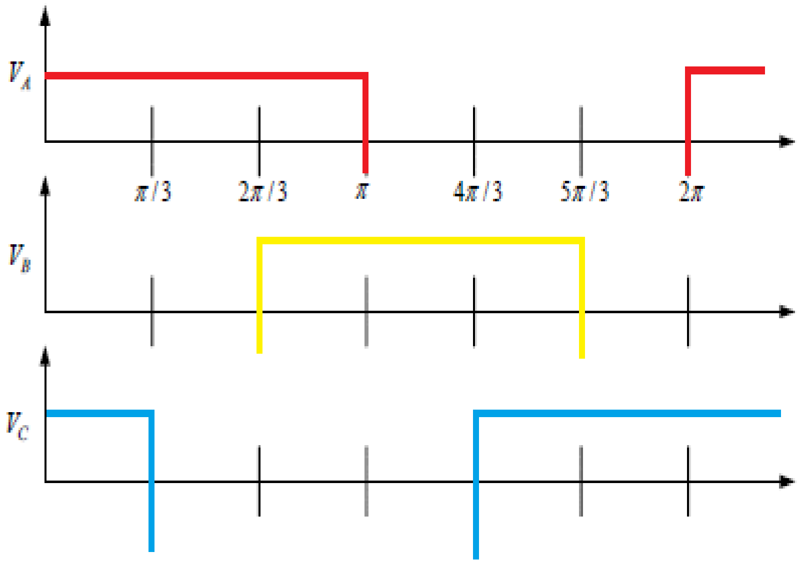

Figure.2. Voltage source inverter waveform for 180 degree mode of conduction

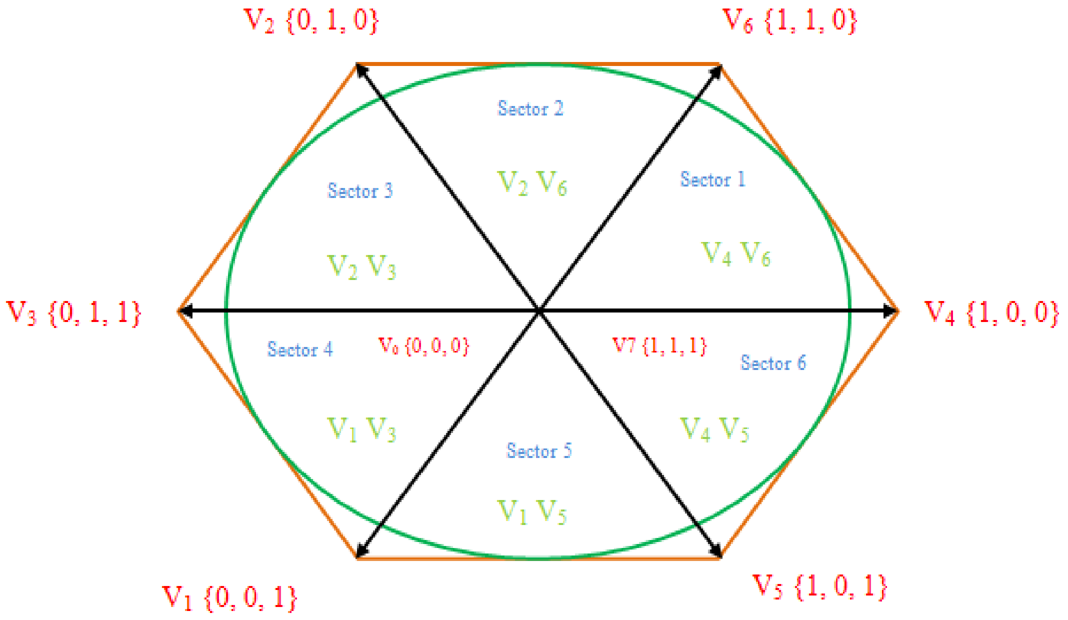

Figure.3.Space vector diagram for three level inverter

The vector forms the hexagon as shown in figure.3. At the same time it consists of six sector spanning 60 degree each. Actually it consist of eight switching states which includes two zero states and six active states generated by the voltage source inverter. The three phase voltage is represented by reference vector and it is generated by using space vector pulse width modulation by switching between two nearest active vectors and zero vectors.

