Unit-IV

1. Explain the construction and features and principle of operation of single phase induction motor.
2. Explain the principle of operation of capacitor start induction motor.
3. Explain briefly about capacitor start and capacitor run 1 phase induction motor.
4. What is the principle operation of DC generator? Derive the e.m.f equation of a D.C generator.
5. Describe the construction of a D.C generator and write the functions of each part with neat sketch.
6. Classify the generators based on excitation. Draw the figure and write the current, voltage equation for each configuration.
7. Draw the internal and external characteristics of different types of DC generators and explain them.
8. Classify and Draw different types of DC motors .Give the power, voltage and current equations for different types of D.C motors. State their application
9. What is the principle operation of DC motor? Explain the significance of back E.M.F. Derive torque equation of DC motor. Mention the losses in DC machine.
10. Explain briefly about capacitor start and capacitor run 1 phase induction motor.

UNIT V

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1)

1. Introduction:

A **single-phase induction motor** is a type of AC motor which operates on a single-phase power supply. These are widely used in household appliances such as fans, washing machines, and pumps.

2. Construction of Single-Phase Induction Motor:

It consists of two main parts:

a) Stator:

- It is the stationary part of the motor.
- It has a laminated iron core with slots for winding.
- A **single-phase winding** is placed in the slots and connected to an AC supply.
- For starting purpose, it often includes **an auxiliary winding** placed 90° electrically apart from the main winding.

b) Rotor:

- Usually a **squirrel cage type** rotor is used.
- It consists of laminated iron core with copper or aluminum bars shorted at both ends by end rings.
- No electrical connection is made to the rotor (induced current due to transformer action).

3. Features of Single-Phase Induction Motor:

- Simple and rugged construction.
- Operates on single-phase AC supply.
- Requires **auxiliary starting methods** as it is **not self-starting**.
- Low cost and maintenance.
- Widely used in domestic and small industrial applications.
- Generally available in fractional kilowatt ratings (less than 1 HP).

4. Principle of Operation:

- When single-phase AC is supplied to the stator, it produces an **alternating (pulsating) magnetic field**.
- This field does **not produce a rotating magnetic field**, so the motor **does not start on its own**.
- Once the rotor is given a push, the alternating field can be seen as the sum of two rotating fields moving in opposite directions (**Double Revolving Field Theory**).
- These two fields induce currents in the rotor, which interact with the magnetic field to produce torque.
- Once the rotor starts rotating, one of the fields becomes dominant, and the motor continues to run in that direction.

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continues to run in that direction.

5. Starting Methods (brief mention):

Since it is not self-starting, several starting methods are used:

- **Split Phase Motor**
- **Capacitor Start Motor**
- **Shaded Pole Motor**
- **Capacitor Start Capacitor Run Motor**

6. Applications:

- Ceiling fans
- Refrigerators
- Washing machines
- Blowers and exhaust fans
- Water pumps

7. Diagram:

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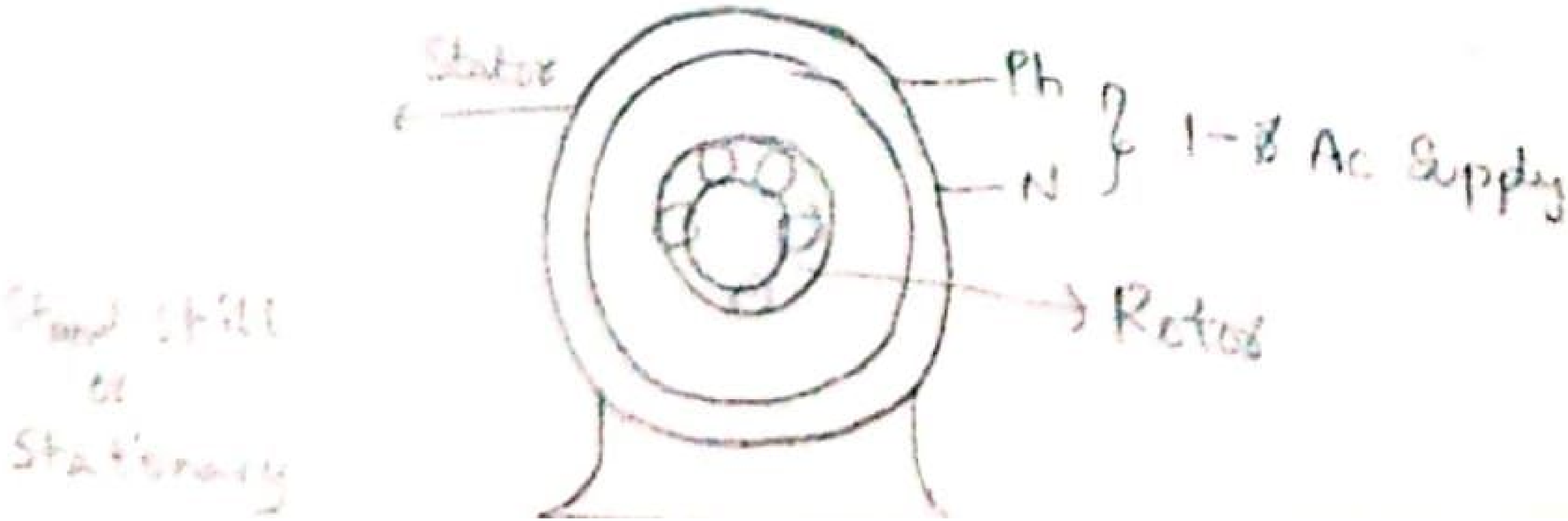
2) SINGLE PHASE INDUCTION MOTOR

