Analysis of Speed for Separately Excited DC Motor using All Types of Single-Phase and Three-Phase Rectifiers

Ruchita Namdeo
PG Scholar/Deptt. of EE
Samrat Ashok Technological Institute Vidisha (M.P.)

C. S. Sharma
Asso. Prof./Deptt. of EE
Samrat Ashok Technological Institute Vidisha (M.P.)

Rajnee Bala Minz
PG Scholar/Deptt. of EE
Samrat Ashok Technological Institute Vidisha (M.P.)

Abstract: **In this paper the value of speeds for separately excited DC motor is analysed by using single-phase half wave and full wave rectifiers ,three-phase half wave and full wave rectifiers and also by dual converters in single as well as in three-phase. The output value of speed is analysed at different firing angles under no load as well as under constant load conditions.**

Keywords: Separately excited DC motor, DC drive system, rectifiers.

Abbreviations used: SEDCM- Separately excited DC motor, NL-no load, CL-constant load.

I. INTRODUCTION

The different rectifiers are analysed at different firing angles for obtaining the speed of the separately excited DC motor which is fed by these rectifiers.

1. Single-phase half wave rectifier fed drives:

Here a separately excited DC motor drive system is fed through single-phase half wave converter for the analysis.

The single-phase half wave rectifier feeding a separately excited DC motor drive provides the one-quadrant operation and is used in the drive system so as to reduce the ripple contents in the field circuit.

For single-phase half wave rectifier feeding a DC motor of separately excited type:

$$V_t = E_a + I_a R_a$$

Also, $Vt = V_m(1+\cos\alpha)/2\Pi$

And $E_a = K_1 w_m$

$$T_e = K_1 I_a$$

Thus for different firing angles both at no load as well as constant load condition, the speed of the motor can be calculated and analysed.

2. Single-phase full wave rectifier fed drives:

In full wave rectifier feeding separately excited DC motor two rectifiers (say rectifier1 or converter1 and rectifeir2 or converter2) 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

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

For converter2 feeding field circuit

$$V_f = 2V_m \cos\alpha_2/\Pi \; ; \; 0<\alpha_2<\Pi$$

$$I_{s\,rms} = Ia$$

$$I_{t\,rms} = Ia/\sqrt{2}$$

$$P_f = 2\sqrt{2}\cos\alpha/\Pi$$

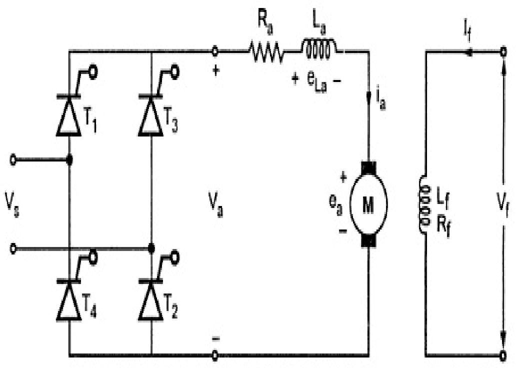


FIG 1-Single-phase full-wave rectifier fed drive

3. Three-phase half wave rectifier fed drives:

In three-phase half wave rectifier two rectifiers and a separately excited DC motor(SEDCM) is employed. These drives are used for drives up to 40 kw.

Three-phase half wave rectifier feeds the armature circuit of the motor and three-phase semi-converters feeds the field circuit. One-quadrant operation is offered by this drive system. If the field winding of the motor in this drive system is energised from single-phase or three-phase full-rectifier, then the system offers two-quadrant operation also.

$$V_0 = (3V_m \cos\alpha)/2\Pi \quad \alpha \; \varepsilon \; [0,\Pi)$$

$$I_{a\ rms} = I_a\sqrt{1/3}$$

Average thyristor current,

$$I_{TA} = 1/3 Ia$$

$$I_{T\ rms} = \sqrt{1/3}\ I_a$$

4. *Three-phase full wave rectifier:*

This circuit consists of two three-phase full rectifier feeding the armature and field circuit respectively. This system offers two quadrant operations.

