0.1 Module 4

DC Generator: Principle of operation, Construction D.C. Generator, Expression of induced emf, Types of DC Generators, Relation between induced emf and terminal voltage.

DC motors: Principle of operation, back Emf, torque equation, Types of D.C. motors (shunt and series motors only), and applications.

0.2 DC Generator

0.2.1 Working principle of DC Generator

Working principle of D.C.generator as a motor: . Whenever a current coil is placed under a magnetic field the coil experiences a mechanical force, and is given by F= B*I*l*Sin. Newton/coil side where, I is the current through the coil. . Applying Fleming's left hand rule, we note torque Te will be produced in the counter clockwise direction causing the rotor to move in the same direction.

0.2.2 Construction of DC Generator

The detailed construction of DC generator is as shown in Figure1. DC generator mainly consists of stationary part and rotating part. The constant magnetic field is created by stationary part and converging mechanical energy into electrical energy is done by rotating part.

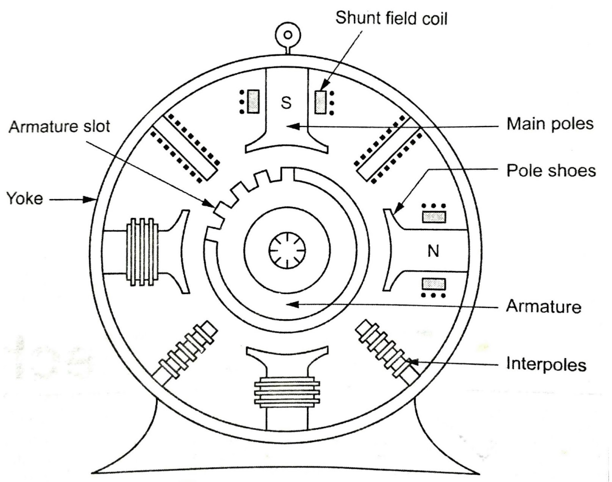

Figure 1

The parts of a D.C. generator are:

- Yoke
- Field poles
- Armature
- Commutator
- Brushes

Yoke:

Yoke serves as a outermost cover (frame) of the D. C. Generator. The functions of Yoke are:

- It provides mechanical support to the poles.
- It protect atmospheric harmful effects.
- It provides a path of low reluctance for magnetic flux.

Poles:

Poles are used to produce a magnetic flux. These poles are fixed to yoke. Each pole is divided into two parts.

- Pole core.
- Pole shoe.

The functions of Poles are:

- Pole core carries a field winding to produce the flux.
- Pole shoe enlarges the area of armature core to come across the flux to produce larger induced emf.
- It provides a path of low reluctance for magnetic flux.

Field coils:

The field winding is wound on the pole core to act as an electromagnet, to produce necessary magnetic flux.

Armature:

Armature is made up of two parts, those are

- Armature core.
- Armature winding.

The detailed diagram of the armature is as shown in Figure 2. The armature core is cylindrical in shape mounted on the metal shaft. It consists of slots on its periphery to accommodate the armature winding. When the armature start rotating it cuts the magnetic flux and emf is is generated.