Construction & working principle of 1-ø IM



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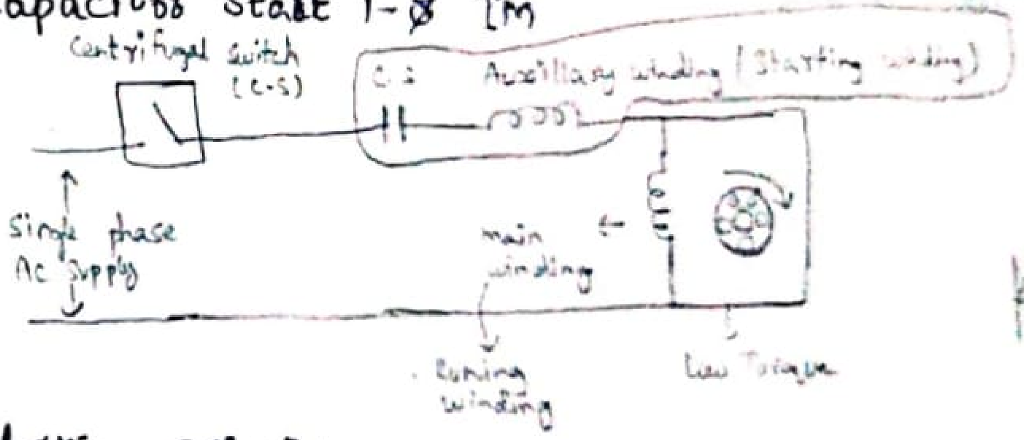
opposite (to that of main flux) will

Types of Single phase IM

Capacitor Start 1-ø IM



Working principles

The capacitor start IM consists of two windings
1. Auxillary winding 2. Main winding
The auxillary winding and main winding are displaced ~~that~~ at 90° whenever a single phase AC supply is given to the stator of single phase IM through air gap the stator flux will link with the rotor conductors according to faraday's law of electromagnetic IM and emf will produce or induced inside the rotor conductors the capacitor is connected in series with the auxillary winding when the motor starts to rotate and ~~attains~~ attains 80% of rated speed disconnect the capacitor and auxillary winding with the help of centrifugal switch.

Applications of 1-ϕ IM

→ House Hold Appliances

1. Fans 2. Refrigerators 3. Washing machines 4. Grinders

→ Industrial

1. Pumps 2. Blowers 3. Drilling machines

→ Other ~~applications~~ appliances

1. Toys 2. Shaving machine

Capacitor Run IM (or) Capacitor Start & Capa...

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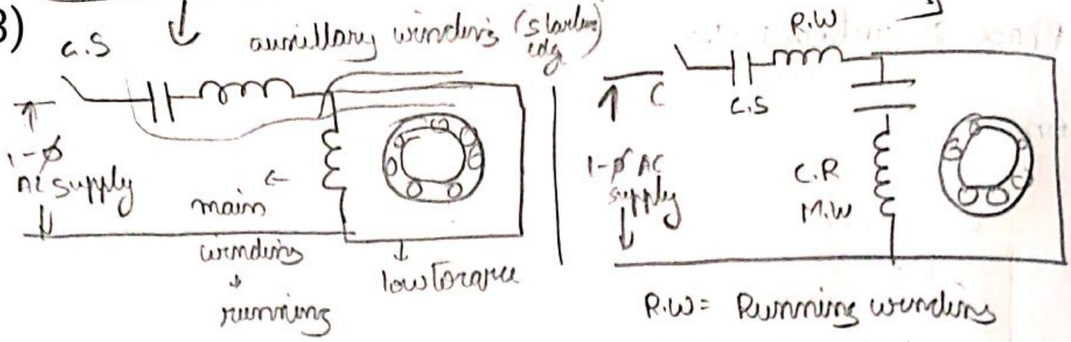
b) capacitor start & Capacitor Run Induction Motor

3)



R.W = Running winding

MW = Main winding

C.S = starting capacitor

CR = Running capacitor

Construction

Similar to split phase but has a capacitor in series with auxillary winding to improve phase difference

Two types

a) Capacitor Start : Capacitor is used only during starting

b) Capacitor Run : Two capacitor, one for starting and one for running

Working

- The capacitor improves the phase diff b/w the main & auxillary winding, creating a stronger RMF
- After starting in the capacitor start motor, the capacitor is disconnected by a switch. In the capacitor run motor, it remains connected for smooth operation

Applications

- Air conditioner
- pumps
- compressors
- refrigerators

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Q4. What is the principle of operation of a DC generator? Derive the e.m.f equation of a D.C generator.

---

1. Principle of Operation:

A **DC generator** works on the principle of **Faraday's Law of Electromagnetic Induction**, which states:

> **"When a conductor cuts magnetic lines of flux, an electromotive force (e.m.f) is induced in it."**

In a DC generator, conductors (armature winding) rotate inside a magnetic field. The induced e.m.f is collected using **commutator and brushes**, giving **unidirectional output**.

---

2. Construction (Brief):

- **Field system:** Produces the magnetic field.
- **Armature core & winding:** Rotates and cuts the magnetic field.
- **Commutator:** Converts AC induced in armature into DC.
- **Brushes:** Collect current from commutator.

---

3. E.M.F Equation Derivation:

Let:

- P = Number of poles
- ϕ = Flux per pole (in Weber)
- Z = Total number of armature conductors
- N = Speed of armature (rpm)
- A = Number of parallel paths (A = 2 for wave winding, A = P for lap winding)

Total flux cut per revolution by all conductors = $\phi \times P$

Time for one revolution = $60/N$ seconds

Average e.m.f. (E) induced =

$$E = \frac{\text{Total flux cut per second}}{\text{Time}} = \frac{P\phi ZN}{60A}$$

✅ Final e.m.f Equation:

$$\boxed{E = \frac{P\phi ZN}{60A}}$$

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EMF equation of a DC generator

let,

P = No of poles

ϕ = Flux per pole in weber

Z = Total no of conductors

E_g = generated Voltage (V)

N = Speed in rpm

A = Number of parallel paths

let

$e = N\frac{d\phi}{dt}$ (at N=1)

