

## A Comparative Analysis of Firing Angle Based Speed Control Scheme of DC Motor

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### ABSTRACT

This paper describes the speed control scheme of DC motor and provides a comparative analysis of firing angle based speed control technique. The best control characteristics of DC motor have used in industries for different rang of loading condition. A dual converter comprised of two single phase AC-DC thyristor converter is proposed. Speed of DC machine is control the armature voltage. Armature voltage is controlled using AC-DC converter. This paper also describe the circulating operation of dual converter, in which rectifier 1 will be rectifying ( $0 < \alpha_A < 90^\circ$ ) and rectifier 2 will be inverting ( $90^\circ < \alpha_B < 180^\circ$ ). The linear & non-linear regions are clearly visible in control characteristics. Firing control scheme improve armature voltage & also reduce ripple content & possibility of discontinuous conduction in circuit. The controlled performance exhibited is superior & also firing angle smoothly controlled with fast response. The dual converter simulation is done in MATLAB.

**Key Skill** – AC-DC converter, DC motor, speed control.

### I. INTRODUCTION

The motion plays an important role in industries. The production process of varies industries different for require speed profile. DC drives are widely used due to high starting, acceleration & retarding torques. Also the speed control of DC motor is simpler & less costly compare to other drive. DC drives are widely used in rolling mills, machine tools, cutting tools, overhead cranes and other industries application which require large starting torque.

DC machine is highly versatile & flexible machine. They also employ in many cutting application such as actuators & speed or sensors that is DC motor are very versatile for the purpose of speed control. The aim of this paper is describe the principle of separately excited dc motor speed control using armature voltage control method..In armature control mode the field current held constant & adjustable voltage applied to the armature. This paper provides a comparative

technique for different firing based speed control. Simulation models of DC motor, speed control method for DC motor drive have developed using MATLAB/Simulink.

### II. MODELING OF DC MOTOR

The versatile control characteristics of separately excited DC motor shows the dynamic & steady state model. The schematic representation of separately excited DC motor is shown in figure.

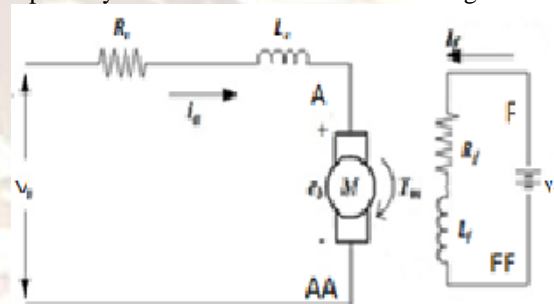


Figure.1 Equivalent circuit of separately excited DC motor

Where,

$V_a$  is applied voltage of DC motor &  $E_b$  back emf in circuit & A-AA, F-FF are armature and field connection across armature & field in figure 1. General equation of dc motor for steady state representation.

The basic equation is

$$V_a = I_a R_a + E_b \text{ Volts}$$

&  $E_b$  is given by

$$E_b = \frac{\phi Z N P}{60 A} \text{ Volts}$$

Also the torque

$$T = \frac{1}{2\pi} \phi P \frac{Z}{A} I_a$$

$$T = K_e \phi I_a$$

The greatest advantages of DC motor are smooth speed control. Parameter  $V_a, R_a, \phi$  control the speed. Following are the methods of speed control of DC motor .

- 1/ Armature voltage control
- 2/ Field flux control
- 3/ Armature resistance control

Generally armature voltage control is preferred because of better efficiency, good transient response & good speed regulation & also

it provide speed control below base speed, because of armature voltage cannot allow above base value. For speed control above base speed the field flux control method is used

$$\omega_m = \frac{V}{K_e \phi} - \frac{R}{(K_e \phi)^2}$$

Also,

- i)  $\omega_m \propto V$
- ii)  $\omega_m \propto 1/\phi$
- iii) Adjusting armature voltage or field current will change the motor speed.

In case of armature resistance control, speed is control using external resistance connected in series with armature circuit i.e. wasting of power. So this method is not used.

