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Inner Current Loop Speed Control for Closed Loop Separately Excited DC Motor

Sheeshant Anand[#], Anupam Masih[*]

[#]Electrical Engineering, Sam Higginbottom University of Agriculture Technology and Sciences Allahabad, Uttar Pradesh India.
Email: shishantee@gmail.com
*Assistant Professor, Dept. of Electrical Engineering, SIET, SHUATS, Allahabad, Uttar Pradesh, India
Anupam.masih@shiats.edu.in

***Abstract*— In DC device the armature resistance and impedance are small and due to less time constant the armature current increases drastically with small increase in terminal voltage which may damage the device in power convertor. So to increase the current slowly the current control loop is placed between speed control and power converter.**

***Keywords*: armature, terminal voltage, power converter.**

I. INTRODUCTION

The speed of independently energized DC [SEDC] engine can be controlled underneath the evaluated speed by utilizing controlled rectifier as a converter. The controlled rectifier terminating circuit gets signals from the controllers and after that controlled rectifier gives variable voltage to the armature of the dc engine for accomplishes required speed. There are two control circles, initial one for controlling present and another for control of speed. Relative Integral [PI] sort controllers are utilized, which expels the postponement and gives quick control. [1][8]. In this paper at first scientific examination of SEDC engine is performed trailed by outlining of current and speed controllers. At that point modulus embracing approach is utilized to configuration speed controller. At last reproduction show is produced to get the outcomes.

II. EQUIVALENT CIRCUIT OF SEDC MOTOR AND EQUATIONS

The equivalent circuit of SEDC motor is given as:
Where: Va is the armature voltage in volts.
: Ia is the armature current in amps.
: Ra is the armature resistance in ohms.
: La is the armature inductance in henrys.
: Eb is the back emf in volts.
:Vf and If is the field voltage and current respectively.

The armature voltage equation is given as:

$$Va = Ia\,Ra + La\,d\,Ia/d\,t + Eb \qquad (2.1)$$

The developed torque is given as:

$$Td = J\,dw/dt + Bw + TL \qquad (2.2)$$

Where:

- Td is the developed torque in the motor in Nm.
- TL is the load torque in Nm.
- J is the moment of inertia in Kg/m2.
- B is the friction coefficient of the motor.
- ω is the angular velocity of motor in rad/sec.

Let assume that B=0, then
The developed torque is given as:

$$Td = J\,dw/dt + TL \qquad (2.3)$$

The back emf of the motor will be:

$$Eb = K\,\dot{\omega}w \qquad (2.4)$$

Where: K is the back emf constant in volt-sec/rad.
The developed torque is also given as:

$$Td = K\,\dot{\omega}\,Ia \qquad (2.5)$$

After taking the Laplace Transform of above equations and the simplified equations:
The armature current is obtained as:

$$Ia(S) = (Va - Eb) / Ra\,(1+TaS) \qquad (2.6)$$

The equivalent circuit of SEDC motor is given as:

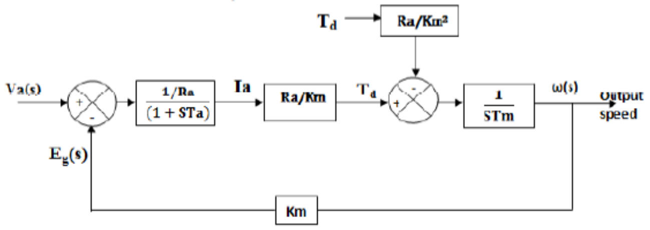


Figure2. Block model of SEDC motor.

III. REPRESENTATION OF THREE PHASE FULLY CONTROLLED RECTIFIER

Let the converter is a three phase fully controlled converter for a typical firing angle α= 60.

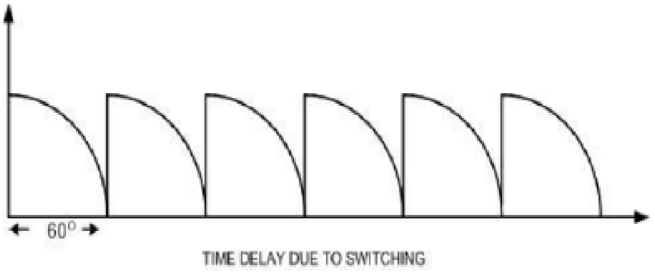


Figure 3. Output of three phase controlled rectifier.