$e = \frac{d\phi}{dt}$, Consider $d\phi = \phi \times P$

$dt = \frac{60}{N}$ - Score → SI revolutions

emf per conductor $e = \frac{\phi P}{\frac{60}{N}} = \frac{\phi NP}{60}$

Emf per parallel path = Emf per conductor × $\frac{\text{Conductor}}{\text{Path}}$

$$E_g = \frac{\phi NP}{60} \times \frac{Z}{A}$$

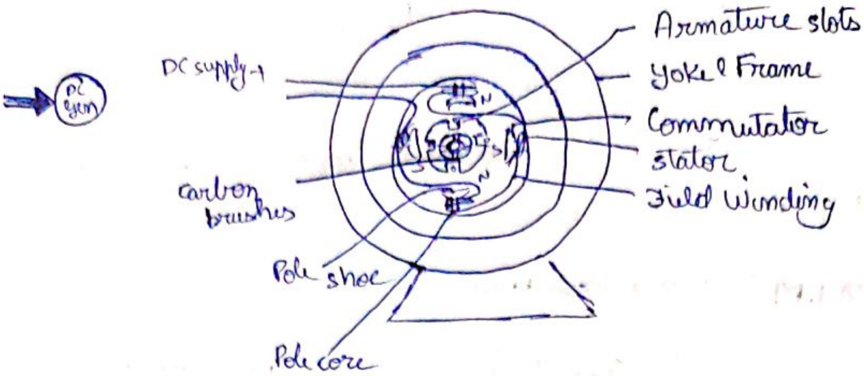
, where A = P for lap winding

A = 2 for Wave winding

Unit -4

DC Machine

5)



DC generator

DC generator is a machine which converts Mechanical energy into electrical energy

Construction of DC gen

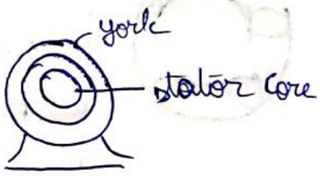
1) Yoke Frame

(outer part of a DC generator) (made up of cast iron)

Purpose :

It provides mechanical strength it protects the inner parts of a generator (from mechanical damage)

2) Stator Core



It consists of pole core & pole shoe

i) Pole Core : it consists of field winding
(energy is given to core through this winding)
(winding is done on pole core)

ii) Pole Shoe : It distributes uniform flux

3) Armature Core :

The rotating part of a dc generator is called armature

4) Commutator

is a device which converts AC to DC

5) Carbon brushes

In order to collect current from commutator segments

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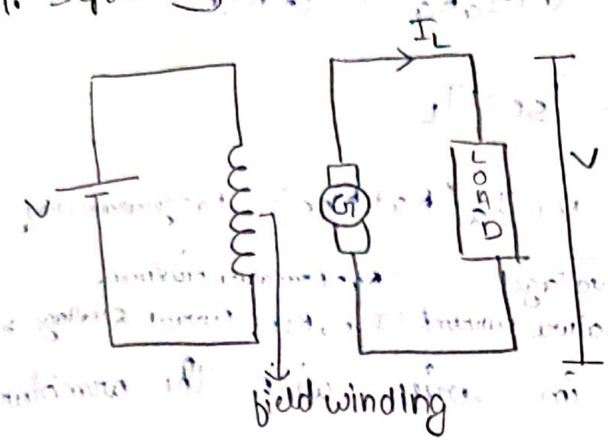
Types of DC Generator 6)

1. Seperately Excited DC Generated



$$E_g = V + I_a R_a$$

where

V = Load Voltage (V)

I_a = Armature Current (A)

R_a = Armature Resistance (Ω)

I_L = load current

- The field winding is powered by an external DC source (battery or another generator)
- The field current is independent of the armature EMF
- Used where constant and controllable field current is required

2. Self Excited DC generator

- Self Excited
  - Series Wound
  - Shunt Wound
  - Compound
    - Long Shunt
    - Short shunt

- In self excited DC generator, the field winding gets supply from the EMF generated in the armature itself.

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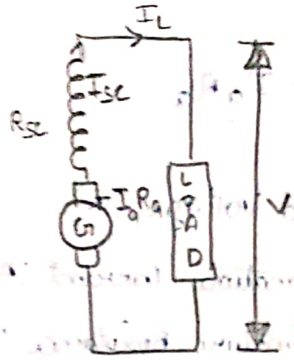
i) Series Wound



$$E_g = V + I_aR_a + I_{se}R_{se}$$

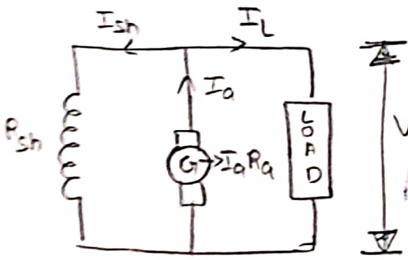
$$I_a = I_{se} = I_L$$

$$E_g = V + I_a(R_a + R_{se})$$, E_g = generator emf

where V = load voltage, I_a = armature current | R_a = Armature resistance, I_{se}, R_{se} = Current & voltage series

- Field winding is connected in series with the armature
- The field winding has few turns of thick wire with low resistance
- Produces high current and low voltage
- Rarely used, sometimes in DC boosters,

ii) Shunt Wound



$$I_a = I_L + I_{sh}$$

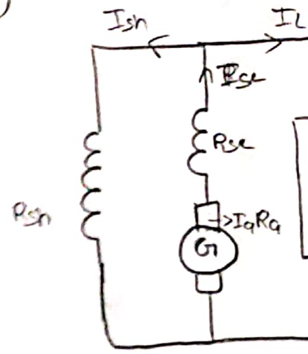
$$E_g = V + I_aR_a \text{ (volts)}$$

$$I_{sh} = V/R_{sh}$$

- Field winding is connected in parallel (shunt) with the armature
- The field winding has many turns of thin wire with high resistance.
- Used in battery charging and electroplating

