

Speed control of separately excited DC motor using chopper

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Abstract

This paper describes speed control of separately excited DC motor using Chopper as power converter and PI as speed and current controller. The separately excited DC motor can be controlled from below and up to rated speed . Optimization filter of speed is obtained using Modulus Hugging Approach . After obtaining the complete model of DC drive system, the model is simulated by MATLAB. The simulation is done and analyzed under varying speed and varying load torque conditions like rated speed and load torque, half the rated load torque and half speed .

المستخلص :

يوضح البحث طريقة السيطرة على سرعة محرك تيار مستمر ذو اثاره مستقلة باستخدام مقطع (مغير قدره) مع مسيطر تناسبي تكاملي بهذه الطريقة يمكن السيطرة على سرعة المحرك لغاية السرعة المطلوبة. تستلم دائرة قرح المقطع الاشارة من المسيطر لتجهيز فولتية متغيره الى منتج ا لمحرك للوصول الى السرعة المطلوبة . تم تصميم وتنفيذ مسيطرين الاول للسرعة والثاني للتيار وذلك للحصول على سرعة دوران ذات استجابة جيدة وباستقراريه عاليه. تم اخذ نموذج لمحرك تيار مستمر ذو اثاره مستقلة وتمثيله بنموذج محاكاة باستخدام الماتلاب . تم تنفيذ المحاكاة وتحليل النتائج و العلاقات بين السرعة و عزم الحمل مثل علاقة السرعة المطلوبة مع عزم الحمل الكامل والعلاقة بين نصف السرعة المقرره مع نصف الحمل بوجود ملف تحسين السرعة مرة وبعدمه مرة اخرى .

1- Introduction:

DC motor is considered a(Single Input and Single Output) system having torque/speed characteristics compatible with most mechanical loads. This makes a D.C motor controllable over a wide range of speeds by proper adjustment of the terminal voltage [1,2]. Now days Induction motors, Brushless D.C motors and Synchronous motors have gained widespread use in electric traction system. Hence dc motors are always a good option for advanced control algorithm because the theory of dc motor speed control is known more than other types. Speed control techniques in separately excited dc motor By varying the armature voltage for below rated speed. By varying field flux should to achieve speed above the rated speed. The PI based speed control has many advantages like fast control, low cost and simplified structure [3].

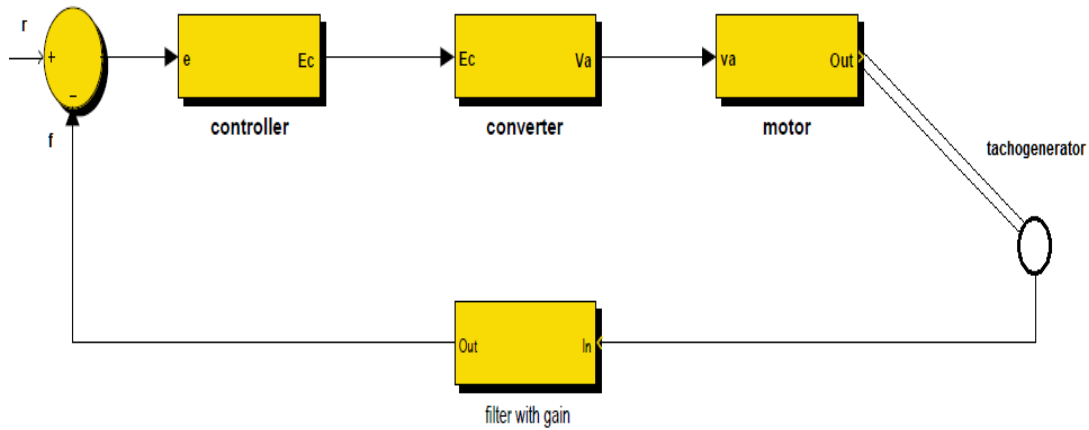
1-1- DC Chopper

A chopper is a static power electronic device that converts fixed dc input voltage to a variable dc output voltage. A Chopper may be considered as dc equivalent of an ac transformer since they behave in an identical manner. Chopper involves one stage conversion, these are more efficient Chopper systems offer smooth control, high efficiency . A chopper is a high speed on or off semiconductor switch. It connects source to load and disconnect the load from source at a fast speed [4]

1-2- Basic idea :

