Yoke:

→ It serves the purpose of outermost cover of the d.c machine. It provides mechanical support to the poles. Also forms the part of the magnetic circuit.

→ For small generators, yoke is made of cast iron, but for large generators, it is made of cast steel.

→ Yoke supports the field system. The lifting eye, base plate and the terminals box are cast integral with the yoke.

Poles:

→ Each pole has two parts namely pole core and pole shoe.

→ The pole core is laminated to reduce eddy current losses. Thin sheets of alloy steel are insulated from one another and pressed together to form the core.

→ The laminations are held tightly with the help of end plates. The poles are fixed to the yoke with the help of bolts. The pole core supports the field coil.

→ The pole shoe is also laminated, being insulated from one another, pressed together.

→ The pole shoe is fixed to the pole core by screws. The shape of the pole shoe is cylindrical at the bottom, so that the flux produced is spread out uniformly in the air gap.

→ Field windings are wound around the pole core. When a direct current is passed thro' the field coils, the pole core becomes an electromagnet and produces the main flux

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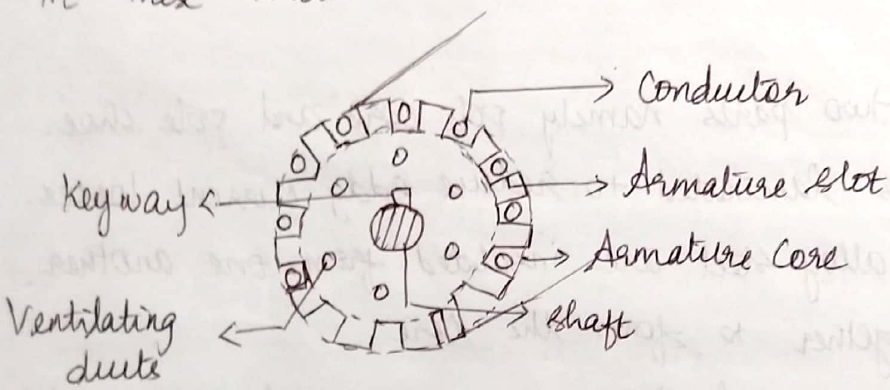
Armature

→ The armature consists of armature core and armature winding. The armature core is made of high permeability and low loss silicon steel laminations which are usually 0.4 to 0.5mm thick and are insulated from one another by varnish.

→ There are slots cut uniformly on the outer periphery of the armature core and armature conductors are placed in these slots.



→ The armature laminations are directly keyed to the shaft and hence the armature also rotates, when the shaft is rotated.

→ Axial ventilating ducts are provided thro' the armature core, so that free air can circulate thro' them and cool the armature.

→ The armature conductors are connected together either as as lap winding or wave winding.

Commutator

→ It is cylindrical in shape and is made up of wedge shaped segments of hard drawn, high conductivity copper.

