Lecture No. 47
DC Generator (Types & Characteristics)

Lecture delivered by

Objectives

At the end of this lecture, student will be able to:

- Derive an expression for induced E.M.F.
- Classify DC Generators based upon methods of excitation
- Discuss Open Circuit and Load characteristics of DC Generators
- Explain the losses associated with DC machines

E.M.F. Generated in An Armature Winding

Z = number of armature conductors,

ϕ = useful flux per pole, in webers

p = number of **pairs of poles**

and n = armature speed in rev/s

- The e.m.f. generated by the armature is equal to the e.m.f. generated by one of the parallel paths.

E.m.f. generated in an armature winding

- Each conductor passes 2p poles per revolution and thus cuts $2p\phi$ webers of magnetic flux per revolution.

$$= 2p\phi n \qquad \text{Wb}$$

so the average e.m.f. *E* generated per conductor is given by:

$$E = 2p\phi n \qquad \text{Volts}$$

(since 1 volt = 1 Weber per second)

E.m.f. generated in an armature winding

- c = number of parallel paths through the winding between positive and negative brushes

c= 2 for a wave winding

c= 2p for a lap winding

- The number of conductors in series in each path Z/c
- The total e.m.f. between brushes

= (average e.m.f./conductor)(number of conductors in series per path)

= 2pϕn*Z/c

$$i.e., \quad generated\ e.m.f., \ E = \frac{2p\Phi nZ}{c} volts$$

E.m.f. generated in an armature winding

- Since Z, *p* and c are constant for a given machine, then E α ϕ_n. However

  2πn is the angular velocity ω in radians per second, hence the generated e.m.f. is proportional to ϕ and ω, i.e.,

$$generated\ e.m.f.,\ E\,\alpha\,\phi_{\omega}$$

Problem

- **Problem 1.** An 8-pole, wave-connected armature has 600 conductors and is driven at 625 rev/min. If the flux per pole is 20 mWb, determine the generated e.m.f.

Sol^n

$$Z = 600,\ c = 2\ (\,for\ a\ wave\ winding),\ p = 4\ pairs$$

$$n = \frac{625}{60} rev/s,\ \ \Phi = 20\text{x}10^{-3} Wb$$

$$Generated\ e.m.f.,\ \ E = \frac{2p\Phi nZ}{c}$$

$$= \frac{2(4)(20\text{x}10^{-3})\left(\dfrac{625}{60}\right)(600)}{2} = 500\ volts$$

DC Generator

- DC generators are classified according to the method of their field excitation. These groupings are
  - **Separately-excited generators**
  - **Self-excited generators**

