كلية الهندسة	الكلية
الكهرباء	القسم
Electrical Drives	المادة باللغة الانجليزية
المسوقات	المادة باللغة العربية
الرابعة	المرحلة الدراسية
م.م. زياد طارق محمد	اسم التدريسي
Separately excited DC Motor	عنوان المحاضرة باللغة الانجليزية
محرك التيار المستمر ذو تغذية منفصلة	عنوان المحاضرة باللغة العربية
2	رقم المحاضرة
1) Mohummed Rashid" Power electronics circuits, Devices application" 4th edition, 2014 and 2)Gopal K.Dubey "power semiconductor controlled Drives" 1st edition, 1989	المصادر والمراجع

1. separately excited Dc Motor
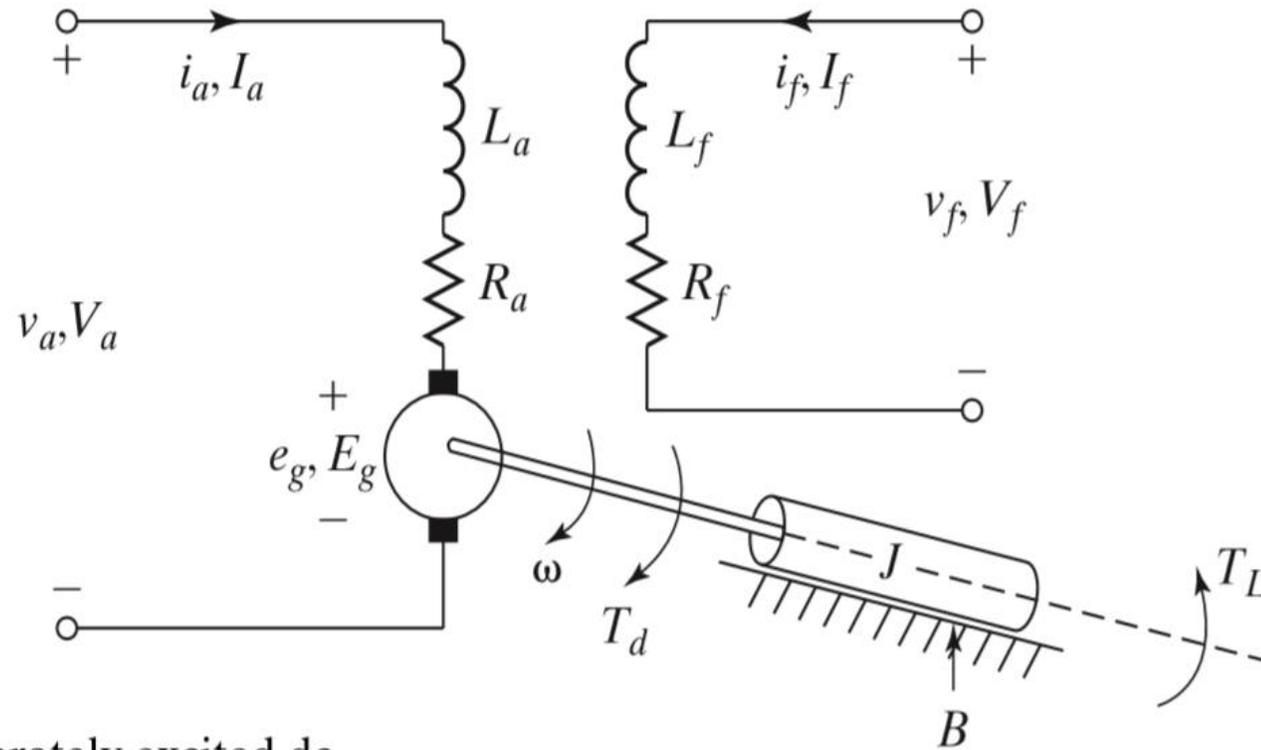
Equivalent circuit of separately excited dc motors.