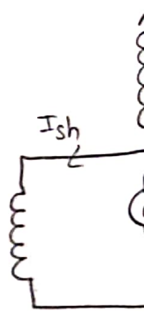
iii) Compound DC generator

1) Long Shunt



- Shunt field is conne
- ~~Used in~~

2) Short Shunt



$$E_g = V + I_aR_a + I_{se}R_{se}$$

$$I_a - I_{sh} = I_{se} = I$$

$$I_{sh} = \frac{V + I_{se}R_{se}}{R_{sh}}$$

- Short Shunt : Field only

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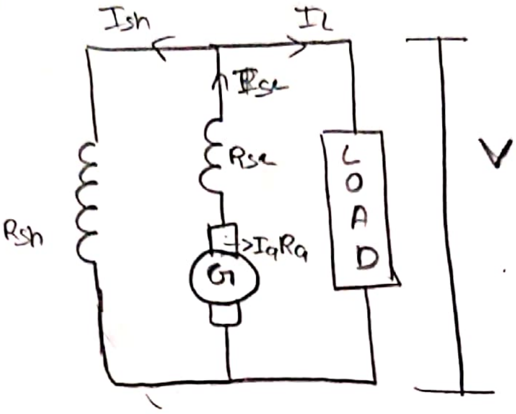
iii) Compound DC generator : contains both shunt & series field winding for better voltage regulation

1) Long Shunt



$E_g = V + I_a R_a + I_{se} R_{se}$

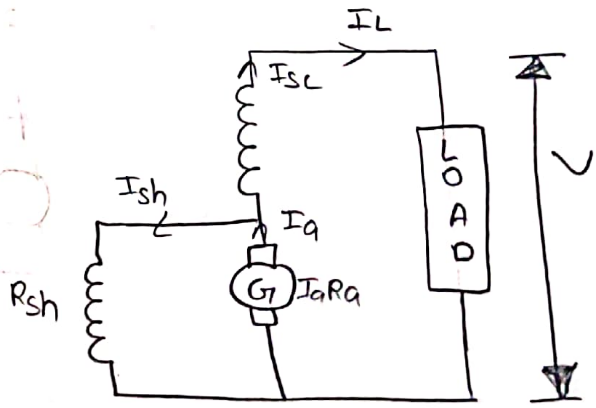
$I_a = I_{se} = I_L + I_{sh}$

$E_g = V + I_a(R_a + R_{se})$

$I_{sh} = V/R_{sh}$

- Shunt field is connected both armature & series field
- ~~Used in~~

2) Short Shunt



$E_g = V + I_a R_a + I_{se} R_{se}$ (volts)

$I_a - I_{sh} = I_{se} = I_L$

$$I_{sh} = \frac{V + I_{se} R_{se}}{R_{sh}}$$

- Short Shunt : Field is connected across the armature only

Q7. Draw the internal and external characteristics of different types of DC generators and explain them.

---

1. Introduction:

DC generator characteristics show how **terminal voltage** and **generated EMF** vary with **load current**.
There are three main characteristics:

- **Open-circuit or no-load (Magnetization) characteristics**
- **Internal (E vs Ia) characteristics**
- **External (V vs IL) characteristics**

This question focuses on **internal and external characteristics.**

---

2. Types of DC Generators & Their Characteristics:

A) Separately Excited DC Generator

- **Internal Characteristic:** Shows slight drop due to armature reaction as load increases.
- **External Characteristic:** Terminal voltage decreases slightly due to armature reaction and $I_a R_a$ drop.

Diagram Sketch (label axes):

- X-axis: Load current (Ia or IL)
- Y-axis: EMF (E) or Terminal Voltage (V)
- Two curves:
  - Internal: E vs Ia (above)
  - External: V vs IL (below, slightly sloped downward)

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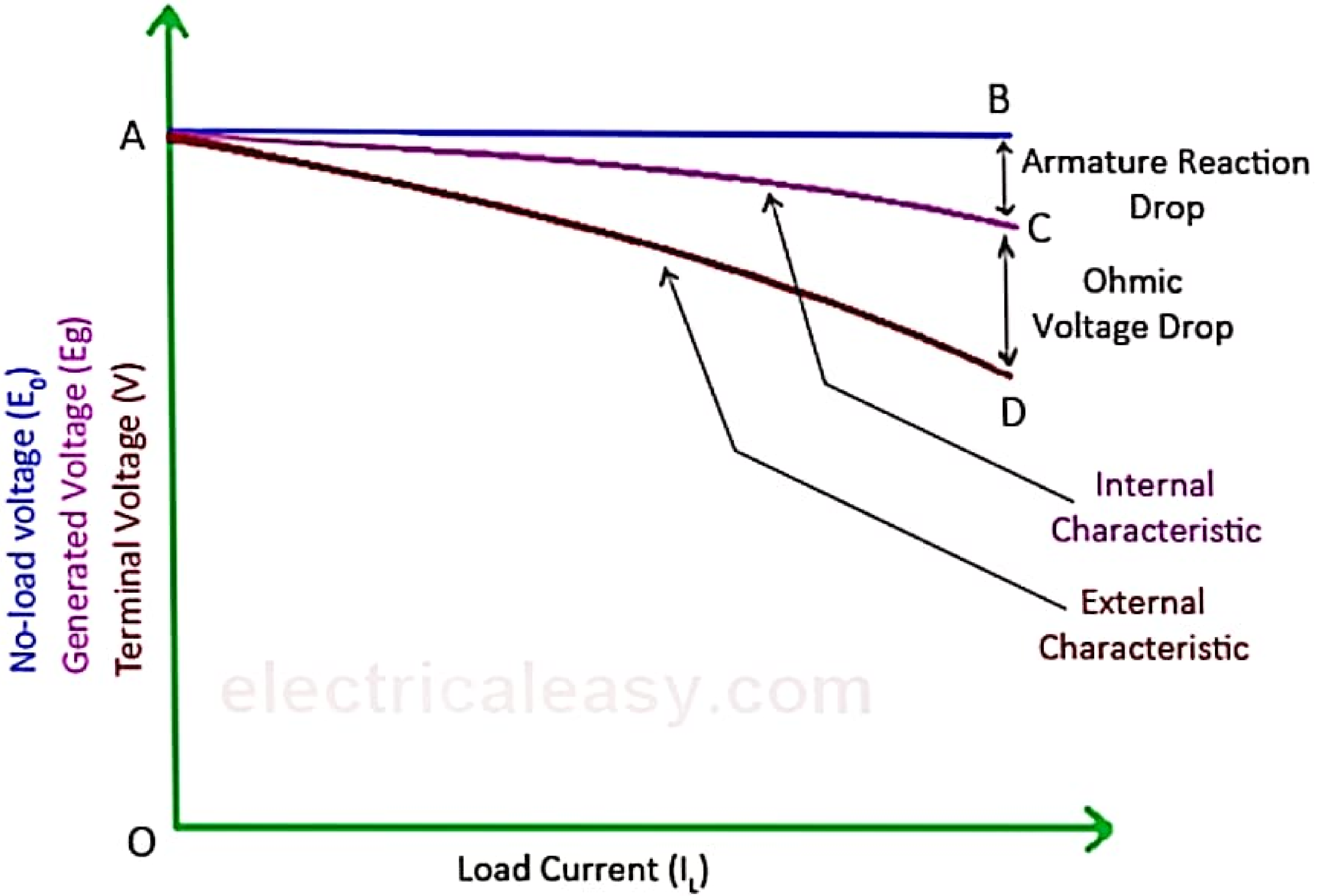