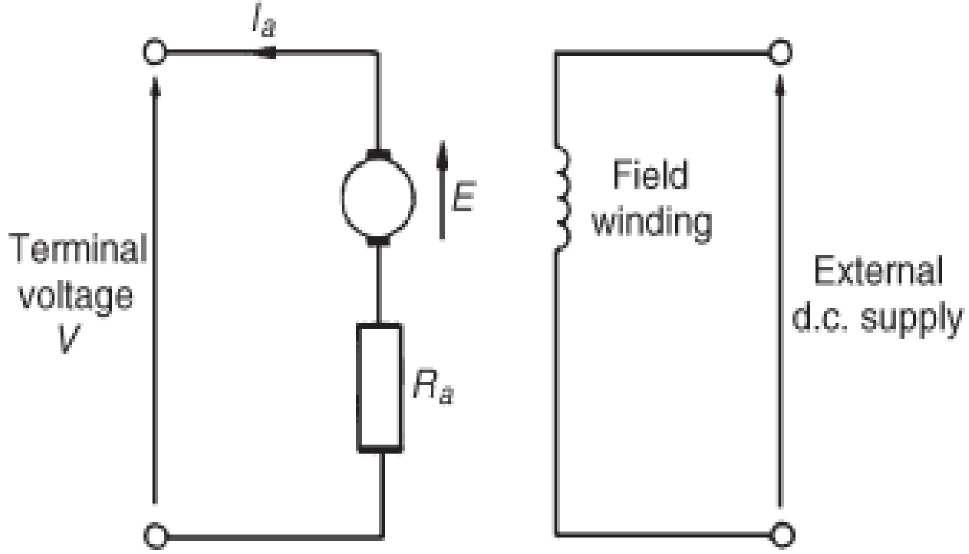
    (a) shunt

    (b) series, and

    (c) compound wound generators

Types of DC generator

- **Separately-excited generator -**



terminal voltage,

$$\boldsymbol{V = E - I_a R_a}$$

Problem

- **Problem 7**. Determine the terminal voltage of a generator which develops an e.m.f. of 200 V and has an armature current of 30 A on load. Assume the armature resistance is 0.30
- ***Sol^n*** V = E-IaRa = 200-(30)(0.30) = 200 9 = **191 volts**
- **Problem 8**. A generator is connected to a 60Ω load and a current of 8 A flows. If the armature resistance is 1Ω determine (a) the terminal voltage, and (b) the generated e.m.f.

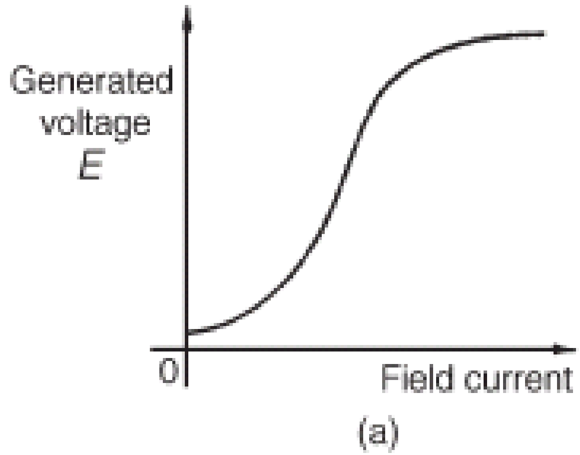
(a) Terminal voltage, $V = I_a R_L$ = (8)(60) = **480 volts**

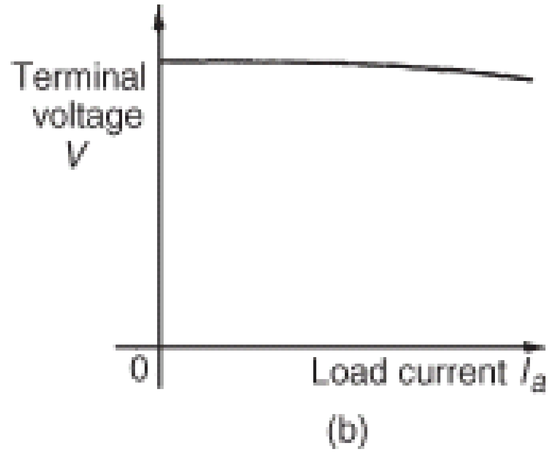
(b) Generated e.m.f., $E = V + I_a R_a$

= 480 + (8)(1) = 480 +8 = **488**

volts

Separately-excited Generator Characteristics

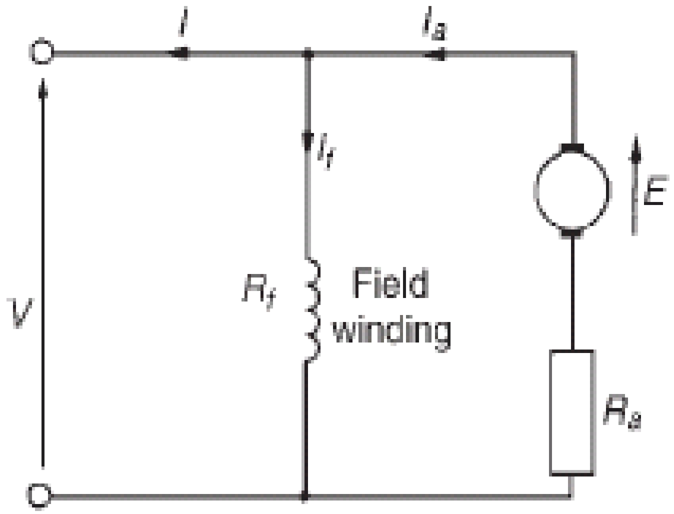




a) Open circuit characteristics
b) Load characteristics

Shunt-wound generator

- In a shunt wound generator the field winding is connected in parallel with the armature as shown in Figure. The field winding has a relatively high resistance and therefore the current carried is only a fraction of the armature current



