A THYRISTOR BASED SPEED CONTROL TECHNIQUES OF SEPARATELY EXCITED DC MOTOR

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***ABSTRACT*: With joint progress of the industrial electronics and technology it is possible to design more efficient control circuit for motors and high dynamic performance can be obtain from the induction machine. Induction machines are the basic building block to design a electrical drive system which are widely used in many industrial applications. Due to their low cost and maintenance the induction machines are preferred over DC machines. In the conventional methods of speed control there was power loses in the system these power lose can be minimize by the use of power electronics control strategy in the system. In this paper report thyristor based control of induction machine for two-phase and three-phase system is describe and model was simulated in the MATLAB simulation. The speed was controlled using the various types of bridge circuit. The variation in speed and torque behaviour of the motor is shown in the result section. In this the voltage and current source are ideal there may be some variation in the output for practical implementation of the system. This may occur due to the input-output behaviour of the equipments, other physical and electrical parameter variation.**

***Keywords*: AC/DC converter, DC motor, speed control**

I. INTRODUCTION

The modern era of power electronics and drives began in 1958 when the General Electrical Company introduced a commercial thyristor just after two years, it was invented by Bell Telephone Laboratory. Soon all industrial applications that were based on mercury-arc rectifiers and power magnetic amplifiers were replaced by silicon-controlled rectifiers(SCRs). Less than 20 years after introducing commercial SCRs, significant improvements came in semiconductor physical and fabrication technology. Operation were made as well as many different types of power semiconductor devices appeared.

The growth in power electronics was made possible with their evolution of microelectronic in 1970s and 1980s in which the low power IC control chips provided the intelligence and brain to control the high-power semiconductor devices . Moreover the introduction of the microprocessors made it possible to apply the modern control theory to power electronics. In the last 20 years the rapid growth in power electronics application because of this introduction of very fast and high-power switching devices engage with the utilization of state-of –the –art control algorithms. An electric power can be converted from one form to other form with the help of Power electronics devices. The function of the power electronics circuits by using semiconductor devices as a switch is modifying or controlling the voltage. The goal of power electronics circuits are to change electrical energy from one form to other from source to load with highest efficiency high availability and high reliability with lowest cost, smallest size and weight.

The main objective of this paper work is to observe the/to;

1. Motor characteristic for various control circuitry.
2. Develop a suitable control circuit which makes the system more dynamic and efficient.

Mathematical modeling of DC motor

To analyze the torque speed characteristics, power factor and total harmonics distortion, the dynamic and steady-state model of separately excited DC motor is required. Figure 1 shows the schematic representation of the model of a separately excited DC motor, in which *ea* is the terminal voltage applied to the motor, *Ra* and *La* are the resistance, and inductance of the armature circuit respectively, *Rf* and *Lf* are the resistance, and inductance of the field circuit respectively, *eb* is generated back emf and *Tm* is the electromagnetic torque developed by the motor. The related DC Motor parameters are mentioned in appendix A. Due to the interaction of field flux with current in armature conductors, the torque is produced which is given by Eq. (1)

$$Tm = Kt\varphi ia \quad (1)$$

Here Kt is a constant depending on motor windings and geometry and φ is the flux per pole due to the field winding. The direction of armature current decides the direction of the torque produced. When armature rotates, the flux linking the armature winding will vary with time and therefore according to Faraday's law, an emf will be induced across the winding. This generated emf, known as the back emf, depends on speed of rotation as well as on the flux produced by the field and given by Eq. (2)

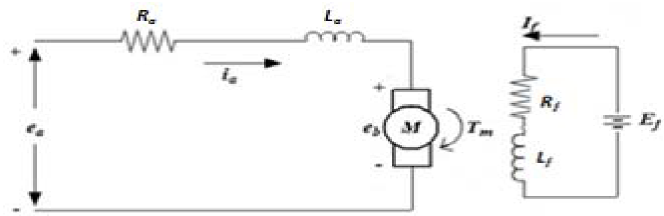

Figure 1. Equivalent circuit of separately excited DC motor

$$e_b = K_t \phi \omega \tag{2}$$

By applying KVL at input side of in figure 1,

$$e_a = i_a R_a + L_a \frac{di_a}{dt} + e_b \tag{3}$$

In steady state condition,

$$E_a = I_a R_a + E_b \tag{4}$$

In terms of torque and speed, the steady state equation will be given by Eq. (5)

$$E_a = \frac{T_m}{K_t \phi} R_a + K_t \omega \phi \tag{5}$$

So,

$$\omega = \frac{E_a}{K_t \phi} - \frac{T_m}{(K_t \phi)^2} R_a \tag{6}$$

Adding external resistor to the DC drive to control the speed of DC motor is not a healthy practice as large part of energy get loosed in terms of heat due to the external resistor Rext. Armature voltage controlled is preferred for speed up to rated speed (base speed), and flux control for speed beyond rated speed but at the same time the maximum torque capability of the motor is reduced since for a given maximum armature current, the flux is less than the rated value and so as the maximum torque produced is less than the maximum rated torque.

Figure 2 illustrate the ideal torque speed characteristic which reflects equation (6), using armature voltage control method in which the voltage applied across the armature *ea* is varied keeping field voltage constant.

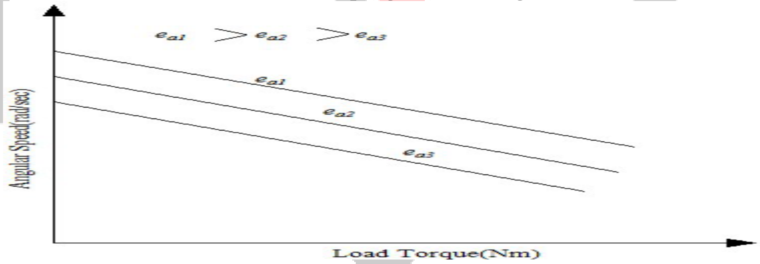

Figure 2. Torque speed characteristics of the separately excited DC motor at different armature voltages

Thyristor based techniques of DC motor speed control

Figure 3 shows a separately excited DC motor fed through single phase half wave converter. It offers only one quadrant drive. Such type of drives, are used up to about 0.5 KW DC motor.

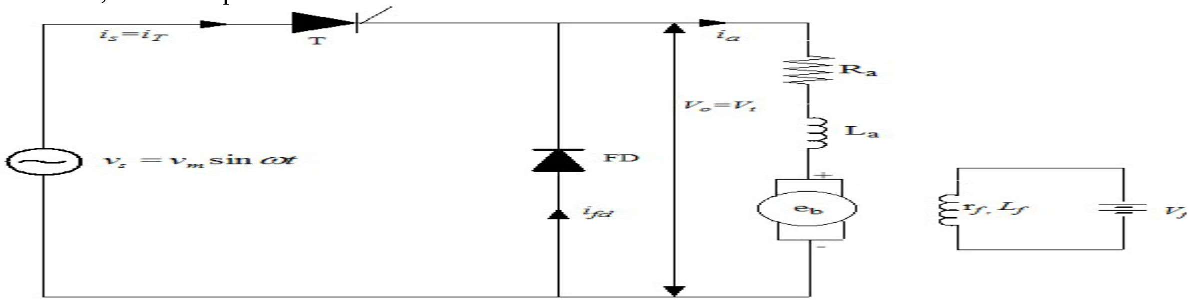

Figure 3. Single phase half wave converter drive

For single phase half wave converter, average output voltage of converter can be calculated as, given by Eq. (7)

$$V_0 = \frac{V_m}{2\pi}(1+\cos\alpha)\text{, for } 0<\alpha<\pi \tag{7}$$

An ideal DC source is preferred over half wave converter for field circuit of half wave converter drive otherwise the magnetic losses of the motor increase due to high ripple content in the field excitation current. A separately excited DC motor fed through single phase semi converter is shown in figure 4. This converter also offer only one quadrant drive and is used up to 15 kW DC drives.