The instantaneous field current if is described as

$$V_f = R_f i_f + L_f di_f / dt$$

The instantaneous armature current can be found from

$$V_a = R_a i_a + L_a d_{ia} /dt + e_g$$

The motor back emf, which is also known as speed voltage, is expressed as $e_g = K_v \omega i_f$

The torque developed by the motor is

$$T_d = K_t i_f i_a$$

The developed torque must be equal to the load torque:

$$T_d = Jd\omega/ dt + B\omega + T_L$$

where ω = motor angular speed, or rotor angular frequency, rad/s; B = viscous friction constant, N.m/rad/s; K_v = voltage constant, V/A-rad/s; Kt = torque constant, which equals voltage constant, K_v; L_a = armature circuit inductance, H; L_f = field circuit inductance, H; R_a = armature circuit resistance, Ω; R_f = field circuit resistance, Ω; TL = load torque, N.m.

Under steady-state conditions, the time derivatives in these equations are zero and the steady-state average quantities are

$$V_f = R_f I_f$$

$$E_g = Kv\, \omega I_f$$

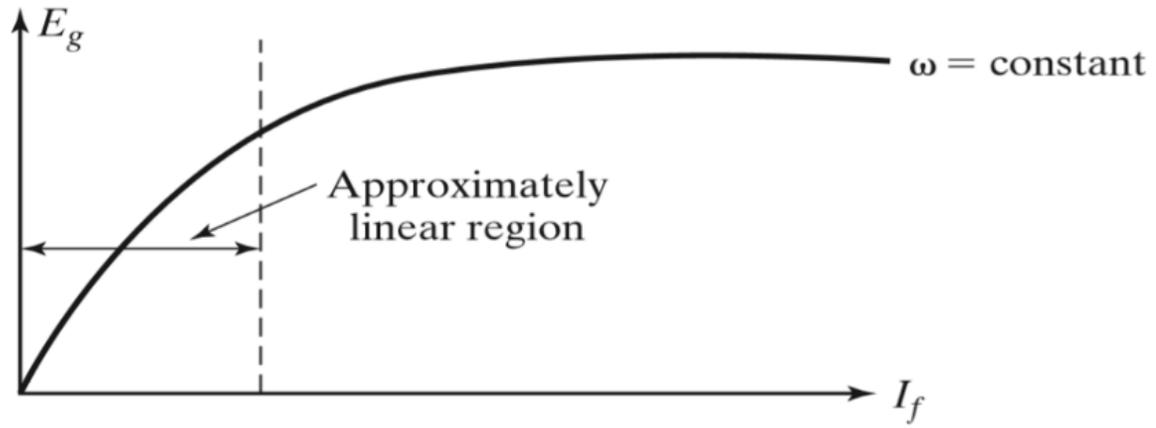$$V_a = R_a I_a + E_g = R_a I_a + Kv\, \omega I_f$$

$$Td = K_t I_f I_a = B\omega + T_L$$

The developed power is

$$P_d = T_d\, \omega$$

$$\omega = \frac{V_a - R_a I_a}{K_v I_f} = \frac{V_a - R_a I_a}{K_v V_f / R_f}$$

The relationship between the field current If and the back emf E_g is nonlinear due to magnetic saturation.

Magnetization characteristic.

CHARACTERISTICS	AC DRIVES	DC DRIVES
Supply	Run by AC supply	Run by DC supply
Maintenance	Requires less maintenance.	Requires comparatively more and frequent maintenance.
Use/ Application	Are generally used for AC motors.	Are used for DC motors normally.
Locational use	Are used in almost all the locations.	are used in very few locations
Breaking Mechanism	Breaking and accelerating when supply frequency (F s) changes	Breaking occurs when resistance is applied at rotor.
Power & Control Circuitry	Power and control circuits are difficult and quite complex in design.	Power and control circuits are simple to design and less expensive as compared to their counter-parts.
Size in terms of Power Rating	Power to Weight ratio is very large.	Power to Weight ratio is considerably small.
Components	Have converter and inverter.	Have converter and chopping circuit.
Commutation	There is no commutation which makes AC Drives less bulky and inexpensive.	Because of commutation, they are more heavy and costly.

