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SPEED CONTROL OF (SEDM) ADOPTING CHOPPER CONVERTER AND PI CONTROLLER

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ABSTRACT This paper describes speed control of separately excited DC motor (SEDM) adopting Chopper converter and PI as speed and current controller. The chopper firing circuit receives signal from controller and then chopper gives variable voltage to the armature of the motor for achieving desired speed. There are two control loops, the first for controlling current and the other one for speed. Modeling of separately excited DC motor is done. The complete layout of DC drive mechanism is obtained. The designing of current and speed controller is carried out. The optimization of speed controller is done using modulus hugging approach, in order to get stable and fast control of DC motor. After obtaining the complete model of DC drive system, the model is simulated using (MATLAB/SIMULINK).The simulation of DC motor drive is done and analyzed under varying speed with load torque conditions like rated speed and load torque, half the rated load torque and speed, step speed and load torque and stair case load torque and speed.
Keywords: SEDM, PI controller, chopper converter.

1. INTRODUCTION

Development of high performance motor drives are very essential for industrial applications. A high performance motor drive system must have good dynamic speed command tracking and load regulating response. DC motors provide excellent control of speed for acceleration and deceleration. The power supply of a DC motor connects directly to the field of the motor which allows for precise voltage control, and its necessary for speed and torque control applications DC drives, because of their simplicity, ease of application, reliability and favorable cost have long been a backbone of industrial applications. DC drives are less complex as compared to AC drives system. DC drives are normally less expensive for low horsepower ratings. DC motors have a long tradition of being used as adjustable speed machines and a wide range of options have evolved for this purpose. Cooling blowers and inlet air flanges provide cooling air for a wide speed range at constant torque. DC regenerative drives are available for applications requiring continuous regeneration for overhauling loads. AC drives with this capability would be more complex and expensive. Properly applied brush and maintenance of commutator is minimal. DC motors are capable of providing starting and accelerating torques in excess of 400% of rated [1].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 [2].[3].

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 a dc equivalent of an ac transformer since they behave in an identical manner. As chopper involves one stage conversion these are more efficient. Choppers are now being used all over the world for rapid transit systems. These are also used in trolley cars, marine hoist, forklift trucks and mine haulers. The future electric automobiles are likely to use choppers for their speed control and braking. Chopper systems offer smooth control, high efficiency, faster response and regeneration facility.The power semiconductor devices used for a chopper circuit can be force commutated thyristor, power BJT, MOSFET and IGBT.GTO based chopper are also used. These devices are generally represented by a switch. When the switch is off, no current can flow. Current flows through the load when switch is on. The power semiconductor devices have on- state voltage drop of 0.5V to 2.5V across them. For the sake of simplicity, this voltage drop across these devices is generally neglected As mentioned above, a chopper is dc equivalent to an ac transformer, have continuously variable turn's ratio. Like a transformer, a chopper can be used to step down or step up the fixed dc input voltage[4]

PRINCIPLE OF CHOPPER OPERATION:

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. In this manner, a chopped load voltage as shown in Fig(1). is obtained from a constant dc supply of magnitude Vs. For the sake of highlighting the principle of chopper operation, the circuitry used for controlling the on, off periods is not shown. During the period Ton, chopper is on and load voltage is equal to source voltage Vs. During the period T_{off}, chopper is off, load voltage is zero. In this manner, achopped dc voltage is produced at the load terminals[4]

$Vo = (Ton/ (T_{on}+T_{off}))*Vs$ ....(1-1)

Vo = Average Voltage,

$Vo = (T_{on}/T)*Vs$ ....(1-2)

$Vo = \alpha\ Vs$ ....(1-3)

T_{on}=on-time.

T_{off}=off - time.

$T=T_{on}+T_{off}$ .... (1-4)

T = chopping period.

$\alpha=T_{on}/T_{off}=\alpha Vs$ ... (1-5)

Thus, the voltage can be controlled by varying duty cycle α

$V_O=f*T_{on}*Vs$ .... (1-6)

$F=1/T$ .... (1-7)

F=chopping frequency.