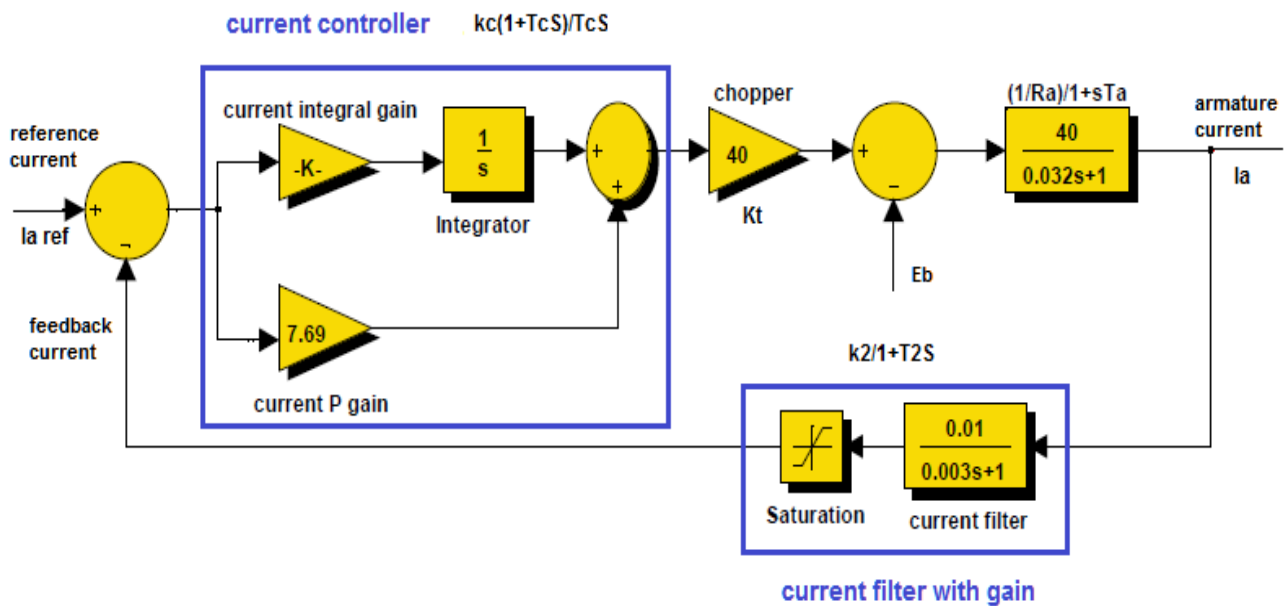
The basic principle behind DC motor speed control is that the output speed of DC motor can be varied by controlling armature voltage for speed below and up to rated speed keeping field voltage constant. The output speed is compared with the reference speed and error signal is fed to speed controller [5] . Controller output will vary whenever there is a difference in the reference speed and the speed feedback. The output of the speed controller is the control voltage that controls the

operation duty cycle of (here the converter used is a Chopper) . The converter output give V_a required to make the motor return to the desired speed. The reference speed is provided through a potential divider because the voltage from potential divider is linearly related to the speed of the DC motor[8]. The output speed of motor is measured by Tacho-generator and since Tacho voltage will not be perfectly dc and will have some ripple. So, we require a filter with a gain to bring Tacho output back to controller level [6].



Fig(1):Closed loop system model for speed control of dc motor [7,8].

1-3- Current controller design :

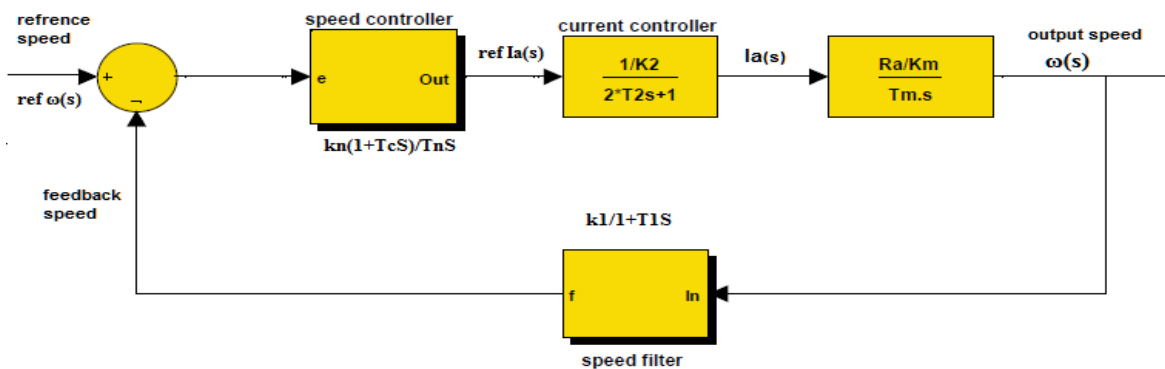


Fig(2): Block Model for Current Controller Design .

Transfer function of the above model:

$$\left[\frac{I_a(S)(f)}{I_a(S)(ref)} \right] (1 + ST_2) = \left[\left(\frac{1}{K_2} \right) (1 + T_2S) \right] / [2S^2T_2^2 + 2ST_2 + 1]$$

1-4- Speed controller design[9] :