CHARACTERISTICS	AC DRIVES	DC DRIVES
Rectifier	There is no need of rectifier circuit	Rectifying circuit is necessary
Speed Control	Sped control is achieved by changing the frequency	Speed control is achieved by armature and field control
Corrosive and Wet Environment	Can be used in such environment since their operation is spark free	Cannot be used because sparks can be produced in brushes easily.
Cost	In AC Drives, motors are less expensive especially squirrel cage motors.	In DC Drives, motors are significantly expensive.
Speed limit	There is no upper limit for speed.	Speed is limited because of commutation process.
Harmonics	Converters produce harmonics in supply as well as in load	Converters do not produce harmonics
Motor speed	Can reach up to 10000 RPM	Can reach up to 2500 RPM
Speed regulation	~1% speed regulation is attainable	Not possible to achieve 1 % speed regulation
Dynamic response	Offer high dynamic response	Offer low dynamic response

CHARACTERISTICS	AC DRIVES	DC DRIVES
Battery use	Cannot be run directly by batteries without using extra circuitry	Can be run directly through batteries without adding an extra components
Noise	Operation is noisy which is highly unfavorable in certain applications	They are not noisy as compared to AC Drives
Power consumption	Consume less power	Consume more power
Circuit complexity	More complex as it involves inverter (DC → AC) and converter (AC → DC)	Less complex because of single power conversion process from AC to DC
Brushes life	Very high (~10000h)	Low (~3000h)

Conclusion

Although the DC drives are quite well-known for offering high starting torque, bearing simplified circuitry and are effective with constant speed applications, they are believed to have a lot of problems because of commutation process and brushes in the DC Motors which require periodic and extensive maintenance. On the other side, AC drives are quite energy efficient and can manage abrupt speed changes very well. They frequently have numerous programmable parameters for protections.

METHODS OF SPEED CONTROL

The speed-torque relation of de motors, equation (1), shows that the speed can be controlled by any of the following three methods:

1. Armature voltage control.
2. Field flux control.
3. Armature resistance control.

$$\omega = \frac{V_a - R_a I_a}{K_v I_f} = \frac{V_a - R_a I_a}{K_v V_f / R_f} \qquad (1)$$

1-Armature Voltage Control

If the armature voltage of a separate or series excited dc motor running at a steady state speed is reduced (by a small amount), then, the armature current, and, therefore, the motor torque will decrease. As the motor torque will be less than the load torque, the motor will decelerate, causing speed and back emf to decrease. It, will finally settle at a lower speed at which its torque equals the load torque. If the armature voltage of a separately excited motor is reduced by a large amount, it may become less than the back emf. The armature current will then reverse and the motor will work as a generator producing negative torque. This operation will continue until the motor speed has fallen to a value at which the motor back emf becomes equal to the applied voltage. After that, deceleration will occur in the manner just explained. In the case of a series motor, even when the armature voltage is changed by a larger step, it does not work as a generator, and the deceleration occurs because the motor torque is lower than the load torque.

The variable dc voltage can be obtained by using either of the
following semiconductor converters:
 a . Controlled rectifier (or ac to dc converter).
 b. Chopper (dc to dc converter).

2 -Field Control

If the field of a separately or series excited motor running at a speed is weakened, its induced emf decreases. The current increases by an amount much larger than the decrease in the field flux. As a result, in spite of the weakened field, the torque is increased by a large amount, considerably exceeding the load torque. The extra torque thus available causes the motor to accelerate and the back ermf to rise. The motor will finally settle down to a new speed, higher than the previous one, at which the motor torque with the weakened field becomes equal to the load torque. Any attempt to weaken the field by a large amount will cause a dangerous inrush of current. Care should therefore be taken to weaken the field only slowly and gradually.

On the other hand, when the field of a separately excited motor is increased, the induced emf increases and often exceeds the supply voltage; thus, not only the armature current reduces but it often reverses. When this happens, the motor works as a generator and feeds energy to the supply

