Software Base Minor Project Synopsis

MATLAB Based Simulation of Speed Contol of DC Motor By Using Chopper

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DECLARATION

This is to certify that Report entitled ” Matlab Based Simulation of speed control of DC motor by using chopper ” which is submitted in partial fulfillment of the requirements for the Bachelor of Technology(Third Year) in Electrical Engineering of the Dr.A.P.J.Technical University, Lucknow, during the academic year 2017-18, comprises only our own work and due acknowledgement has been made in the text to all other material used.

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Certificate

This is to certify that this software based mini project entitled “Matlab Based Simulation of speed control of DC motor by using chopper” by Sonu Kumar (Roll No 1606820904), Indra Kumar (1606820902) & Sardeep Kumar (1606820903) submitted in partial fulfillment of the requirements for the Bachelor of Technology(Third Year)) in Electrical Engineering to MIET, Meerut, Dr. A.P.J Abdul Kalam Technical University, Lucknow is a record of the candidate own work carried out by him under my supervision. The matter embodied in this thesis is original and has not been submitted for the award of any other degree

Prof. A. K RAJPUT	Prof. S. K. GOEL
(Guide)	(Head of Department)

ACKNOWLEDGEMENT

I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals and organizations. I would like to extend my sincere thanks to all of them.

I am highly obliged of Prof. Ashok Kumar Rajput for the guidance and constant supervision as well as for providing necessary information regarding the project & also for their support in completing the project.

I would like to express my gratitude towards my Head of Department Prof. S.K Goel of MIET for their kind co-operation and encouragement which help me in completion of this project.

My thanks and appreciations also go to my class mates in developing the project and people who have willingly helped me out with their abilities.

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ABSTRACT

The speed of separately excited DC motor can be controlled from below and up to rated speed using chopper as a converter. 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, one for controlling current and another for speed. Where we use speed control by using mosfet by provide by firing angle by using PID Controller. The controller used is Proportional-Integral type which removes the delay and provides fast control. 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 and varying 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.

PROPOSED WORK

The circuit diagram of speed control of DC motor by using chopper circuit shown in the figure given below :-

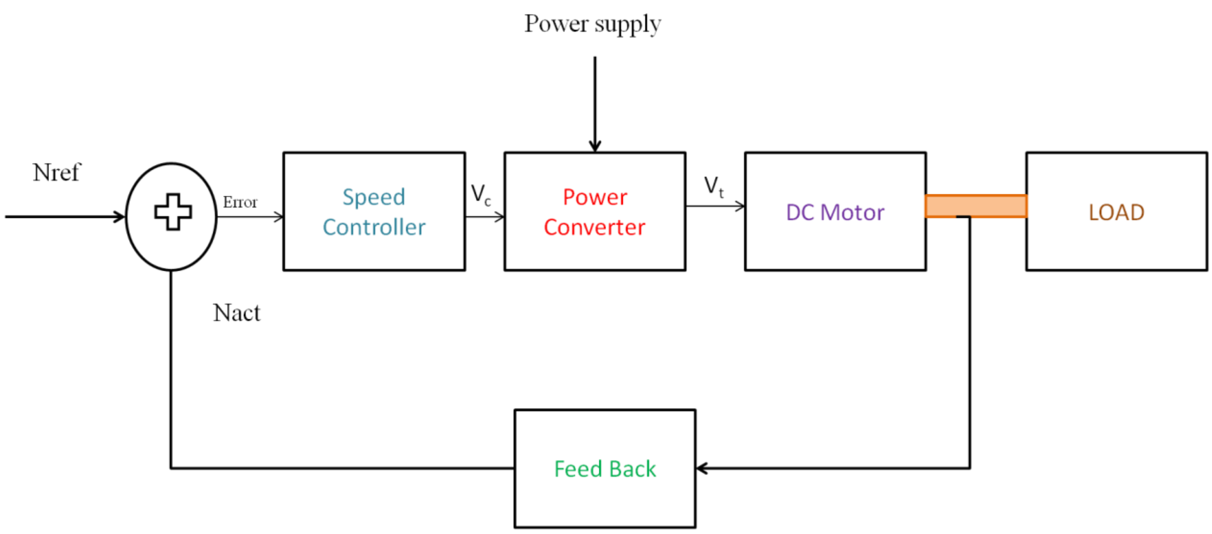


Table of content

DESCRIPTION OF MATLAB SOFTWARE

The software which is used here is MATLAB. MATLAB (**mat**rix **lab**oratory) is a multi-paradigm numerical computing environment. A proprietary programming language developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

The MATLAB application is built around the MATLAB scripting language. Common usage of the MATLAB application involves using the Command Window as an interactive mathematical shell or executing text files containing MATLAB code.

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including Graphical User Interface building

SIMULINK

Simulink is a graphical programming environment for modeling, simulating and analyzing multi-domain dynamical systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in automatic control and digital signal processing for multi-domain simulation and Model-Based Design.

MathWorks and other third-party hardware and software products can be used with Simulink. For example, Stateflow extends Simulink with a design environment for developing state machines and flow charts.

MathWorks claims that, coupled with another of their products, Simulink can automatically generate C source code for real-time implementation of systems. As the efficiency and flexibility of the code improves, this is becoming more widely adopted for production systems, in addition to being a tool for embedded system design work because of its flexibility and capacity for quick iteration. Embedded Coder creates code efficient enough for use in embedded systems.

MATLAB has several advantages over other methods or languages:

1. Its basic data element is the matrix. A simple integer is considered an matrix of one row and one column. Several mathematical operations that work on arrays or matrices are built-in to the Matlab environment. For example, cross-products, dot-products, determinants, inverse matrices.
2. Vectorized operations. Adding two arrays together needs only one command, instead of a for or while loop.
3. The graphical output is optimized for interaction. You can plot your data very easily, and then change colors, sizes, scales, etc, by using the graphical interactive tools.