If the firing-angle delay of converter2 is made more than 900, the field excitation is reversed and hence the polarity of counter emf is reversed. By this reversal process the regenerative braking can be done.

Armature voltage

$$V_0 = 3V_m/\Pi \cos\alpha_1 \; ; \; \alpha_1 \varepsilon \; [0.\Pi)$$

Rotor field voltage

$$V_f = 3\ V_m/\Pi \cos\alpha_2 \; ; \; \alpha 2 \; \varepsilon \; [0,\Pi)$$

5. *Single-phase Dual-converter:*

Single-phase dual converter consists of two converter circuits, one operates in rectifier mode and other in inverter mode. Single-phase dual converter is operated in two modes:

i> Circulating mode
ii> Non-circulating mode

i> **Circulating mode**: Gate pulses in this mode are provided to both converters and at a time both converters operate. One is operated in rectifier mode and other is operated in inverter mode for obtaining the same polarity average output voltage.

ii> **Non-circulating mode:** In this mode at a time only one converter is active.

- **Advantages of circulating mode:**

a) Power flow in either direction is possible due to rectifier-inverter operation of two converters at any time.
b) Circulating current maintains continuous conduction of both converters over the whole control range.
c) Continuous conduction is independent of load.
d) Change of response time from one-quadrant operation to another is faster due to continuous conduction.

- **Disadvantages of circulating current mode:**

a) Efficiency is low due to increased losses caused by circulating current.
b) Low power-factor due to current limiting reactor.
c) For high current rating of thyristor, converter needs to be supplied by $\mathbf{I_L}$ and $\mathbf{I_{cir}}$.

6. *Three-phase dual converter:*

Three-phase dual converters in many variable speed drives are highly used since they provide four-quadrant operation. In this system two three-phase converters are connected back-back.

Converter 1	Converter 2	Avg. V_0 polarity
Rectifier	Rectifier	Opposite
Rectifier	Inverter	Same

$$V_{ac} = (3\sqrt{3}V_m \cos\alpha)/\Pi$$

$$I_r = 3V_m(1-\sin\alpha_1)/wL_r$$

II. SIMULINK MODEL STUDY:

Under the Simulink model study different Simulink models of separately excited DC motor fed through different rectifiers with varying firing angles of the thyristor.

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

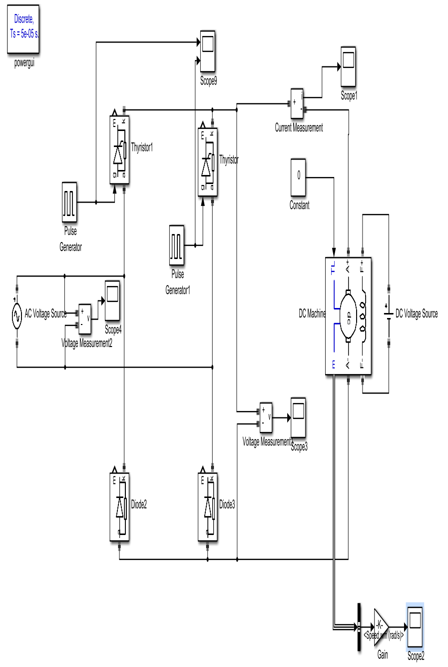
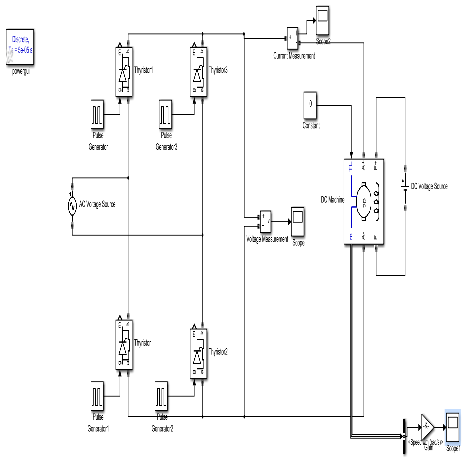


Table 1:Table showing the value of speed at no as well as constant load:

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	0.0133	NL	1545
0	0.000	180	0.01	CL	1420
30	0.0017	210	0.0117	CL	1012
60	0.0033	240	0.0133	CL	768

The simulation of the single-phase half wave controlled rectifier fed to a separately excited DC motor is analyzed with different firing angles of the thyristor under no load as well as at any constant load condition.