3-Combined Armature Voltage and Field Flux Control

In drives requiring a wide range of speed control, armature voltage control is combined with field control. Armature voltage control has the advantage of retaining the maximum torque capability of the motor at all speeds. It is therefore employed wherever it can be, and field control is used only for getting speeds which cannot be obtained by armature control. In such drives, base speed is defined as the normal (rated) armature voltage full field speed. This is the speed at which the motor runs on the natural speed-torque characteristic.
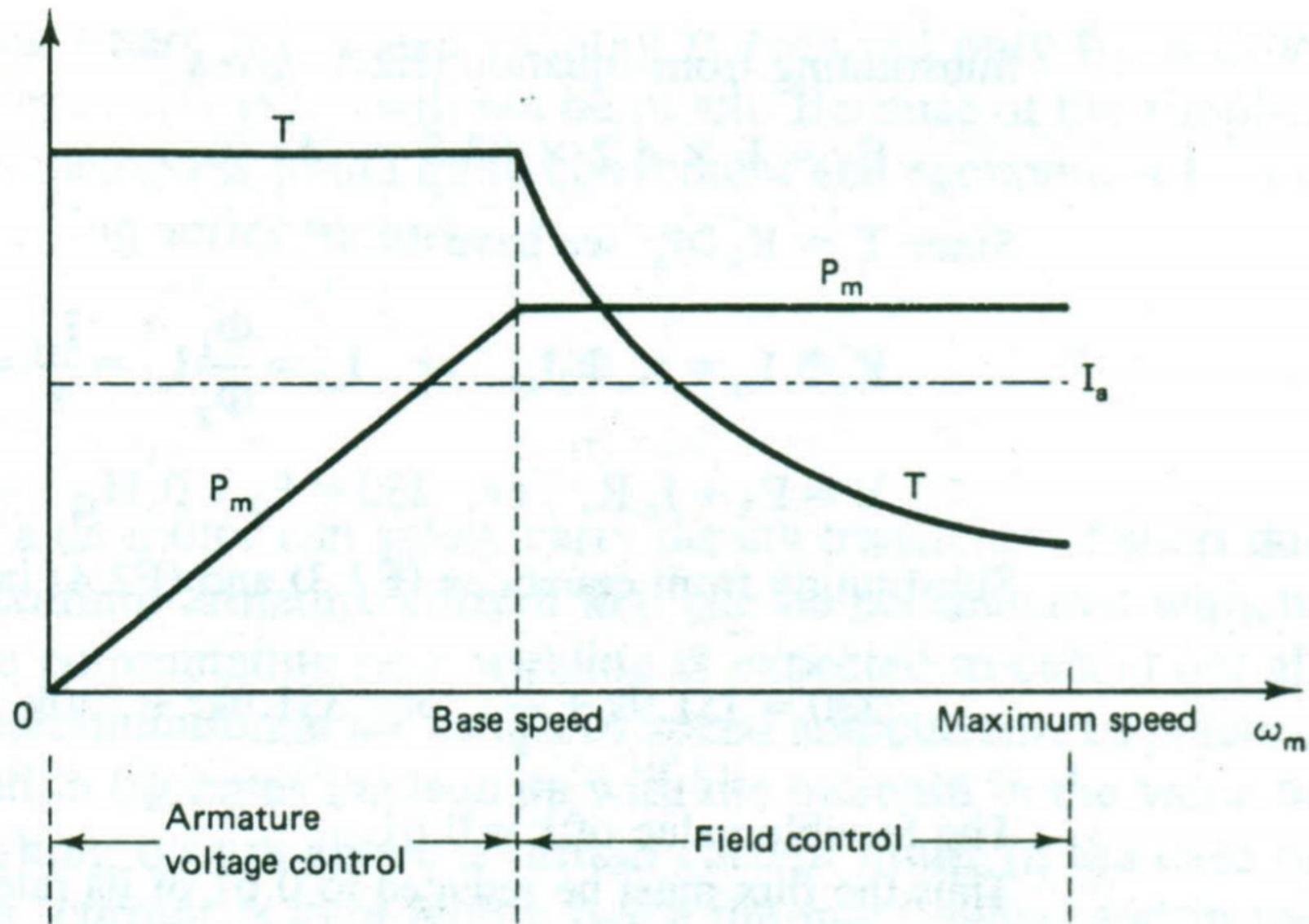
Torque and power limitations in combined armature voltage and field control.