Characteristics of separately excited DC generator

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B) DC Series Generator

- **Internal Characteristic:** Voltage increases rapidly with load due to series excitation.
- **External Characteristic:** After a certain point, voltage drops due to saturation and increased losses.

Graph Shape: Initially rising, then peaks and may fall.

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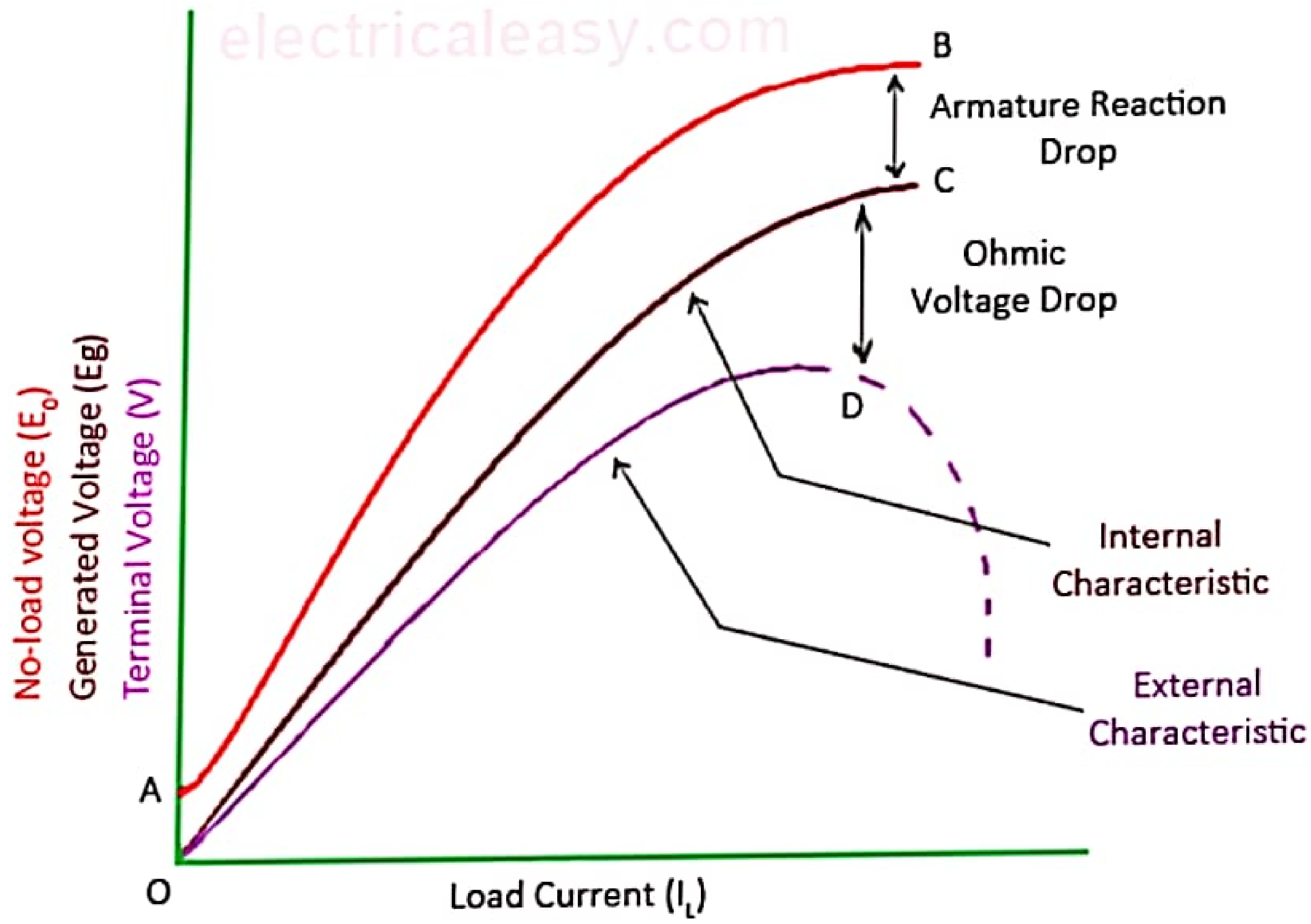

Characteristics of DC series generator

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C) DC Shunt Generator

- **Internal Characteristic:** Slight decrease in E due to armature reaction.
- **External Characteristic:** Terminal voltage drops sharply with load due to voltage drop and constant field excitation.

Graph Shape: Starts high and slopes downward smoothly.