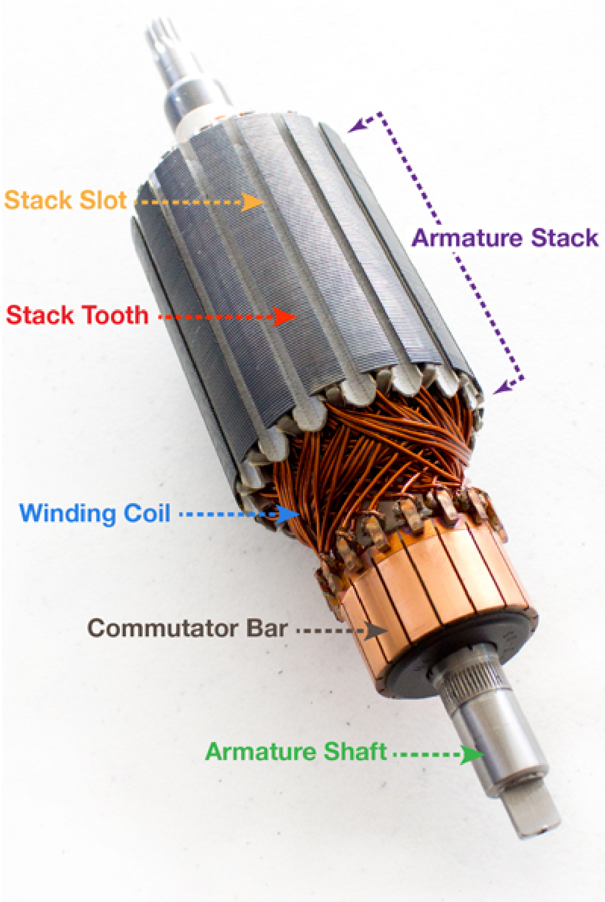

Figure 2: Armature (Ref:https://www.elprocus.com/)

Commutator:

Commutator helps to collect the generated emf from the conductors and connect it to the load. The generated Emf induced in the armature conductors is alternating. Commutator also helps to convert generated ac alternating emf to it to DC voltage (rectification).

Brushes:

The Brushes made of carbon which are placed on the commutator pressed by springs. Through brushes current is collected from commutator and connected to the external load.

0.2.3 E.M.F. Equation

Consider

$$\phi = flux/pole\ weber$$
$$P = No.\ of\ generator\ poles$$
$$N = speed\ of\ the\ armaturer(rpm)$$
$$A = Number\ of\ parallel\ paths$$

The flux cut by conductor in one revolution is

$$\phi P = d\phi$$
$$Time\ for\ one\ revolution\ is = \frac{60}{N}$$

$$Time\ for\ one\ revolution\ is = \frac{60}{N}$$

The induced emf of in one conductor is

$$= \frac{d\phi}{dt} = \frac{\phi P}{60/N}$$
$$= \frac{\phi PN}{60} Time\ for\ one\ revolution\ is \quad = \frac{60}{N}$$

Induced emf per parallel path

$$= induced\ emf/\ conductor \times No.\ of\ conductor/path$$
$$= \frac{\phi PN}{60} \times \frac{Z}{A} = \frac{\phi ZPN}{60A}$$

For wave winding generator A = 2

$$E = \frac{\phi ZPN}{120}$$

0.2.4 Types of DC Generators:

Generators are classified based on the field winding excited. In general classified into two groups.

1. Separately Excited DC Generators:
2. Self Excited Field DC Generators:

Separately Excited DC Generators:

The separately excited dc generator is excited by a separate DC voltage source. When the current start flowing though field winding, which will creates magnetic flux. When the armature start moving it will cut the magnetic flux which will induce an EMF. When an external load is connected across the generator then the current I_L start flowing in the load. The detailed diagram of generator is as shown in Figure 3.

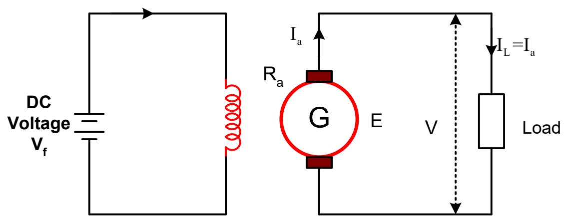

Figure 3

Self Excited DC Generators:

In this type of generator the magnetic field is produced by itself without external DC source. The emf produced by the generator is supplied to a field winding.

Self Excited DC Generators are classified as:

1. DC Shunt generator
2. DC Series generator
3. DC Compound generator.

DC Shunt generator

In this type of generator, shunt field winding is connected across the armature winding which are in parallel. The detailed diagram of shunt generator is as shown in Figure 4.