SEPARATELY EXCITED DC MOTOR

BASIC OF SEPARATELY EXCITED DC MOTOR:

Separately Excited DC motor has field and armature winding with separate supply .

- The field windings of the dc motor are used to excite the field flux.
- Current in armature circuit is supplied to the rotor via brush and commutator segment for the mechanical work.
- The rotor torque is produced by interaction of field flux and armature current.

OPERATION OF SEPARATELY EXCITED DC MOTOR

- When a separately excited dc motor is excited by a field current of if and an armature current of ia flows in the circuit, the motor develops a back EMF and a torque to balance the load torque at a particular speed
- The field current if is independent of the armature current ia. Each winding is supplied separately. Any change in the armature current has no effect on the field current. The if is generally much less than the ia.[5]

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. 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 Ec that controls the operation duty cycle of (here the converter used is a Chopper) converter. The converter output give the required Va required to bring motor back 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. 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[7]. The basic block diagram for DC motor speed control is show below:[8].[9].

CONTROLLER DESIGN

CONTROLLER FUNDAMENTALS

The controller used in a closed loop provides a very easy and common technique of keeping motor speed at any desired set-point speed under changing load conditions. This controller can also be used to keep the speed at the set-point value when, the set-point is ramping up or down at a defined rate. The essential addition required for this condition to the previous system is a means for the present speed to be measured.In this closed loop speed controller, a voltage signal obtained from a Tacho-generator attached to the rotor which is proportional to the motor speed is fed back to the input where signal is subtracted from the set-point speed to produce an error signal. This error signal is then fed to work out what the magnitude of controller output will be to make the motor run at the desired set-point speed. For example, if the error speed is negative, this means the motor is running slow so that the controller output should be increased and vice-versa[6].

CURRENT CONTROLLER DESIGN:

TheBlock Model for Current controller design as shown in fig (4).
Transfer function of the above model:
$Ia(S)\,(f) / Ia(S)\,(ref) = (1/K2)/\,(2S^2T2^22ST2+1)$

SPEED CONTROLLER DESIGN

The Block model for Speed Controller design as shown in fig (5).[10]
Now, converting the block model in transfer function, we will get:
$\omega(s)/\omega(s)(ref.)=(KnRa/K2KmTmTn)(1+T1S)/\{K2KmTnS2(1+T1S)+KnRaK1\}$
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.[8][10].

PROBLEM STATEMENT:

A separately excited DC motor with nameplate ratings of 300KW, 420V (DC), 50 rad/sec is used in all simulations. Following parameter values are associated with it.

- Moment of Inertia، J = 75 Kg-m2.
- Back EMF Constant = 7 Volt-sec/rad.
- Rated Current = 700 A.
- Maximum Current Limit = 1000 A.
- Resistance of Armature، Ra = 0.026 ohm.
- Armature Inductance، La = 0.749 mH.

- Speed Feedback Filter Time Constant T1 = 22 ms.
- Current Filter Time Constant T2 = 3ms.

Current Controller Parameter[1]:
Current PI type controller is given by:
Kc {(1+ TcS)/TcS}
Here, Tc = Ta and Kc = RaTa/ (2K2KtT2)
Ta = La/Ra = 0.749*10-3/0.026 = 28.80 ms.
For analog circuit maximum controller output is ± 10 Volts.
Therefore, Kt = 420/10 = 42.
Also, K2 = 10/1000 = 1/100.
Now, putting value of Ra, Ta, K2, Kt and T2 we get: Kc = 0.297.
Speed Controller Parameter[1]:
Speed PI type controller is given by:
Kn{(1+TnS)/TnS}
Here, Tn = 4δ = 4(T1+2T2) = 4(22 + 2*3) = 112 ms.
Also, Kn = TmKmK2/(2K1Raδ).
K1 = 10/50 = 0.192.
Tm = JRa/Km = 75*0.026/7 = 0.278 ms.
Now, Kn = (0.278*7*0.01)/ (2*0.192*0.026*31*100) = 6.28.