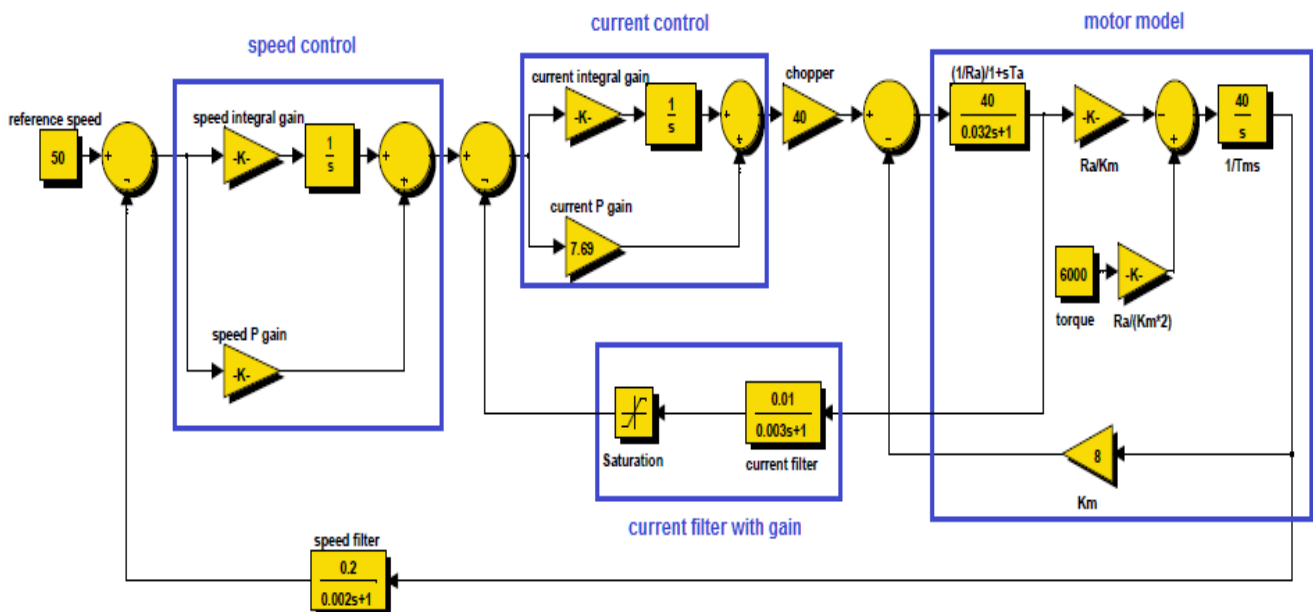
Fig(3): Block model for Speed Controller design[7].

By converting the block model in transfer function, we will get:

$$\left[\frac{\omega(S)}{\omega(S)(ref)} \right] = [(K_n R_a / K_2 K_m T_m T_n)(1 + T_1 S)] / [K_2 K_m T_n S^2 (1 + T_1) + K_n R_a K_1]$$

Ideally, $\omega(s) = 1/S (S^2 + \alpha s + \beta)$. The damping constant is zero in above transfer function because of absence of S term, which results in oscillatory and unstable system. To optimize this we must get transfer function whose gain is close to unity [10 ,5] .

1-5- Complete layout for DC motor speed control :



Fig(4): Complete layout for DC motor speed control

2- Problem statement :

A separately excited DC motor with name plate ratings of 300KW, 400V(DC), 50 rad/sec is used in all simulations. Following parameter values are associated with

- Moment of Inertia, $J = 80 \text{ Kg-m}^2$.
- Back EMF Constant = 8 Volt-sec/rad.
- Rated Current = 670 A.
- Maximum Current Limit = 1000 A.

- Resistance of Armature, $R_a = 0.025 \text{ ohm}$.
- Armature Inductance, $L_a = 0.812 \text{ mH}$.
- Speed Feedback Filter Time Constant , $T_1 = 20 \text{ ms}$.
- Current Filter Time Constant , $T_2 = 3\text{ms}$.

2-1- Current controller parameter :

Current PI type controller is given by

$$K_c [(1 + T_c S)/T_c S] \text{ Here, } T_c = T_a \text{ and } K_c = R_a T_a / (2K_2 K_t T_2)$$

$$T_a = L_a / R_a = 0.812 * \frac{1}{25} = 32 \text{ ms.}$$

For analog circuit maximum controller output is $\pm 10 \text{ Volts}$.

Therefore, $K_t = 400/10 = 40$.

Also, $K_2 = 10/1000 = 1/100$.

Now, putting value of R_a , T_a , K_2 , K_t and T_2 we get: $K_c = 0.333$

2-2- Speed controller parameter :