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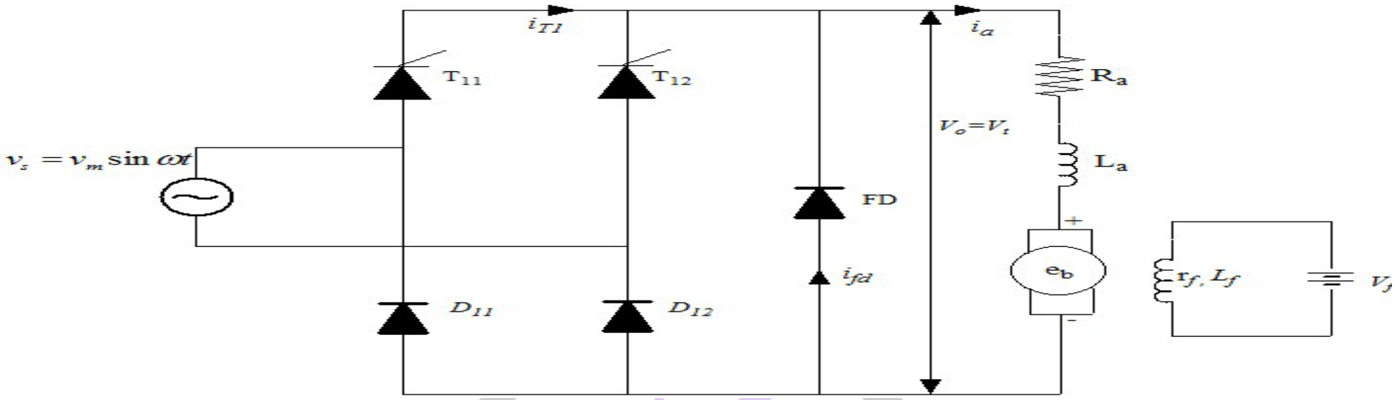


Figure 4. Single phase semi converter drive

With a single phase semi converter in the armature circuit, equation (8) gives the average armature voltage as,

$$V_0 = V_t = \frac{V_m}{\pi}(1+\cos\alpha)\text{, for } 0<\alpha<\pi \tag{8}$$

A single phase full converter drive offers a two quadrant drive operation and is limited to applications up to 15kW, which is shown in figure 5. The armature converter gives +*Vo* or –*Vo* and allows operation in the first and fourth quadrant. The converter in the field circuit could be semi, full or even dual converter. The reversal of the armature or field voltage allows operation in the second and third quadrant.

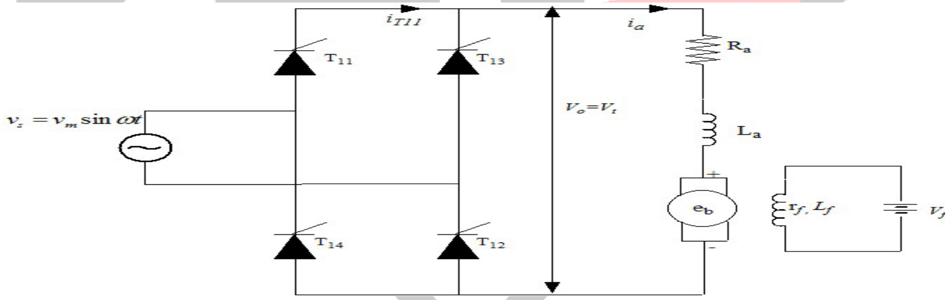


Figure 5. Single phase full converter drive

The average armature voltage in armature circuit for single phase full converter drive is given by Eq. (9)

$$V_0 = V_t = \frac{2V_m}{\pi}(1+\cos\alpha)\text{, for } 0<\alpha<\pi \tag{9}$$

To realize single phase dual converter, two single phase full converters are connected as shown in figure.

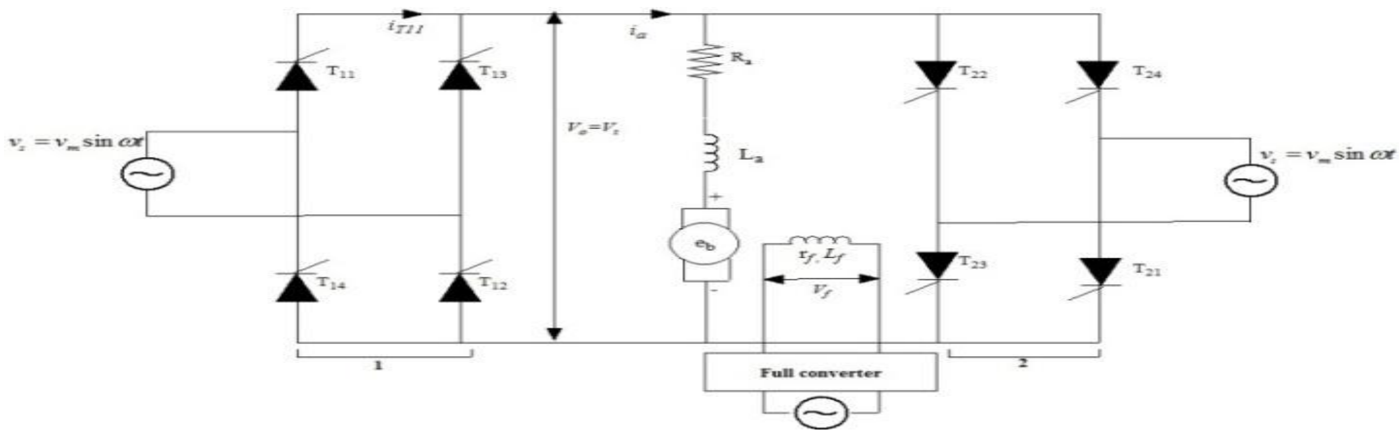


Figure 6. Single phase dual converter drive

In figure 6, there are two single phase full wave converters either converter 1 operates to supply a positive armature voltage *Vo*, or converter 2 operates to supply negative armature voltage –*Vo*. Converter 1 provides operation in first and fourth quadrants, and converter 2 provides operation in second and third quadrants. It is four quadrant drives and provides four modes of operation: forward powering, forward braking (regeneration), reverse powering, and reverse breaking (regeneration). The field converter could be a full wave converter, a semi converter, or a dual converter. If converter 1 operates at a firing angle of $\alpha 1$ then equation (10) gives the armature voltage as,

$$V_0 = V_t = \frac{V_m}{\pi}(1+\cos\alpha_1), \text{ for } 0<\alpha<\pi \tag{10}$$

And similarly, if converter 2 operates at a firing angle of α_2 then equation (11) gives the armature voltage as, [11].

$$V_0 = V_t = \frac{V_m}{\pi}(1+\cos\alpha_2) \tag{11}$$

SIMULATION AND RESULTS

SIMULATION CIRCUIT

The control circuit for the dc motor is successfully simulated on the MATLAB and the result is shown below