THE SIMULATION RESULTS AND DISCUSSION

From simulation results, it is clear that the SIMULINK model as shown in figure (7) gives larger overshoot in speed before settling to steady state

When the load is constant the speed response is smooth after attaining steady state. When load is constant and reference speed is varying (figure 8) then speed response is shifting accordingly with a time delay. But when the load is varying , (figure 9) speed response have ripples due to time delay in achieving desired speed. When Reference speed and load is varying (figure 10) then in speed response, there is some ripple due to delay in achieving current reference speed

The speed of a dc motor has been successfully controlled by using Chopper as a converter and Proportional-Integral type Speed and Current controller based on closed loop system model. Initially a simplified closed loop model for speed control of DC motor is considered and requirement of current controller is studied. Then a generalized modeling of dc motor is done. After that a complete layout of DC drive system is obtained. Then designing of current and speed controller is done. The optimization of speed control loop is achieved through Modulus Hugging approach. A DC motor specification is taken and corresponding parameters are found out from derived design approach. The simulation results under varying reference speed and varying load are also studied and analyzed. The model shows good results under all conditions employed during simulation

FUTURE SCOPE:

MATLAB simulation for speed control of separately excited DC motor has been done which can be implemented in hardware to observe actual feasibility of the approach applied in this thesis. This technique can be extended to other types of motors. In this thesis, we have done speed control for rated and below rated speed. So the control for above the rated speed can be achieved by controlling field flux. The problem of overshoot can be removed using a Neural Network and Fuzzy approach

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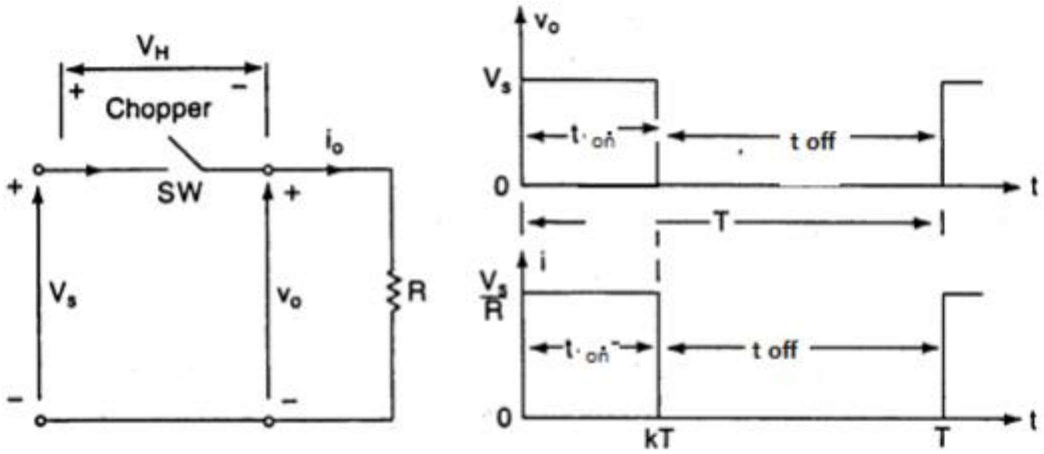


(a) Chopper circuit. (b) voltage waveform.