Speed PI type controller is given by

$$K_n [(1 + T_n S)/T_n S] \text{ Here,}$$

$$\text{Also } K_n = T_m K_m K_2 / (2K_1 R_a \delta)$$

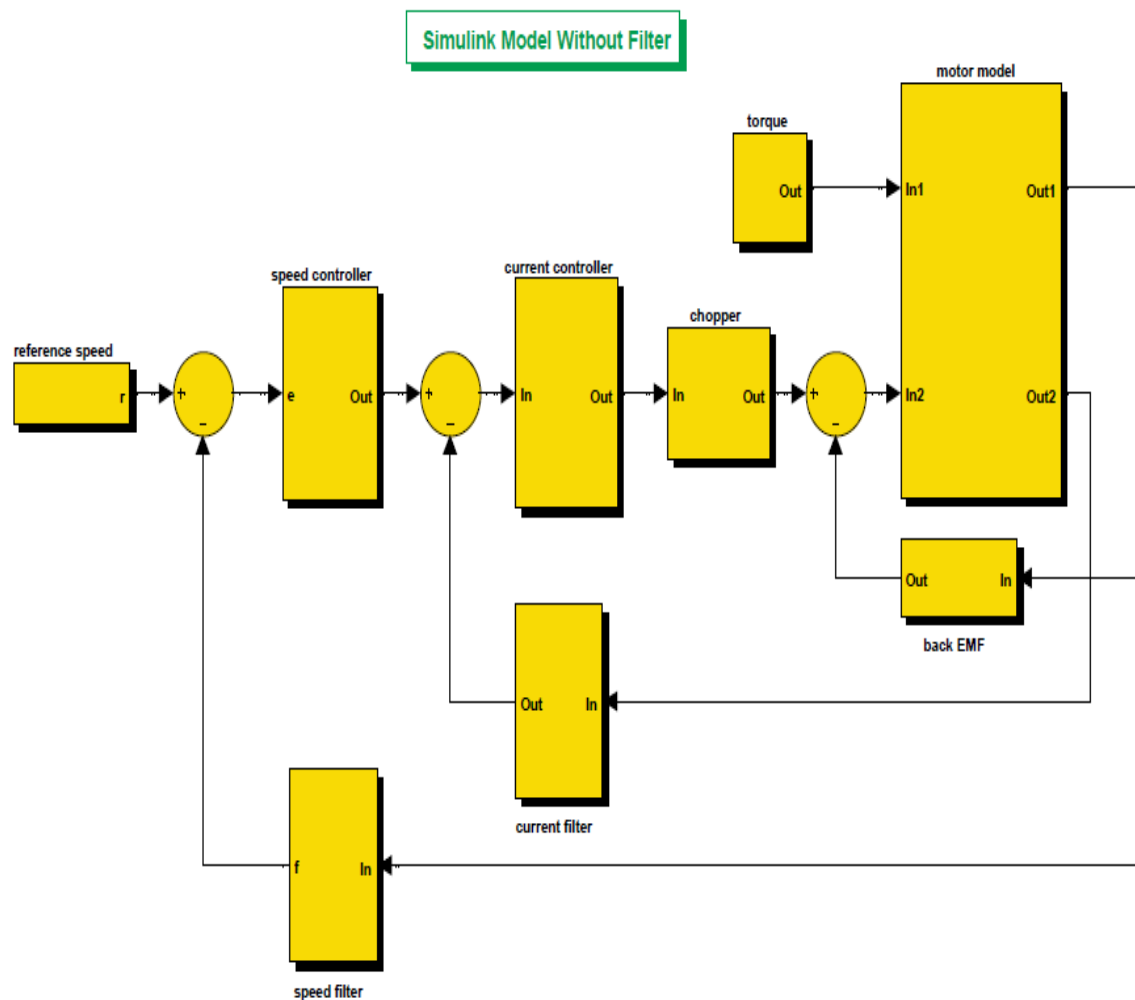
$$T_n = 4\delta = 4(T_1 + 2T_2) = 4(20 + 6) = 104 \text{ ms.}$$