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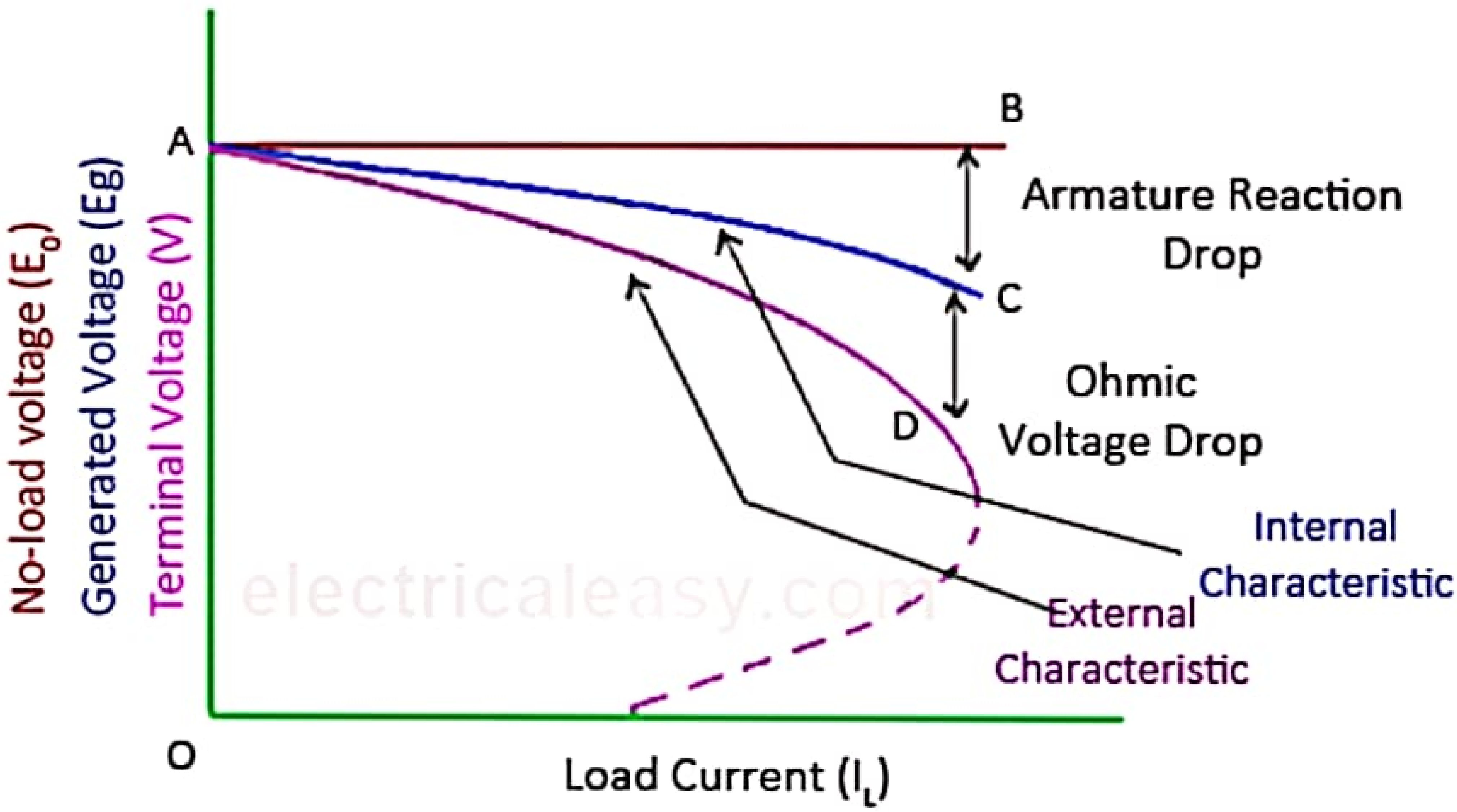

Characteristics of DC shunt generator

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D) DC Compound Generator

Types:

- **Cumulative Compound:**
  - Voltage remains almost constant or rises slightly with load.
  - Used in applications requiring **constant voltage.**
- **Differential Compound:**
  - Voltage **drops sharply** with load due to opposing fluxes.

Graph Shape:

- Cumulative: Flat or slightly rising curve.
- Differential: Steep downward slope.