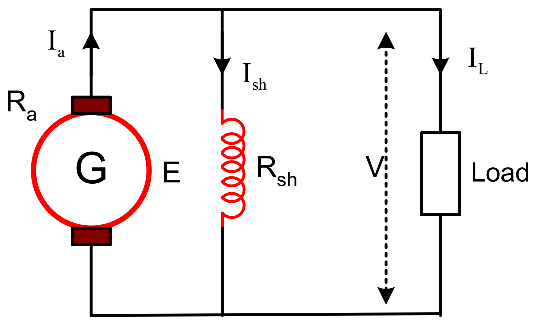

Figure 4

DC Series generator

In this type of generator, field winding is connected in series with the armature winding. The field winding is directly connected to the load, hence the current flowing in the load and field winding are same. The detailed diagram of shunt generator is as shown in Figure 5.

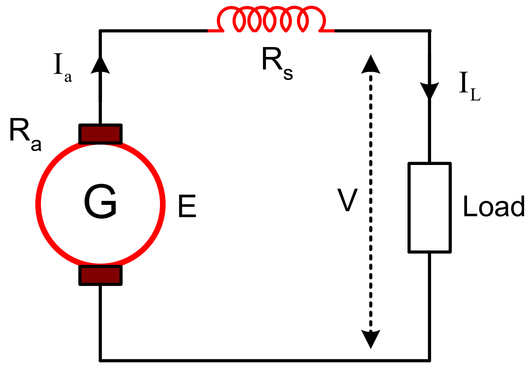

Figure 5

Compound generator:

Compound generator consists of shunt and series field winding for exciting DC generator. To carry the load, series field winding is made up of a few heavy turns of wire. The shunt field has many turns of fine wire and caries of a small current.

There are two types of Compound generators which are

1. Long shunt Compound Generator
2. Short Shunt Compound Generator

Long shunt Compound Generator

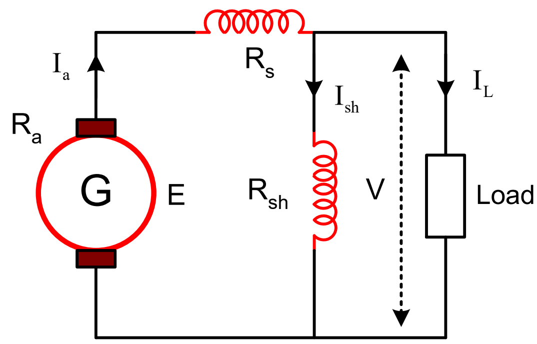

Figure 6

0.3 Problems on DC Generator

Model paper 1 8 c) A 4 pole lap wound DC shunt generator delivers 200 A at terminal voltage of 250 V. It has a field and armature resistance of 50 Ω and 0.05 Ω respectively. Neglecting brush drop determine i) armature current ii) current per parallel path iii) EMF generated iv) power delivered.

Solution:

i) armature current

$$I_{sh} = \frac{V}{R_{sh}} = \frac{250}{50}$$
$$= 5A$$

$$I_a = I_L + I_{sh} = 200 + 5$$
$$= 205A$$

ii) current per parallel path

$$= \frac{I_a}{4} = \frac{205}{4}$$
$$= 51.25A$$

iii) EMF generated

$$E_g = V + I_a R_a = 250 + 205 \times 0.05$$
$$= 260.25V$$

iv) power delivered

$$= E_g I_a = 260.25 \times 205$$
$$= 53.35kW$$

Model paper 2 8 c) A 30 kW 300 V DC shunt generator has a armature and field resistance of 0.05 Ω and 100 Ω respectively. Calculate the power delivered by the armature when it delivers full output power.

Solution:

$$I_L = \frac{P}{V} = \frac{30 \times 10^3}{300}$$
$$= 100A$$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{300}{100}$$
$$= 3A$$

$$Ia = I_L + I_{sh} = 100 + 3$$
$$= 103A$$

$$E_g = V + I_a R_a = 300 + 103 \times 0.05$$
$$= 305.15V$$

power delivered

$$= E_g I_a = 305.15 \times 103$$
$$= 31.43kW$$

Model paper 3 8 c) A 4 pole generator with wave wound armature has 51 slots each having 24 conductors rotate to give an induced emf of 220 V. What will be the voltage developed if the winding is lap and the armature rotates at the same speed