$$K_1 = 10/50 = 0.20$$

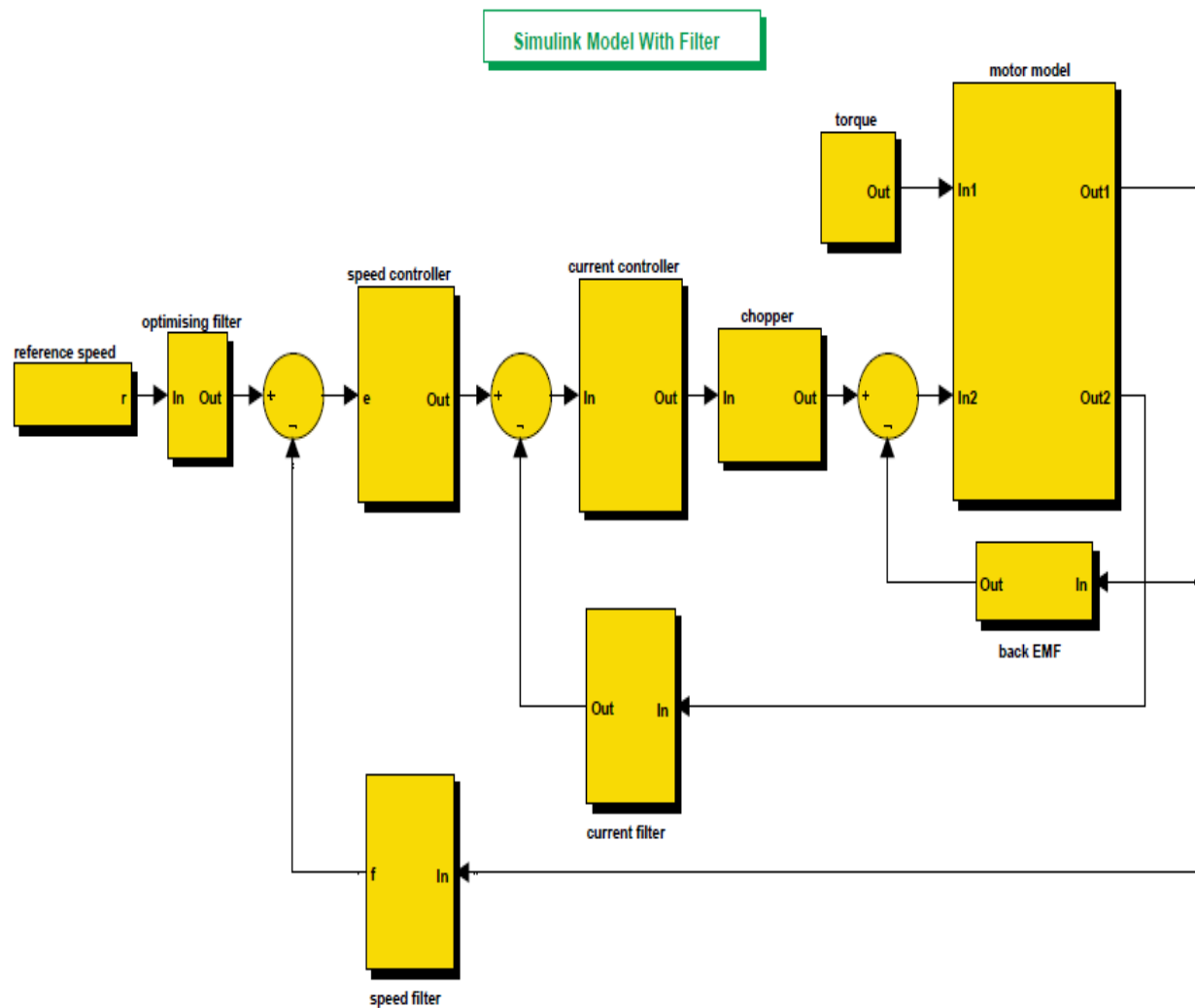
$$T_m = \frac{jR_a}{K_m} = 80 * 0.025/8 = 25 \text{ ms.}$$

Now, $K_n = 7.69$

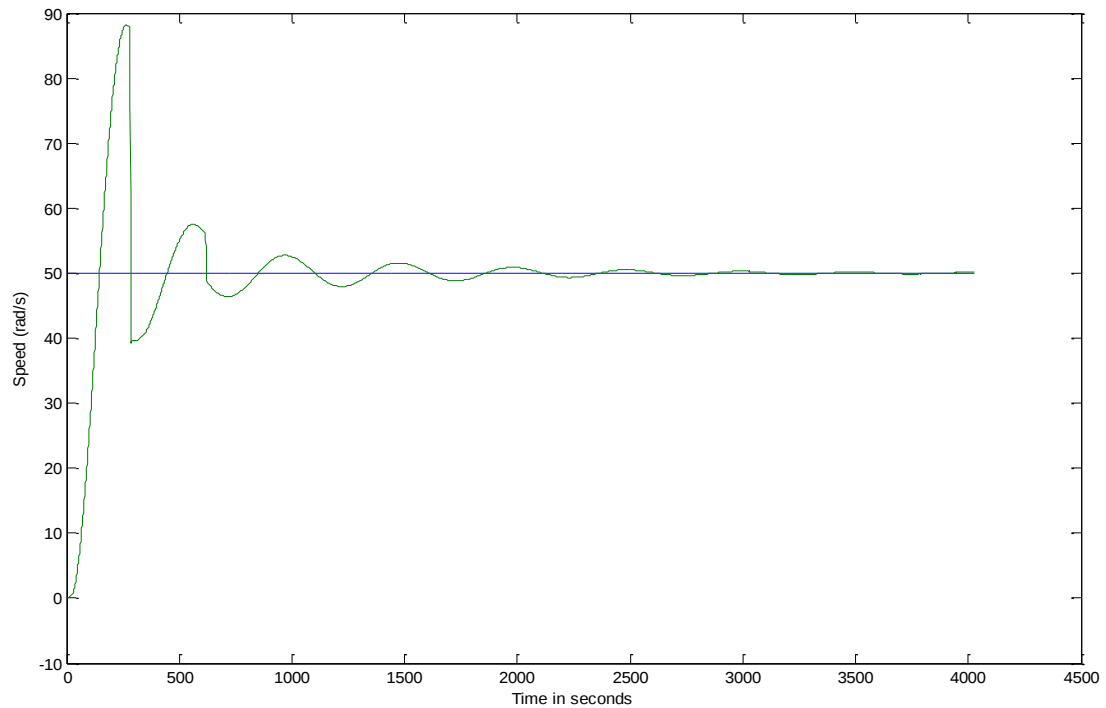
3-MATLAB simulation and results :