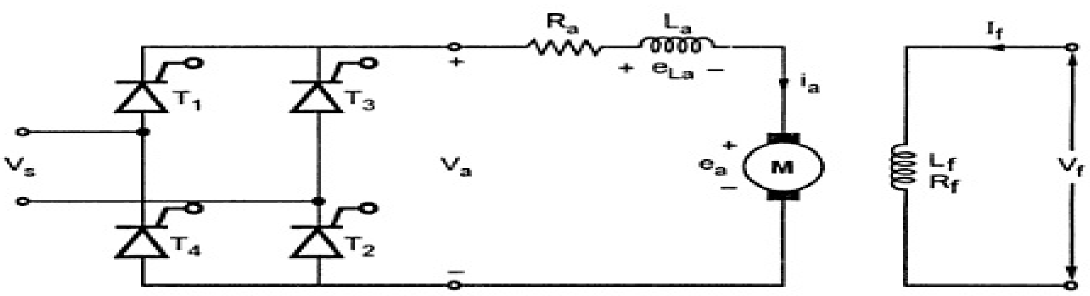
Single-phase full wave rectifier fed drives:
In full wave rectifier feeding separately excited DC motor two rectifiers (say rectifier1 or converter1 and rectifier 2 or converter 2) are used for feeding the armature and the field circuit separately. Here converter1 feeds armature circuit and converter2 feeds field circuit as shown in fig. 1. This drive system provides the two quadrant operation.

For converter1 feeding armature circuit

$$\mathbf{V_0 = V_t = 2V_m\cos\alpha_1/\Pi;\ 0<\alpha_1<\Pi}$$

For converter2 feeding field circuit

$$\mathbf{V_f = 2V_m\cos\alpha_2 / \Pi;\ 0<\alpha_2<\Pi}$$
$$\mathbf{I_{srms} = Ia}$$
$$\mathbf{I_{trms} = Ia/\sqrt{2}}$$
$$\mathbf{P_f = 2\sqrt{2}\cos\alpha/\Pi}$$



1. **Simulink model of single phase half controlled rectifier fed to separately excited dc motor**

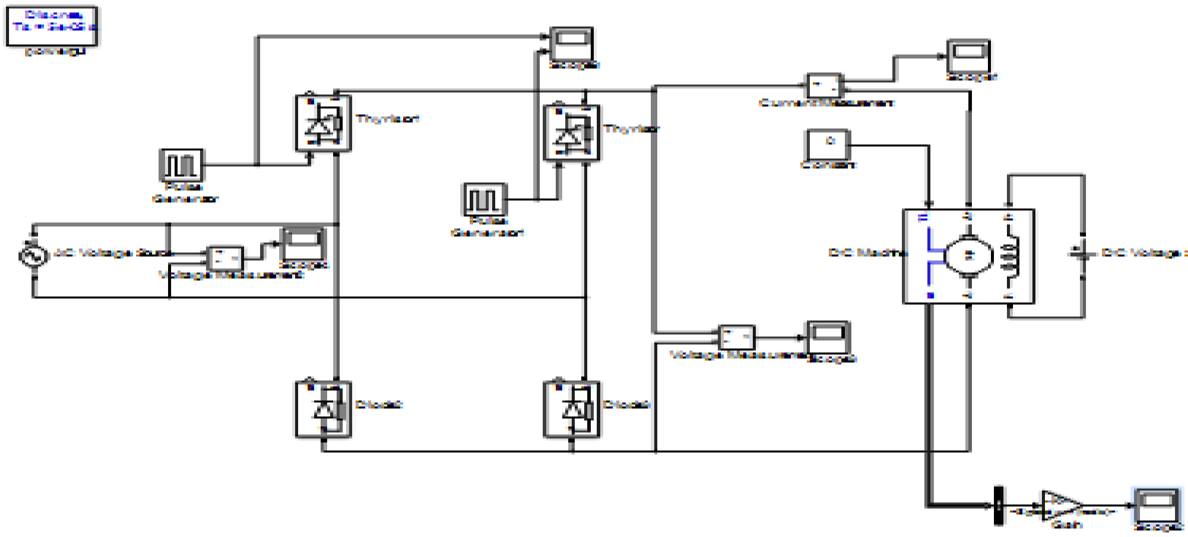


Table 1:Table showing the value of speed at no as well as constant load:

Firing angle(T1)	Phase delay(T1)	Firing angle(T2)	Phase delay(T2)	Load	Speed
0	0.000	180	0.01	NL	1650
30	0.0017	210	0.0117	NL	1615
60	0.0033	240	0.05.3	NL	1545
0	0.000	180	0.01	CL	1420
30	0.0017	210	0.0117	CL	1012
60	0.0033	240	0.05.3	CL	768

2. **Simulink model of single phase fully controlled rectifier fed DC separately excited Motor**

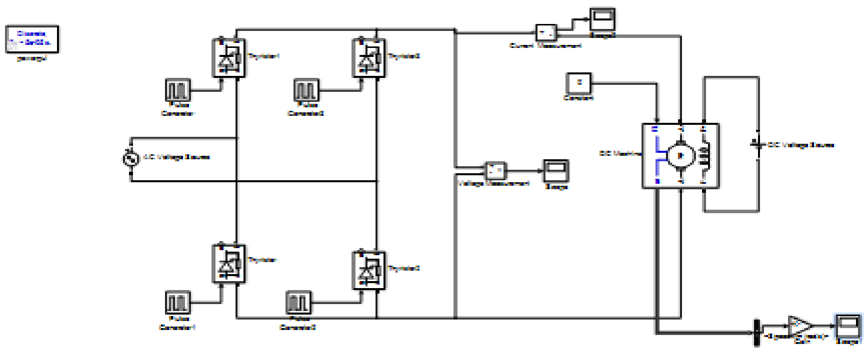


Table 2:Table showing the value of speed at no as well as constant load:

Firing angle(T1)	Phase delay(T1)	Firing angle(T2)	Phase delay(T2)	Load	Speed
0	0.000	180	0.01	NL	1250
30	0.0017	210	0.0117	NL	1218
60	0.0033	240	0.05.3	NL	950
0	0.000	180	0.01	CL	1195
30	0.0017	210	0.0117	CL	895
60	0.0033	240	0.05.3	CL	480

3. **Simulink model of Three phase half controlled rectifier fed separately excited DC Motor:**

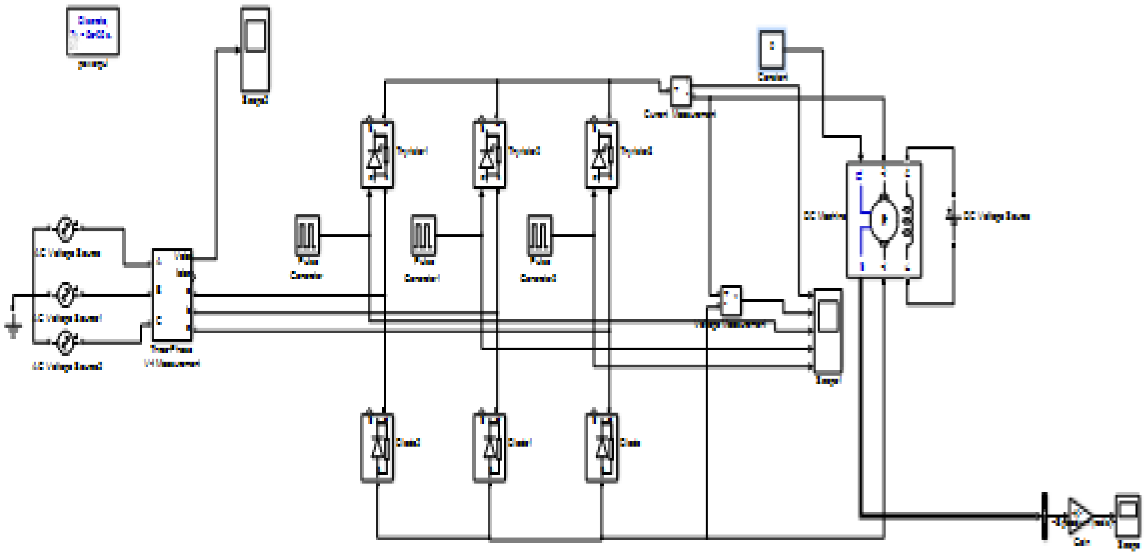


Table 3:Table showing the value of speed at no as well as constant load:

Firing angle(T1)	Phase delay(T1)	Firing angle(T2)	Phase delay(T2)	Firing angle(T3)	Phase delay(T3)	Load	Speed
0	0.000	120	0.01	240	0.05.3	NL	2695
30	0.0017	150	0.0117	270	0.0150	NL	2671
60	0.0033	180	0.05.3	300	0.0167	NL	2658
0	0.000	120	0.01	240	0.05.3	CL	2398
30	0.0017	150	0.0117	270	0.0150	CL	2474
60	0.0033	180	0.05.3	300	0.0167	CL	2387

4. Simulink model of Three phase fully controlled rectifier fed separately excited DC Motor:

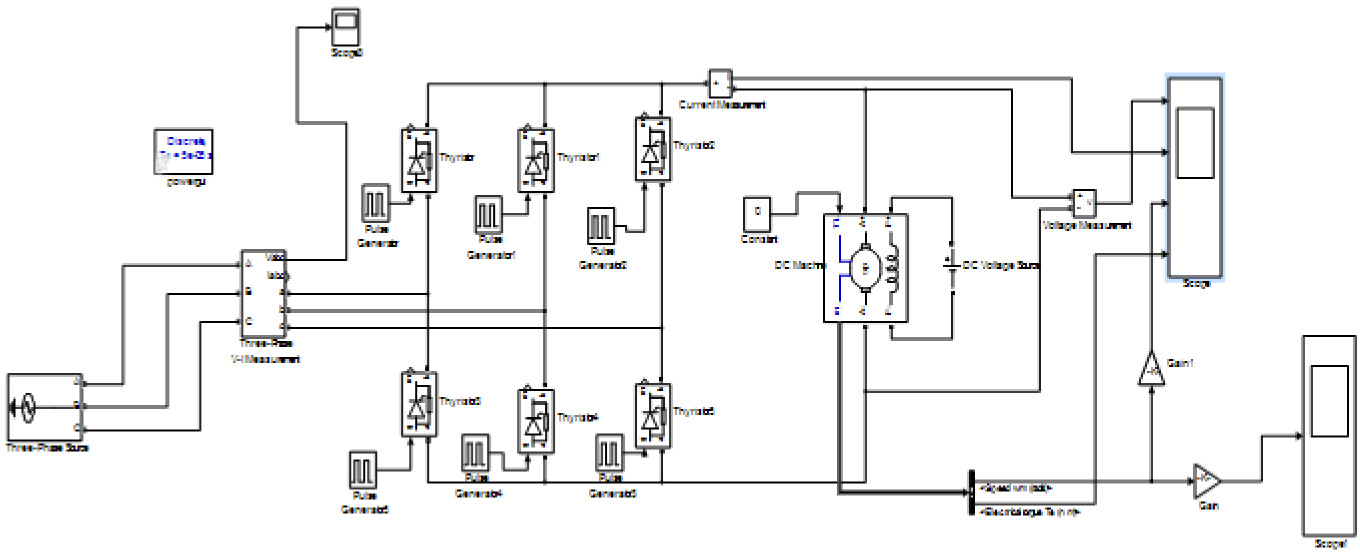
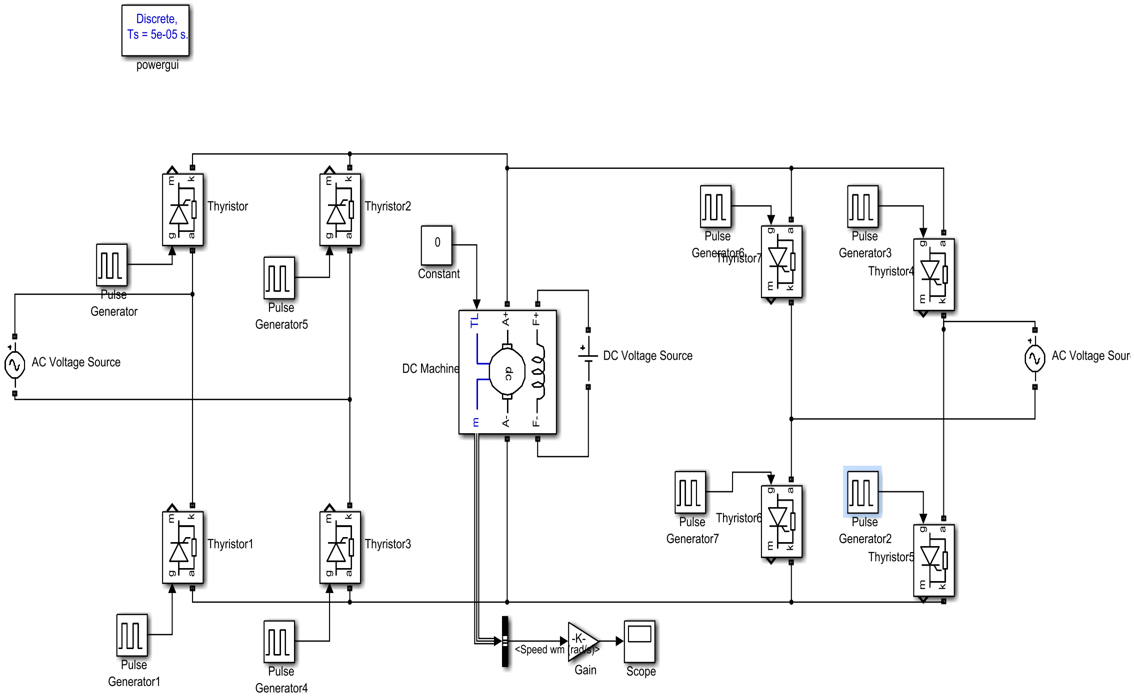


Table 4:Table showing the value of speed at no as well as constant load:

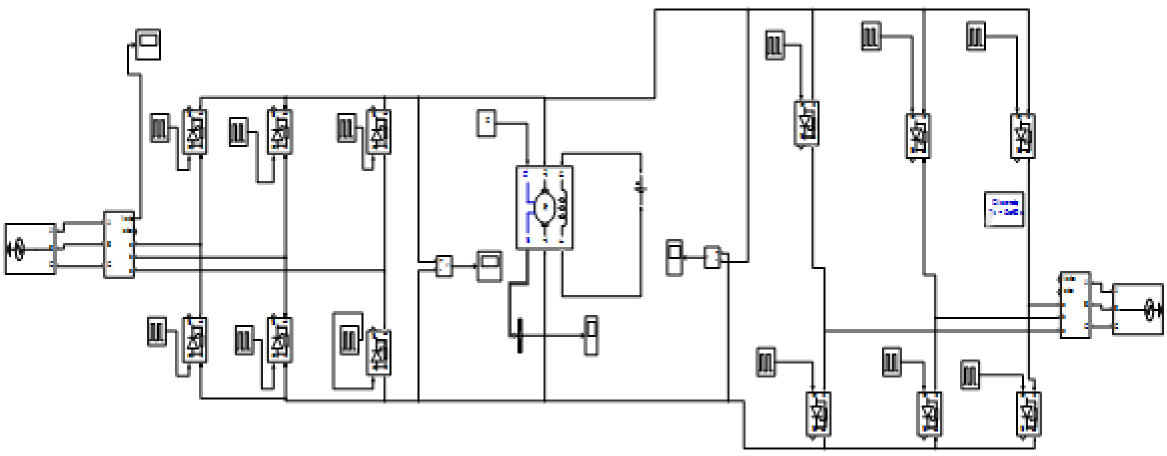
FA(T1)	FA(T2)	FA(T3)	FA(T4)	FA(T5)	FA(T6)	Load	Speed
0	60	120	180	240	300	NL	5.50
30	90	150	210	270	330	NL	1238
60	120	180	240	300	360	NL	1158
0	60	120	180	240	300	CL	1220

30	90	150	210	270	330	CL	1200
60	120	180	240	300	360	CL	1000

5. Simulink model of single phase dual converter fed separately excited DC Motor

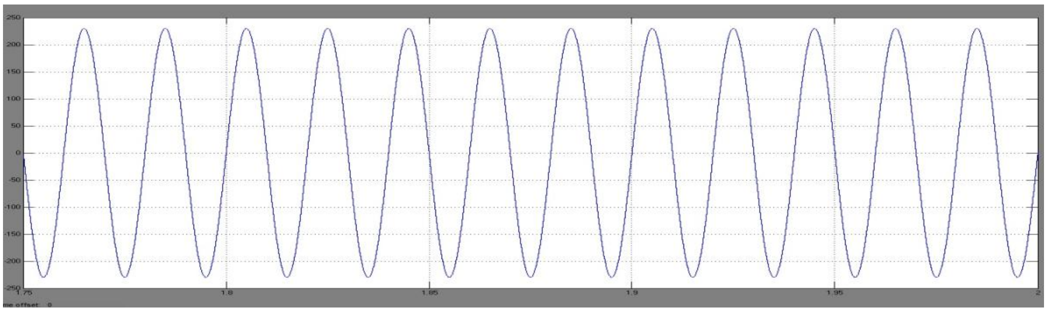


6. Simulink model of three-phase dual converter fed separately excited DC Motor

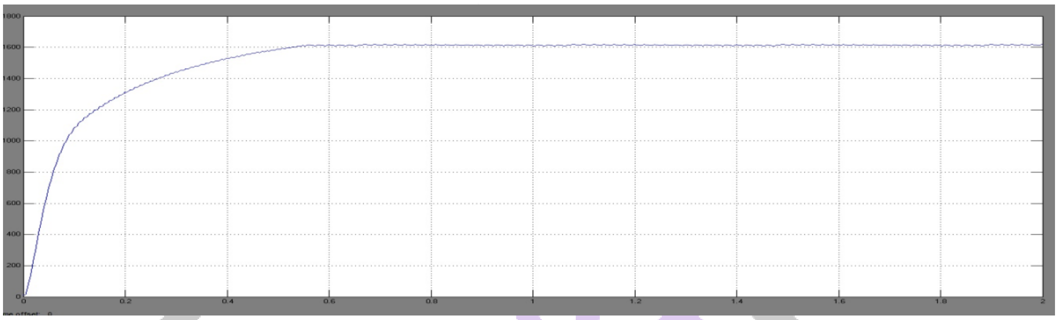


SIMULATION RESULT

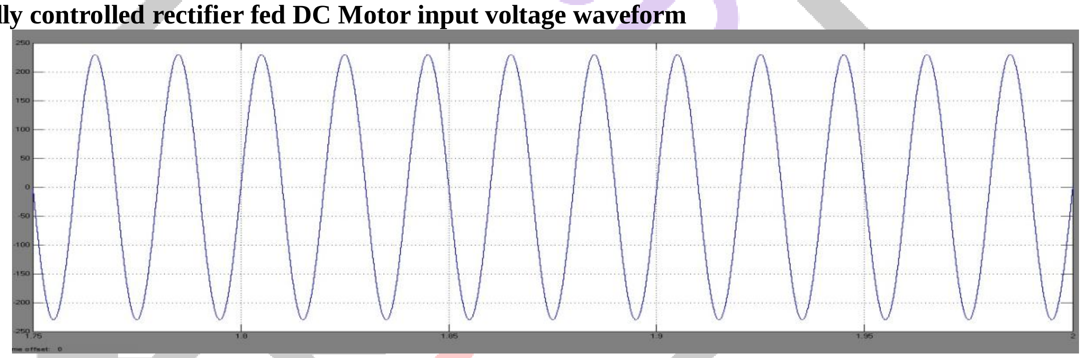
1. **Single phase half controlled rectifier Input voltage waveform**



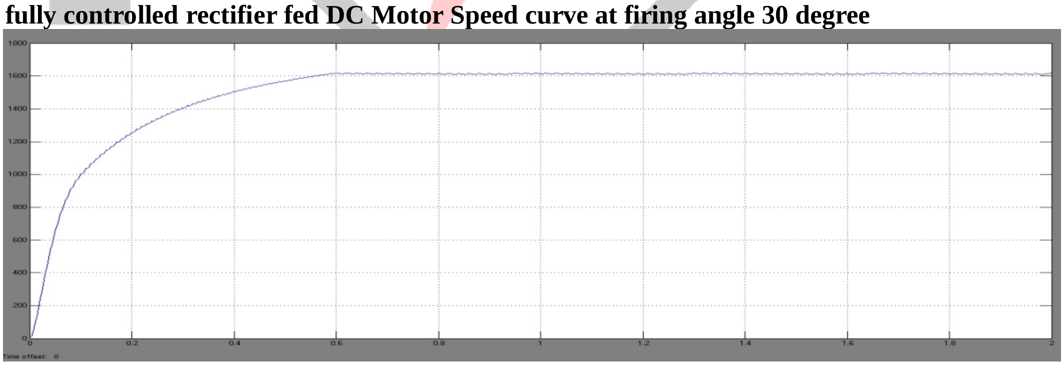
Single phase half controlled rectifier fed to dc separately excited motor speed curve



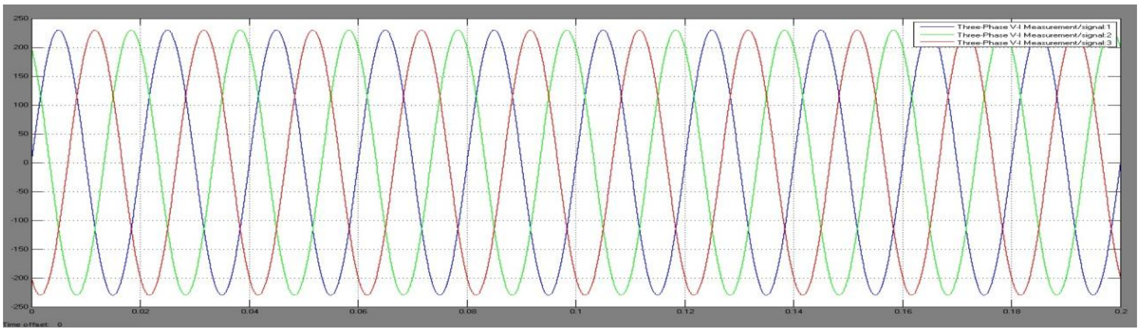
2. Single phase fully controlled rectifier fed DC Motor input voltage waveform