Ripple will be six times the fundamental frequency. So the duration of each ripple will be 60 Degree.
Let for 50 Hz supply:
For 360 degrees, Time period T = (1/50) = 0.02 s.
For 60 degree, t = (0.02 * 60)/360 = 3.3 ms.
A change in converter firing angle occurs after every 60 degree. It's not instantaneous. That means a
delay of 3.3 ms. It can have a maximum delay of 3.3 ms or a minimum of zero.
So, let us take an average Tr = (3.3 ms + 0)/2 = 1.7 ms.

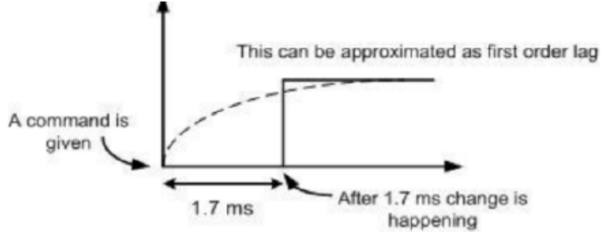


Figure 4. Ripples with 60 degree duration for 50 Hz waveform.

So, converter can be represented as a first order delay with a gain. So, converter can be represented as first order lag with some gain Kt.

$$\boxed{\frac{Kt}{1 + STt}}$$

IV. CONTROLLERS DESIGN

The controllers used in closed loop system to provide a very easy control and common technique of keeping motor speed at desired set point by continuously control of motor input. If the loads will increases then speed of the motor will decrease and the error will be negative. To compensate the speed, motor controller output should be increase and vice-versa.

A. Designing of current controller:

We need to design of current controller because at the time of starting, back emf is zero (due to zero speed) that is during starting period large current flows through the motor.

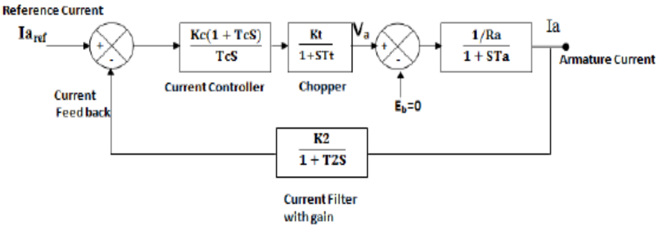


Figure 5. Block model of current controller design.

Transfer function of above block model is given as:

$$\frac{Ia(s)}{Iaref(s)} = \frac{KtKc(1 + STc)(1 + ST2)}{RaTcS(1 + STt)(1 + STa)(1 + ST2) + KtKcK2(1 + STc)} \quad (4.1)$$

Here, Tc (Current Controller Parameter) can be varied as when required. Tc should be chosen such that it cancels the largest time constant in the transfer function in order to reduce order of the system. Therefore the response will be much faster. So Tc=Ta. [3][9] Put the value in above equation (4.1), we get

$$\frac{Ia(s)}{Iaref(s)} = \frac{Ko\ (1 + ST2)}{\delta\ S^2 +\ S + KoK2} \quad (4.2)$$

Then

$$Kc = \frac{RaTa}{2\delta KtK2}$$

The value of Kc and Ko put in equation (4.2) then we get:

$$\frac{Ia(s)}{Iaref(s)} = \frac{1/K2}{1 + 2\delta S} \quad \mathbf{(4.3)}$$

B. Designing of speed controller:

The block model of speed controller design is given below:

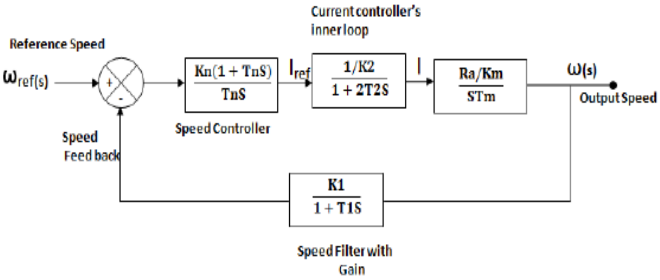


Figure 6. Block model of Speed controller design.