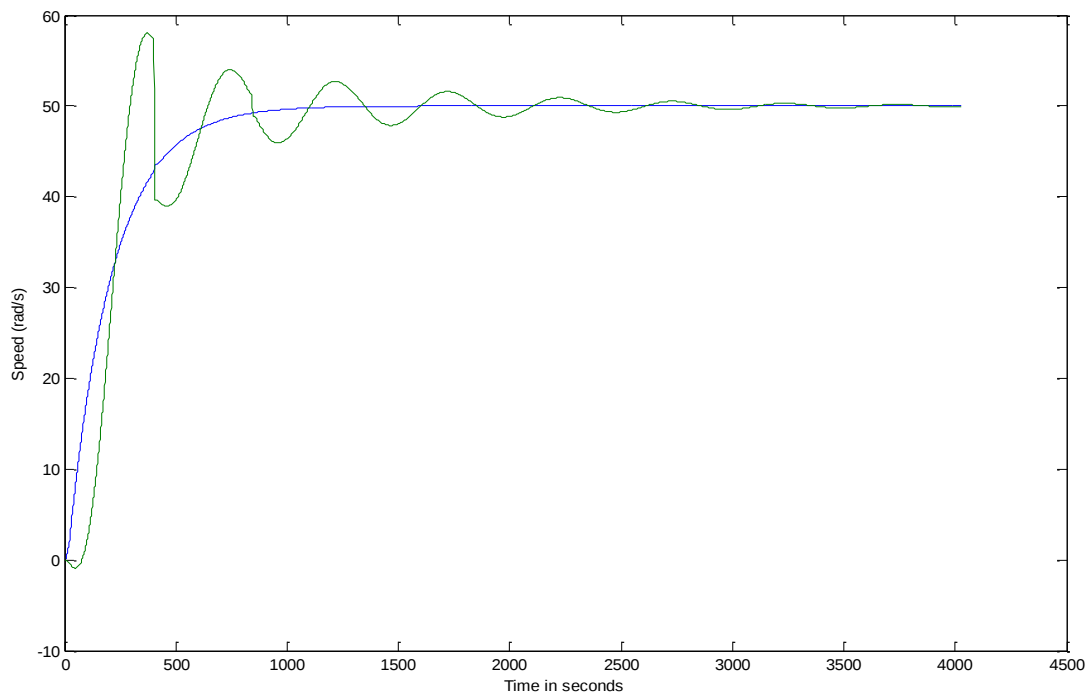
Fig(5):Simulink Model for Speed Control of Separately Excited DC motor using Chopper Converter (without filter after reference speed)



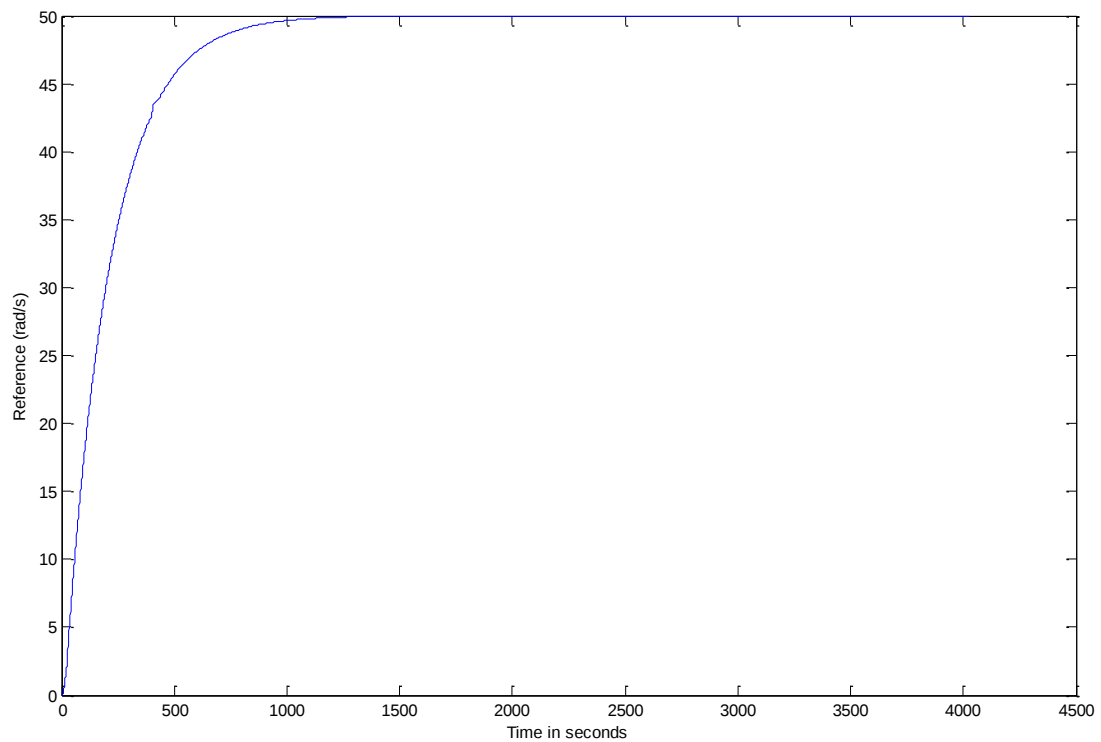
Fig(6):Simulink Model for Speed Control of Separately Excited DC motor using Chopper Converter (with filter after reference speed)