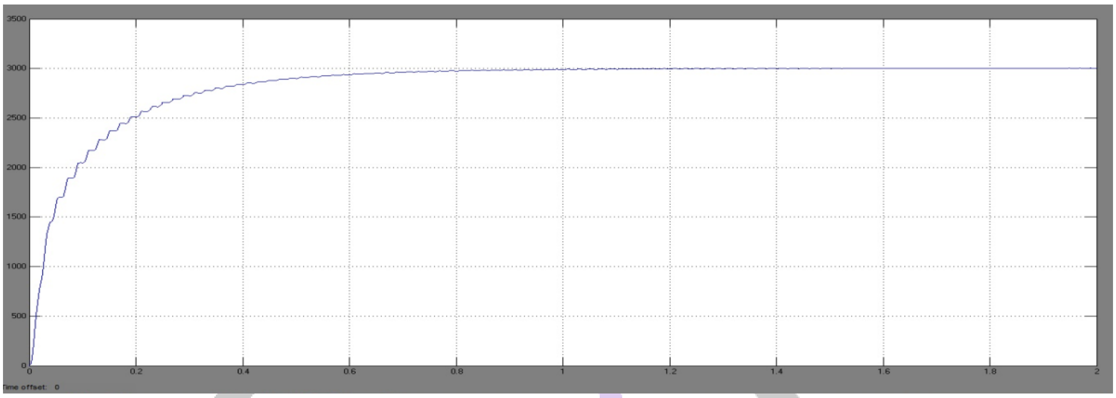
Single phase fully controlled rectifier fed DC Motor Speed curve at firing angle 30 degree



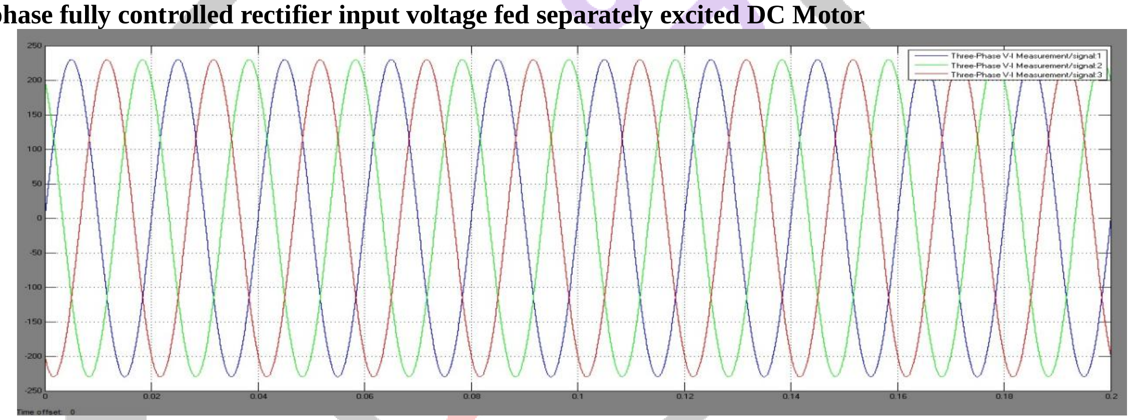
3.1 Three phase half controlled rectifier input voltage fed separately excited DC Motor



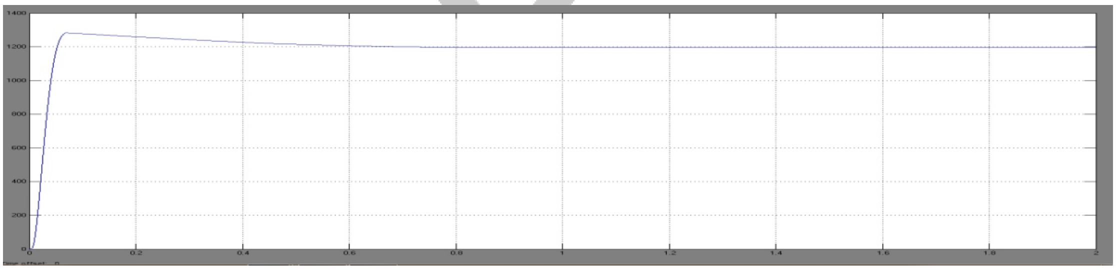
3.2Three phase half controlled rectifier fed Separately excited DC Motor Speed curve



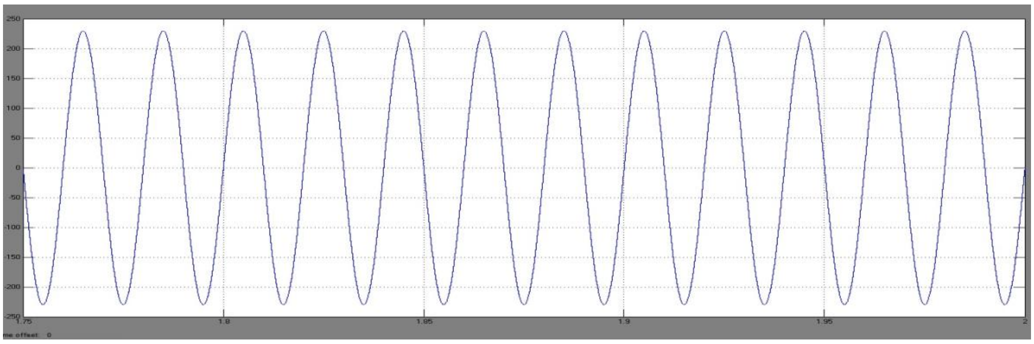
4.0 Three phase fully controlled rectifier input voltage fed separately excited DC Motor



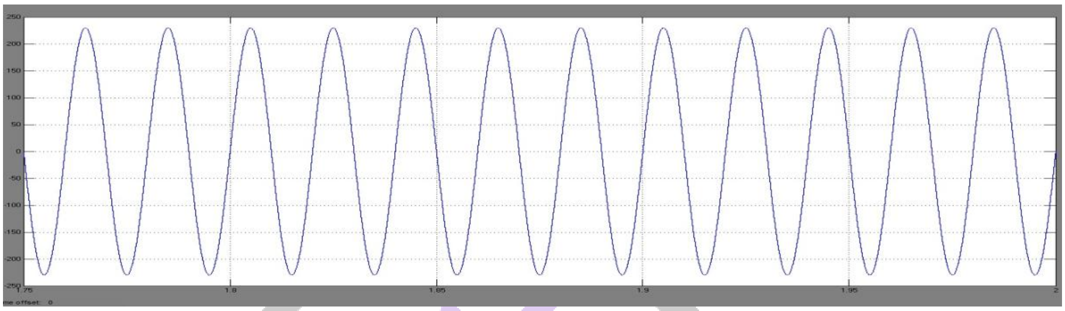
4.1 Three Phase fully controlled rectifier separately excited DC Motor speed curve