For the circuit shown:

$$\text{terminal voltage } V = E - I_a R_a$$

$$\text{or generated e.m.f., } E = V + I_a R_a$$

$$I_a = I_f + I, \text{ from kirchhoff's current law,}$$

$$\text{where } I_a = \text{armature current}$$

$$I_f = \text{field current} \left(\frac{V}{R_f} \right)$$

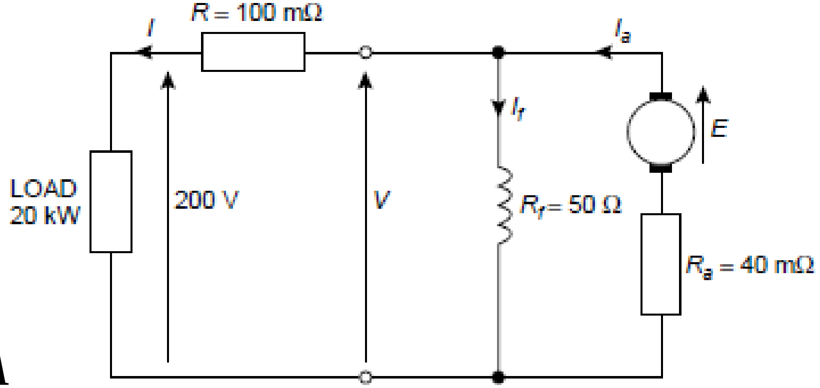
$$\text{and } I = \text{load current}$$

Problem

- **Problem 10**. A shunt generator supplies a 20 kW load at 200 V through cables of resistance, R = 100 m. If the field winding resistance, Rf = 50 and the armature resistance, Ra = 40 m, determine (a) the terminal voltage, and (b) the e.m.f. generated in the armature

***Sol**^n* : -The circuit is as shown in Figure

(a)



$$Load\ current,\ I = \frac{20000 watts}{200\ volts} = 100A$$

Problem

$$Volt\ drop\ in\ the\ cables\ to\ the\ load = IR = (100)(100\text{x}10^{-3})$$
$$= 10V$$

$$Hence\ terminal\ voltage, V = 200 + 10 = 210 volts$$

$$(b)\ Armature\ current\ I_a = I_f + I$$

$$Field\ current, I_f = \frac{V}{R_f} = \frac{210}{50} = 4.2A$$

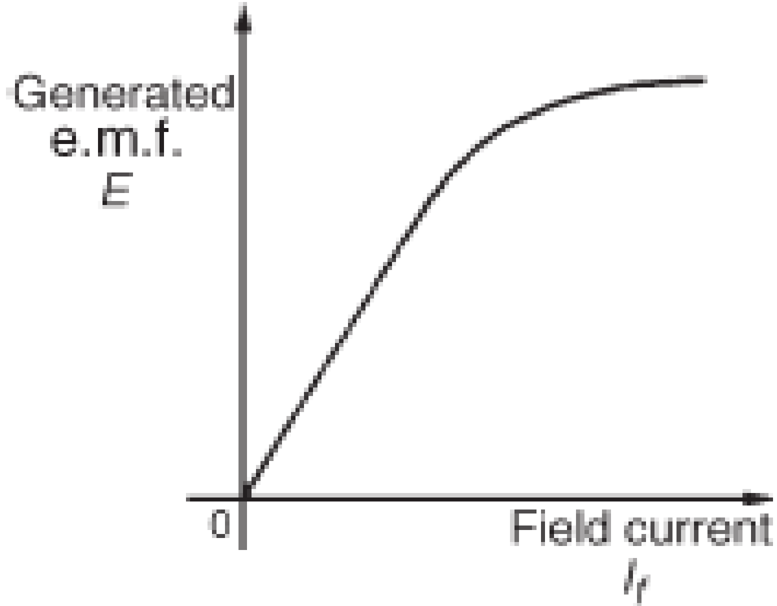
$$Hence \qquad I_a = I_f + I = 4.2 + 100 = 104.2A$$