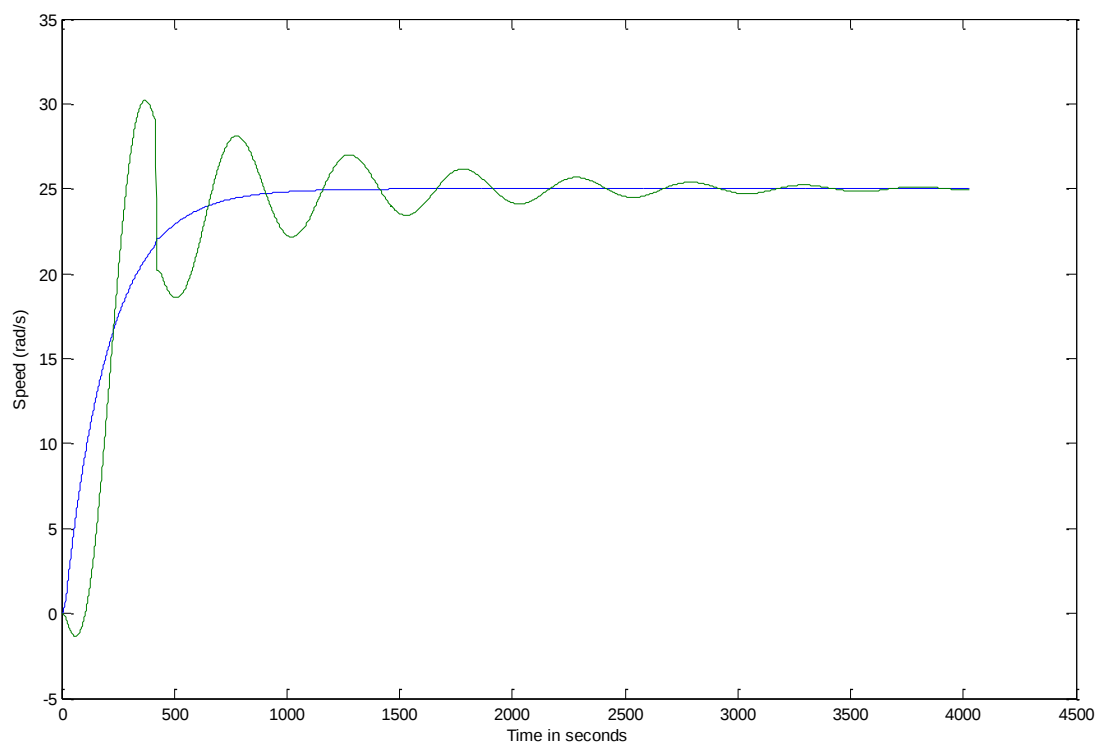
Fig(7):Speed Response at reference speed same as rated speed and full load(without Filter)



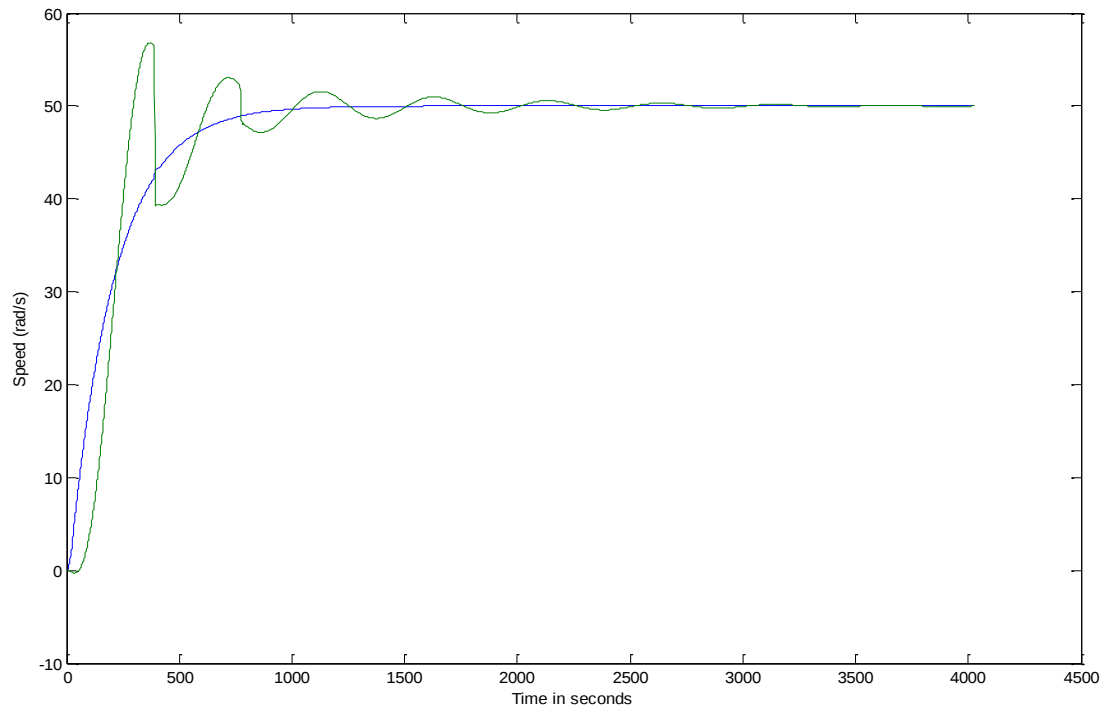
Fig(8):Speed Response at reference speed same as rated speed and full Load (with Filter)