Figure (1) Chopper Circuit and Voltage and Current Waveform

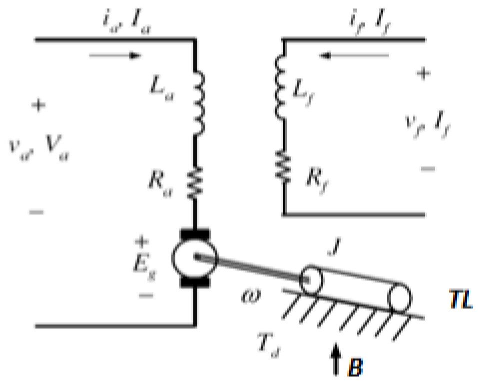
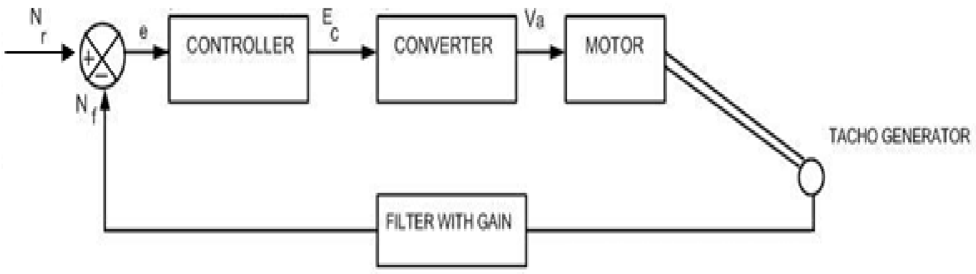
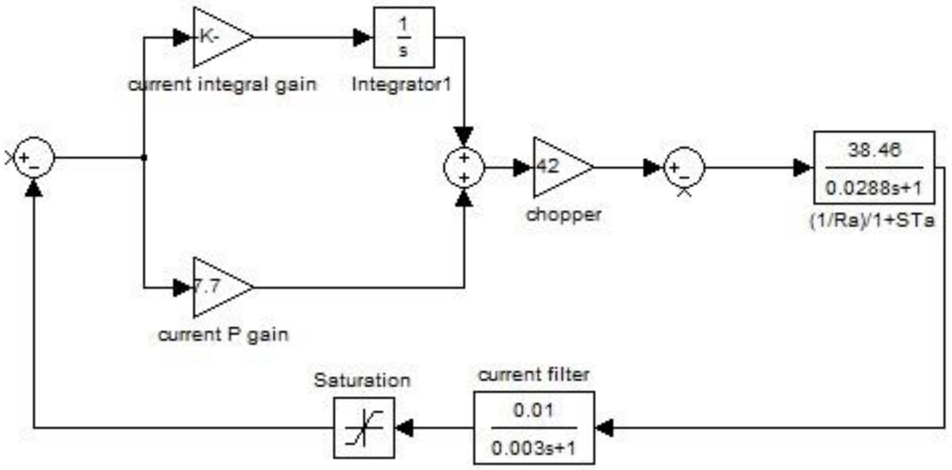


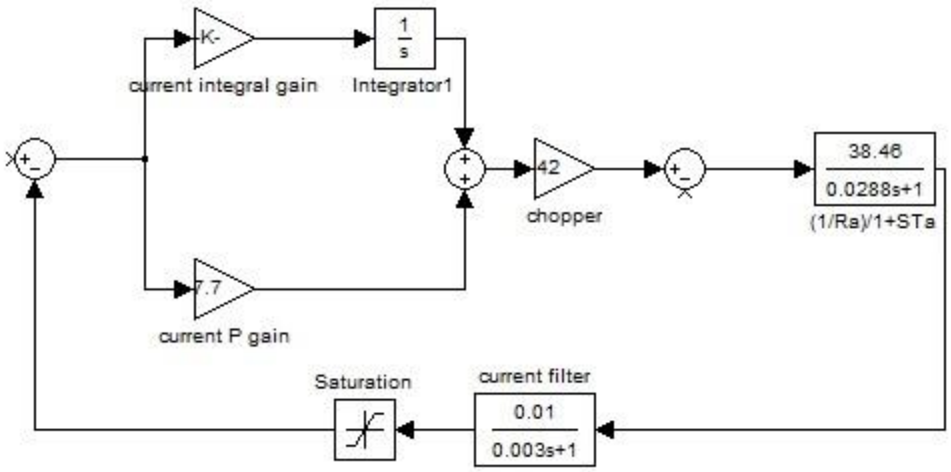
Figure (2). Separately Excited DC motor equivalent circuit.



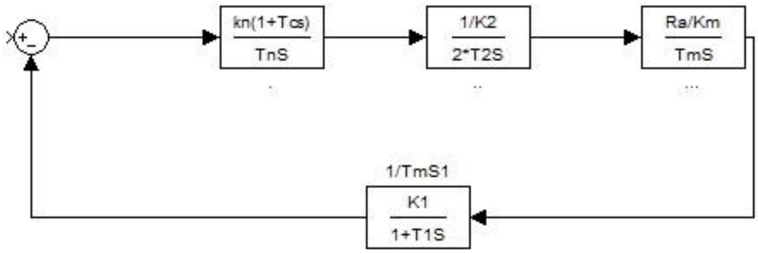
Figure(2). Separately Excited DC motor equivalent circuit.