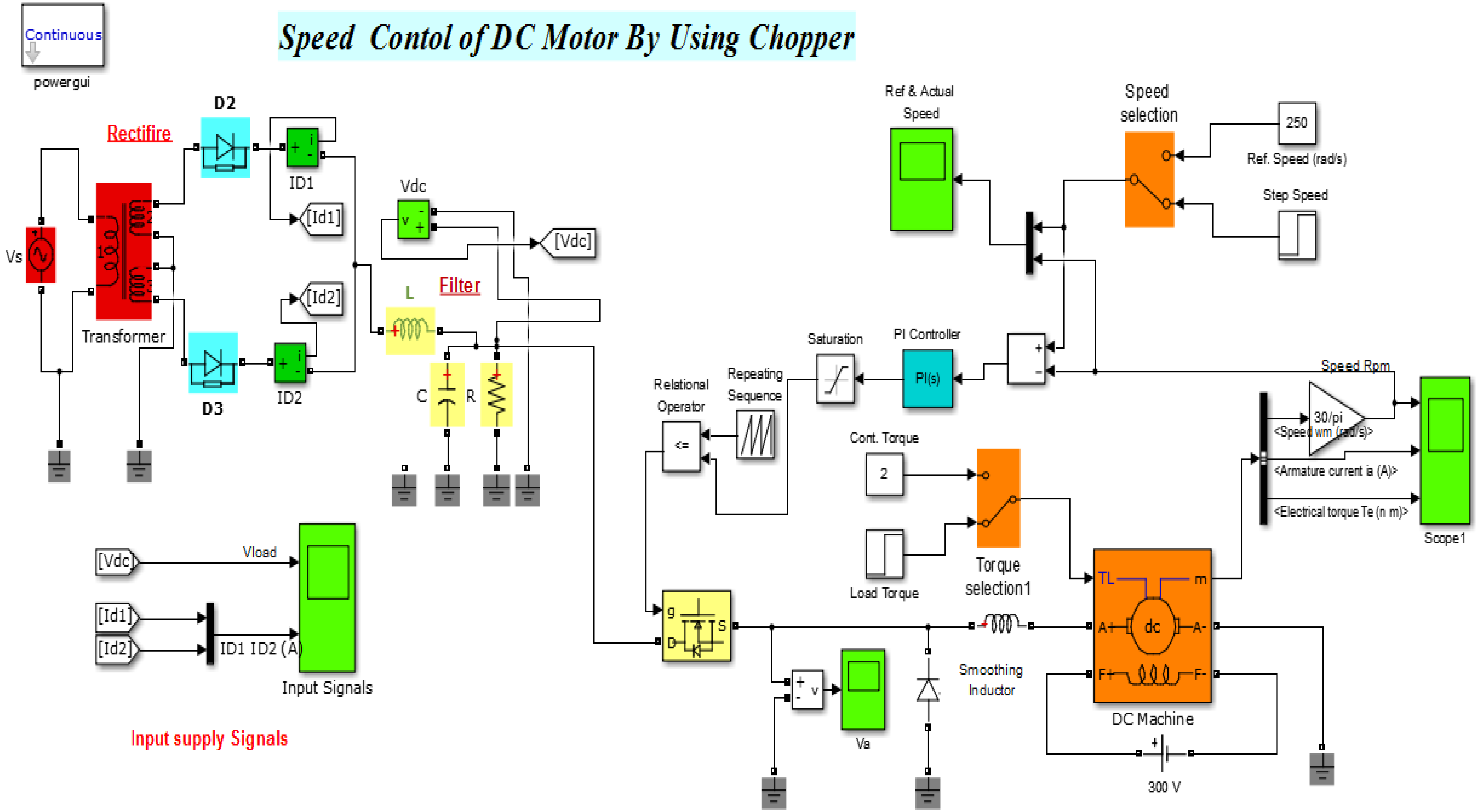
Matlab's functionality can be greatly expanded by the addition of toolboxes. These are sets of specific functions that provided more specialized functionality. Ex: Excel link allows data to be written in a format recognized by Excel, Statistics Toolbox allows more specialized statistical manipulation of data.

1. DESIGN

The circuit arrangement of “ speed control of dc motor by using chopper “ in our MATLAB simulink program is shown in figure 3.1.Here, we have to convert the AC voltage into DC voltage and then filter it by using electrical elements and after fed into the mosfet where the mosfet gate terminal is triggering by using feedback of speed of the dc machine.

Components used from Simulink library:-

1. Mosfet
2. AC voltage source
3. DC voltage source
4. Transformer
5. Series RLC branch
6. Ideal switch
7. Logical operator
8. Goto block
9. From block
10. Powergui
11. Current measurement
12. Voltage measurement
13. scope
14. diode
15. Constant
16. Step selection
17. PI Controller
18. Saturation
19. Relational operator
20. Mux
21. Ground
22. DC Motor
23. Repeating sequence
24. Transformer
25. Bus Selector

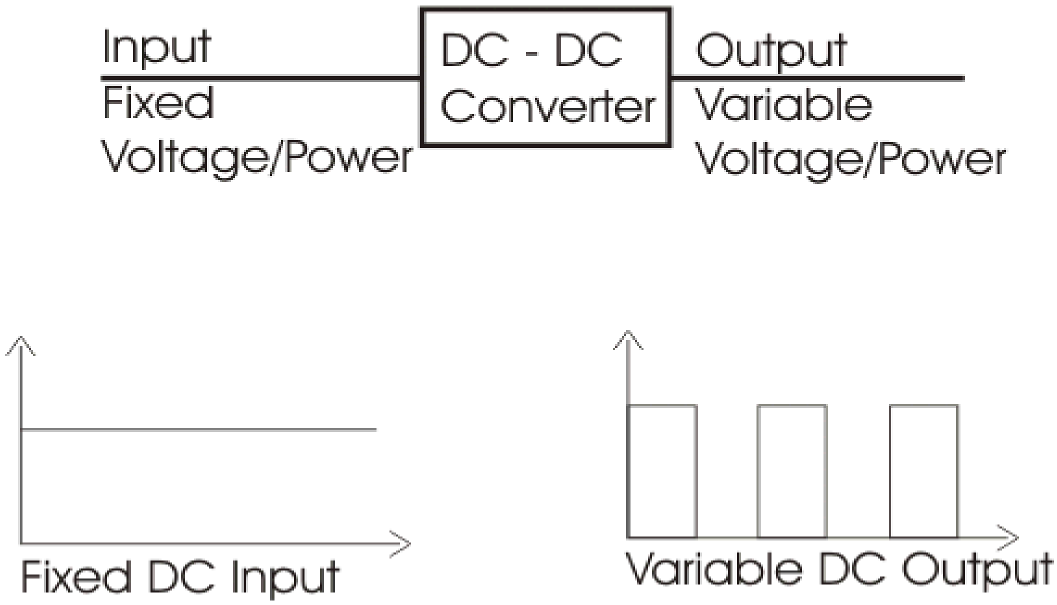

Speed Contol of DC Motor By Using Chopper
Continuous
powergui
Rectifire
D2
D3
Vs
Transformer
ID1
ID2
[Id1]
[Id2]
Vdc
[Vdc]
L
Filter
C
R
Vload
ID1 ID2 (A)
Input Signals
Input supply Signals
Relational Operator
Repeating Sequence
Saturation
PI Controller
PI(s)
Ref & Actual Speed
Speed selection
250
Ref. Speed (rad/s)
Step Speed
Cont. Torque
2
Load Torque
Torque selection1
Speed Rpm
30/pi
<Speed wm (rad/s)>
<Armature current ia (A)>
<Electrical torque Te (n m)>
Scope1
Smoothing Inductor
Va
DC Machine
300 V

Introduction of chopper

Chopper - Definition

A chopper is a static device that converts fixed dc input voltage to a variable dc output voltage directly.

- A



chopper is considered as *DC equivalent of an AC transformer* since it behaves in an identical manner.

- The choppers are more efficient as they involve in one stage conversion.
- The choppers are used in trolley cars, marine hoists, forklift trucks and mine hauler.
- The future electric automobiles are likely to use choppers for their speed control and braking.
- The chopper systems offer smooth control, high-efficiency, fast response and regeneration.

<u>Chopper - Principle of Operation:</u>

A chopper is a high-speed on/off semiconductor switch. It connects source to load and disconnects the load from source at high-speed.

- In other words, the principle of chopper is application of fixed dc voltage intermittently to the load.
- This is achieved by continuously triggering ON and triggering OFF the power switch(SCR) at rapid speed.

Classification of Choppers

(a) Depending upon the direction of the output current and voltage, the converters can be classified into five classes namely

Class A [One-quadrant Operation] (1st quadrant only)

Class B[One-quadrant Operation] (2nd quadrant only)

Class C [Two-quadrant Operation] (1,2 quadrants only)

Class D [Two-quadrant Operation] (1,4 quadrants only)

Class E[Four-quadrant Operation] (All four quadrants)

(b) Based turn off process (commutation process)

- Natural Commutated Chopper (Occurs in AC input circuits)
- Forced Commutated Chopper (Occurs in DC input circuits)

The forced commutation type is further classified as

- Voltage Commutated Chopper
- Current Commutated Chopper

(c) Based on the output voltage of the output, the choppers are classified as

(i) Step-Down Chopper

In this case the average output voltage is less than the input voltage. It is also known as step down converter

(ii) Step-Up Chopper

Here the average output voltage is more than the input voltage. It is also known as step up converter

(iii) Step-Up/Down Chopper

This type of converter produces an output voltage that is either lower or higher than the input voltage

WORKING PRINCIPAL

The principle of operation can be understood with the help of figure 3.2 The model simulates Chopper fed DC motor drive for speed control of DC motor. Actual speed is compared with reference speed command and error is manipulated by a PI controller whose output is the duty cycle. Duty cycle in converted in PWM by comparing the duty cycle voltage with saw tooth waveform. Pulses are applied to MOSFET controlling the chopper circuit. Chopper circuit is basically a first quadrant buck converter.