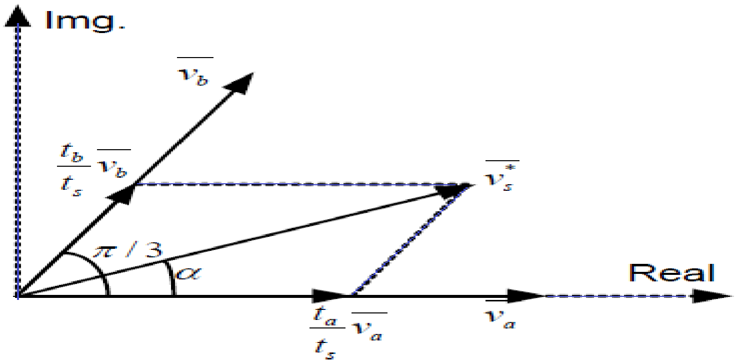

Figure.4.Space vector time calculation

The above figure.4 has to be taken in to account to calculate time of application of different vectors. At the first sector depict the position of different available space vectors and reference vectors. In each leg the changes takes place only once in one switching period to obtain optimum harmonic performance and fixed switching frequency from space vector pulse width modulation. This can be achieved by applying zero state vectors followed by two adjacent active vectors in half switching period and in the next half of the switching period it contains the mirror image of the first half. In this case the total switching period is divided in to seven parts after that the ‘0’ vector is applied for one fourth of the total ‘0’ vector time first and then followed by the application of active vectors for half of their application time and then again ‘0’ vector is applied for one fourth of ‘0’ vector time. Now once again this is repeated in the next half of the switching period. This is repeated in the next half of the switching period. This is how the space vector pulse width modulation is obtained. The leg voltage and space vector disposition for one switching period in sector 1 is shown in figure.5. [4-8] has explained in detail about space vector pulse width modulation technique of induction motor and simulation model is developed in addition to this it is tested successfully in MATLAB / SIMULINK software.

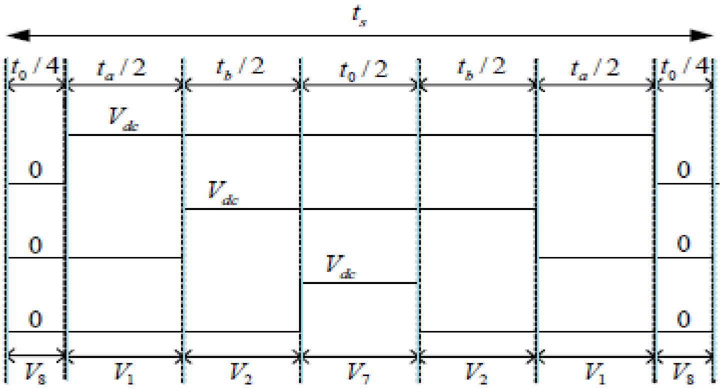

Figure.5. leg voltage and space vector disposition for one switching period in sector 1

III. MATHEMATICAL MODEL OF SPACE VECTOR PULSE WIDTH MODULATION

Step 1: For finding the values of $U_a, U_b, U_c, U_{alpha} and U_{beta}$ the equations 1, 2, 3, 4 and 5 are used.

$$U_a = u(1) * \sin\{u(2) * 2 * pi * u(3)\} \rightarrow Equation.1$$

$$U_b = u(1) * \sin\{u(2) * 2 * pi * u(3) - 2 * \frac{pi}{3}\} \rightarrow Equation.2$$

$$U_b = u(1) * \sin\{u(2) * 2 * pi * u(3) + 2 * \frac{pi}{3}\} \rightarrow Equation.3$$

$$U_{alpha} = \frac{2}{3} * (U_a - 0.5 * U_b - 0.5 * U_c) \rightarrow Equation.4$$

$$U_{beta} = \frac{2}{3} * (\frac{\sqrt{3}}{2} U_b - \frac{\sqrt{3}}{2} U_c) \rightarrow Equation.5$$

Step 2: To Find the suitable sector judgment

$$U_{beta} > 0, A = 1 \rightarrow Equation.6$$

$$3U_{alpha} - U_{beta} > 0, B = 1 \rightarrow Equation.7$$

$$3U_{alpha} + U_{beta} > 0, C = 1 \rightarrow Equation.8$$

Once A, B, C values are determined then find the N value, by substituting the values of A, B, C in equation 9.

$$N = A + 2B + 4C \rightarrow Equation.9$$

Sector	I	II	III	IV	V	VI
N	3	1	5	4	6	2

Step 3: Calculate the operating time of the fundamental vectors

The values of X, Y, Z are calculated by the following equations,

$$X = 2T(U_{beta}) / (2 * U_{dc}) \rightarrow Equation.10$$

$$Y = T(3U_{alpha} + U_{beta}) / (2 * U_{dc}) \rightarrow Equation.11$$

$$Z = T(-3U_{alpha} + U_{beta}) / (2 * U_{dc}) \rightarrow Equation.12$$

$$T_1 + T_2 \leq T \rightarrow Equation.13$$

If $T_1 + T_2 \geq T \rightarrow Equation.14$ then,

$$T_1 = T_1\{T / (T_1 + T_2)\} \rightarrow Equation.15$$

$$T_2 = T_2\{T / (T_1 + T_2)\} \rightarrow Equation.16$$

N	1	2	3	4	5	6
T1	Z	Y	-Z	-X	X	-Y
T2	Y	-X	X	Z	-Y	-Z

Step 4: Calculate the switching operating time

$$T_a = \{T - T_1 - T_2\} / 4 \rightarrow Equation.17$$

$$T_b = T_a + \{T_1 / 2\} \rightarrow Equation.18$$

$$T_c = T_b + \{T_2 / 2\} \rightarrow Equation.19$$

N	1	2	3	4	5	6
Tcm1	Tb	Ta	Ta	Tc	Tc	Tb
Tcm2	Ta	Tc	Tb	Tb	Ta	Tc
Tcm3	Tc	Tb	Tc	Ta	Tb	Ta

IV. PROPORTIONAL INTEGRAL CONTROLLER

Because of easy design, low cost and simple structure the proportional integral controllers are most widely used in industries. As an on-off controller the proportional integral controller eliminates forced oscillation and steady state error. The overall stability and response of the speed will have negative impact due to integral mode. Therefore the proportional integral controller will not increase the speed of the response. Because proportional controller does not have means to predict what will happen with the error in near future. So by introducing derivative mode this problem will be solved. So now the proportional controller now gets the ability to predict error in future and then decreases reaction time. In industries speed of the response is not an issue then proportional integral controller is most widely used. Actually proportional integral controller is an integral error compensation scheme.