Solution:

$$\begin{aligned} E_g &= \frac{\phi Z N}{60} \times \frac{P}{A} \\ 220 &= \frac{0.01 \times 51 \times 24 \times N}{60} \times \frac{4}{2} \\ N &= 539.2156rpm \end{aligned}$$

Voltage developed with lap wound

$$\begin{aligned} E_g &= \frac{\phi Z N}{60} \times \frac{P}{A} \\ &= \frac{0.01 \times 51 \times 24 \times 539.215}{60} \times \frac{4}{4} \\ &= 110V \end{aligned}$$

2020 Jan 7 c) A shunt wound DC generator delivers 496 A at 440 V to load. The resistance of the shunt field coil is 110 Ω and that of armature winding is 0.02 ohm. Calculate the emf induced in the coil armature.

Solution:

$$\begin{aligned} E &= V - I_a R_a \\ &= 440 - 496 \times 0.02 \\ &= 440 - 9.92 \\ &= 430.08V \end{aligned}$$

Load at which the maximum efficiency is

$$\begin{aligned} I_a &= I_L + I_{sh} \\ &= 50\sqrt{\frac{400}{600}} \end{aligned}$$

2019 June 7 b) A 4 pole 230 V DC series wave connected armature with 1254 conductors with flux/pole of 22 mWb, takes 50A for motoring. The armature and series filed coil resistances are 0.3Ω and 0.2Ω respectively. Calculate the speed and torque developed in Watts.

Solution:

i) For lap wound connection. The emf generated in the armature is

$$\begin{aligned} E &= V + I_a(R_a + R_{sc}) \\ &= 230 + 50(0.3 + 0.2) \\ &= 255V \end{aligned}$$

$$\begin{aligned} E &= \frac{\phi ZN}{60} \times \frac{P}{A} \\ 255 &= \frac{22 \times 10^{-3} \times 1254 \times N}{60} \times \frac{4}{2} \\ N &= 277rpm \end{aligned}$$

$$\begin{aligned} T_a &= 0.159 \times \phi I_a Z \times \frac{P}{A} \\ &= 0.159 \times 22 \times 10^{-3} \times 50 \times 1254 \times \frac{4}{2} \\ &= 438.6Nm \end{aligned}$$

2019 June 8 b) A shunt generator has 4 pole with lap wound armature having 24 slots with 10 conductors/slot. If the flux/pole is 0.04 Wb and the speed is 1500 rpm, calculate the emf generated in the armature. What would be generated emf if the winding is wave connected?

Solution:

i) For lap wound connection. The emf generated in the armature is

$$\begin{aligned} E &= \frac{\phi ZNP}{60A} \\ &= \frac{0.04 \times (24 \times 10) \times 1500 \times 4}{60 \times 4} \\ &= 240 \end{aligned}$$

ii) For wave wound connection. The emf generated in the armature is

$$\begin{aligned} E &= \frac{\phi ZNP}{120} \\ &= \frac{0.04 \times (24 \times 10) \times 1500 \times 4}{120} \\ &= 480 \end{aligned}$$

2019 Jan 7 b) A 4 pole armature of dc generator has 624 lap connected conductors and is driven at 1200 rpm. Calculate the useful flux per pole required to generate an emf of 250 V.

Solution:

$$\begin{aligned} E &= \frac{\phi ZN}{60} \times \frac{P}{A} \\ \phi &= \frac{E60}{ZN}\frac{A}{P} \\ &= \frac{250 \times 60 \times 4}{624 \times 1200 \times 4} \\ &= 0.02wb \end{aligned}$$

2019 Jan 8 c) A shunt generator running at 500 rpm delivers 50 kW at 200 V. The armature and field resistances are 0.02 Ω and 40 Ω respectively. Calculate generated emf if brush drop of 1 V per brush.