When chopper is ON motor gets supply but when chopper is off motor does not get the supply. So as shown in figure let us say chopper is on for Ton time and it is off for Toff time. So depending upon the Ton and Toff time the DC voltage applied to motor is

$$Vdc = [T_{on} / (T_{on} + T_{off})] \times V_{fixed}$$

But $T_{on} + T_{off} = T_{total}$

So $Vdc = [T_{on} / T_{total}] \times V_{fixed}$

Here T_{on} / T_{total} is called duty cycle. So as duty cycle is more the average DC voltage supplied to motor is more and so speed of motor is increased. So as duty cycle is varied by varying on and off time of chopper, the speed of motor can be varied.

This model mainly divided into two parts where first part is rectifier where ac voltage is converting into dc voltage which is using filter for removing unvented ac signals voltage. After that this is feed into the mosfet

1 Rectifier

2 **Chopper Fed DC Motor Control**

- Rectifier

The full wave rectifier circuit consists of two *power diodes* connected to a single load resistance with each diode taking it in turn to supply current to the load. This AC input is given to the full wave rectifier. there rectifier will produce rectified DC output as shown in first waveform and second waveform is diode D1 & D2 output at shown in figure(a)-

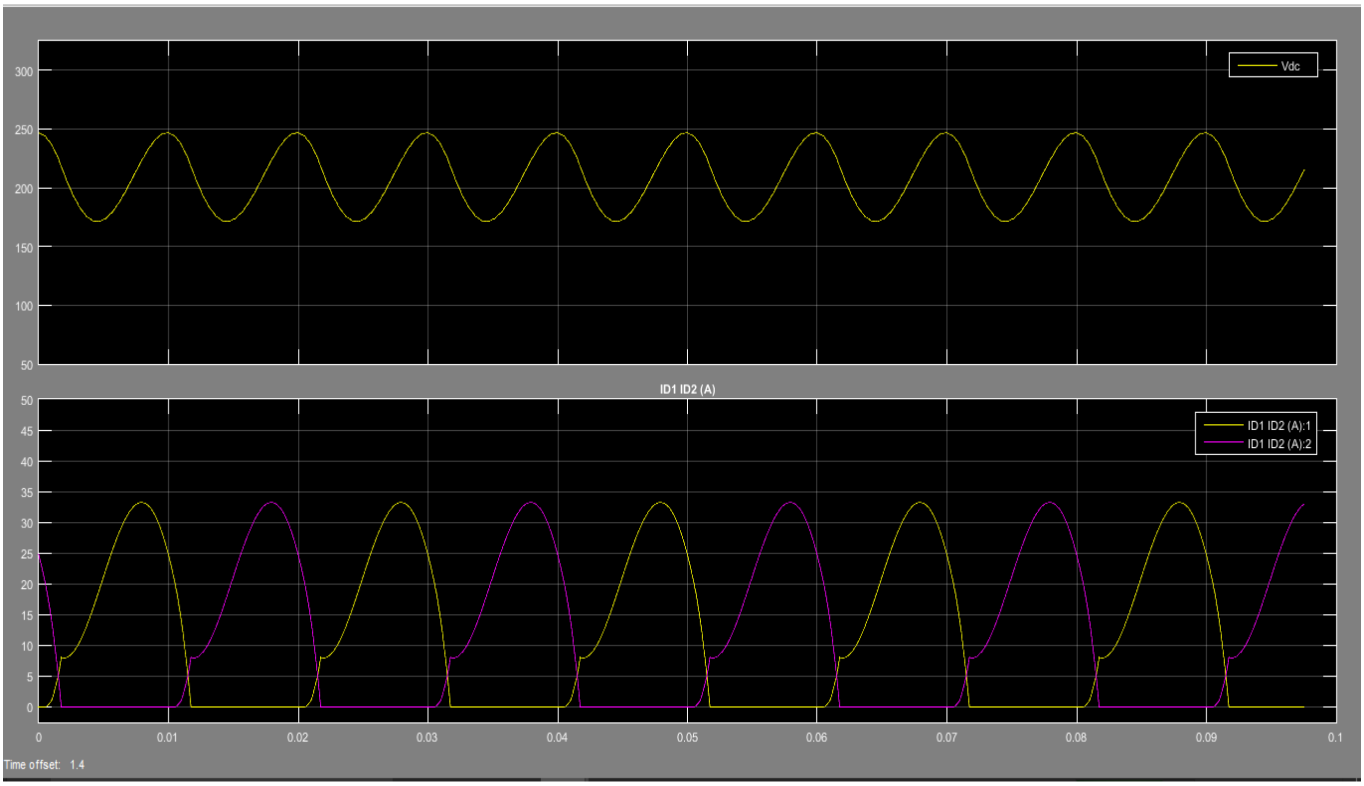


Fig (a).

- **Chopper Fed DC Motor Control**

Chopper Fed DC Motor Control is a technique used to control the speed of the motor by reducing that is by chopping the fixed DC voltage to variable DC voltage. Here the first quadrant chopper method is used that is one switching devices mosfet are used to control the speed of the motor. The motor speed can be controlled by controlling the duty cycle applied to the switching devices. The output voltage totally depends on the ON time of the device if the on time of the switching frequency increases then the output voltage is also increased.

Closed loop control of chopper fed DC Motor Control is used to control the speed of the motor and maintain the set speed of the motor. This operation can be achieved by obtaining the speed as a feedback and controlling the switching frequency duty cycle. Thus the motor speed is matched with the set speed

Operations cycle

1 Voltage across mosfet

There are in this figure(b) shown the voltage across mosget

When the Torque and Speed is constant-

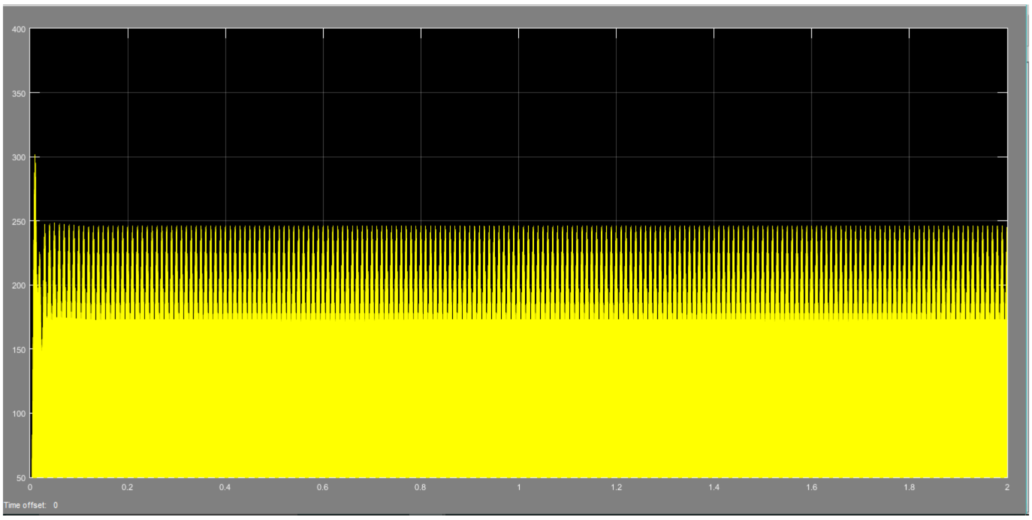


Fig (b)

There are in this figure(c) show

When the torque is variable by using step sequence. Or as well alternative speed.