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



The above Simulink model shows the single phase full-wave controlled rectifier fed to a separately excited DC motor. The speed of this motor drive system is analysed under no load as well as under a constant load condition. This analysis is done by changing the firing angles. The values of speed at different firing angles and at no load as well as constant load condition is shown in table 2 for single-phase full wave controlled rectifier fed separately excited DC 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	0.0133	NL	950
0	0.000	180	0.01	CL	1195
30	0.0017	210	0.0117	CL	895
60	0.0033	240	0.0133	CL	480

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

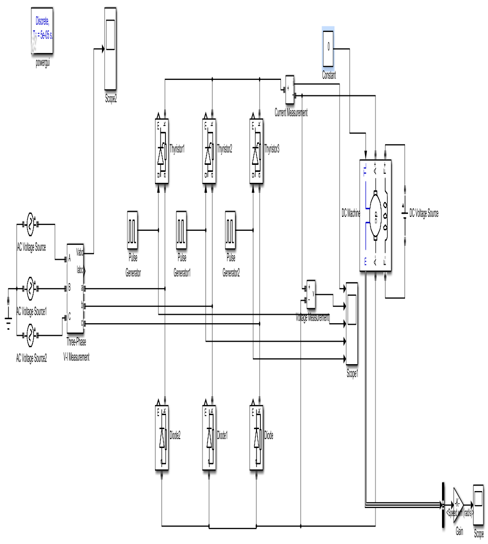


Table 3: Table showing the value of speed at no as well as constant load:

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	0.0133	NL	2695
30	0.0017	150	0.0117	270	0.0150	NL	2671
60	0.0033	180	0.0133	300	0.0167	NL	2658
0	0.000	120	0.01	240	0.0133	CL	2398
30	0.0017	150	0.0117	270	0.0150	CL	2474
60	0.0033	180	0.0133	300	0.0167	CL	2387

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

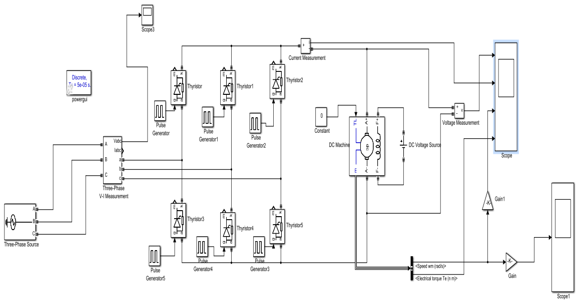
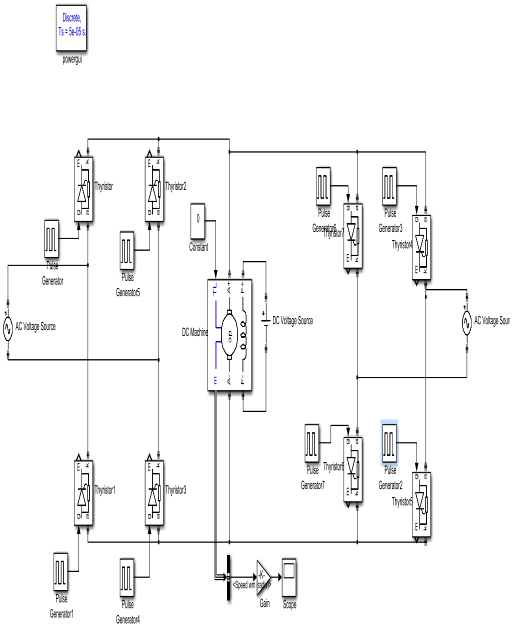