Example.1. A 230 Y, 500 rpm, 100 A separately excited dc motor has an armature resistance of 0.1 Ω. The motor is driving, under rated conditions, a load whose torque is constant and independent of speed. The speeds below the rated speed are obtained with armature voltage control (with full field) and the speeds above the rated speed are obtained by field control (with rated armature voltage).

1. Calculate the motor terminal voltage when the speed is 400 rpm.
2. By what amount should flux be reduced to get a motor speed of 800 rpm?

Neglect the motor's rotational losses.

Solution Back emf at 500 rpm. $E_g = V - R_a I_a = 230 - 10 = 220$ V

Rated speed = $\omega_m = (500/60) \times 2\pi = 52.4$ rad/sec.

Let the flux at rated conditions = ϕ_1

$E_g = K_v I_f \omega = K_e \phi \omega$ where $K_v I_f = K_e \phi$ ➡ $K_e \phi = 220/52.4 = 4.2$

1. Back emf at 400 rpm, $220 \times 400/500 = 176$V Since the load torque is constant, Ia = 100 A
Now the motor terminal voltage $V = 176 + 100 \times 0.1 = 186$V

2. Let the new flux the new flux ϕ_2 which = $k \times \phi_1$ (reducing the flux k<1)

E_g at 800 r.p.m = $K_e \phi_2 \omega = k \times 4.2 \times (800 \times 2\pi /60) = 351.9$ K Volt.

Since $T = K_v I_f I_a = K_e \phi I_a$, constant rated torque. $= K_e \phi_1 I_{a1} = K_e \phi_2 I_{a2}$ ➡ $I_{a2} = \dfrac{\Phi_1}{\Phi_2} I_{a1} = \dfrac{I_{a1}}{k} = \dfrac{100}{k}$

$V = E_g + I_a R_a$ or $230 = 351.9$ K $+ 0.1 I_a$ Where $I_{a2} = \dfrac{\Phi_1}{\Phi_2} I_{a1} = \dfrac{I_{a1}}{k} = \dfrac{100}{k}$

$230 = 351.9k + 10/K$ or $351.9k^2 - 230k + 10 = 0$ or k = 0.61 or 0.05

The feasib1e value of k = 0.61. Thus the flux must be reduced to 0.61 of its rated value.

4- Armature Resistance Control

Speed torque characteristics of separately excited (or shunt) and series motors for various values of external resistance Re in series with the armature are shown in figures below, respectively. The main drawback of this method of speed control is its poor efficiency. The losses in Re .

(a) Separately excited   (b) Series
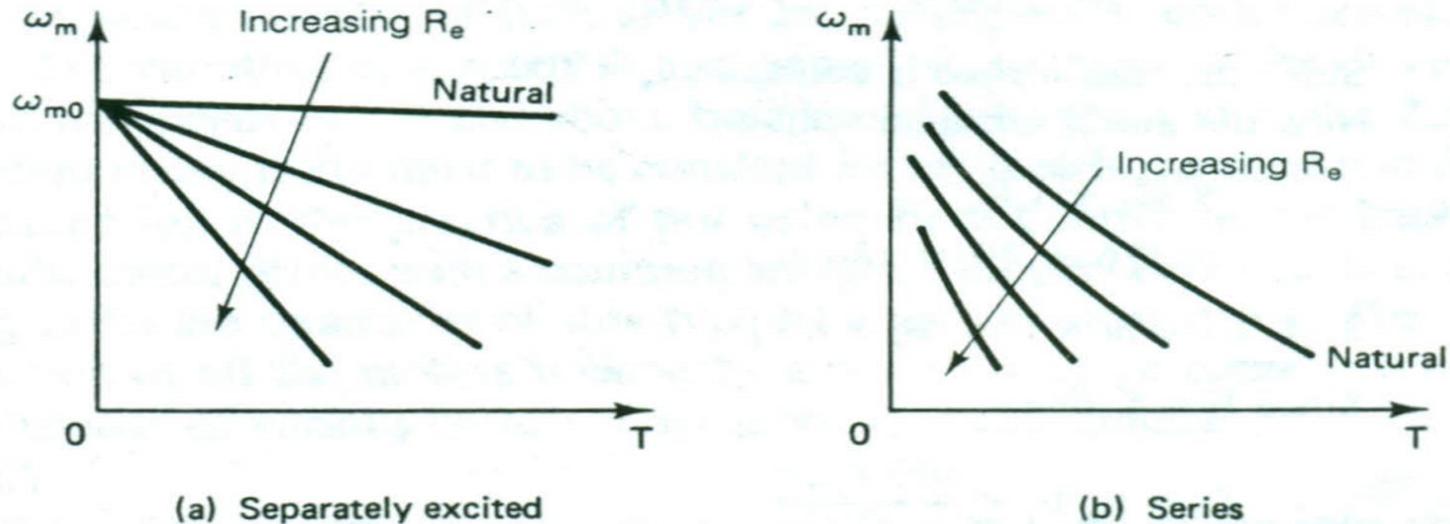
Speed-torque curves of dc motors with resistance control.