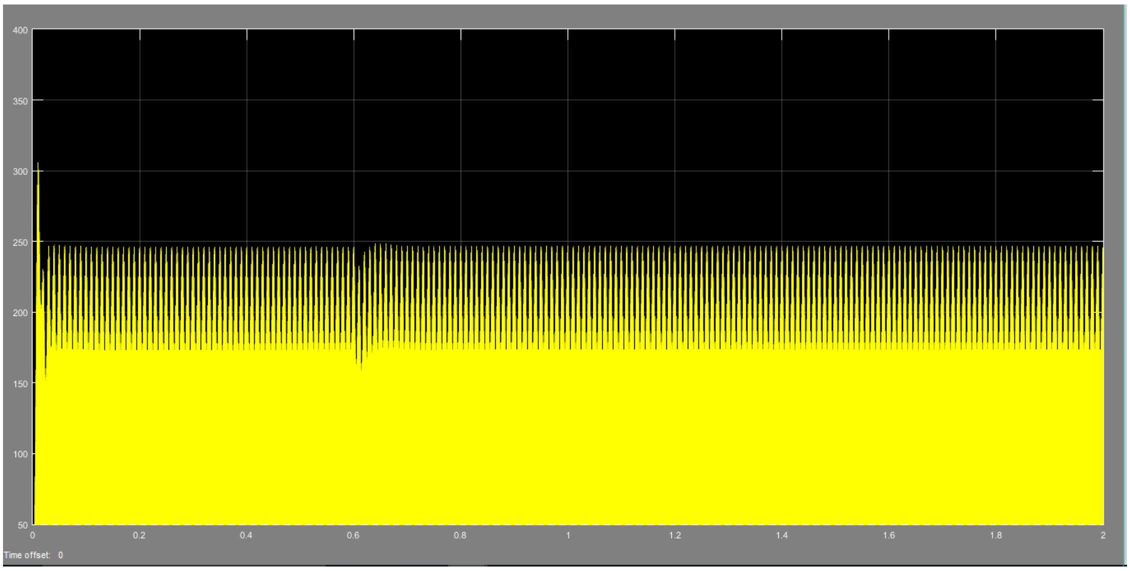


Fig (c)

2 Actual Speed & Desired Speed

There are in this figure (d)

When the Torque is Constant But Speed is Varying

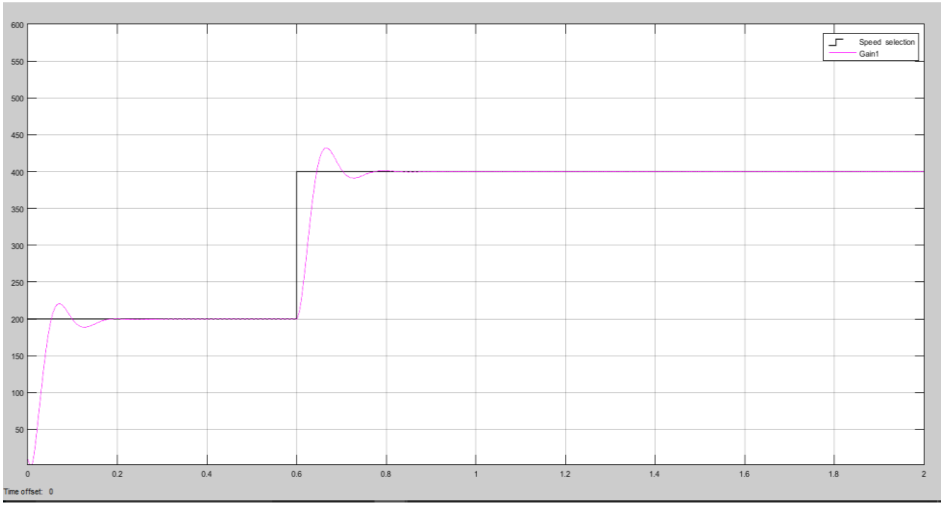


Fig (d)

There are in this figure (e)

When the Speed and Torque is varying

Torque applied 3 to 6 Nm after 1.2 Sec and speed is varying after 0.6 Sec.

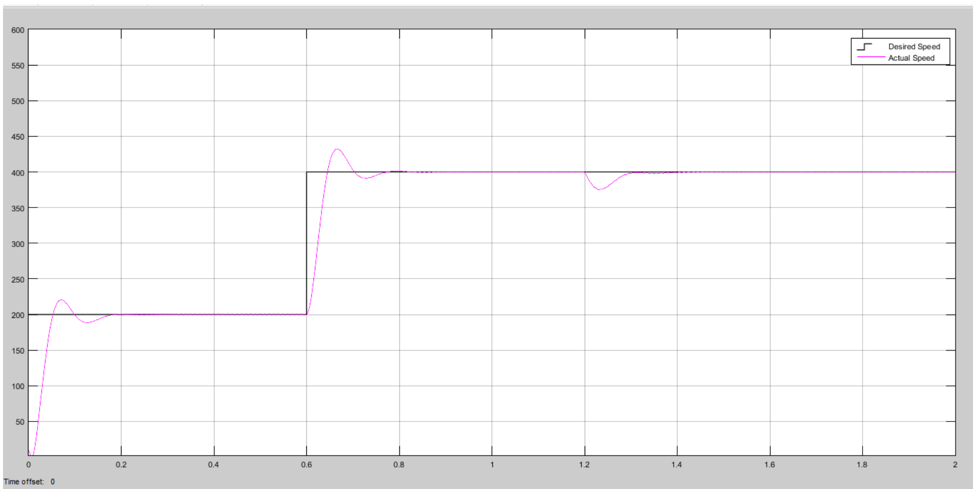


Fig (e)

3 Armature Current, Torque and Speed

There are in this figure shown

There in the dc motor speed torque and current is varying from different timeline as shown in graph-

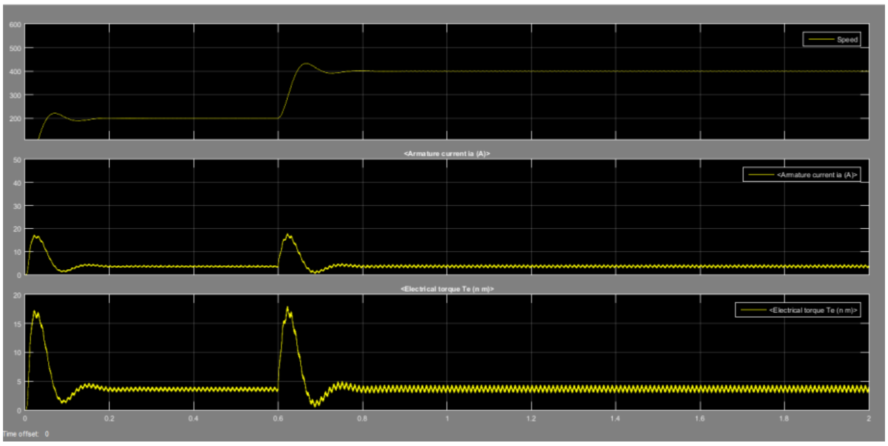


Fig (f)

There are in this figure(g) shown

Speed and current torque where the current is varying which is depend upon the motor speed and as well motor torque. Torque applied 3 to 6 Nm after 1.2 Sec and speed is varying after 0.6 Sec.