### III. PROPOSED MODEL OF DUAL CONVERTER

Speed control scheme is Proposed based on thyristraised dual converter. General purpose microprocessor based control circuit for single phase dual converter. The performance exhibited is superior & also firing angle is smoothly controlled with fast response.

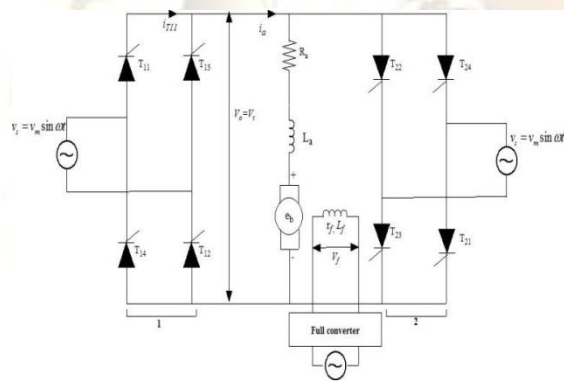


Figure.2 Single phase dual converter drive

In proposed scheme, a converter system is used of DC motor. A pulse generator is used for firing angle control of converter design. The thyristor of converter receive conduction the firing pulse either mode of continuous or discontinuous operation. To simplify single phase dual converter, two of these full converter are connected back to back as shown in figure 2. The system will provide four quadrant operations & is called a dual converter. Dual converter are normally used in high power variable speed drive. Delay  $\alpha_A$  &  $\alpha_B$  are angle of converter 1 & 2 respectively & corresponding average output voltage are  $V_1$  &  $V_2$ . The delay angle are controlled such that one converter operate as a rectifier & other converter operates as an inverter, but both converter produce same average output voltage.

The average output voltage of converter 1 operates with firing angle  $\alpha_a$

$$V_1 = \frac{2V_m}{\pi} \cos \alpha_A$$

$(0 < \alpha_A < 90^\circ)$

& similarly average output voltage of converter 2 operates with firing angle  $\alpha_b$ .

$$V_2 = \frac{2V_m}{\pi} \cos \alpha_B$$

$(90^\circ < \alpha_B < 180^\circ)$

Also ,if firing pulse of converter are controlled , so that

$$\alpha_A + \alpha_B = 180^\circ$$

For achieving the average DC voltage of two converters are equal to one another.

For speed reversal  $\alpha_A$  is increased and  $\alpha_B$  is decreased to satisfy above equation .The motor back emf exceeds the magnitude of  $V_1$  &  $V_2$  .The armature current shift to rectifier 2 & motor operates in second quadrant. The current is controlled & adjust the firing angle  $\alpha_A$  &  $\alpha_B$  continuously, so as to break the motor at maxi. Allowable current for initial speed to zero & then accelerates to the desired speed in reverse direction. The power rating up to around 10 KW single phase fully controlled rectifier can be used.

### IV. SIMULATION

To observe the effect of armature voltage on torque speed curve four different firing angle are used with the voltage applied to the field circuit kept constant 150 V. A 240 V, 50 HZs, constant AC supply is applied to input of single phase dual converter. The different output voltage & current are obtained on armature of motor. When firing angle are  $30^\circ$  &  $150^\circ$ ,  $60^\circ$  &  $120^\circ$ ,  $120^\circ$  &  $60^\circ$ ,  $150^\circ$  &  $30^\circ$ .

The average value of of output voltage can be controlled by controlling or changing the firing angle  $\alpha$ .