$$= 210 + (104.2)(40\text{x}10^{-3})$$

$$= 214.17 volts$$

Shunt Generator Characteristics

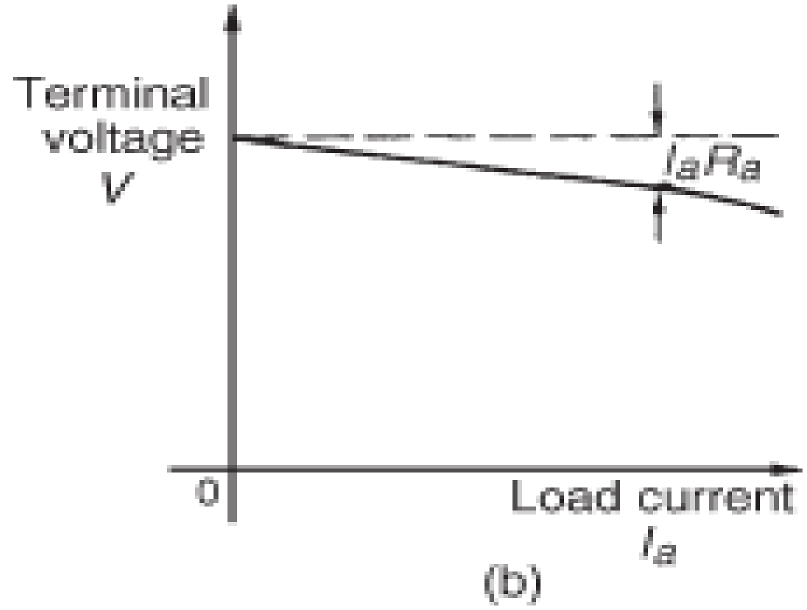
- The generated e.m.f., E, is proportional to ϕ, hence at constant speed, since ω=2ϕn,
- E / ϕ Also the flux ϕ is proportional to field current I_f until magnetic saturation of the iron circuit of the generator occurs.



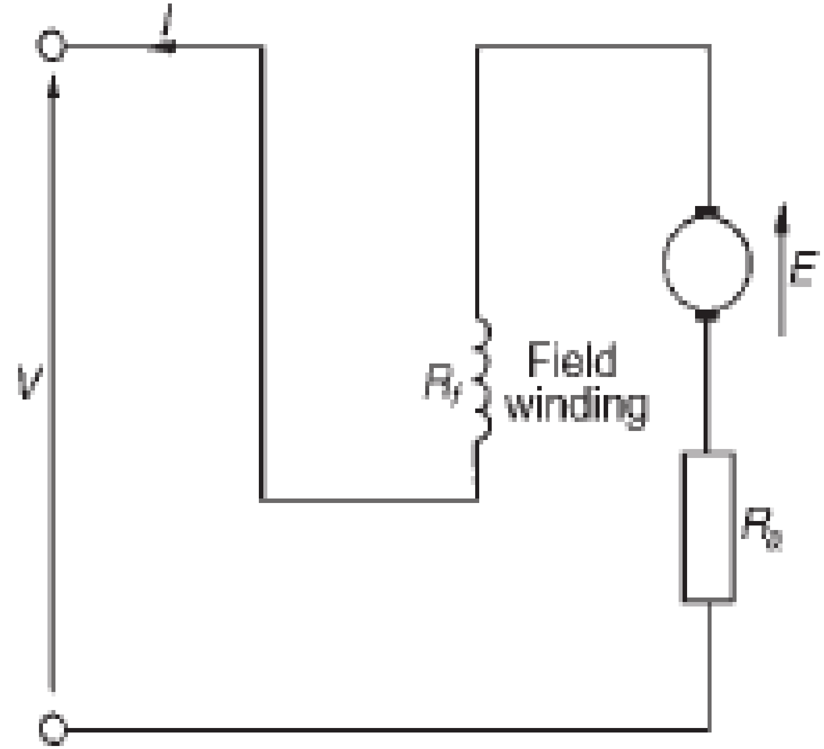
(a)