Transfer function of above block model is given as:

$$\frac{\omega(s)}{\omega ref(s)} = \frac{KnRa(1 + STn)(1 + ST1)}{TnK2KmTmS^2(1 + 2\delta S)(1 + T1S) + KnRaK1(1 + TnS)} \quad (4.4)$$

To cancels the largest time constant of the transfer function so Tn= 2μδ then, Transfer function of above block model is given as:

$$\frac{\omega(s)}{\omega ref(s)} = \frac{KnRa(1 + ST1)}{TnK2KmTmS^2(1 + T1S) + KnRaK1} \quad (4.5)$$

In above transfer function, the S term is absent. So that damping constant (€) will be zero. Due to this the system will be oscillatory and unstable. To optimize this we must get transfer function whose gain is close to unity. For this purpose the MODULUS HUGGING APPROCH is used. [2][3][5].

V. SIMULINK MODEL OF CLOSED LOOP SPEED CONTROL OF SEDC MOTOR USING CONTROLLED RECTIFIER

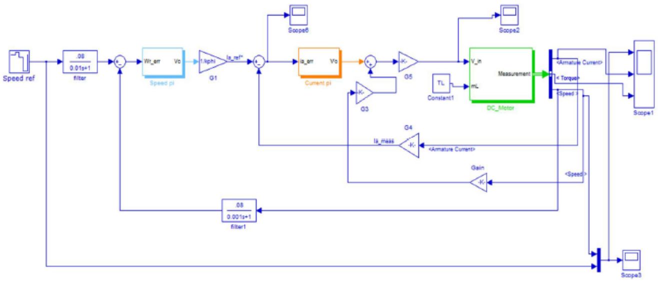


Figure 8.Simulation model of closed loop separately excited dc motor

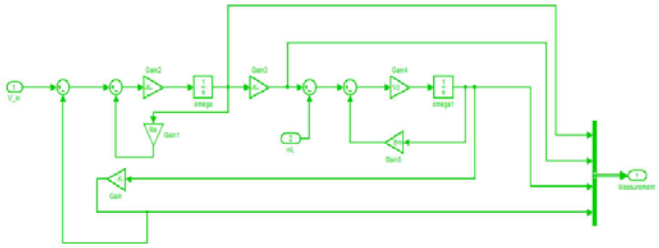


Figure 9. Subsystem simulation model of dc motor

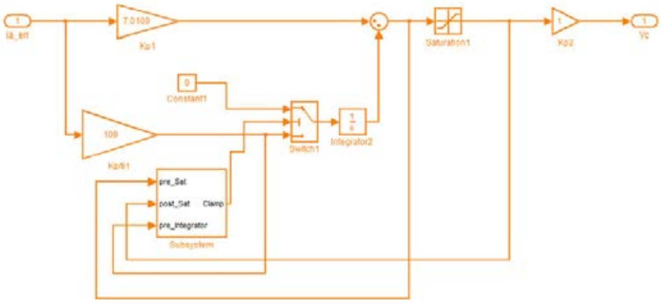


Figure 10. Subsystem simulation model of current block

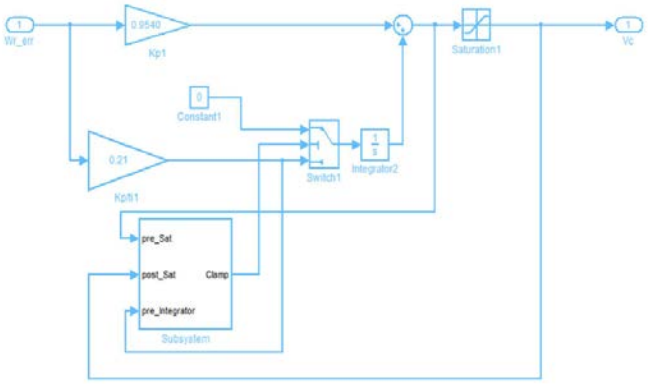
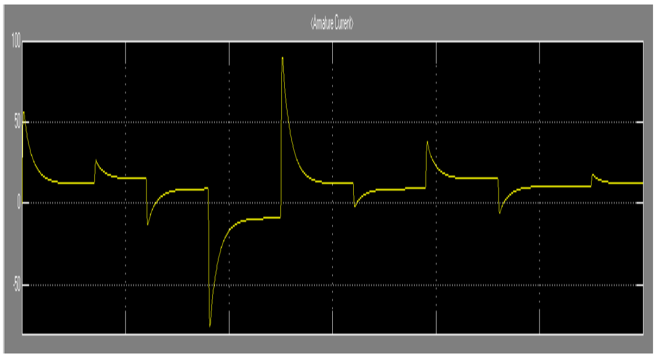