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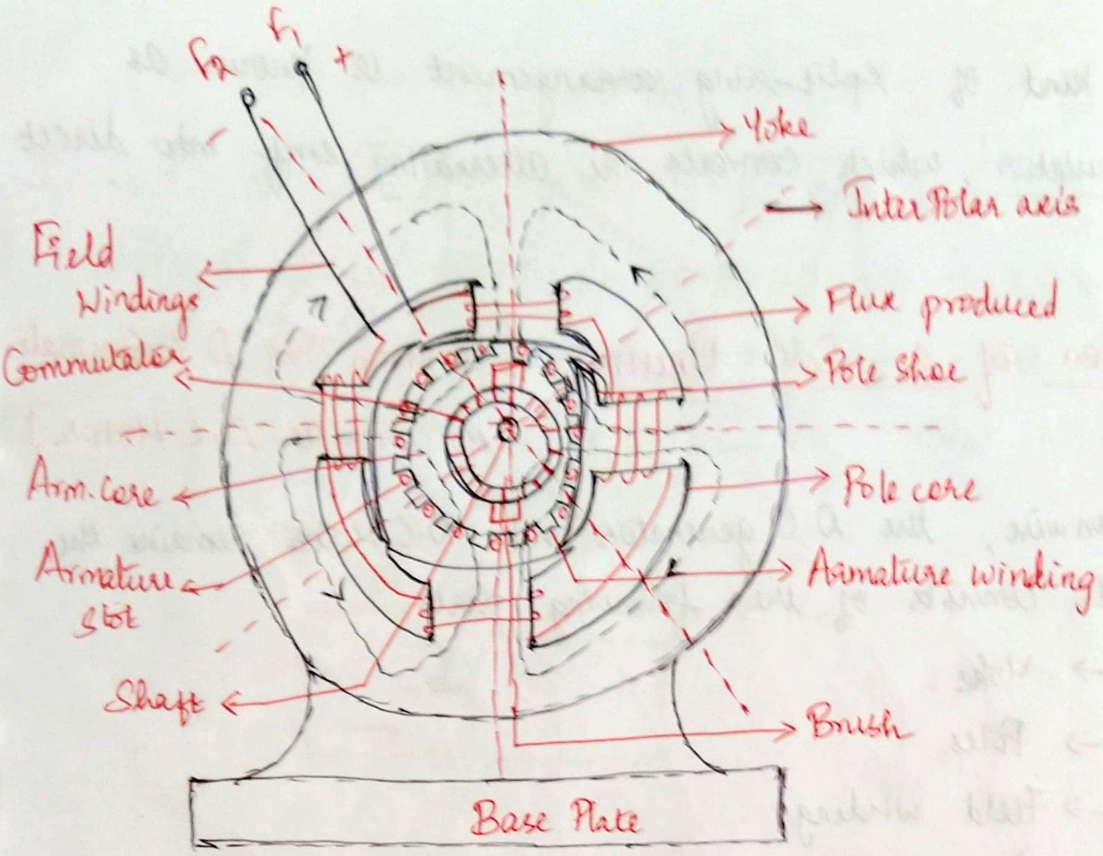

Fig. D.C Machine.

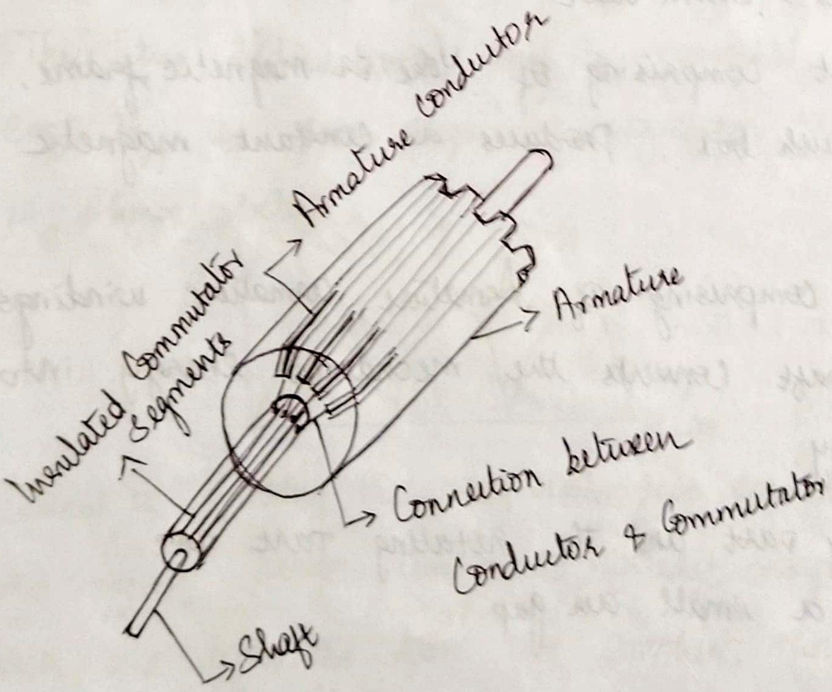

Fig. Commutator.

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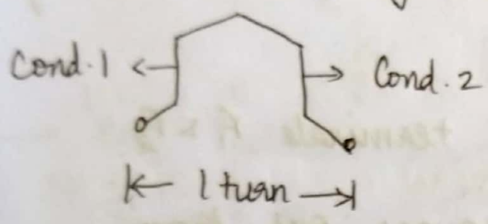
~~Coil~~ Turn

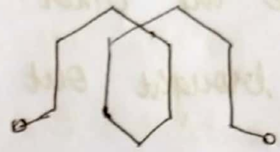
Two conductors placed in different slots when connected together forms a turn.

ie No. of armature conductors = 2 × No. of turns.

Coil: Turns are grouped together to form a coil.



(single turn)



Two turn.