Solution:

$$\begin{aligned} I_{sh} &= \frac{V}{R_{sh}} = \frac{200}{40} \\ &= 5A \\ I_L &= \frac{P}{V} = \frac{50 \times 10^3}{200} \\ &= 250A \\ I_a &= I_L + I_{sh} = 250 + 5 \\ &= 255A \end{aligned}$$

$$\begin{aligned} E &= V + I_a R_a + Brush\ drop \\ &= 200 + 255 \times 0.02 + 2 \\ &= 207.1V \end{aligned}$$

2019 Jan 4 c (17 scheme)) A 4 pole DC shunt generator with lap connected armature has field and armature resistances are 50 Ω and 0.1 Ω respectively. If the generator supplies sixty 100 V 40 W lamps calculate the total armature current, the current in each armature conductor and the generated EMF. Take 1 V per brush as contact drop.

Solution:

Power delivered is

$$\begin{aligned} P &= 60 \times 40 \\ &= 2400W \end{aligned}$$

$$\begin{aligned} I_{sh} &= \frac{V}{R_{sh}} = \frac{100}{50} \\ &= 2A \\ I_L &= \frac{P}{V} = \frac{2400}{100} \\ &= 24A \\ I_a &= I_L + I_{sh} = 24 + 2 \\ &= 26A \end{aligned}$$

Current in each conductor is

$$\frac{I_a}{A} = \frac{26}{4} = 6.5A$$

$$\begin{aligned} E_g &= V + I_aR_a + Brush\ drop \\ &= 100 + 26 \times 0.1 + 2 \\ &= 104.6V \end{aligned}$$

2019 Dec 4 b (17 scheme)) An 8 pole lap connected armature has 960 conductors, a flux of 40 mWb per pole and a speed of 400 rpm. Calculate the emf generated. If the armature were wave connected at what speed must it be driven to generate 400 V.

Solution:

$$\begin{aligned} E_g &= \frac{\phi ZN}{60} \times \frac{P}{A} \\ &= \frac{40 \times 10^{-3} \times 960 \times 400}{60} \times \frac{8}{8} \\ &= 256 \end{aligned}$$

When wave connected

$$\begin{aligned} E_g &= \frac{\phi ZNP}{120} \\ N &= \frac{120 \times E_g}{\phi ZP} \\ N &= \frac{120 \times 256}{40 \times 10^{-3} \times 960 \times 8} \\ &= 100\ rpm \end{aligned}$$

2019 Dec 4 b (17 scheme)) An 8 pole DC generator has 500 armature conductors, and useful flux/ple of 0.065Wb. What will be the emf generated if it is lap connected and runs at 1000 rpm. At what speed it must be driven to produce the same emf if it is wave connected.

Solution:

When lap connected:

$$\begin{aligned} E_g &= \frac{\phi ZNP}{60A} \\ &= \frac{0.065 \times 500 \times 1000 \times 8}{60 \times 8} \\ &= 541.67 \end{aligned}$$

When wave connected

$$\begin{aligned} E_g &= \frac{\phi ZNP}{120} \\ N &= \frac{120 \times E_g}{\phi ZP} \\ N &= \frac{120 \times 541.67}{0.065 \times 500 \times 8} \\ &= 250\ rpm \end{aligned}$$

2018 Dec 4 c (15 scheme)) An 8 pole lap connected armature has 40 slots with 12 conductors per slot, generate a voltage of 500 V. Determine the speed at which it is running if the flux pole is 50 mWb.

Solution:

When lap connected:

$$\begin{aligned} E_g &= \frac{\phi ZNP}{60A} \\ N &= \frac{60 \times A \times E_g}{\phi ZP} \\ &= \frac{60 \times 8 \times 500}{50 \times 10^{-3} \times 40 \times 12 \times 8} \\ &= 1250\ rpm \end{aligned}$$

2019 Dec 4 c (15 scheme)) A 4 pole 1500 rpm DC generator has lap wound armature having 24 slots with 10 conductors per slot. If the flux per pole is 0.04 wb. Calculate the emf generated in the armature. What would be the generated emf if the winding is wave connected.