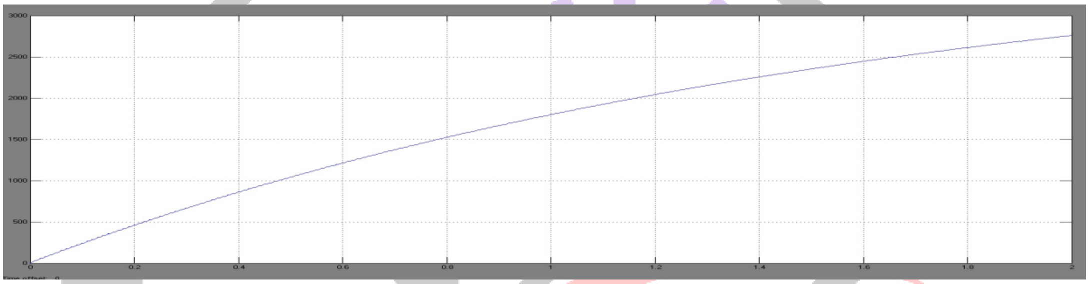
5.0 Single phase dual converter supplied separately excited DC Motor converter 1 input voltage



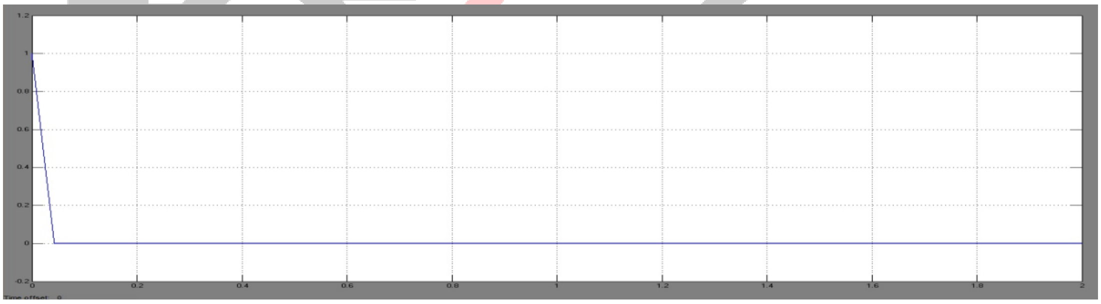
5.1 Single phase dual converter fed separately excited DC Motor converter 2 input voltages



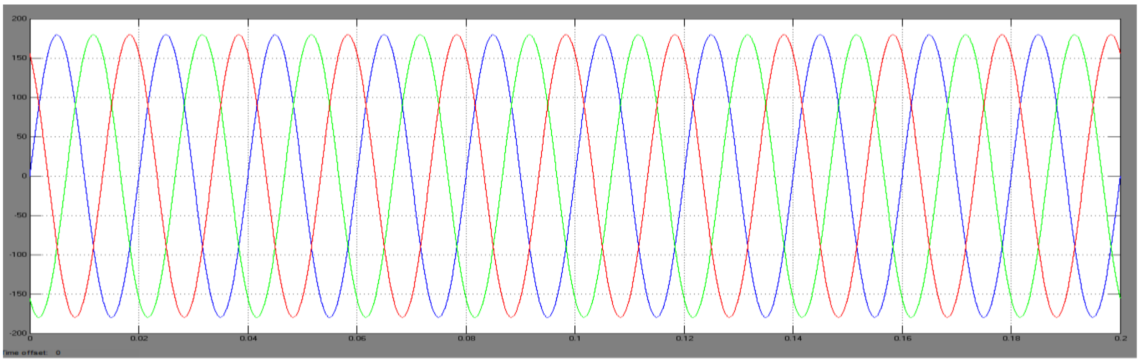
5.2 Single phase dual converter fed separately excited DC Motor speed curve at firing angle 30 degree delay



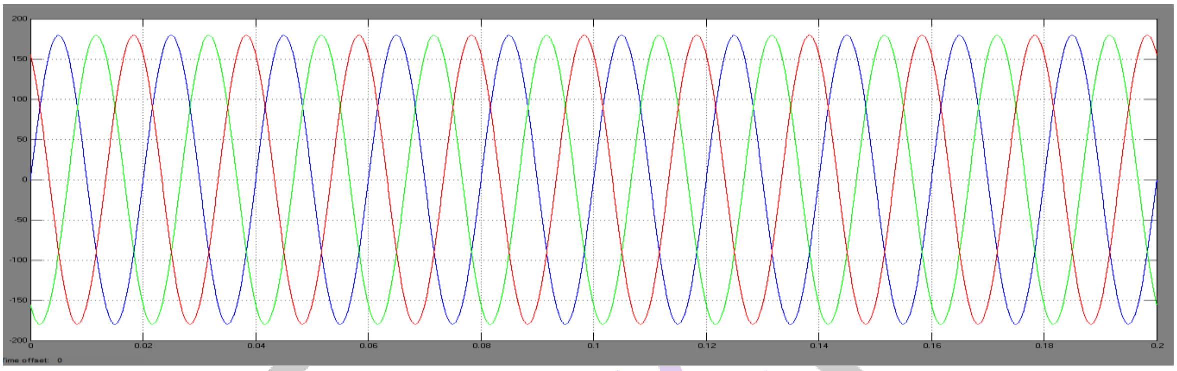
5.3 Single phase dual converter fed separately excited DC Motor at firing angle 90 degree



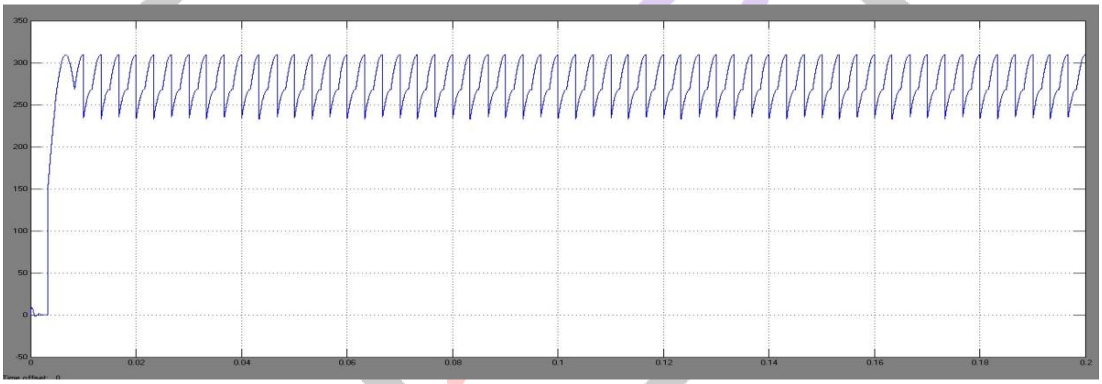
6.0 Three-phase dual converter fed separately excited dc motor converter 1 input voltage



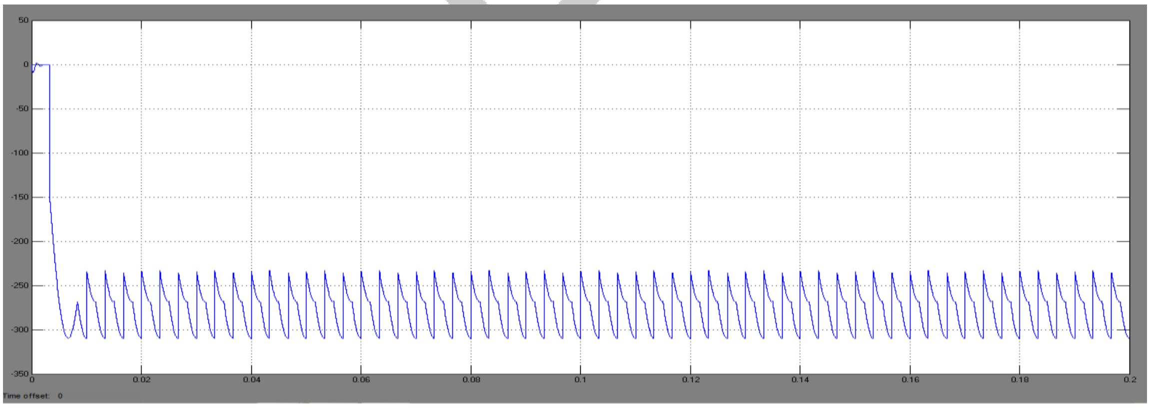
6.1 Three-phase Dual converter fed separately excited DC Motor converter 2 input voltage