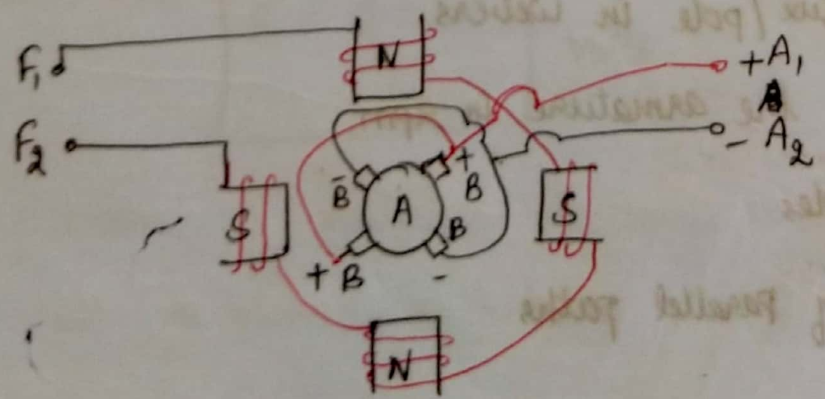
Multi turn.

Pole-Pitch. The distance between the two adjacent poles is called a pole-pitch. It is measured in terms of no. of slots. The total slots along the periphery of armature divided by the total number of poles is called a pole pitch.

$$\text{Pole pitch} = \frac{\text{Tot. No. of slots}}{\text{No. of poles}}$$

Symbolic Representation of D.C Generator.

→ The overall armature and field connections is done as shown below for a four-pole d.c machine.



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Losses in DC Machines

DC Gen.

$$\eta = \frac{P_o}{P_{in}} = \frac{V_o \times I_L}{P_{in}}$$

→ Total losses $= P_{in} - P_o$

→ $P_{in} = P_o + \text{losses}$

→ $\eta = \dfrac{\text{O/P Power}}{\text{O/P Power} + \text{losses}}$

1. Copper Loss
   - Arm. Cu. loss $I_a^2 R_a$
   - Field Cu. loss $I_{sh}^2 R_{sh}$ or $I_{se}^2 R_{se}$
   - Brush Contact loss
2. Iron losses (Mag. losses)
   - eddy ct.
   - Hysteresis
3. Mechanical losses
   - Air friction loss
   - Bearing-loss
   - Stray losses.

DC Motor

→ $\eta = \dfrac{P_o}{P_{in}} = \dfrac{P_{in} - [\text{Losses}]}{P_{in}}$

→ Losses = Variable + Constant loss

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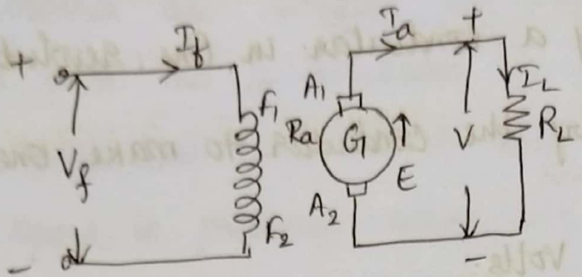
D.C Generator on Load

The D.C generator with its armature and field windings is shown with load.



→ When the armature rotates by the rotation of shaft, the armature conductors cut the magnetic flux and an emf 'E' is generated.

→ When the armature terminals are connected to a load, say R_L, a load current I_L flows thro' it. Thus, 'V' is the terminal voltage of the generator.

→ This terminal voltage 'V' is sligntly less than the gen. emf 'E' ~~during~~ due to the following drops,

① Armature Resistance Drop: ($I_a R_a$)

When D.C generator is loaded, a current I_a (armature current), flows thro' the armature conductors. Due to the resistance R_a possessed by armature conductors, a small voltage drop $I_a R_a$ ~~due to~~ occurs.

② Armature Reaction Drop: (A.R.D)

When current flows thro' the armature conductors, the armature sets up its own flux known as the

→ Each Commutator segment is insulated from each other by thin layer of mica.

→ Each segment is connected to the armature conductor by means of Copper strip.

→ Since it collects current from armature, it is also made up of copper segments.

→ It also facilitate the development of unidirectional torque in case of motors.

Brushes & Brush Gear:

→ Brushes are made of soft material preferably carbon, which are stationary and slide on surface of the Commutator.

→ It collects current from commutator and make it available to the stationary external circuit.

→ The brushes are held on the commutator segments by means of spring, so that the brush is in contact with the rotating commutator all the time.