Shunt-wound Generator Characteristics

- As the load current on a generator having constant field current and running at constant speed increases, the armature volt drop, Ia Ra increases

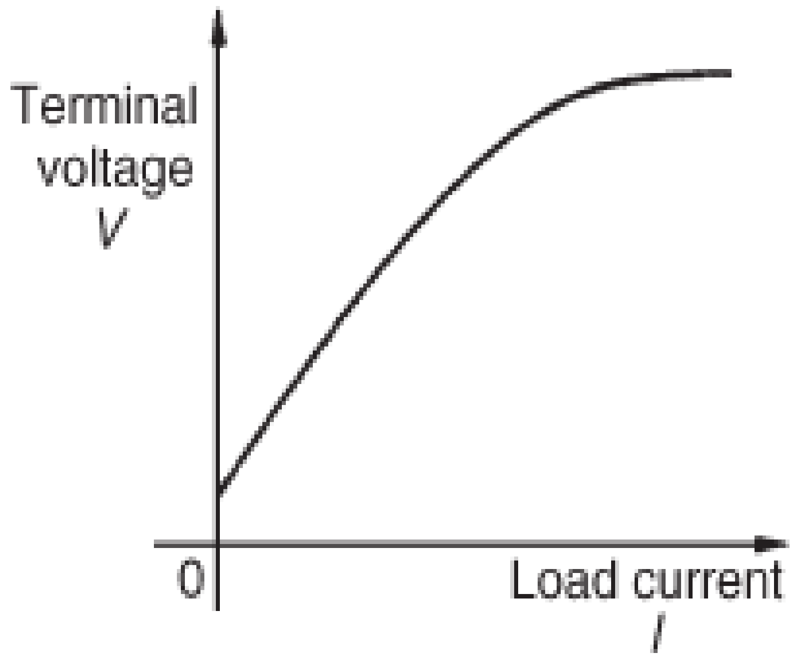


Series-wound Generator



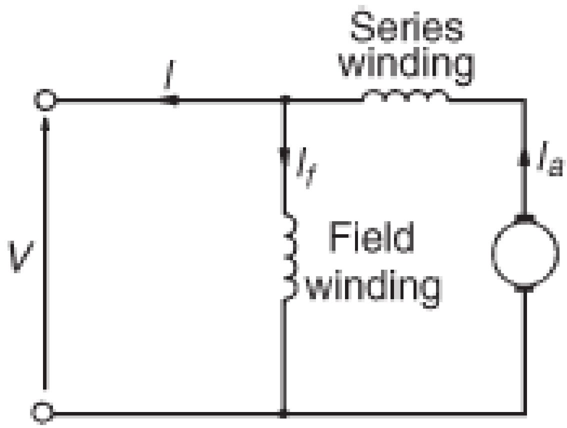
Series-wound Generator

- The values of field resistance and armature resistance in a series wound machine are small, hence the terminal voltage V is very nearly equal to E.