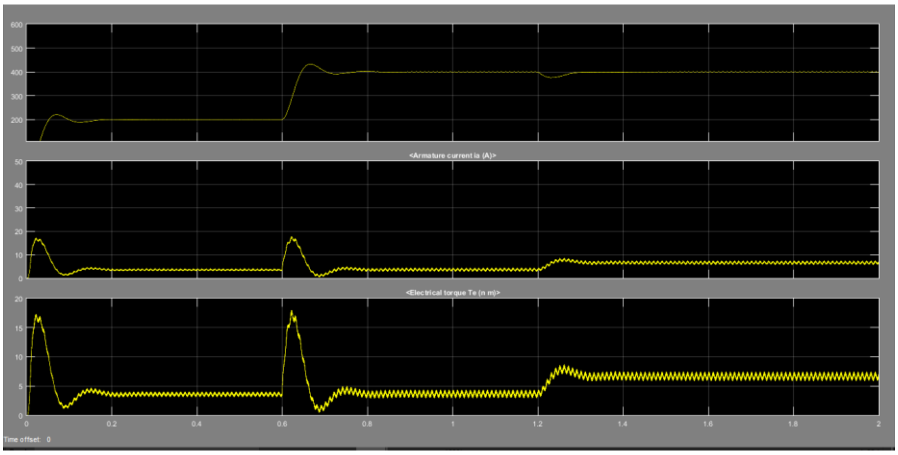


Fig (g)

Rating of the elements used in the Chopper based control DC Motor simulation:

AC voltage source

Peak amplitude voltage – 400

Frequency - 50

Dc voltage source

DC voltage – 24o

DC Motor Specification

Rating – 50 HP,

Voltage – 500 V

Speed - 1750 rpm

Field Voltage – 300 V

Torque –

Constant – 2

Torque varying time 3 to 6 after 1.2sec.

Mosfet

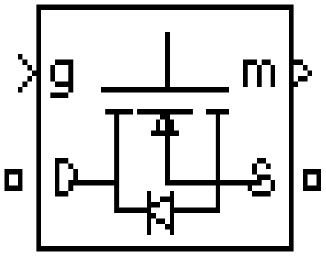
Internal resistance – 0.1

Internal diode resistance – 0.001

Electrical elements and their working Used in Model

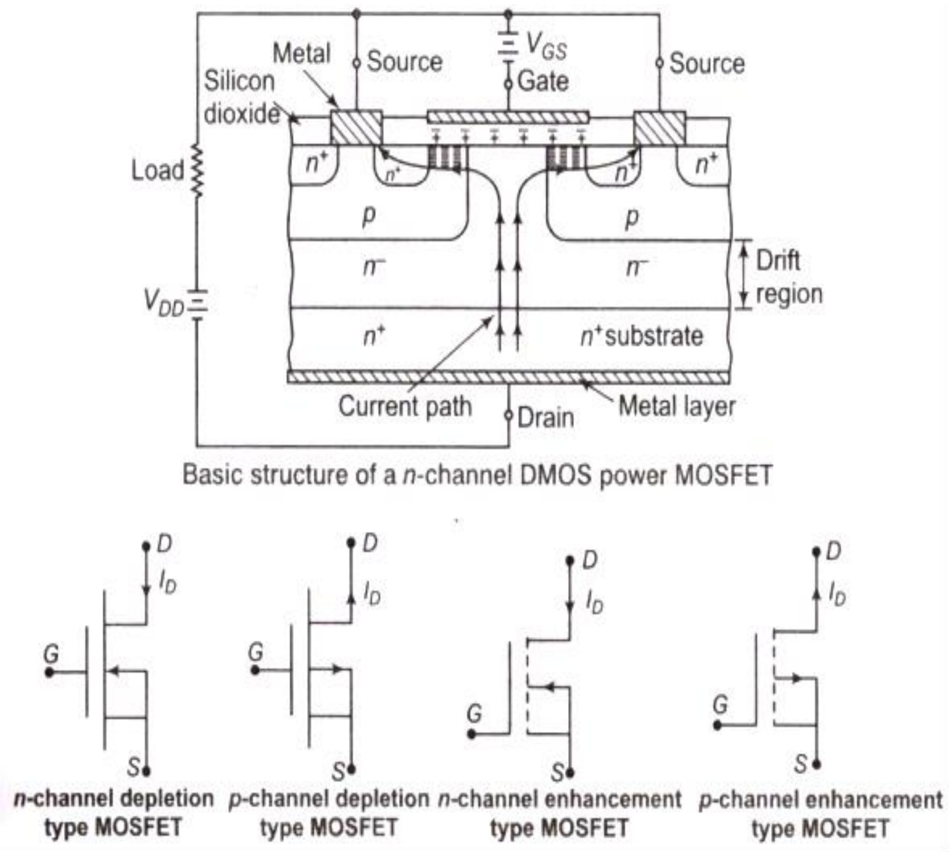
➢ Mosfet

The metal–oxide–semiconductor field-effect transistor (MOSFET, MOS-FET, or MOS FET)



is a type of field-effect transistor (FET), most commonly fabricated by the controlled oxidation of silicon. It has an insulated gate, whose voltage determines the conductivity of the device. This ability to change conductivity with the amount of applied voltage can be used for amplifying or switching electronic signals.

There is an figure shown the types of mosfet and their internal characteristics



Mosfet Characteristics

MOSFETs are tri-terminal, unipolar voltage-controlled, high input impedance devices which form an integral part of vast variety of electronic circuits. These devices can be classified into two types viz., depletion-type and enhancement-type, depending on whether they possess a channel in their default state or no, respectively. Further, each of them can be either p-channel or n-channel devices as they can have their conduction current due to holes or electrons respectively. However inspite of their structural difference, all of them are seen to work on a common basic principle which is explained in detail in the article "MOSFET and its Working".

This further implies that all of them exhibit almost similar characteristic curves, but for differing voltage values.

1 Transfer characteristics

2 Output Characteristics

3 Swithing Chatacteristics

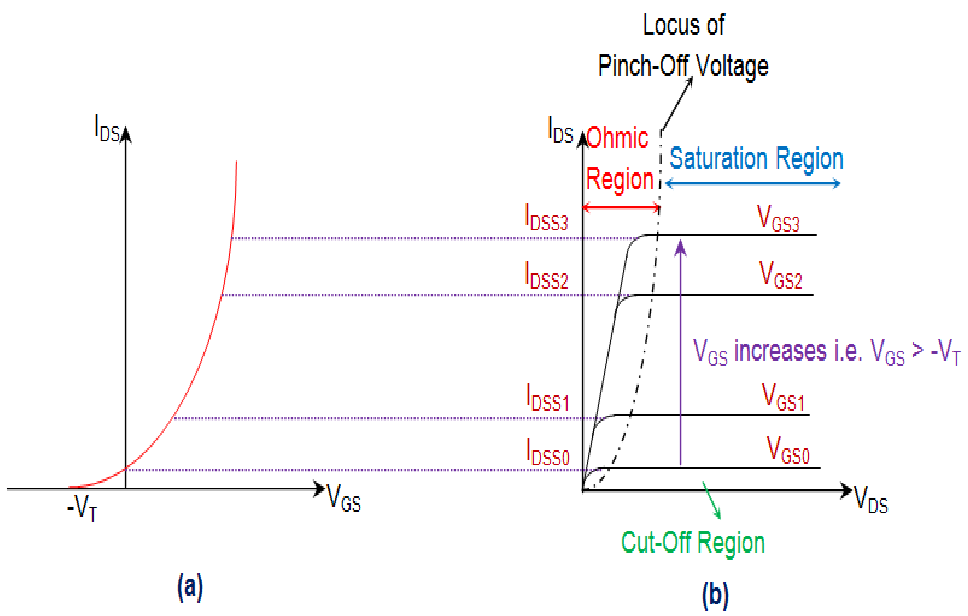
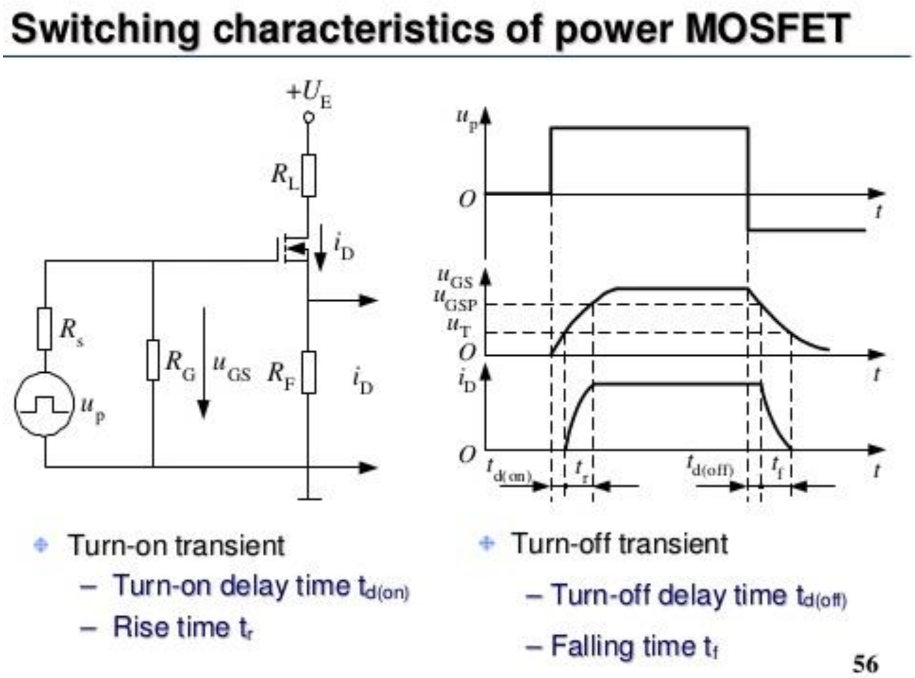