The integral of the actuating signal is the reason for the response of the output. The output produced by this type of controller consists of two terms. In those two terms one is the proportional to the actuating signal and other is proportional to its integral. Therefore in general this type of controller is known as PI controller or proportional plus controller. [9] Has implemented the proportional integral controller for the speed control of induction motor.

$$output(t) = K_p e(t) + K_I \int_0^t e(\tau) d\tau \rightarrow Equation.20$$

$e(t)$ =Set Reference Value – Actual Calculated Value

$$e(t) = \omega_{ref} - \omega_m(t) \rightarrow Equation.21$$

$$T_{ref}(t) = T_{ref}(t-1) + K_p[e(t) - e(t-1)] + K_1 e(t) \rightarrow Equation.23$$

K_p & K_I -Speed controller's gain

V. SIMULATION MODEL OF SVPWM AND PROPORTIONAL INTEGRAL CONTROL

The simulation results are given for the induction motor for the following specification:
Number of poles [P] = 4, Frequency [F] = 50 Hz, Number of phases = 3, Stator resistance [Rs] = 6 ohms, Rotor resistance [Rr] = 10 ohms, Stator inductance [Ls] = 450 mH, Mutual inductance [Lm] = 390 mH, Moment of inertia [J] = 0.00388 Kg-m/sec.

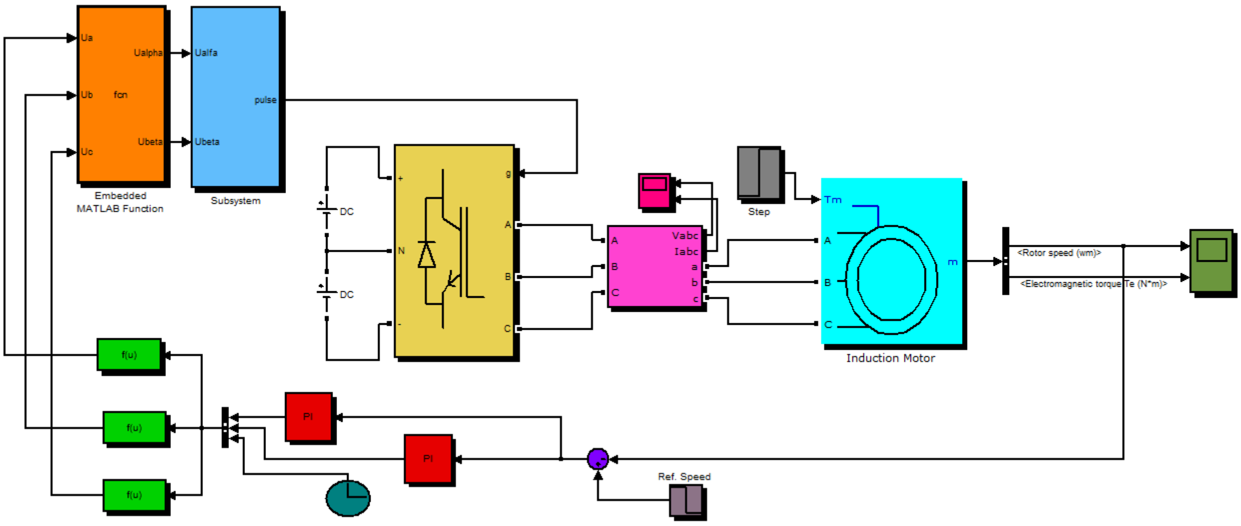

Figure.6.MATLAB simulink model of SVPWM based induction motor

The figure.6 shows the complete MATLAB / SIMULINK model of the space vector pulse width modulation based induction motor with v/f control. The step by step subsystem model of the SVPWM method is shown figure.7, figure.7, figure.10, figure.11 and figure.12. These subsystem models are designed on the basis of the mathematical equation of SVPWM methods as it is discussed in chapter 3.