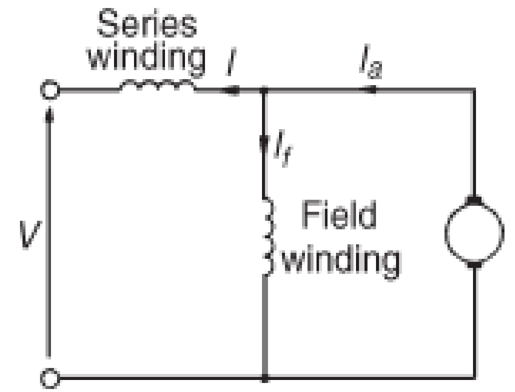
Compound-wound Generator

- Compound-wound generator consists both shunt and series windings



(a)

Long Shunt

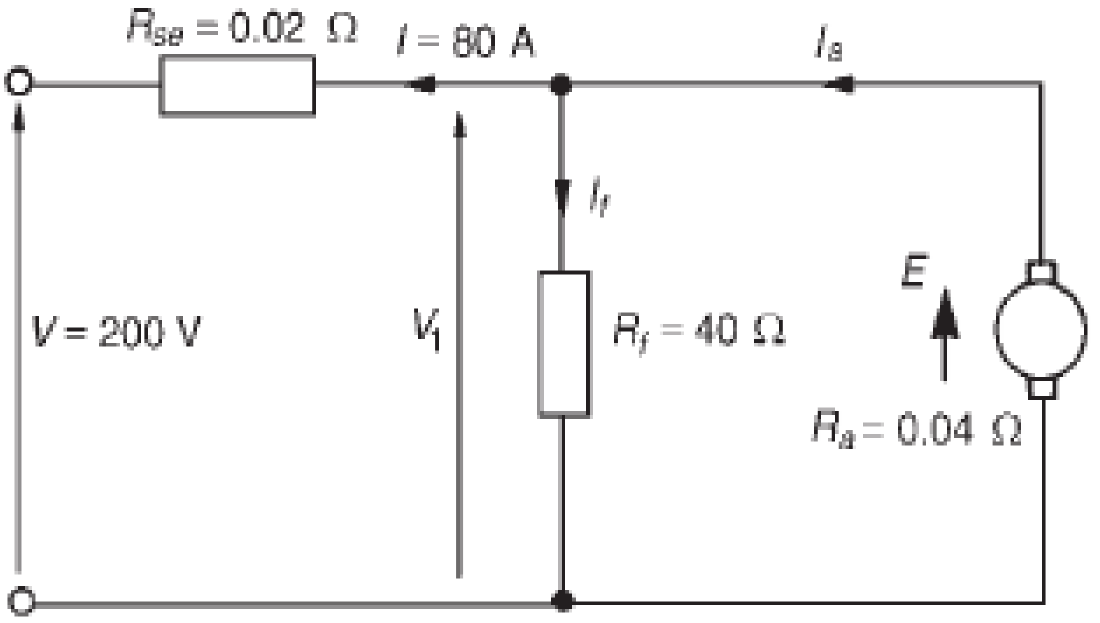


(b)

Short Shunt

Problem

- Problem 11. A short-shunt compound generator supplies 80 A at 200 V. If the field resistance, $R_f = 40$, the series resistance, R_{Se} = 0.02 and the armature resistance, $R_a = 0.04\Omega$, determine the e.m.f. generated.