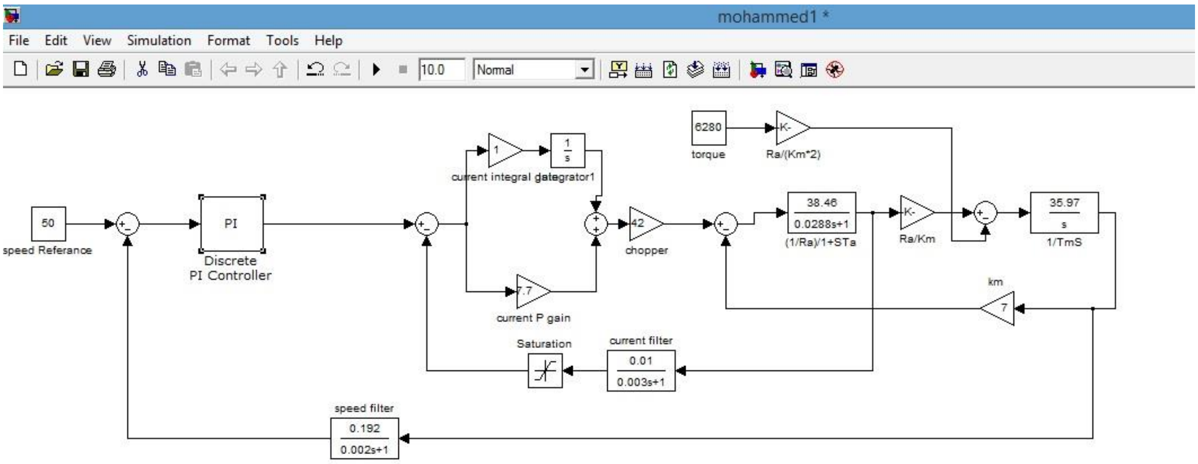
Fig(3):Closed loop system model for speed control of dc motor