Figure 3 *n*-Channel Depletion type MOSFET (a) Transfer Characteristics (b) Output Characteristics



In general, any MOSFET is seen to exhibit three operating regions viz.,

1. **Cut-Off Region**

   Cut-off region is a region in which the MOSFET will be OFF as there will be no current flow through it. In this region, MOSFET behaves like an open switch and is thus used when they are required to function as electronic switches.

2. **Ohmic or Linear Region**

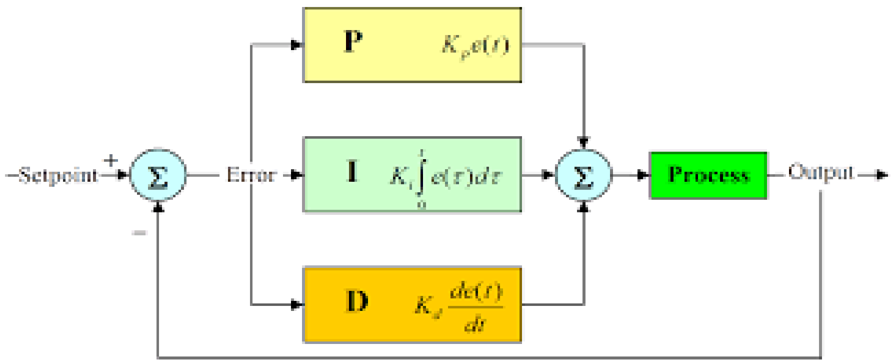
   Ohmic or linear region is a region where in the current I_{DS} increases with an increase in the value of V_{DS}. When MOSFETs are made to operate in this region, they can be used as amplifiers.

3. **Saturation Region**

   In saturation region, the MOSFETs have their I_{DS} constant inspite of an increase in V_{DS} and occurs once V_{DS} exceeds the value of pinch-off voltage V_P. Under this condition, the device will act like a closed switch through which a saturated value of I_{DS} flows. As a result, this operating region is chosen whenever MOSFETs are required to perform switching operations.

PID Controller

A **proportional–integral–derivative controller** (**PID controller** or **three term controller**) is a control loop feedback mechanism widely used in industrial control systems and a variety of other applications requiring continuously modulated control. A PID controller



continuously calculates an error value as the difference between a desired setpoint (SP) and a measured process variable (PV) and applies a correction based on proportional, integral, and derivative terms (denoted *P*, *I*, and *D* respectively) which give the controller its name.

Mathematical form

The overall control function can be expressed mathematically as:

$$u(t) = K_{\mathrm{p}} e(t) + K_{\mathrm{i}} \int_0^t e(t')\, dt' + K_{\mathrm{d}} \frac{de(t)}{dt},$$

Where

Kp , ***Ki*** and ***Kd*** all non-negative, denote the coefficients for the proportional, integral and derivative terms, respectively (sometimes denoted *P*, *I*, and *D*).

In the standard form of the equation ***Ki*** and *Kd* are respectively replaced by *Kp/Ti*, and *Kp Td*; the advantage of this being that *Ti*, and *Td* have some understandable physical meaning, as they represent the integration time and the derivative time respectively.

Selective use of control terms

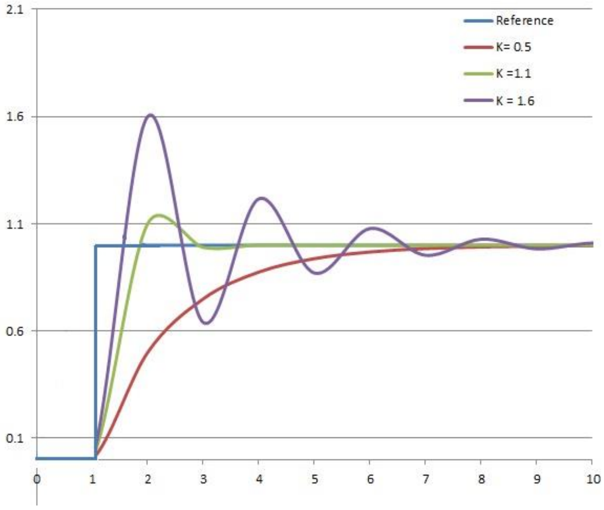
Although a PID controller has three control terms, some applications use only one or two terms to provide the appropriate control. This is achieved by setting the unused parameters to zero, and is called a PI, PD, P or I controller in the absence of the other control actions. PI controllers are fairly common, since derivative action is sensitive to measurement noise, whereas the absence of an integral term may prevent the system from reaching its target value.

1.1 Proportional Action

Proportional action provides an instantaneous response to the control error. This is useful for improving the response of a stable system but cannot control an unstable system by itself. Additionally, the gain is the same for all frequencies leaving the system with a nonzero steady-state error.

The proportional term is given by

$$P_{out} = K_p \, e(t)$$



Steady-state error

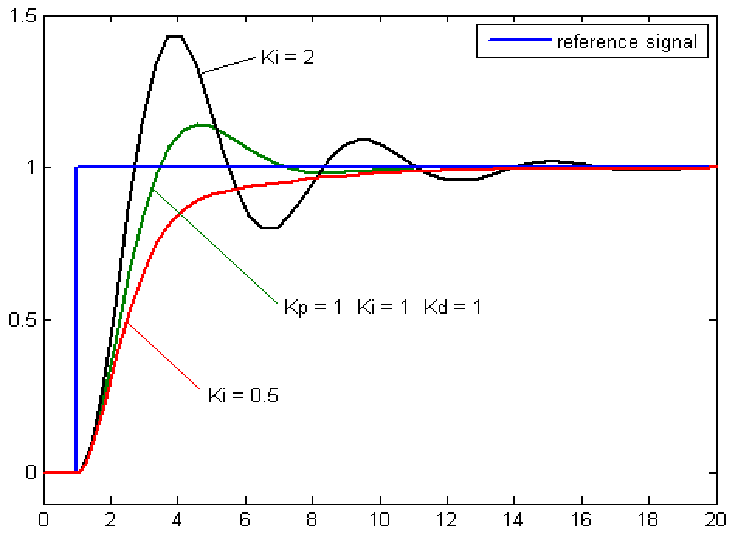
Because a non-zero error is required to drive it, a proportional controller generally operates with a so-called steady-state error.[a] Steady-state error (SSE) is proportional to the process gain and inversely proportional to proportional gain. SSE may be mitigated by adding a compensating bias term to the setpoint AND output, or corrected dynamically by adding an integral term.