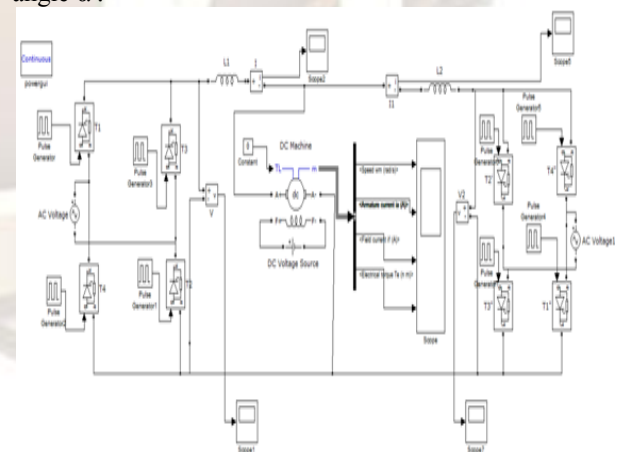


Figure.3f Simulink model of armature voltage speed control method using single phase dual converter

Armature voltage with firing angle of rectifier1  $30^\circ$  & rectifier2  $150^\circ$  for single phase dual converter.

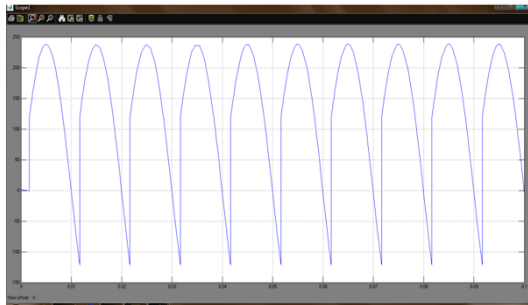


Figure.4 Armature voltage at 50N.m.

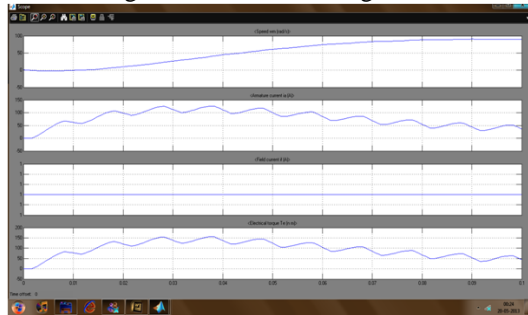


Figure.5 Speeds, armature current, field current & electrical torque at 50N.m. Vs time.

Armature voltage with firing angle of rectifier1  $60^\circ$  & rectifier2  $120^\circ$  for single phase dual converter

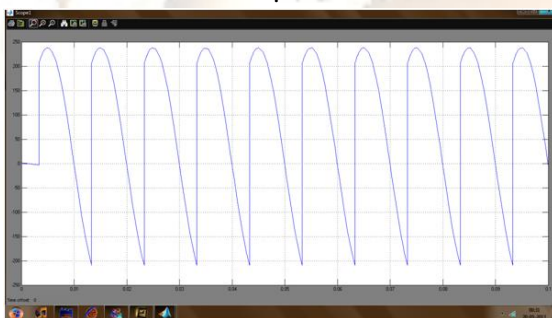


Figure.6 Armature voltage at 50N.m.

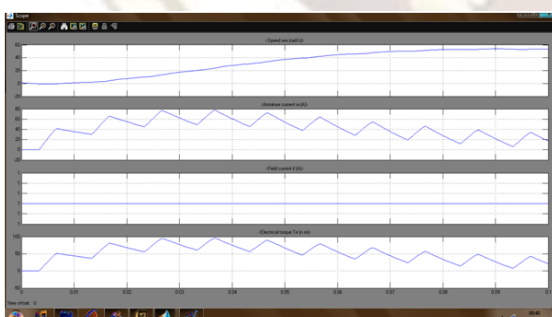


Figure.7 Speeds, armature current, field current & electrical torque at 50N.m. Vs time.

For operation of  $120^\circ$  &  $60^\circ$  Speed, armature current, field current & electrical torque at different loading condition are shown in figure .

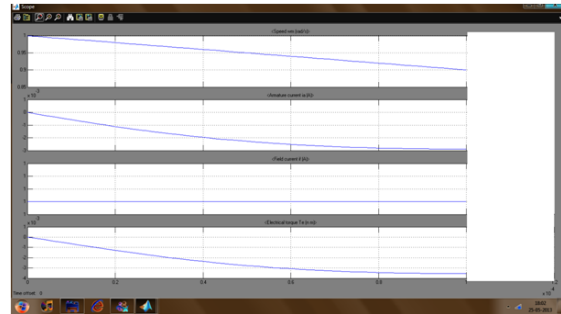


Figure.8 Speed, armature current, field current & electrical torque at 50N.m. Vs. time.