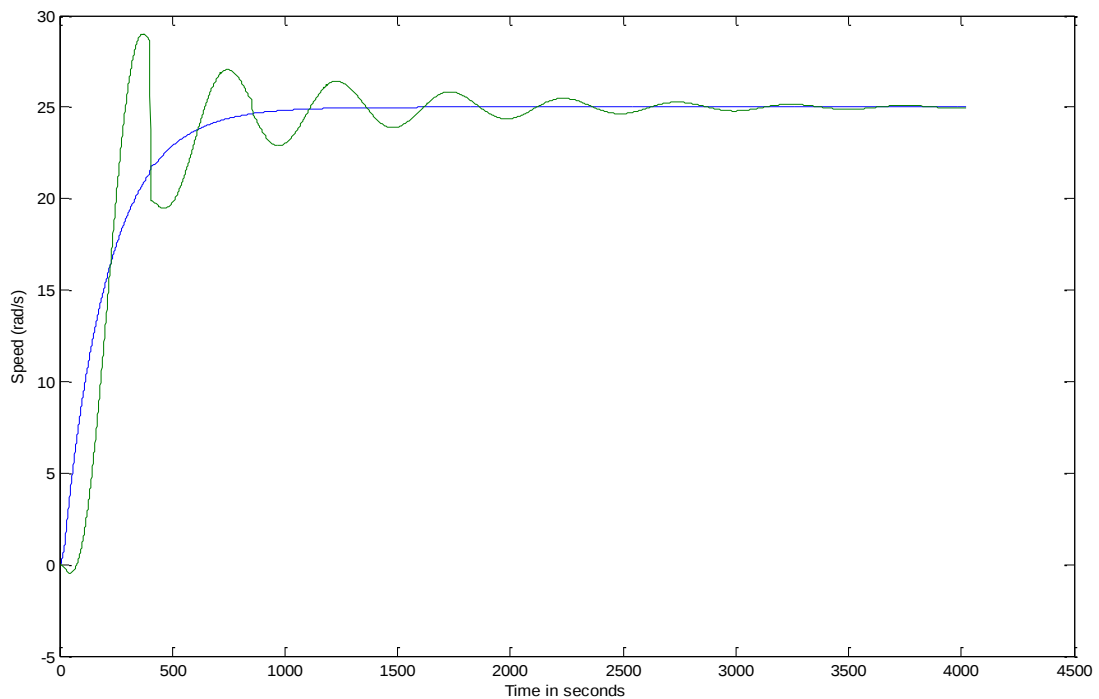
Fig(9):Reference Speed Vs Time while using Filter after reference



Fig(10):Speed Response at reference speed half the rated speed and full Load



Fig(11):Speed Response at reference speed same as rated speed and half of full Load



Fig(12):Speed Response at reference speed of half the rated speed and half of full Load

3-1- Analysis for Graphs:

From above simulation results, it is clear that the SIMULINK model without filter after reference speed (figure 7) gives larger overshoot in speed before settling to steady state and faster response than the model using filter after reference speed (figure 8) .

When the load is constant the speed response is smooth after attaining steady state. When load is constant and reference speed is varying (figure 10) then speed response is shifting accordingly with a time delay. But when the load is varying , (figure 11) speed response have ripples due to time delay in achieving desired speed. When Reference speed and load is varying (figure 12) then in speed response, there is some ripple due to delay in achieving current reference speed. After connecting optimizing filter the over shoot is reduced and speed response is enhanced .

4- Discussion:

Chopper circuit as converter is successful for controlling of speed motor and proportional-Integral model, speed and current controller using simple closed loop system for the beginning . It is a good controller according to the results. The rated current and speed controller is studied. Then a general model of separately excited dc motor is done. Then a generalized Dc drive system is obtained. Current and speed controller is designed . Matlab Simulation is done with and without filter and compared the response of two state .A dc Motor parameters found out from the derived design approach. The simulation results studied and analyzed also show that the proposed controller gives better performance and less settling time under varying reference speed or load. MATLAB simulation For speed control of separately excited DC motor can be use to other types of motors. In this paper , we have done speed control for rated and below rated speed. So the control for above the rated speed can be achieved by controlling of field flux. In future the problem of overshoot can be removed by using PID controller or Fuzzy approach.

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