Problem

*Sol^n^*

Volt drop in series winding $= IR_{Se} = (80)(0.02) = 1.6$ V

P.d.across the field winding = p.d. across armature

$$= V_1 = 200 + 1.6 = 201.6 \text{ V}$$

Field current $I_f = \dfrac{V_1}{R_f} = \dfrac{201.6}{40} = 5.04$ A

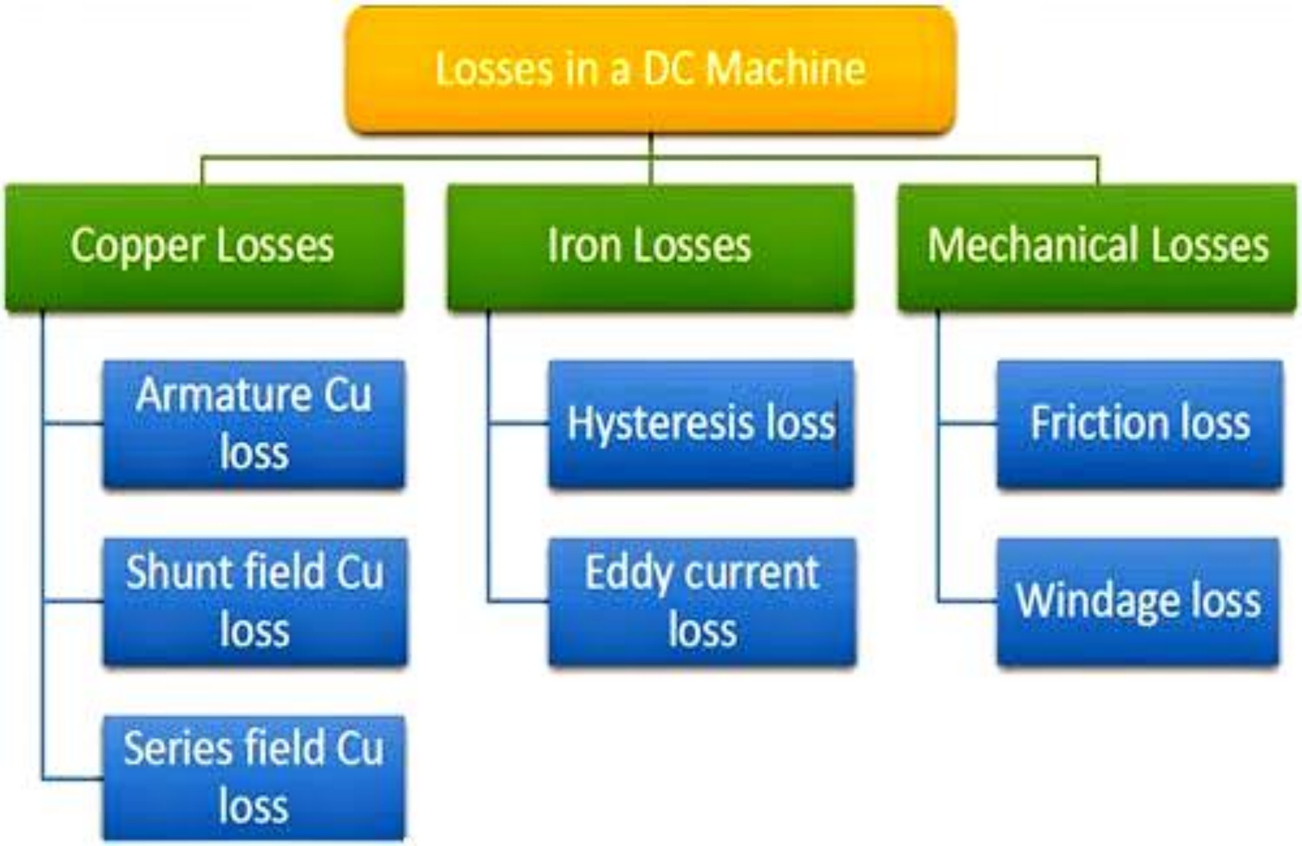
Armature current, $I_a = I + I_f = 80 + 5.04 = 85.04$ A

Generated e.m.f., $E = V_1 + I_a R_a$

$$= 201.6 + (85.04)(0.04)$$

$$= 205 \text{ volts}$$

D.C. Machine Losses



Efficiency of a D.C. Generator

$$\text{efficiency}, \ \eta =$$

$$\text{efficiency}, \eta = \left(\frac{\text{output power}}{\text{input power}} \right) \times 100\%$$

- Armature copper loss- $I^2{}_a \, R_a$
- Field copper loss- $I_f V$

Efficiency of a D.C. Generator

- the total losses is given by

$$I_a^2R_a + I_fV + C \; (I^2_aR_a + I_fV \text{ is, in fact, the 'copper loss'})$$

Total input power = $VI + I^2_aR_a + I_fV + C$. Hence

$$\text{efficiency, } \eta = \frac{\text{output}}{\text{input}} = \left(\frac{VI}{VI + I^2_aR_a + I_fV + C} \right) \times 100\%$$