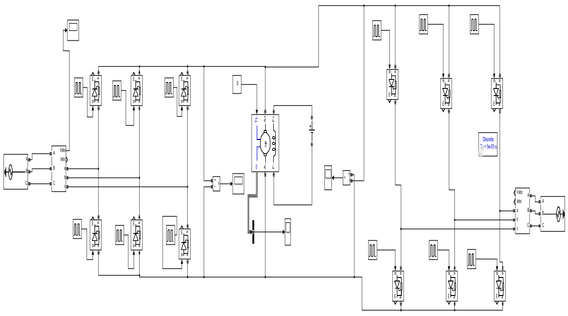
Table 4: Table showing the value of speed at no as well as constant load:

FA(T 1)	FA(T 2)	FA(T 3)	FA(T 4)	FA(T 5)	FA(T 6)	Load	Speed
0	60	120	180	240	300	NL	1350
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

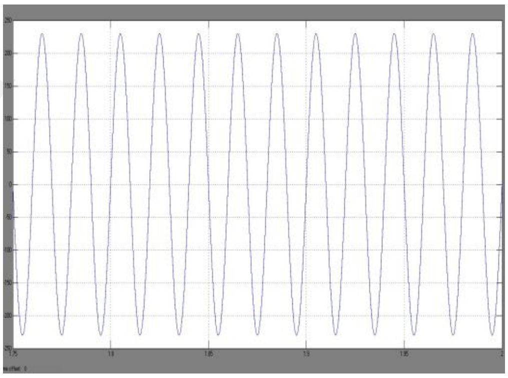


6. Simulink model of three-phase dual converter fed separately excited DC Motor

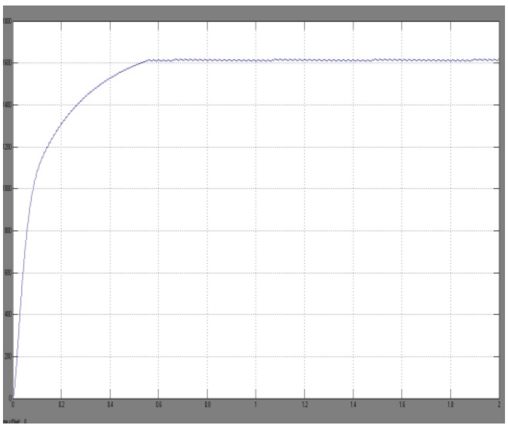


III. SIMULATION STUDY:

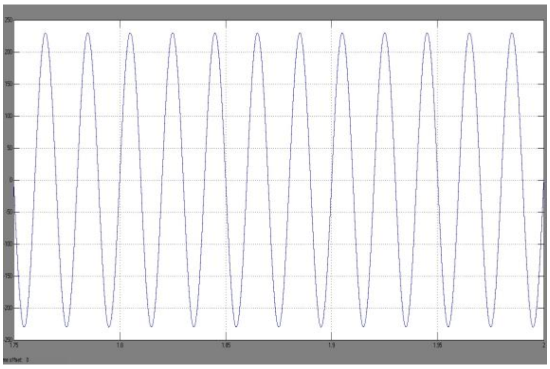
1. Single phase half controlled rectifier Input voltage waveform



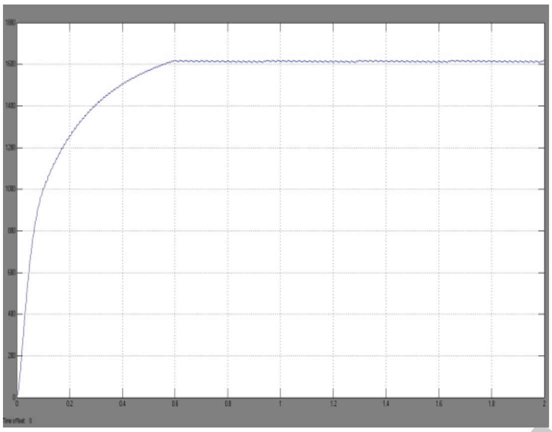
2. Single phase half controlled rectifier fed to dc separately excited motor speed curve