Types of Armature Windings

Based on the way in which end connections of the coil sides are made to the Commutator segments, the armature windings are classified into two types,

1. Lap winding
2. Wave winding.

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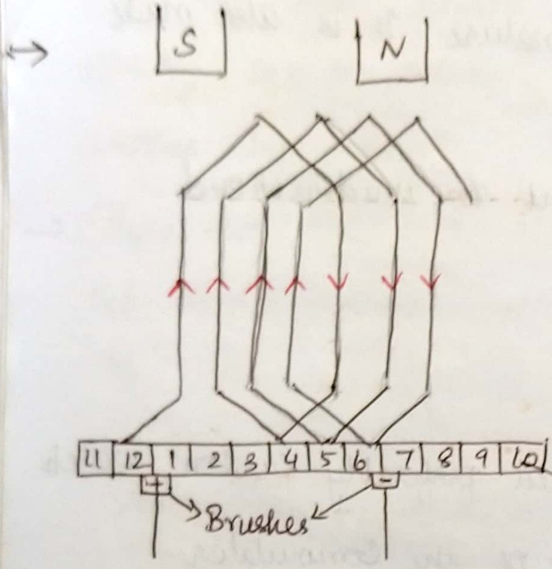
Lap winding

→ In this type, the connections overlap each other as the windings proceed.

→ 

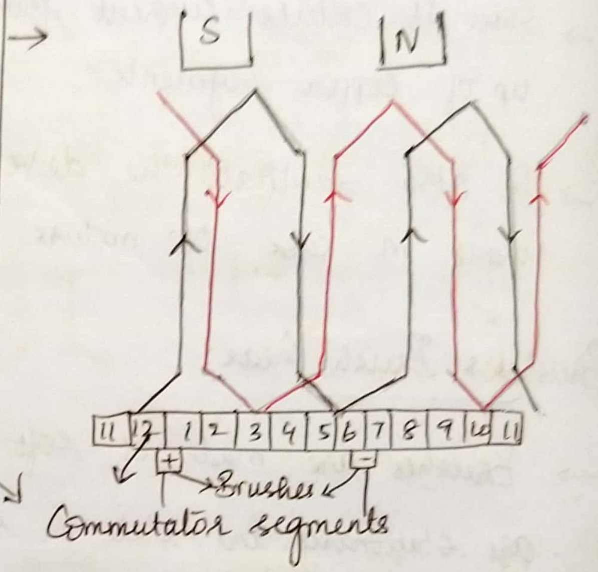
→ The finishing end of one coil is connected via the commutator segment to the starting of the adjacent coil under the same pole.

→ The lap winding has as many parallel paths between the positive and negative brushes as there are poles.

→ ie No. of Parallel paths, $A = P$ where $P \rightarrow$ No. of poles.

Wave winding

→ In this type, the windings are done in the form of wave, thus avoiding overlapping.

→ 

→ Here, one side of a coil under one pole is connected to the other side of a coil which occupies approximately the same position under the next pole thro' back connection.

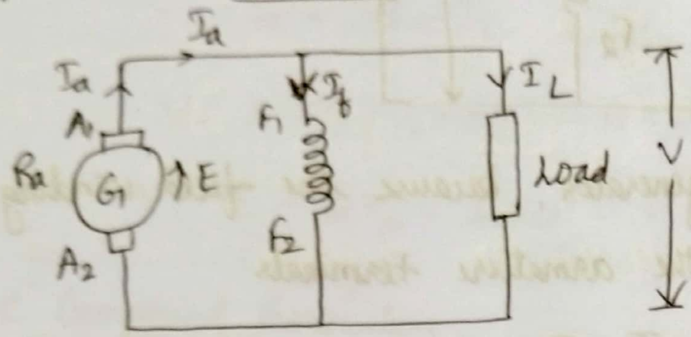
→ Wave winding has two parallel paths, irrespective of the number of poles.

→ No. of Parallel paths $A = 2$.

→ For the load, V is the terminal voltage, which is given by,

$$V = E - I_a R_a - A.R.D - B.C.D.$$

II. Self - Excited D.C Generator.



→ Here the excitation to the field winding is provided by the generator itself.

→ For this self excitation, the pole cores should have some residual magnetism (flux), so that when the armature cond. rotate, a small amount of emf is induced by cutting the lines of residual flux.

→ This emf provides a small current thro' the field windin which in turn increases the flux.