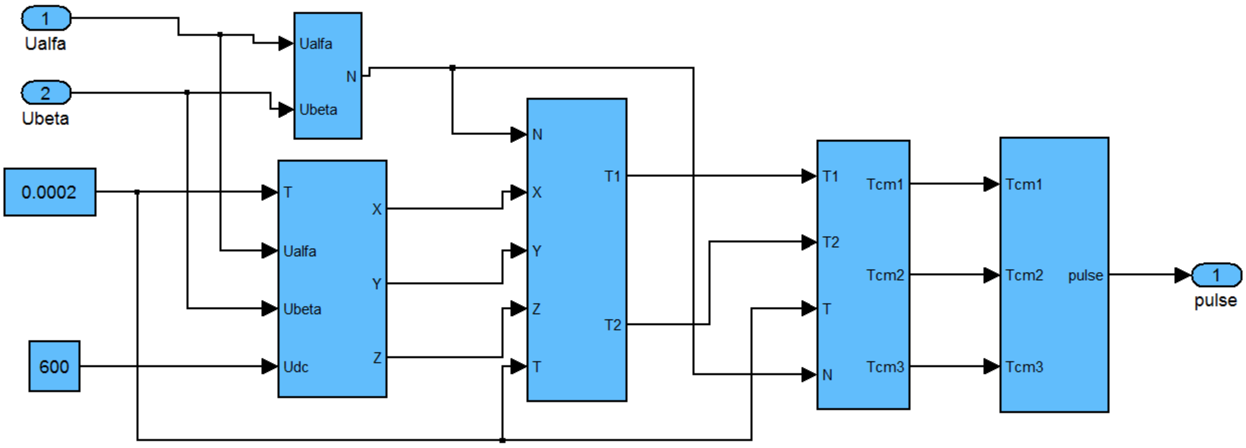

Figure.7.MATLAB simulink subsystem model for the generation of gate pulse

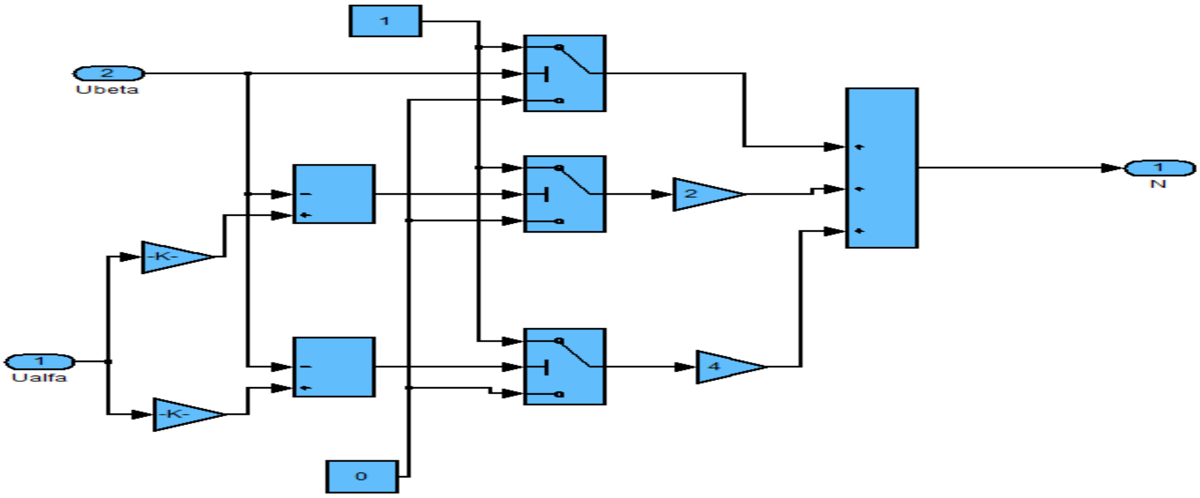

Figure.8.MATLAB simulink subsystem model for sector judgment