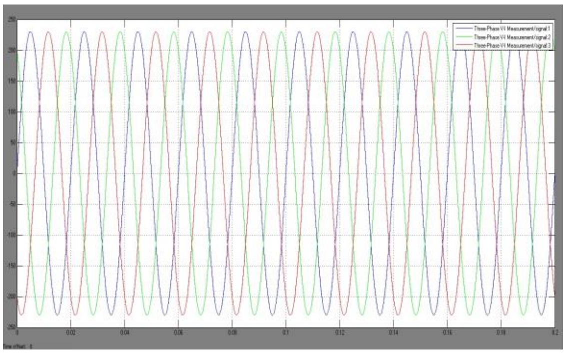
3. Single phase fully controlled rectifier fed DC Motor input voltage waveform



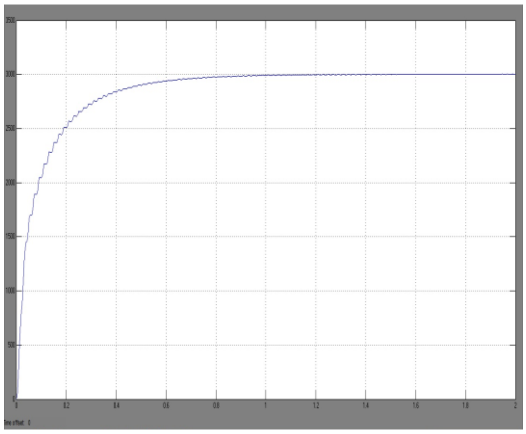
4. Single phase fully controlled rectifier fed DC Motor Speed curve at firing angle 30 degree



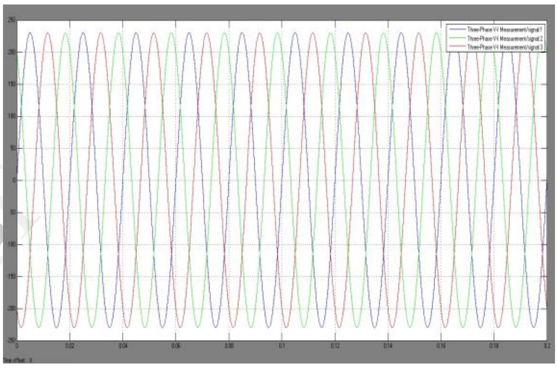
5. Three phase half controlled rectifier input voltage fed separately excited DC Motor



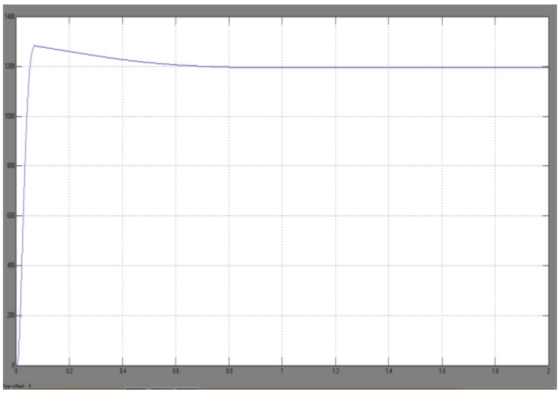
6.Three phase half controlled rectifier fed Separately excited DC Motor Speed curve



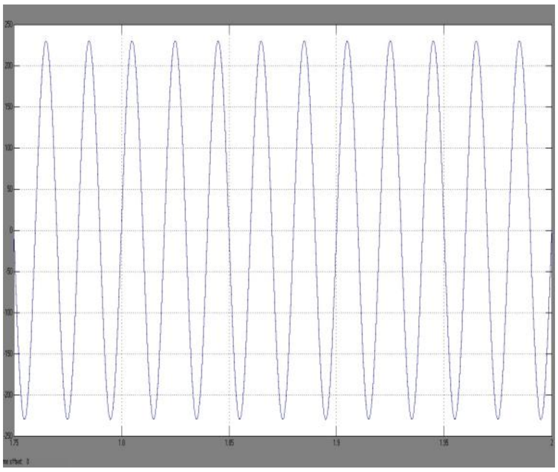
7. Three phase fully controlled rectifier input voltage fed separately excited DC Motor