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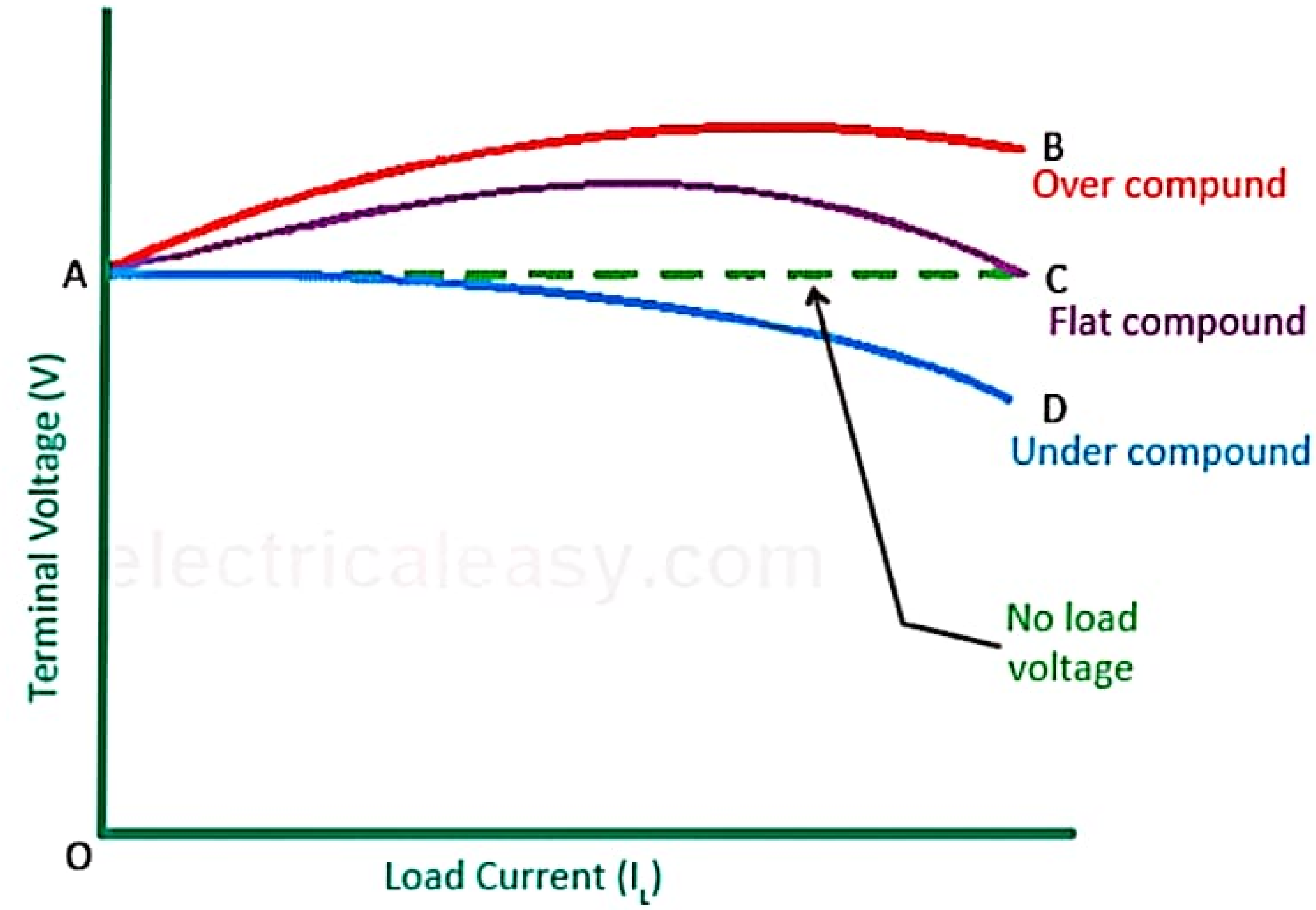

External characteristic of DC compound generator

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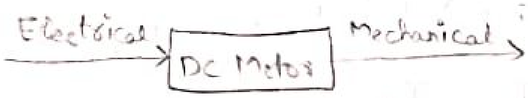
8) DC Motor



It works on the principle of flemings left hand rule

Thumb – Motion of the conductor

Middle Finger – Emf

Fore finger – Magnetic field

Types of DC Motor

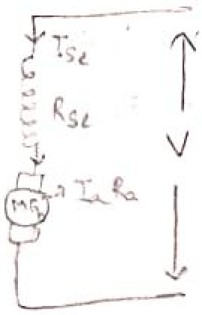
- Separately Excited DC Motor
- Self Excited
  - Series
  - Shunt
  - Compound
    - Long Shunt
    - Short shunt

Back emf

$E_b = \frac{\phi N P}{60} \times \frac{Z}{A}$ (V) , $E_b = V - I_a R_a$

Self Excited DC Motors

Series Wound DC Motor



$E_b = V - I_a R_a - I_{se} R_{se}$

$I_a = I_{se} = I_L$

$E_b = V - I_a (R_a + R_{se})$

Shunt Wound DC Motor

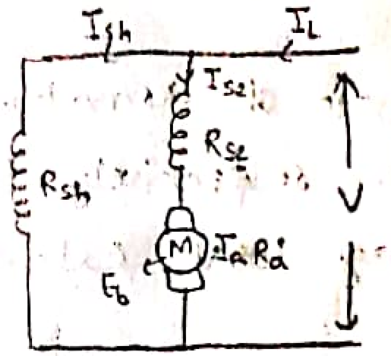
$$E_b = V - I_a R_a$$

$$I_a = I_L - I_{sh}$$

$$I_{sh} = V/R_{sh}$$

Compound DC Motor

Long Shunt DC compound motor

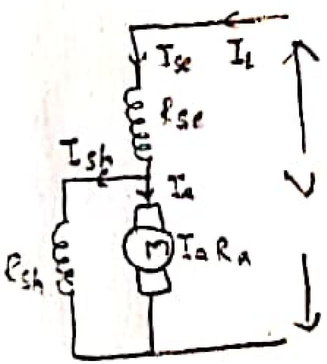


$$E_b = V - I_a R_a - I_{se} R_{se}$$

$$I_a = I_{se} = I_L - I_{sh}$$

$$E_b = V - I_a (R_a + R_{se})$$

Short Shunt DC compound motor



$$E_b = V - I_a R_a - I_{se} R_{se} \ (V)$$

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Q8. Classify and draw different types of DC motors. Give the power, voltage, and current equations for each. State their applications.

---

1. Classification of DC Motors:

DC motors are classified based on **field winding connections:**

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1) Separately Excited DC Motor:

- Field winding is supplied from an **external DC source.**

---

2) Self-Excited DC Motors:

These use their own **armature output** to excite the field winding.

Types:

- **a) DC Series Motor:** Field winding in **series** with the armature
- **b) DC Shunt Motor:** Field winding in **parallel** with the armature
- **c) DC Compound Motor:** Both **series and shunt windings** present
  - **Cumulative Compound**
  - **Differential Compound**

---

2. Voltage and Current Equations:

Let:

- V = Supply Voltage
- E_b = Back EMF
- I_a = Armature current
- R_a = Armature resistance
- R_{sh} = Shunt field resistance
- R_{se} = Series field resistance
- I_{sh} = Shunt field current
- I_L = Line current

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2. Voltage and Current Equations:

Let:

- V = Supply Voltage
- E_b = Back EMF
- I_a = Armature current
- R_a = Armature resistance
- R_{sh} = Shunt field resistance
- R_{se} = Series field resistance
- I_{sh} = Shunt field current
- I_L = Line current