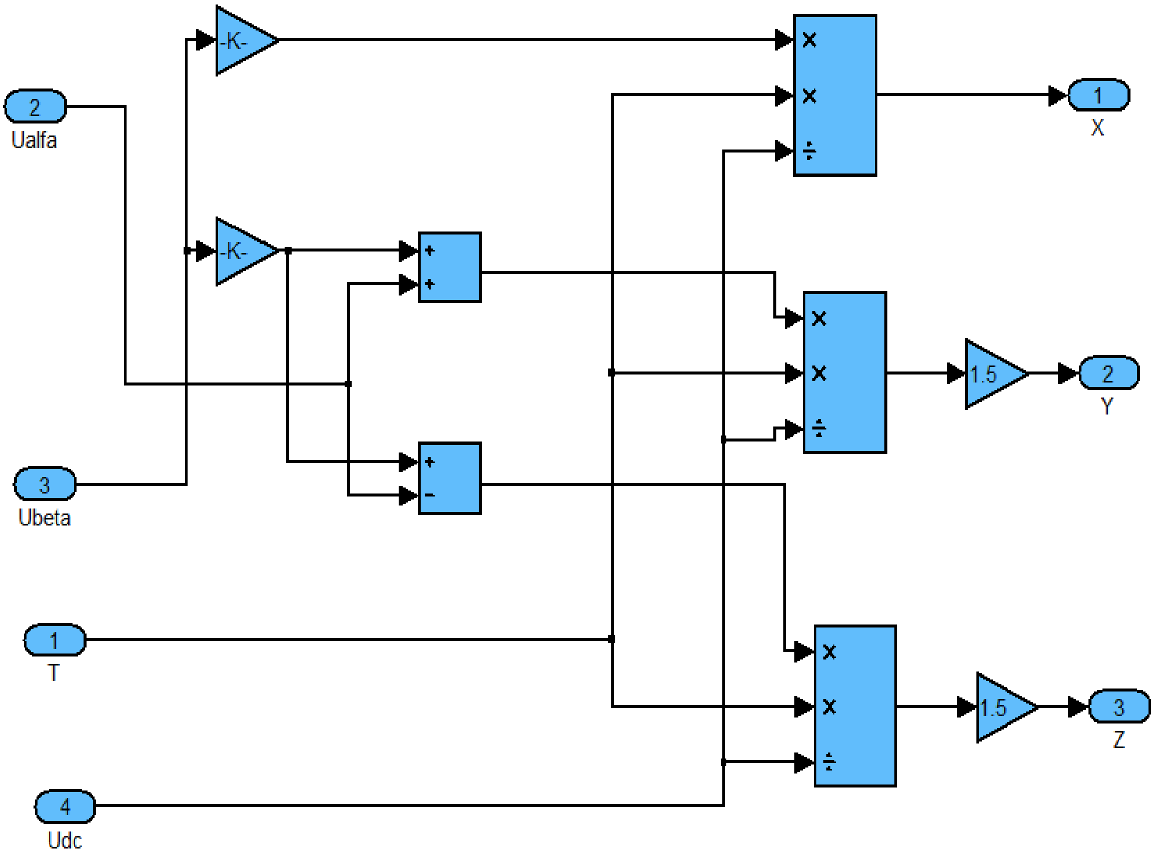

Figure.9.MATLAB simulink subsystem model for calculating X, Y, Z

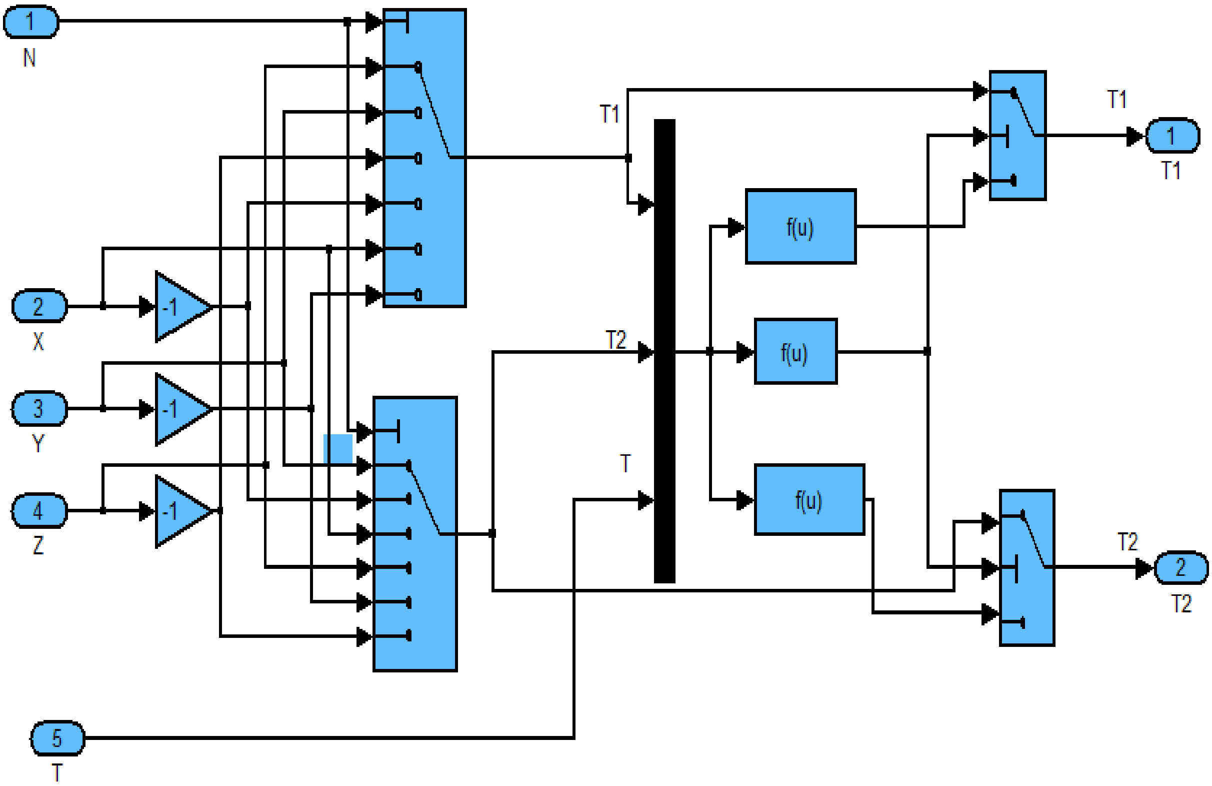

Figure.10.MATLAB simulink subsystem model for calculating operating time of the fundamental vectors