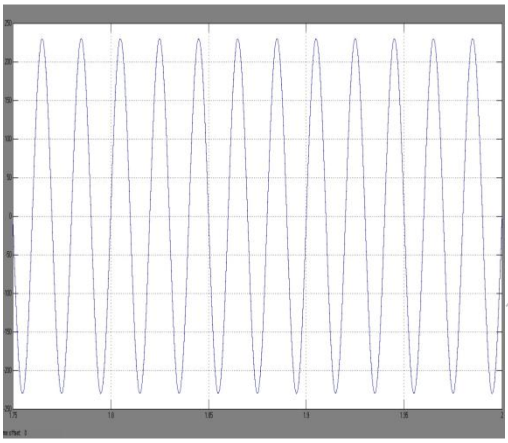
9. Three Phase fully controlled rectifier separately excited DC Motor speed curve



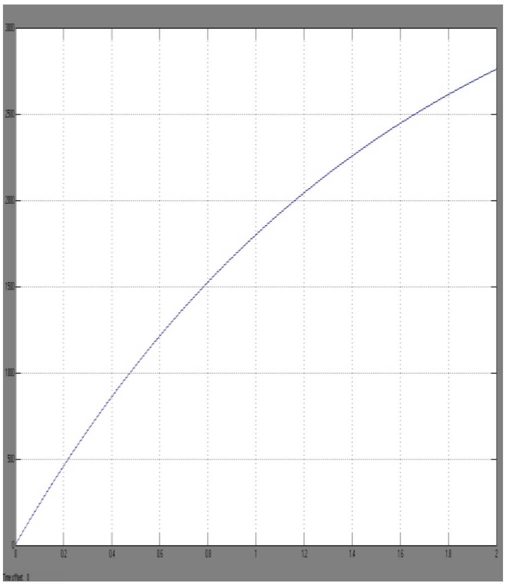
10. Single phase dual converter fed separately excited DC Motor converter 1 input voltage



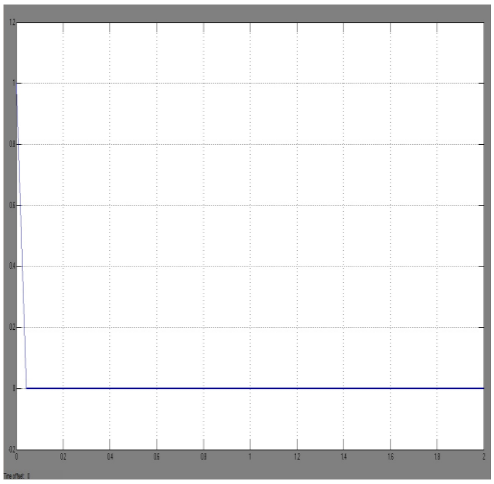
11. Single phase dual converter fed separately excited DC Motor converter 2 input voltages



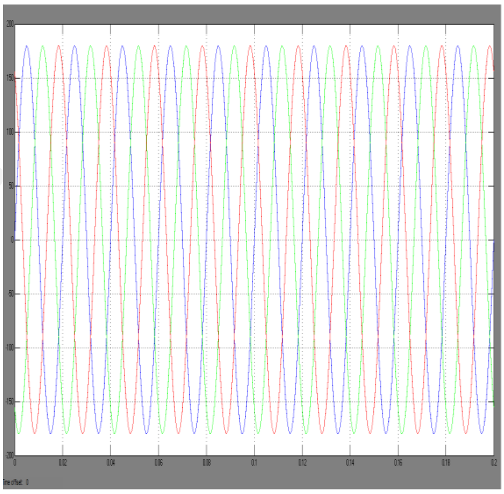
12. Single phase dual converter fed separately excited DC Motor speed curve at firing angle 30 degree delay