→ This increase of flux increases the emf induced. Thus these parameters help each other to achieve the rated val

Hence,

$$I_a = I_L + I_f$$

$$V = E - I_a R_a - A.R.D - B.C.D$$

The types of self-excited D.C generators are shown below,

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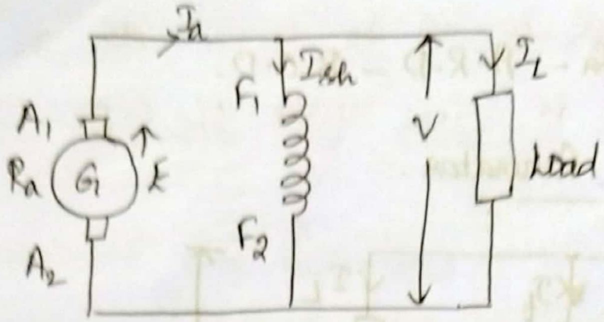
II. 1. D.C Shunt Generator.



→ This is shunt generator, because the field winding is connected across the armature terminals.

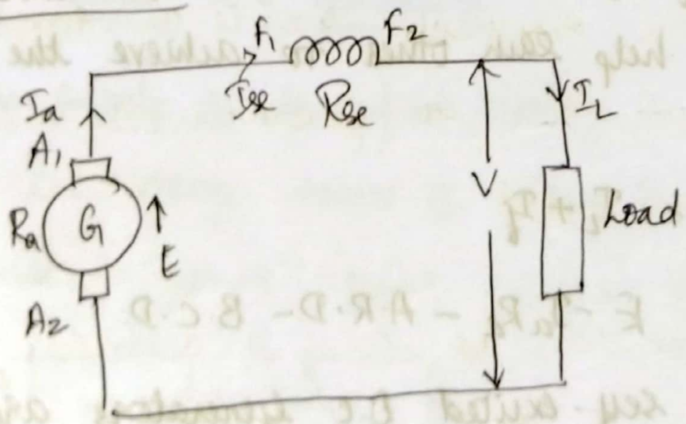
$$I_a = I_L + I_{sh}$$

$$I_{sh} = \frac{V}{R_{sh}}, \quad R_{sh} \rightarrow \text{Shunt Resistance.}$$

$$\rightarrow V = E - I_a R_a - A.R.D - B.C.D$$

→ Here load current should not reduce drastically due to a large current I_{sh} drawn by shunt field winding. So the shunt field windings consist of a large number of very thin turns of copper with high resistance. Thus I_{sh} is ~~made~~ reduced to a lower value.

2. D.C Series Generator



→ Here the field winding is connected in series with the armature.

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armature flux. This armature either opposes the main flux OR support it. When it distorts the flux, the main flux gets reduced sligthly and this affects the emf induced in the D.C generator which in turn reduces the emf sligthly. This is called armature reaction. The reduction in the value of the generated voltage is considered as a voltage drop due to armature reaction.

③ Brush Contact Resistance Drop:

The contact between the commutator and the brushes has some resistance known as brush contact resistance. Due to this resistance, there is some voltage drop called brush contact resistance drop. This is usually expressed as volts/brush. The total voltage in d.c generator due to this drop is 2 times volts/brush, (Since there are two brushes shown finally after the brush connections).

∴ Generated emf = Terminal Voltage + Armature Resistance Drop + Armature Reaction Drop + Brush Contact Resistance Drop.

$$E = V + I_a R_a + A.R.D + B.C.D$$

(or)

Terminal Voltage $V = E - I_a R_a - A.R.D - B.C.D.$

→ Thus the terminal voltage is always sligthly less than the generated voltage in D.C generator.

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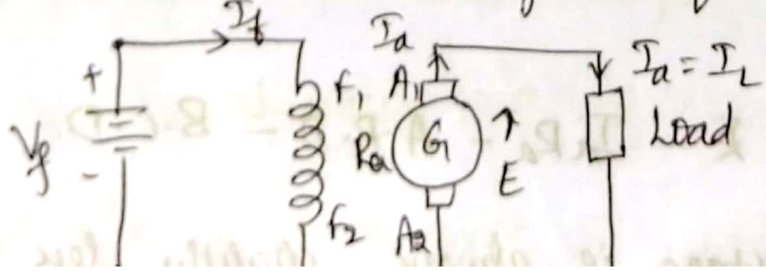
Based on the nature of excitation winding. D.C generators are classified as follows,

D.C Generators.