1.2 Integral Action

zIntegral action drives the steady-state error towards 0 but slows the response since the error must accumulate before a significant response is output from the controler. Since an integrator introduces a system pole at the origin, an integrator can be detrimental to loop stability. Only controllers with integrators can wind-up where, through actuator saturation, the loop is unable to comply with the control command and the error builds until the situation is corrected.

The integral term is given by

$$I_{\mathrm{out}} = K_{\mathrm{i}} \int_0^t e(\tau)\, d\tau.$$

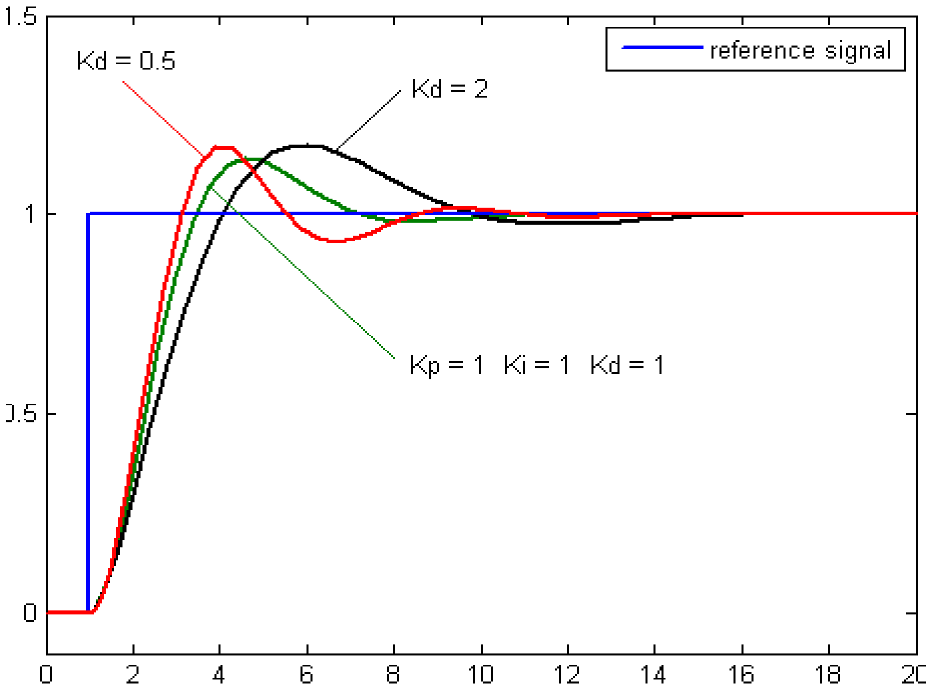


1.3 Derivative Action

The derivative of the process error is calculated by determining the slope of the error over time and multiplying this rate of change by the derivative gain K_d. The magnitude of the contribution of the derivative term to the overall control action is termed the derivative gain, K_d. Derivative action predicts system behavior and thus improves settling time and stability of the system. An ideal derivative is not so that implementations of PID controllers include an additional low-pass filtering for the derivative term to limit the high-frequency gain and noise. Derivative action is seldom used in practice though – by one estimate in only 25% of deployed controllers because of its variable impact on system stability in real-world applications

The derivative term is given by

$$D_{\text{out}} = K_{\text{d}} \frac{de(t)}{dt}.$$



PI controller

A **PI Controller** (proportional-integral controller) is a special case of the PID controller in which the derivative (D) of the error is not used.

The controller output is given by

$$K_P \Delta + K_I \int \Delta \, dt$$

where del is the error or deviation of actual measured value (***PV***) from the setpoint (***SP***)

$$\Delta = SP - PV.$$

A PI controller can be modelled easily in software such as Simulink or Xcos using a "flow chart" box involving Laplace operators:

$$C = \frac{G(1 + \tau s)}{\tau s}$$

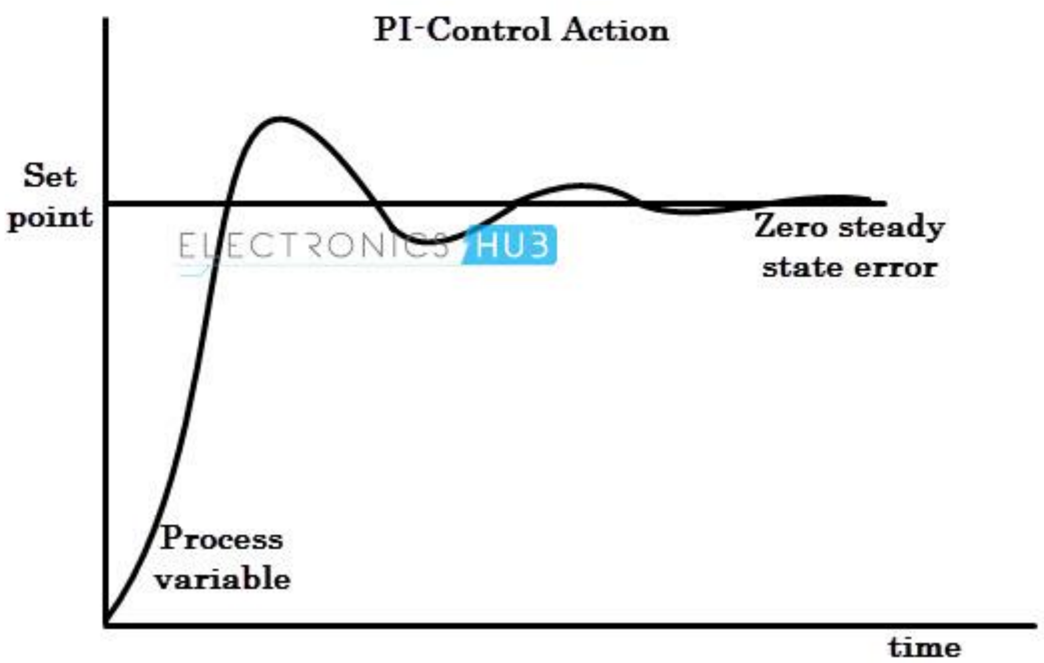
Where

$G = K_P$ = proportional gain
$G/\tau = K_I$ = integral gain

Setting a value for **G** is often a tradeoff between decreasing overshoot and increasing settling time