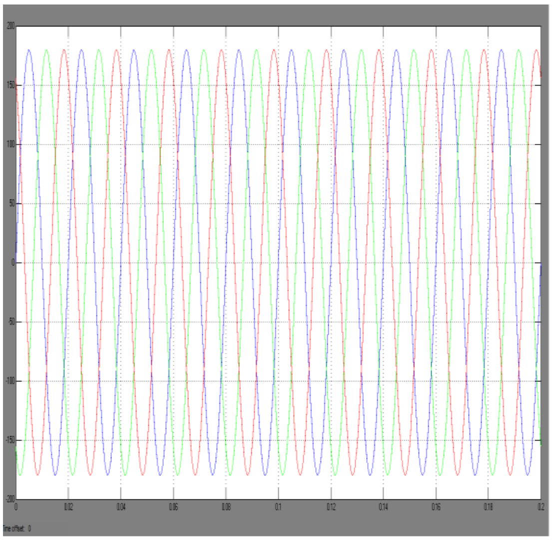
13. Single phase dual converter fed separately excited DC Motor at firing angle 90 degree



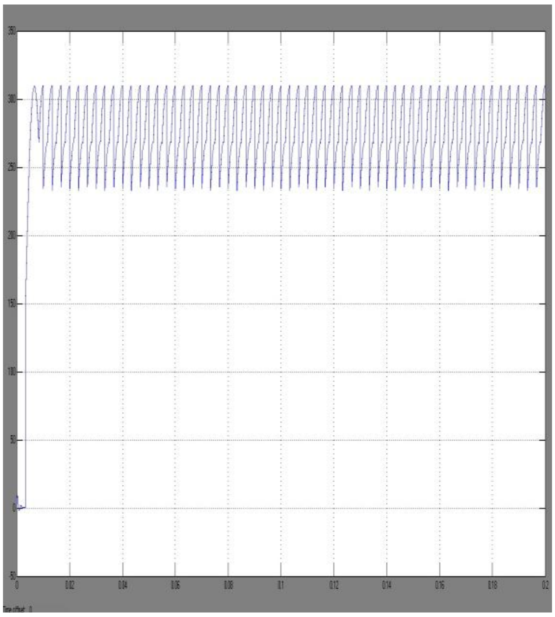
14. Three-phase dual converter fed separately excited dc motor converter 1 input voltage



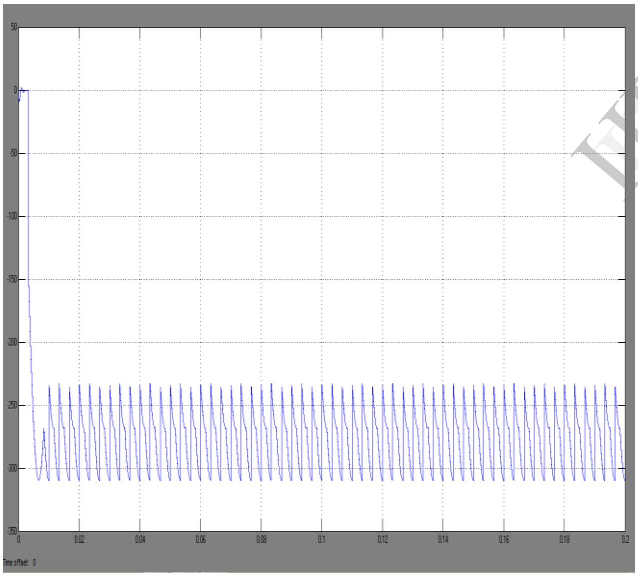
15. Three-phase Dual converter fed separately excited DC Motor converter 2 input voltage