---

a) Separately Excited DC Motor

- Voltage Equation:

$$V = E_b + I_a R_a$$

- Current:

$$I_a = I_L$$

- Power:

$$P = E_b I_a$$

---

b) DC Shunt Motor

- Shunt field connected across the armature.
- Voltage Equation:

$$V = E_b + I_a R_a$$

- Shunt Field Current:

$$I_{sh} = \frac{V}{R_{sh}}$$

- Armature Current:

$$I_a = I_L - I_{sh}$$

- Power:

$$P = E_b I_a$$

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b) DC Shunt Motor

- Shunt field connected across the armature.
- Voltage Equation:

$$V = E_b + I_a R_a$$

- Shunt Field Current:

$$I_{sh} = \frac{V}{R_{sh}}$$

- Armature Current:

$$I_a = I_L - I_{sh}$$

- Power:

$$P = E_b I_a$$

---

c) DC Series Motor

- Entire current flows through armature and field winding.
- Voltage Equation:

$$V = E_b + I_a(R_a + R_{se})$$

- Armature Current:

$$I_a = I_L$$

- Power:

$$P = E_b I_a$$

---

d) DC Compound Motor

- **Long Shunt:** Shunt across both armature and series field

$$V = E_b + I_a(R_a + R_{se})$$

- **Short Shunt:** Shunt across armature only

$$V = E_b + I_a R_a + I_{sh} R_{se}$$

---

3. Applications of DC Motors:

Type	Applications
Series Motor	Cranes, hoists, elevators, traction systems (high torque)
Shunt Motor	Fans, lathes, blowers, conveyors (constant speed)
Compound Motor	Rolling mills, compressors (variable load)
Separately Excited	Speed control systems, labs, testing applications

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Q9. What is the principle of operation of DC motor? Explain the significance of back EMF. Derive torque equation of DC motor. Mention the losses in DC machine.

---

1. Principle of Operation of DC Motor:

A **DC motor** operates on the principle that:

> *"When a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force."*
> (According to **Lorentz Force Law**)

This force causes the armature of the motor to rotate, converting **electrical energy into mechanical energy**.

---

2. Significance of Back E.M.F (Eb):

- When the armature rotates in the magnetic field, it cuts the flux and **induces a voltage** called **back electromotive force (Eb)**.
- This back EMF **opposes the applied voltage (V)** as per **Lenz's Law**.

Why Back EMF is Important:

- **It controls the armature current (Ia).**
- If load increases → speed decreases → Eb drops → Ia increases → more torque is produced.
- If load decreases → speed increases → Eb rises → Ia decreases → motor self-regulates.

Voltage Equation of DC Motor:

$$V = E_b + I_a R_a$$

Where:

- V = Supply Voltage
- E_b = Back EMF
- I_a = Armature current
- R_a = Armature resistance

---

3. Torque Equation of DC Motor:

Let:

- T = Torque (Nm)
- E_b = Back EMF (Volts)
- I_a = Armature current (Amps)
- N = Speed in RPM
- P = Number of poles
- Z = Total number of armature conduct

- E_b = Back EMF (Volts)
- I_a = Armature current (Amps)
- N = Speed in RPM
- P = Number of poles
- Z = Total number of armature conductors
- A = Number of parallel paths
- ϕ = Flux per pole (Weber)

Power developed in armature:

$$P = E_b \times I_a$$

Also,

$$P = \frac{2\pi NT}{60}$$

Equating both:

$$E_b I_a = \frac{2\pi NT}{60}$$

So,

$$T = \frac{60 E_b I_a}{2\pi N}$$

✅ Final Torque Formula (Simplified):

$$\boxed{T \propto \phi I_a}$$

This shows that **torque is directly proportional to flux and armature current.**

---

4. Losses in a DC Machine:

DC machine losses are grouped as:

a) Copper Losses (Variable):

- Armature loss: $I_a^2 R_a$
- Field winding loss: $I_f^2 R_f$

b) Iron Losses (Core Losses):

- Hysteresis loss
- Eddy current loss

c) Mechanical Losses:

- Friction (bearings, brushes)
- Windage loss (air resistance)

d) Brush Contact Losses:

- Due to voltage drop across brushes

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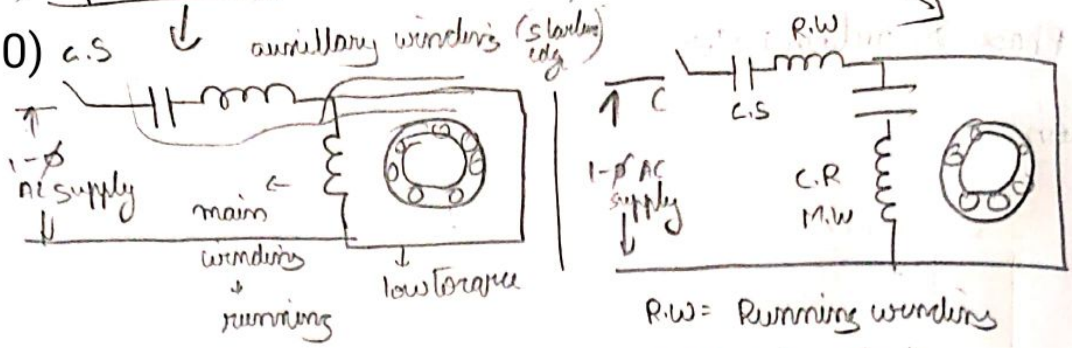
b) Capacitor start & Capacitor Run Induction Motor

10) 

R.W = Running winding
M.W = Main winding
C.S = starting capacitor
CR = Running capacitor

Construction

Similar to split phase but has a capacitor in series with auxillary winding to improve phase difference

Two types

a) Capacitor Start : Capacitor is used only during starting

b) Capacitor Run : Two capacitor, one for starting and one for running

Working

· The capacitor improves the phase diff b/w the main & auxillary winding, creating a stronger RMF

· After starting in the capacitor start motor, the capacitor is disconnected by a switch. In the capacitor run motor, it remains connected for smooth operation

Applications

· Air conditioner
· pumps
· compressors
· refrigerators

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