this method is seldom used with separately excited motors, except for getting speeds which are required for very short times. Because of the simplicity and low initial cost, this method is found quite convenient and economical for intermittent duty drives employing series motors.

STARTING

The maximum current that a dc motor can safely carry during transients of short duration is limited by the maximum armature current that can be commutated without sparking

In the case of an uncompensated machine, current is kept within twice the rated value; and in the case of specially designed and compensated machines, it is allowed up to 3.5 times the rated value.

If started with full voltage across its terminals, a medium size motor will have to carry current of the order of 20 times the rated current. Such a high current will damage the motor due to heavy sparking at the commutator and heating of the winding. Therefore, it becomes necessary to limit the current to a safe value during starting. This is achieved by reducing the voltage across the motor terminals and progressively increasing it as the motor speed increases. The motor voltage is reduced either by decreasing the source voltage or by dropping a part of the source voltage across a series connected resistance.

In applications requiring adjustable speed, a controller is provided for the control of speed. The same controller can also be employed for limiting the current during starting. In applications not requiring frequent starting, the most widely used method is to insert an extra resistance in the armature circuit and to cut it gradually such that the motor current does not exceed a safe value .

Electric Braking

In electric braking, the motor is made to work as a generator producing a negative torque. The electric braking may be required due to the following reasons

1. If a motor running at some speed is disconnected from the supply, the only opposing torque will be'the load torque T_L. The motor will stop only after the kinetic energy stored in its inertia is dissipated. When either the load torque is small or the inertia is large, the motor takes a long time to stop. In applications requiring frequent stops, the stopping time must be reduced by introducing additional opposing torque by the use of electric braking.

2. In some applications, such as traction, rapid emergency stops are essential to prevent accidents. The electric braking helps in achieving quick and smooth stops.

3. There are applications where accurate stops are required, such as in lifts, machine tools, ingot buggy control, and the screwdown mechanism in rolling mills. Electric braking allows accurate steps without subjecting mechanical parts to unduly large stress.

4. In certain applications involving active loads, the drive speed will reach dangerous values if the braking force is not provided by the motor. For example, in a hoist application when a loaded hoist is being lowered, the motor should provide a braking force to hold the speed within safe limits. Similarly in traction, when a train goes down a steep gradient, a braking force is required to hold the train speed within safe limits.

The braking operation is classified in accordance with the manner in which the generated electrical energy is disposed of. There are three methods of braking a dc motor:

1. Regenerative braking.
2. Dynamic braking or rheostatic braking.
3. Plugging or reverse voltage braking.

Regenerative Braking In regenerative braking, the energy generated is supplied to the source. Usually the source will not have the ability to store the energy. The energy supplied is diverted to other loads connected to the source, where it is usefully employed and the source is relieved from supplying this much energy. If the source does not have the ability to store energy nor are there other loads connected to the source, regenerative braking cannot be employed.

Dynamic Braking The dynamic braking of a dc motor is effected by disconnecting it from the source and closing the armature circuit through a suitable resistance .The motor now works as a generator, producing the braking torque.

Plugging If the armature terminals (or supply polarity) of a separately excited (or shunt) motor when running are reversed, the supply voltage and the induced voltage will act in the same direction and the motor current will reverse, producing braking torque. This type of braking is called plugging. In the case of a series motor, either the armature terminals or field terminal s should be reversed. Reversing of both gives only the normal motoring operation.