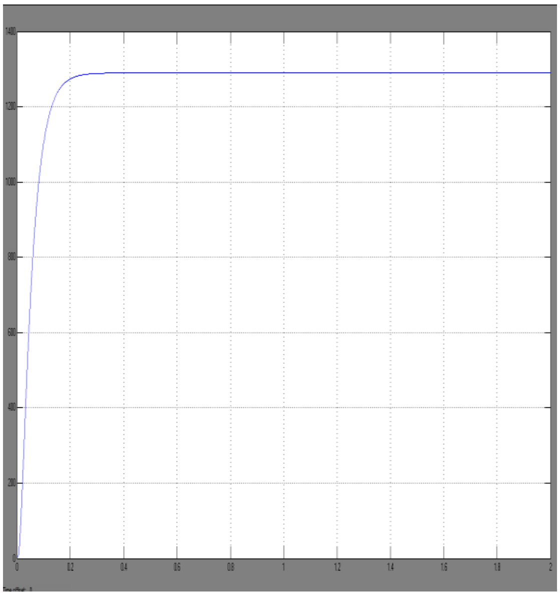
16. Converter 1 output voltage waveform for three-phase dual converter



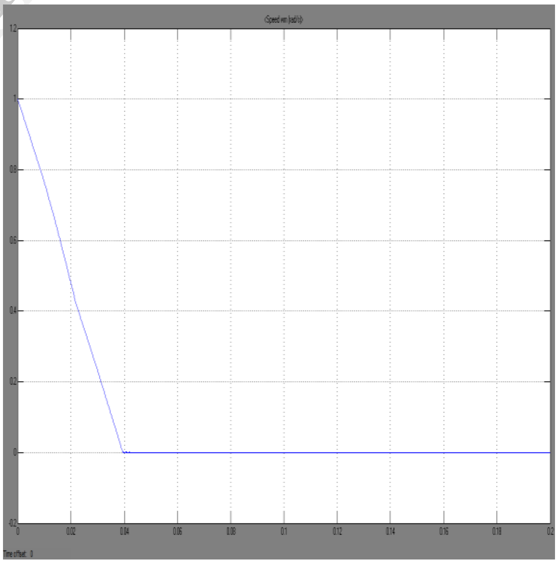
17. Converter 2 output voltage waveform for three-phase dual converter



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



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



IV. CONCLUSION

In this paper separately excited DC motor speed is analysed under different firing angles using different types of rectifiers. For the simulation result and the table shown we conclude that the increase in firing angle of the thyristor reduces the speed of the motor under no load as well as at constant load conditions.

V. REFERENCES

1. Comparative study on dc motor speed control using various controllers by K.Venkateswarlu and Ch.Chengaiah research directions, ISSN:-2321-5488 volume 1 , issue 6 / dec 2013.
2. Speed control of dc motor using combined armature and field control by Mustafa Aboelhassan.
3. Power electronics by Dr. P.S.Bhimra, khana publishers.
4. Industrial and Power Electronics by Deodatta Singhare, Electrotech Publication.
5. AC-DC & DC-DC converters for dc motor drives by G.Ch.Ioannidis, C.S.Psomopoulos, S.D.Kaminaris, P.Pachos, H.Villiotis, S.Tsiolis, P.Malatestas, G.A.Vokas, Proceedings of the 2013 International Conference on Electronics and Communication Systems
6. Performance of DC Motor Supplied From Single Phase AC-DC Rectifier by Dr Othman A. Alnathee.
7. Thyristor Based Speed Control Techniques of DC Motor: A Comparative Analysis by Rohit Gupta, Ruchika Lamba, Subhransu Padhee, International Journal of Scientific and Research Publications, Volume 2, Issue 6, June 2012 1, ISSN 2250-3153.
8. A Comparative Analysis of Firing Angle Based Speed Control Scheme of DC Motor by Sarita Shastri, Pawan Pandey, IJERA ISSN: 2248-9622.
9. Design and Simulation of Closed Loop Speed Control of DC Drives by Using Dual Converter byJaykishan H. Moradiyal, Niraj B. Danidhariya, Volume 1,Issue 3, April 2014, e-ISSN: 2348 - 4470 , print-ISSN:2348-6406.
10. Thyristor Based DC Motor Control with Improved PF & THD by Rohit Gupta and Ruchika, Volume 5, Number 4, December 2013.