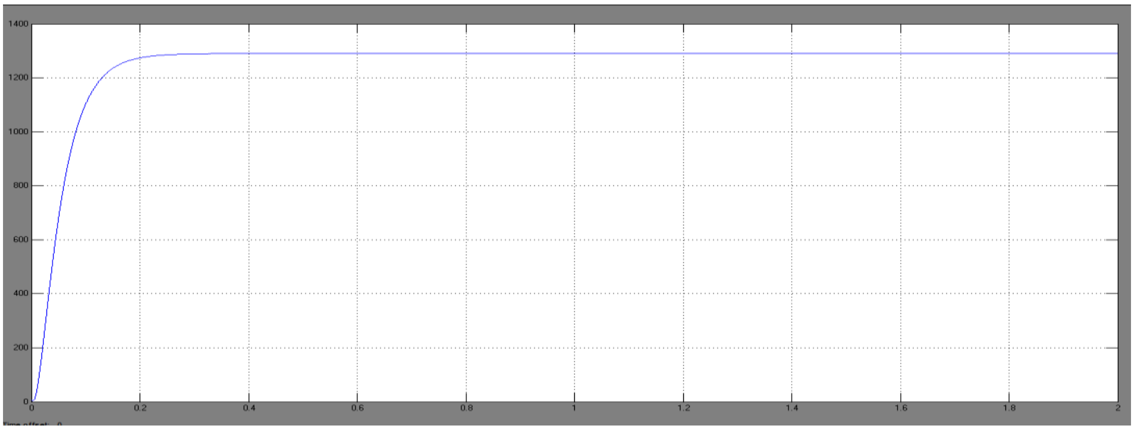
6.2 Converter 1 output voltage waveform for three-phase dual converter



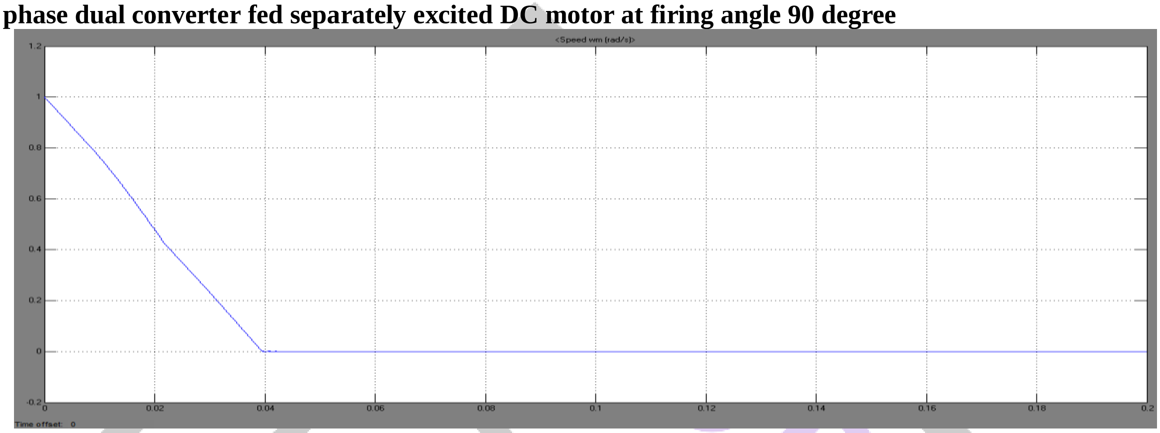
6.3 Converter 2 output voltage waveform for three-phase dual converter



6.4 Three phase dual converter fed separately excited DC motor at firing angle 30 degree



6.5 Three phase dual converter fed separately excited DC motor at firing angle 90 degree



CONCLUSION

The purpose of this dissertation is to study the output characteristic of the motor using thyristor control and the target is achieved with some level of difficulties. The speed control of induction machine is successfully observed for two-phase and three-phase system. The speed control using the power electronics devices gives more power saving than the conventional methods of speed control as in the conventional methods the power is loss in the form of heat energy this loss can be minimize in this technique. The control strategy using the thyristor is successfully implemented on the MATLAB Simulink environment which gives the basic designing help in the dissertation work. The result is shown in the simulation and result section for different values of firing angle.

FUTURE WORK

The dissertation work is gives the basic idea in the field of motor control using electronic switches i.e. thyristor. The ripple can be minimize using the advance control methodology in many cases the control is sluggish and time delay which is the main disadvantage of this technique due to which the power consumption is more in dynamic region or at starting of motor this losses can also be minimized using the advance control techniques. The vector control technique is one of them which gives the batter control of speed and torque of induction motor this technique can minimize the ripples in output characteristic of the motor the vector control technique can control the speed and torque of the induction motor independently is the main advantage of this technique although the circuit become more complex in this case.

REFERENCES

[1] D. A. staton, M. I. McGilp and T. J. E. Miller, “DC machine teaching experiment,” in proceedings of the European Power Electronics Association EPE, Brighton, pp. 35 – 40, 1993

[2] S. J. Chapman, Electric Machinery Fundamentals, New York: WCB/McGraw-Hill,1998.

[3] W. M. Daniels and A. R. Shaffer, “Re-inventing the electrical machines curriculum,” IEEE Transactions on Education, vol. 41, pp. 92-100, May 1998.

[4] N. Mohan, Electric Drives: An integrative approach, University of Minnesota Printing services, 2000.

[5] M. Nedeljkovic and Z. Stojiljkovic, “Fast current control for thyristor rectifiers,” IEE Proceedings- Electr. Power Appl., Vol. 150, No. 6, pp. 636- 638, Nov. 2003.

[6] Alfio Consoli, Mario Cacciato, Antonio Testa and Francesco Gennaro, “Single Chip Integration for Motor Drive Converters With Power Factor Capability,” IEEE Transactions on Power Electronics, Vol. 19, No. 6, pp. 1372-1379, Nov. 2004.

[7] S. Li and R. Challo, “Restructuring an electric machinery course with an integrative approach and computer-assisted teaching methodology,” IEEE Transactions on Education., vol. 49,pp. 16-28, Feb.2006.

[8] Manoj Daigavane, Hiralal Suryawanshi and Jawed Khan, “A Novel Three Phase Series-Parallel Resonant Converter Fed DC-Drive System,” Journal of Power Electronics, Vol. 7, No. 3, pp. 222-232, July 2007.

[9] Wai Phyo Anug, “Analysis on Modeling and Simulink of DC Motor and its Driving System Used for Wheeled Mobile Robot,” World Academy of Science, Engineering and Technology 32, pp. 299-306, 2007.

[10] A. Gelen and S. Ayasun, “Effects of PWM chopper drive on the torque-speed characteristic of DC motor” 43rd International Universities Power Engineering Conference, 2008.

[11] P. S. Bhimbhra, Power Electronic, Khanna publishers, 2010.