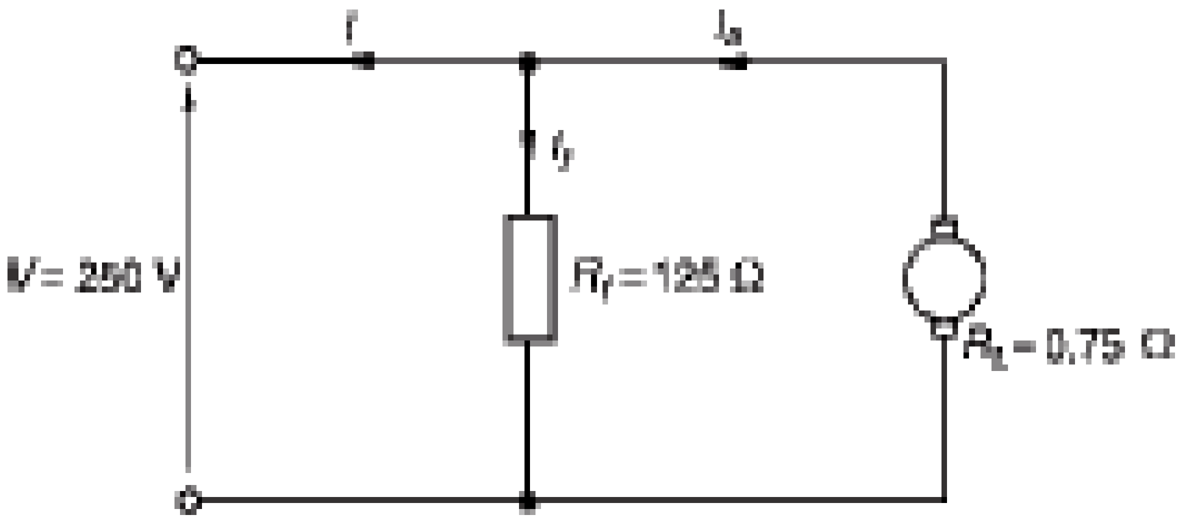
- The efficiency of a generator is a maximum when the load is such that:

$$I^2_a R_a = VI_f + C$$

i.e., when the variable loss = the constant loss

Problem

- **Problem 12**. A 10 kW shunt generator having an armature circuit resistance of 0.75Ω and a field resistance of 125Ω , generates a terminal voltage of 250 V at full load. Determine the efficiency of the generator at full load, assuming the iron, friction and windage losses amount to 600 W.



Problem

Sol^n

Output power = 10 000 W = VI

from which, load current $I = \dfrac{10\,000}{V} = \dfrac{10\,000}{250} = 40$ A

Field current, $I_f = \dfrac{V}{R_f} = \dfrac{250}{125} = 2$ A

Armature current, $I_a = I_f + I = 2 + 40 = 42$ A

$$\text{Efficiency, } \eta = \left(\frac{VI}{VI + I_a^2 R_a + I_f V + C}\right) \text{x } 100\%$$

$$= \left(\frac{VI}{10\,000 + (42)^2(0.75) + (2)(250) + 600}\right) \text{x } 100\%$$

$$= 80.50\%$$

Problem

Problem 13. The armature of a d.c. machine has a resistance of 0.25 and is connected to a 300 V supply. Calculate the e.m.f. generated when it is running: (a) as a generator giving 100 A, and (b) as a motor taking 80 A.

(a) As a generator, generated e.m.f.,

$$E = V + I_a R_a,$$
$$= 300 + (1000)(.25)$$
$$= 300 + 25 = 325 \text{ volts}$$

(b) As a motor, generated e.m.f. (or back e.m.f.),

$$E = V - I_a R_a,$$
$$= 300 - (80)(0.25) = 280 \text{ volts}$$

Summary

- Induced emf in a DC machine is proportional to speed and flux per pole
- OCC of Shunt Generator is similar to B-H curve
- As the load increases on a shunt generator its terminal voltage decreases
- Efficiency of a DC machine is maximum when variable loss is equal to constant loss