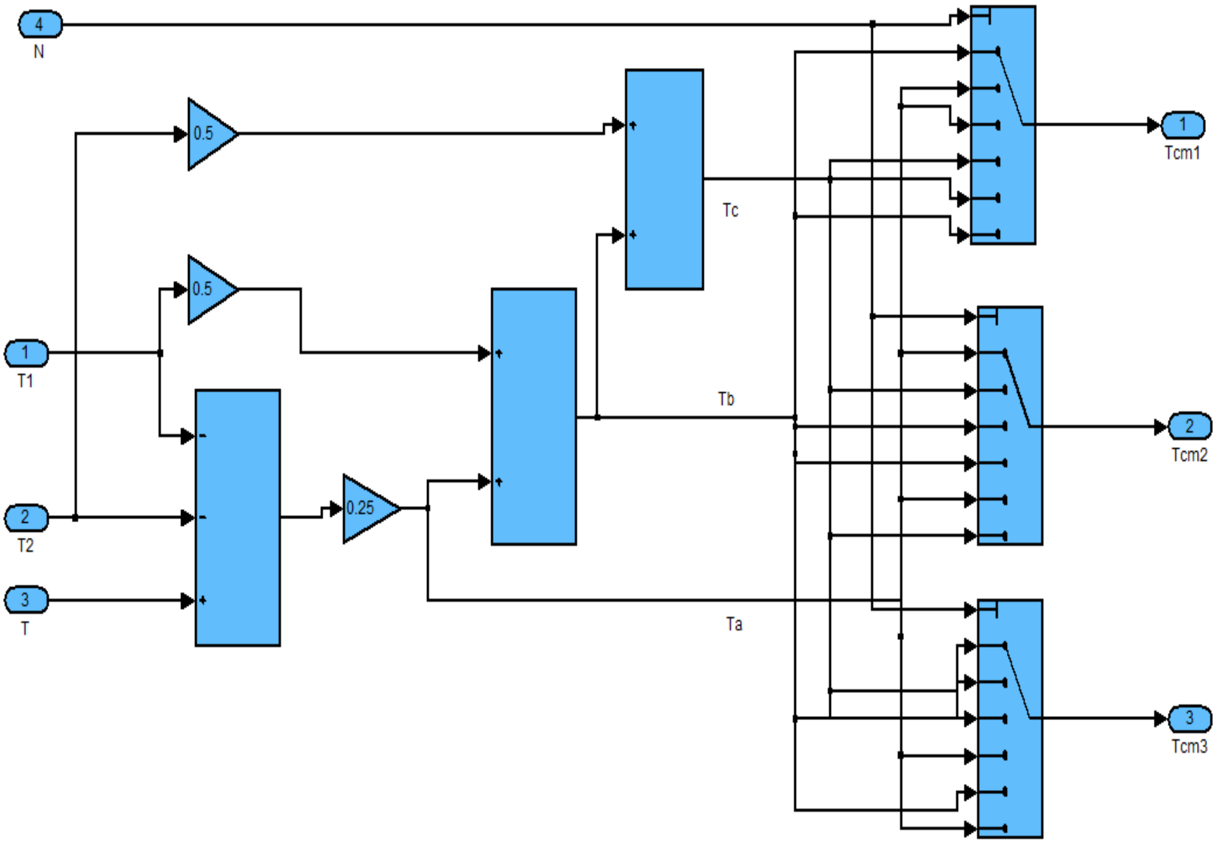

Figure.11.MATLAB simulink subsystem model for calculating switching operating time