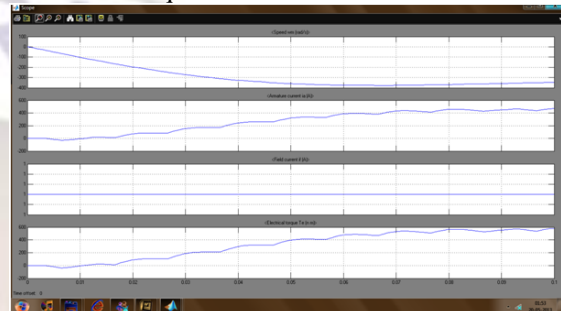


Figure.9 Speed, armature current, field current & electrical torque at 500N.m. Vs. time  
 For operation of  $150^\circ$  &  $30^\circ$  Speed, armature current, field current & electrical torque at different loading condition are shown in figure.

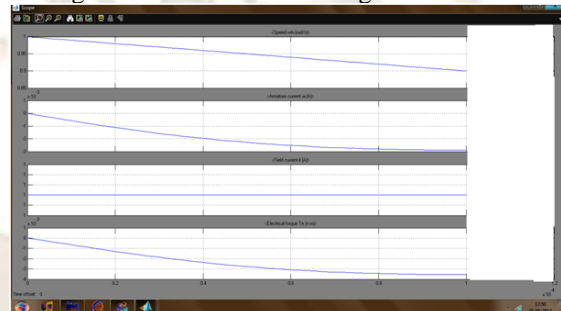


Figure.10 Speed, armature current, field current & electrical torque at 50N.m. Vs. time

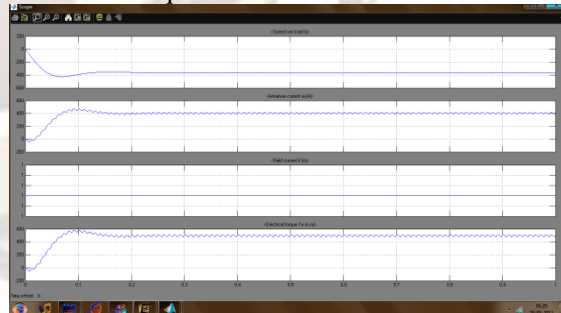


Figure.11 Speed, armature current, field current & electrical torque at 500N.m. Vs. time  
 Simulink model used to get armature voltage & current & also torque speed characteristics for different firing angle are shown in above figure. The figure shows linearity & non- linearity in torque speed curve. Non- linearity because of discontinuous of armature current. When the firing angle increases the non- linearity also increases.

The figure shows the continuous discontinuous operation in dual converter.

## V. CONCLUSION

This paper present speed control of separately excited DC motor using single phase dual converter. A firing scheme for single phase fully controlled dual converter is described & built. The scheme utilise the same circuit for both rectification & regeneration mode of operation. Different torque speed curve are obtained for more range of loading condition. Linear & non- linear region are clearly seen in torque speed characteristics. This paper provides a comparative analysis for different firing angle control scheme. A four quadrant speed control DC drive fed from the proposed dual converter is designed and obtained results shown to be in good interact with experimentally theory. An optimize & efficient method of speed control can be develop. An experiment on DC drive can be developing for UG student for their understanding.

## APPENDIX

The motor used to obtained result was

- 1) Rated Power (P) 5HP
- 2) Rated Armature Voltage 240V
- 3) Armature Resistance  $R_a$  0.78 $\Omega$
- 4) Armature Inductance  $L_a$  0.016H
- 5) Field Resistance  $R_f$  150 $\Omega$
- 6) Field Inductance  $L_f$  112.5H
- 7) Rated Speed 1750RPM
- 8) Rated Field Voltage 150V

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