Figure 11. Subsystem simulation model of speed block

VI. SIMULATION RESULTS

The simulation results of different speed and load torque:



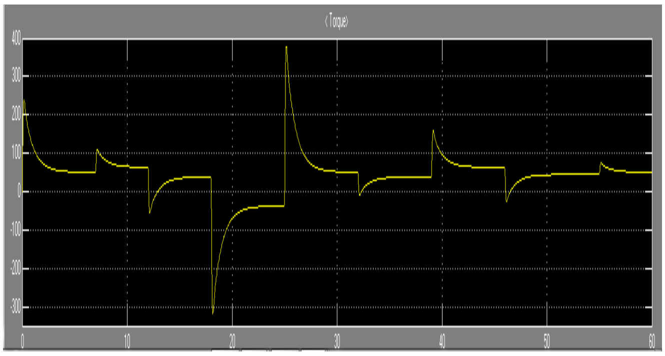
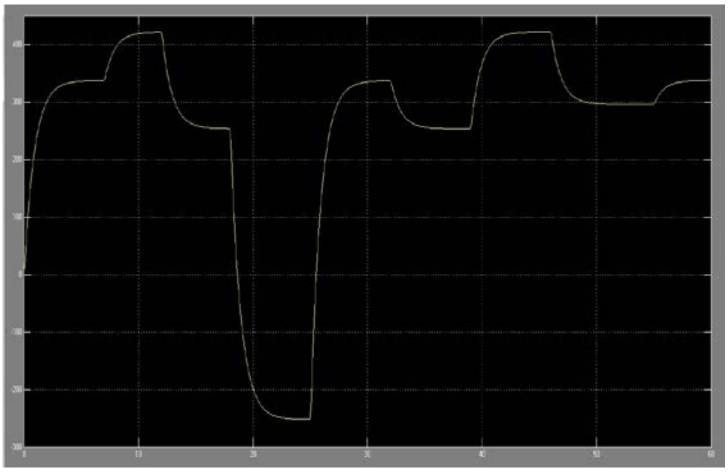


Figure 10. Torque and Armature current



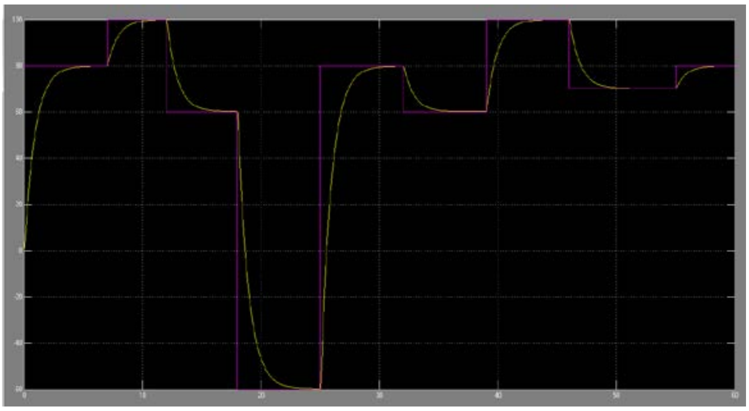


Figure 12. Reference speed and Actual speed

VII.CONCLUSION

This paper presents numerical demonstrating of shut circle speed control of dc engine utilizing three stage controlled rectifier. For stable operation of SEDC engine, the outlining of speed controller is finished utilizing Modulus embracing approach. By this approach the pick-up of framework progresses toward becoming solidarity. The recreation comes about are gotten in the wake of planning of shut circle framework. From the reproduction result we watched that the speed of SEDC engine is consistent at the reference speed which is evaluated or underneath the appraised speed of engine and furthermore watched that the speed blunder is set to be zero. The framework's reaction demonstrates the quick ascent time, quick setting time and additionally quick recuperating time.

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Sheeshant Anand received the B.Tech degree in Electrical Engineering from Sam Higginbottom Institute of Agriculture Technology and Sciences, Allahabad, and currently he is a PG Scholar in Sam Higginbottom University of Agriculture Technology and Sciences Allahabad, Uttar Pradesh India. His main research interests include Electrical Engineering (Power Electronics) and. He is currently doing his project in Power Electronics.