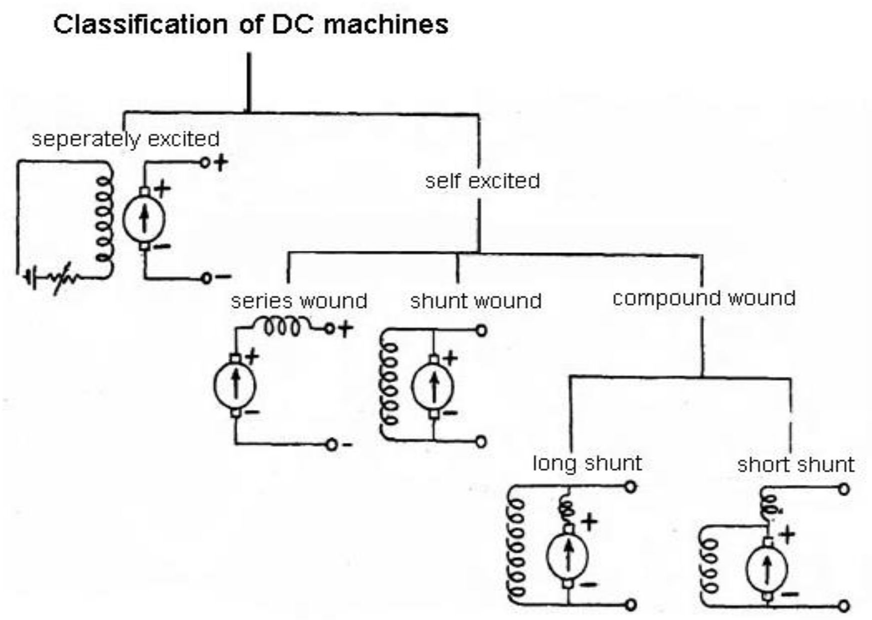
The lack of derivative action may make the system more steady in the steady state in the case of noisy data. This is because derivative action is more sensitive to higher-frequency terms in the inputs.

Without derivative action, a PI-controlled system is less responsive to real (non-noise) and relatively fast alterations in state and so the system will be slower to reach setpoint and slower to respond to perturbations than a well-tuned PID system may be



Separately Excited DC Motor

In this section we will discuss about the separately excited dc motor. Like other DC motors, these motors also have both stator and rotor. Stator refers to the static part of motor, which consists of the field windings. And the rotor is the moving armature which contains armature windings or coils. Separately excited dc motor has field coils similar to that of shunt wound dc motor. The name suggests the construction of this type of motor. Usually, in other DC motors, the field coil and the armature coil both are energized from a single source. The field of them does not need any separate excitation. But, in separately excited DC motor, separate supply Provided for excitation of both field coil and armature coil. Figure below shows the separately excited dc motor.



Here, the field coil is energized from a separate DC voltage source and the armature coil is also energized from another source. Armature voltage source may be variable but, independent constant DC voltage is used for energizing the field coil. So, those.coils are electrically isolated from each other, and this connection is the specialty of this type of DC motor

Equations Of Voltage, current and power for DC motors

In a separately excited motor, armature and field windings are excited form two different dc supply voltages. In this motor,

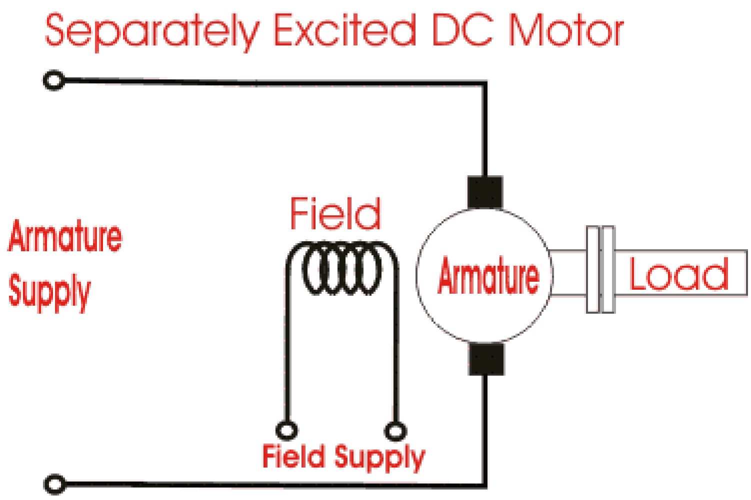
• Armature current Ia = Line current = IL = I

• Back emfdeveloped ,Eb = V – I Ra

where V is the supply voltage and Ra is the armature resistance.

• Power drawn from main supply , P = VI

• Mechanical power developed Pm = Power input to armature – power loss in armature

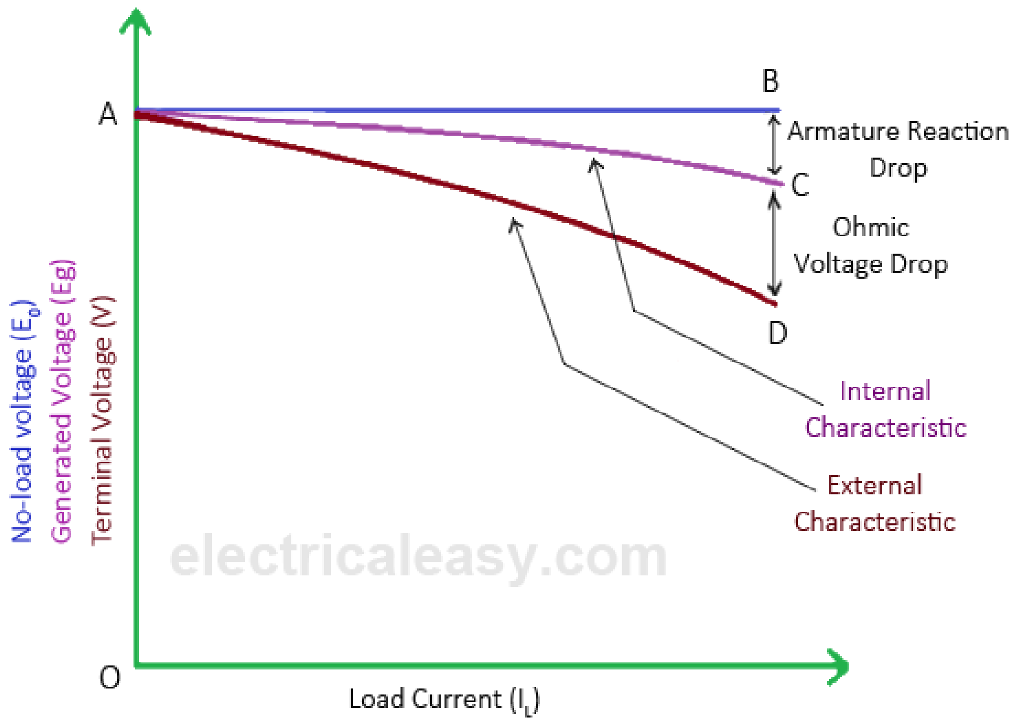


Operating characteristics of Separately excited dc motor

Both in shunt wound dc motor and separately excited dc motor field is supplied from constant voltage so that the field current is constant. Therefore these two motors have similar speed -armature current and torque – armature current characteristics. In this type of motor flux is assumed to be constant.

• **Speed – armature current (N – Ia) characteristics:** We know that speed of dc motor is proportional to back emf / flux i.eEb / φ . When load is increased back emfEb and φ flux decrease due to armature resistance drop and armature reaction respectively .However back emf decreases more than φ so that the speed of the motor slightly decreases with load.

• **Torque – armature current (τ – Ia) characteristics :** Here torque is proportional to the flux and armature current . Neglecting armature reaction, flux φ is constant and torque is proportional to the armature current Ia . τ – Ia characteristics is a straight lien passing through the origin. From the curve we can see that huge current is needed to start heavy loads. So this type of motor do not starts on heavy loads.



Characteristics of separately excited DC generator

Conclusion

The speed of a dc motor has been successfully controlled by using Chopper as a converter And Proportional-Integral type Speed based on the closed loop model of DC motor. Initially a simplified closed loop model for speed control of DC motor is considered and requirement of current controller is studied. Then a generalized modelling of dc motor is done. After that a complete layout of DC drive system is obtained. Then designing of speed controller is done. Now the simulation is done in MATLAB under varying load condition, varying reference speed condition and varying input Torque. The results are also studied and analyzed under above mentioned conditions. The model shows good results under all conditions employed during simulation.

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