Fig(4): Block Model for Current controller design**.**



Fig(5): Block model for Speed Controller design



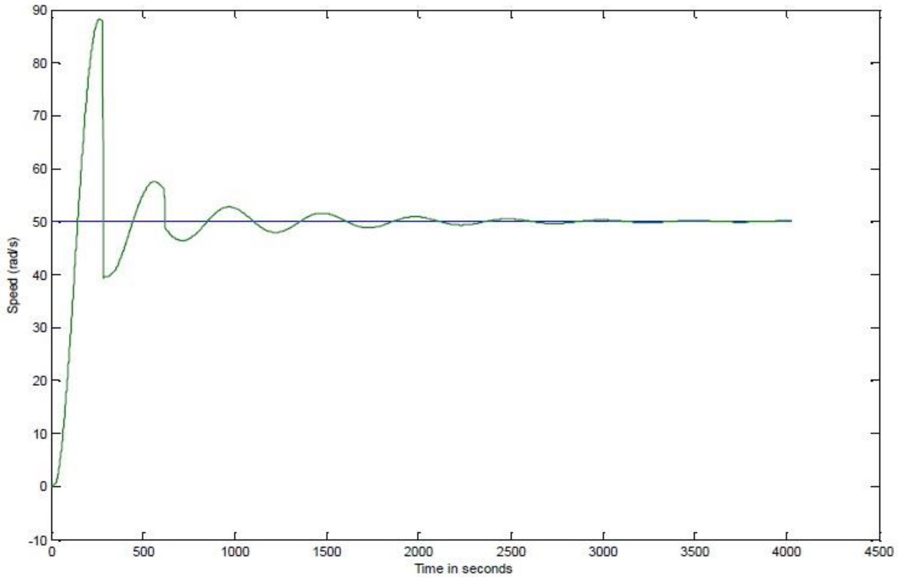


Figure (7) Speed Response at reference speed

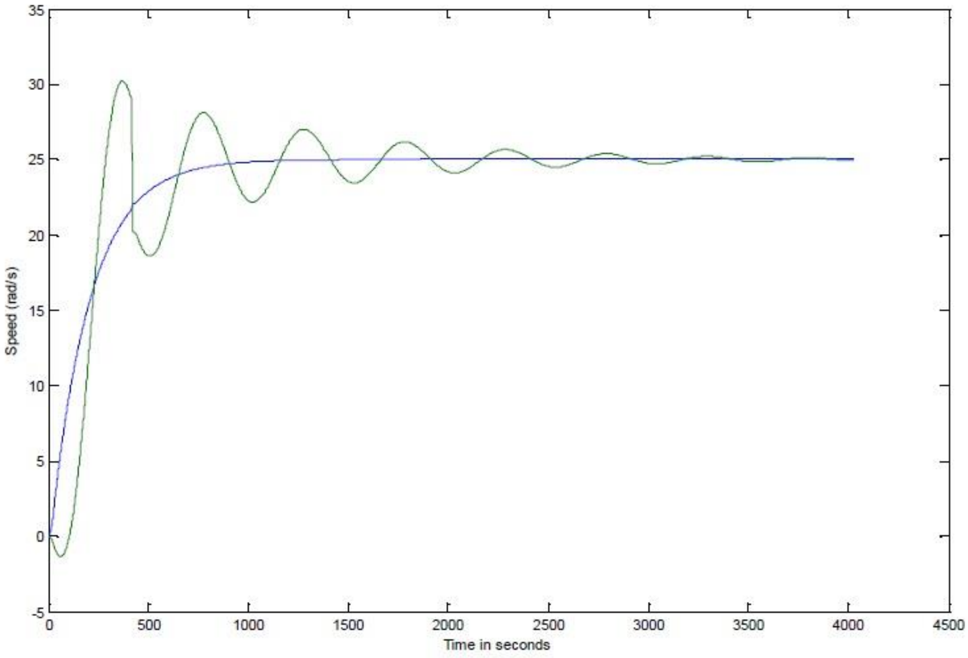


Figure (8) Speed Response at reference speed at half rated and full Load speed

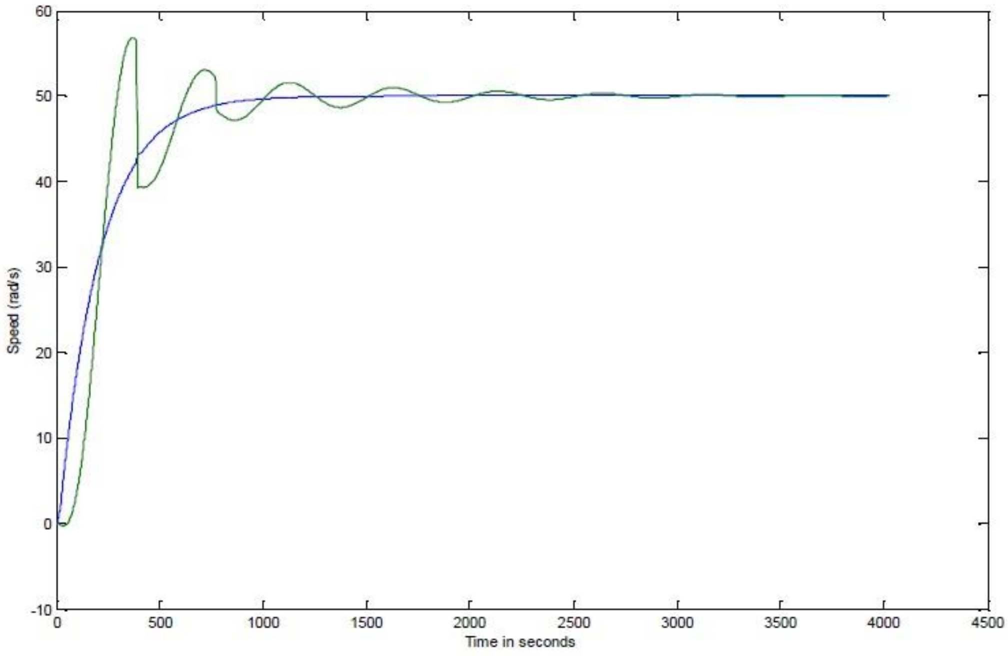


Figure (9) Speed Response at reference speed, rated speed and half of full Load

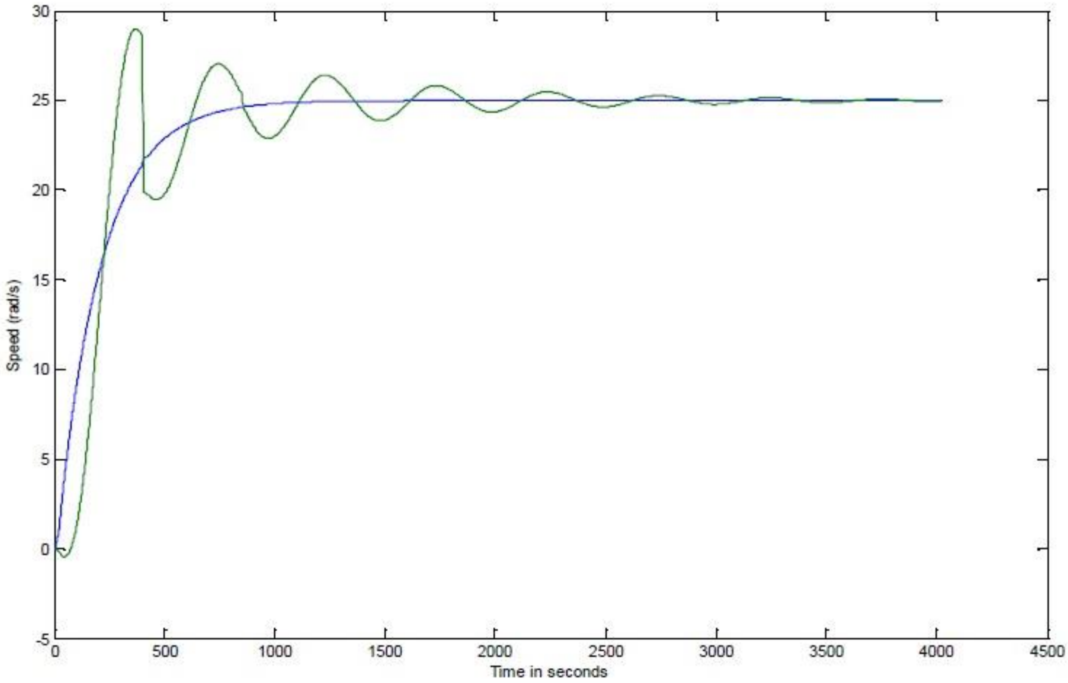


Figure (10) Speed Response at reference speed of half the rated speed and half of full Load

الخلاصة

يوضح البحث طريقة السيطرة على سرعة محرك تيار مستمر ذو اثارة منفصلة باستخدام مقطع مع مسيطر تناسبي تكاملي بهذه الطريقة يمكن السيطرة على سرعة المحرك لغاية السرعة المطلوبة . تستلم دائرة قدح المقطع الإشارة من المسيطر لتجهيز فولتية بقيم متغيرة الى منتج المحرك للوصول الى السرعة المطلوبة . تم تصميم وتنفيذ مسيطرين الأول للسرعة والثاني للتيار وذلك للحصول على سرعة دوران ذات استجابة جيدة وباستقراريه عالية . تم اخذ نموذج لمحرك تيار مستمر ذو اثارة منفصلة وتمثيله بنموذج محاكاة باستخدام الماتلاب . تم تنفيذ المحاكاة وتحليل النتائج والعلاقات بين السرعة وعزم الحمل مثل علاقة السرعة المطلوبة مع عزم الحمل الكامل والعلاقة بين نصف السرعة المقررة مع نصف الحمل