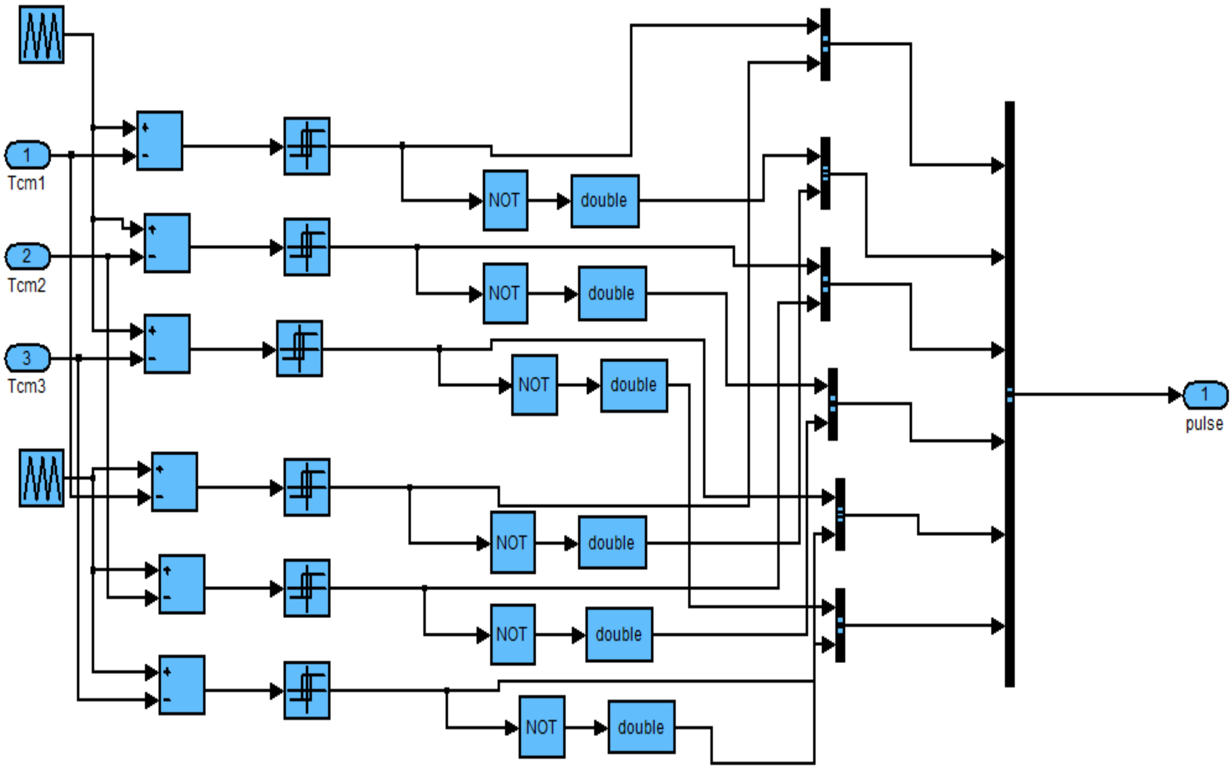

Figure.12.MATLAB simulink subsystem model for generating SVPWM

VI. SIMULATION RESULTS

[A] Stator Current

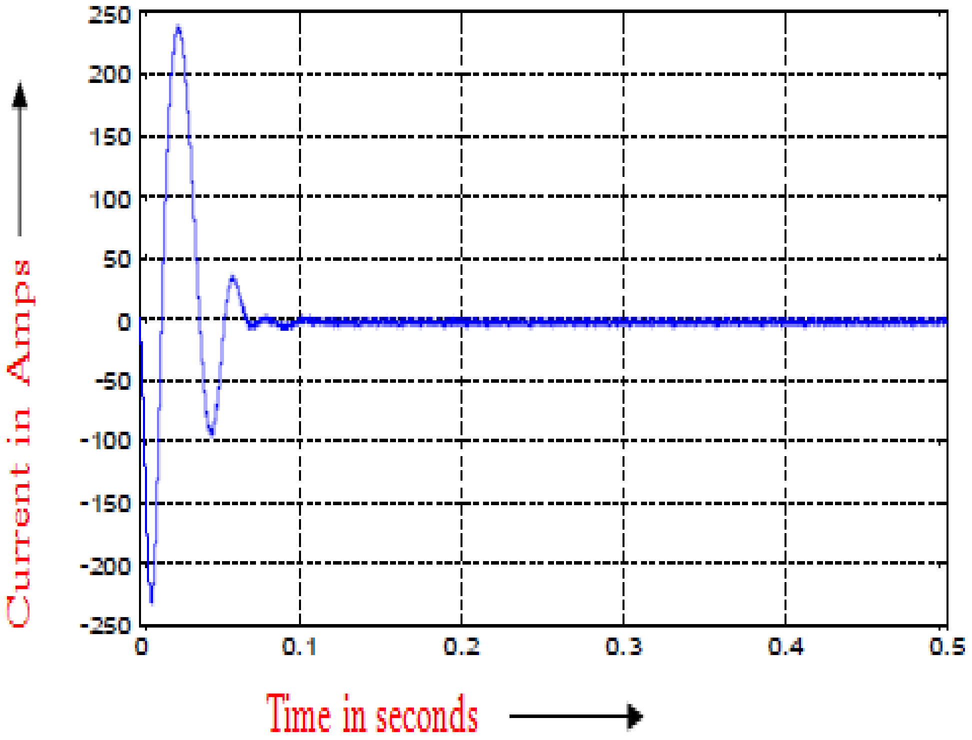

Figure.13.Stator current

[B] Rotor Current

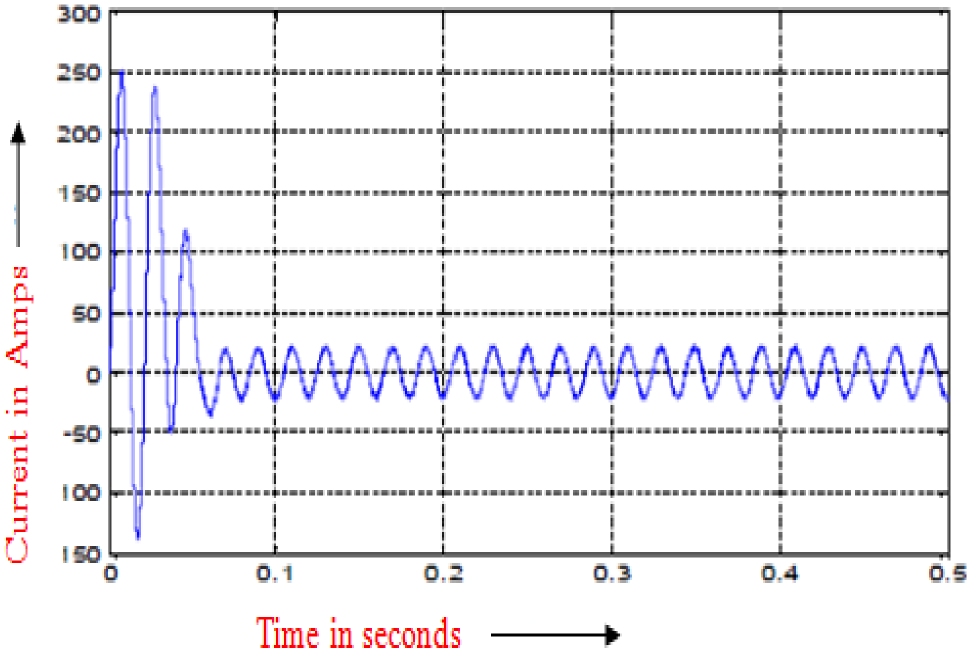

Figure.14.Rotor current

[C] Speed

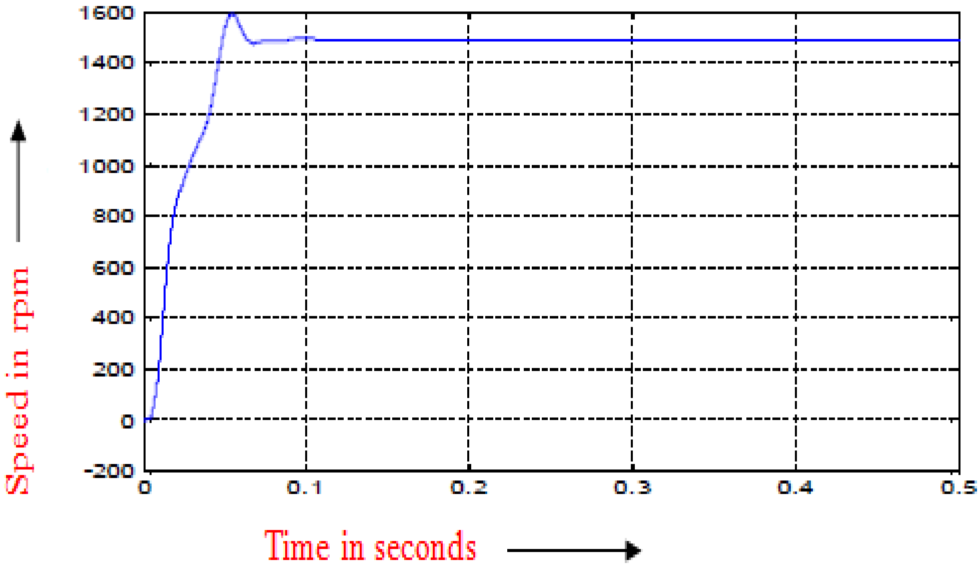

Figure.15.Speed

[D] Torque

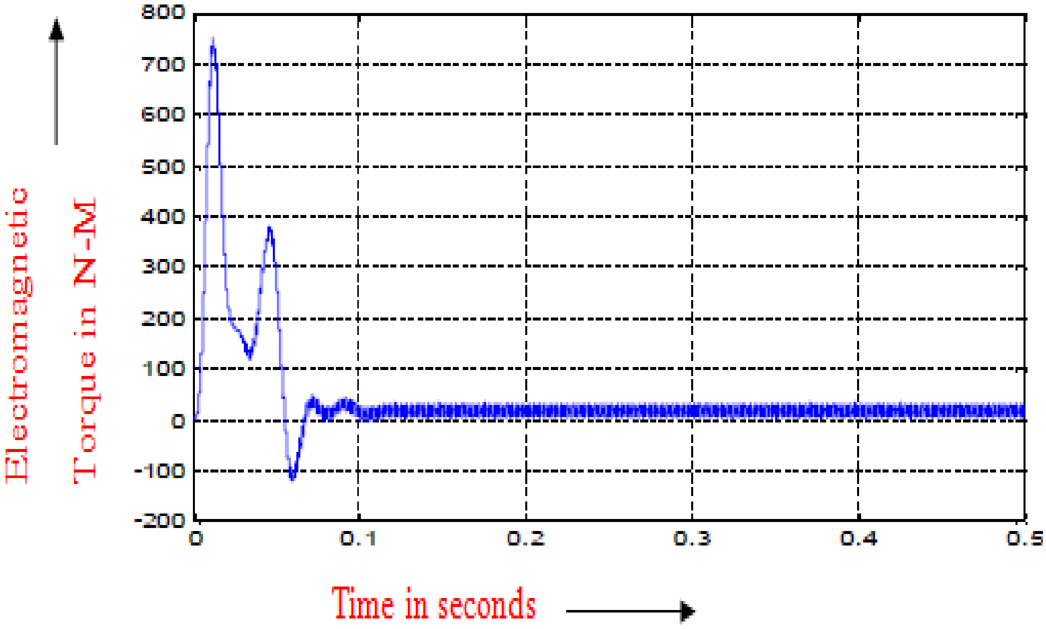

Figure.16.Torque

VII.CONCLUSION

In this research paper space vector pulse width modulation based induction motor with proportional integral control model is designed through MATLAB software and also tested successfully by evaluating the parameters like stator current, stator current, torque and speed. **.** It is due to its characteristics like good power factor, extremely rugged and high efficiency. This scheme leads to be able to adjust the speed of the motor by control the frequency and amplitude of the stator voltage, the ratio of stator voltage to frequency should be kept constant. In addition to that the design and implementation of an induction in simulink is uncomplicated and trouble free. These types of induction motors can be used in lathes, drilling machines, lifts, cranes, conveyors, industrial drives, agricultural and industrial pumps.

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IX.BIOGRAPHY

Mr.J.Vikramarajan received his Master degree in Power Electronics and Drives and Bachelor degree in Electrical and Electronics Engineering from VIT University, India. He has published several international research books and journals. His research interests are electrical machines, power electronic applications, power quality, power electronic converters and power electronic controllers for renewable energy systems.