- I. Seperately excited D.C gen
- II. Self excited D.C gen.
  - D.C Shunt
  - D.C Series
  - D.C Compoun[d]
    - Cumulatively Compounded
      - Long Shunt Cum. Comp. gen.
      - Short Shunt Cum. Comp. gen.
    - Differentially Compound
      - Long Shunt diff. Comp. gen.
      - Short Shunt diff. Comp.

I. Seperately excited D.C generators.

→ Here the supply to the field winding is provided by a seperate D.C Voltage source of voltage V_f. I_f is the field current due to which magnetic flux is produced.



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→ This series winding should have less resistance, so that almost the total current I_a flows thro' it. So the series winding is made of thick turns of copper.

$$\therefore I_a = I_{se} = I_L.$$

$$V = E - I_a(R_a + R_{se}) - A.R.D - B.C.D$$

$$V = E - I_a R_a - I_a R_{se} - A.R.D - B.C.D$$

3. D.C Compound Generator.

→ This generator is one which contains both shunt winding and series winding.

→ If the two field windings are connected in such a way that the fluxes produced by them are in same direction and are additive, then the generator is said to be cumulatively compounded.

→ If the field windings are connected in such a way that the fluxes produced by them are in opposite direction and the resultant flux is the difference between the two, then the generator is said to be differentially compounded.

Depending on connection of series field winding to the shunt field winding, we have

1. Long Shunt Compound Gen.
2. Short Shunt Compound Gen

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④ A 4P generator with wave wound armature has 51
② slots each having 24 conductors. The flux per pole is 0.01wb. At what speed the armature rotates to give an induced emf of 220V. What will be the voltage of the winding in lap and the armature rotates at same speed.

$$E = \frac{\phi Z N P}{60A}$$

Wave.

$$220 = \frac{0.9 \times 51 \times 24 \times 4 \times N}{60 \times 2}$$

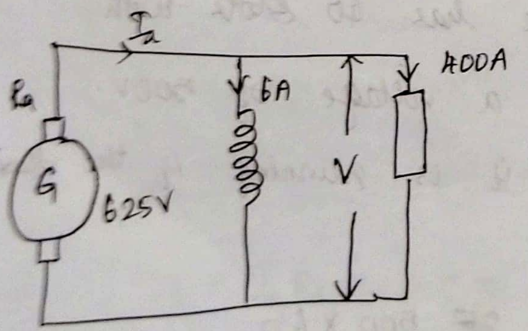
$$\underline{N = 539.22 \text{ rpm}}$$

For lap winding.

$$E = \frac{\phi Z N}{60} = \frac{0.01 \times 51 \times 24 \times 539.22}{60}$$

$$\underline{E = 110V}$$

③
5. The emf generated in the armature of a shunt generator is 625 V, when delivering its full load current of 400A, to the external ckt. The field current is 6A and R_a = 0.06Ω. What is the terminal voltage.



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

$$= 6 + 400 = \underline{406A}$$

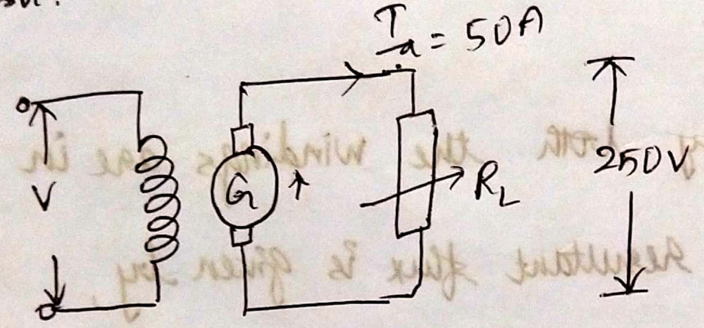
$$\underline{I_a = 406A}$$

$$V = E - I_a R_a = 625 - 406(0.06)$$

$$\underline{V = 600.64V}$$

Problems.

1. A seperately excited DC generator when running at 1000 rpm supplies 50A at 250V. Find how much current it will deliver when the speed falls to 800 rpm. Take armature resistance as 0.01Ω and brush drop of 1V / brush.



$E_1 = V + I_{a_1} R_{a_1} + B.C.D$

$= 250 + 50 \times 0.01 + 2 \times 1 = 252.5V$

$E_1 = 252.5V$

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