Solution:

When lap connected:

$$\begin{aligned} E_g &= \frac{\phi ZNP}{60A} \\ &= \frac{0.04 \times 24 \times 10 \times 1500 \times 4}{60 \times 4} \\ &= 240V \end{aligned}$$

When wave connected

$$\begin{aligned} E_g &= \frac{\phi ZNP}{120} \\ &= \frac{0.04 \times 24 \times 10 \times 1500 \times 4}{60 \times 2} \\ &= 480V \end{aligned}$$

0.4 Module 4

0.5 DC Motors

0.5.1 Working principle of DC Motor

When the a current carrying coil is placed in a magnetic field, the coil experiences a mechanical force. The force exerted on the conductor is expressed as

$$F = BIlSin\theta$$

where,
I is the current through the coil
B is magnitude of flux density Wb/m^2
l is the length of the conductor
θ is the angle with respect to the direction of the magnetic field

0.5.2 Types of DC Motors:

DC Motors are classified based on the field winding excited. In general classified into two groups.

1. DC Shunt motor
2. DC Series motor.

DC Shunt motor:

In this motor the field winding is connected in parallel with armature. The total current supplied by supply voltage V is I_L. The current through the shunt field winding is I_{sh} and I_a is the armature current. The detailed diagram of DC Shunt motor is as shown in Figure 7.

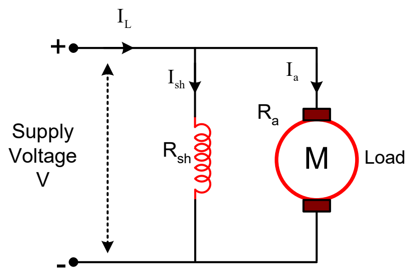

Figure 7: DC Shunt motor

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

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

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

where B.C.D is brush contact drop and A.R.D Armature reaction drop

DC Series motor:

In series motor the field winding is connected in series with armature. The current supplied by supply voltage V is I_L. The same current flows through the shunt field winding I_{se} and also its same as armature current I_a. The detailed diagram of DC series motor is as shown in Figure 8.

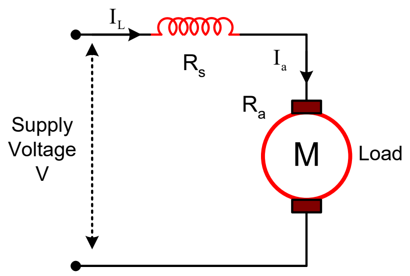

Figure 8: DC series motor

$$I_a = I_L = I_s$$

$$V = E_b + I_a(R_a + R_s) + B.C.D + A.R.D$$

where B.C.D is brush contact drop and A.R.D Armature reaction drop

0.5.3 Torque Equation

Consider

$$V = E_b + I_a R_a$$

Multiply both side by I_a

$$VI_a = E_b I_a + I_a^2 R_a$$

where $I_a^2 R_a$ is the power loss in the armature.
where $E_b I_a$ is the mechanical power developed in armature

Let T be the torque in Nw-m ω the angular velocity in radian per second, then

$$\omega T = E_b I_a$$
$$T = \frac{E_b I_a}{\omega}$$

The back emf is represented as

$$E_b = \frac{\phi ZNP}{60A}$$
$$\omega = \frac{2\pi PN}{60}$$

$$T = \frac{E_b I_a}{\omega} = \frac{\frac{\phi ZNP}{60A} I_a}{\frac{2\pi PN}{60}}$$
$$= \frac{1}{2\pi} \frac{PZ\phi I_a}{A}$$

Characteristics of DC Motors:

The important characteristic of DC Motors are

1. Torque Vs Armature current characteristic (Ta/Ia)
2. Speed Vs Armature current characteristic (N/Ia)
3. Speed Vs Torque characteristic (N/Ta)

DC Shunt Motor Characteristics:

1. **Torque Vs Armature current characteristic (Ta/Ia)**

   In a DC Motor T is

   $$T = \frac{1}{2\pi} \frac{PZ\phi I_a}{A}$$
   $$T \propto I_a$$

   Remaining $P,\ Z,\ A\ \phi$ are constant. From the above equation Torque T is proportional to armature current I_a.

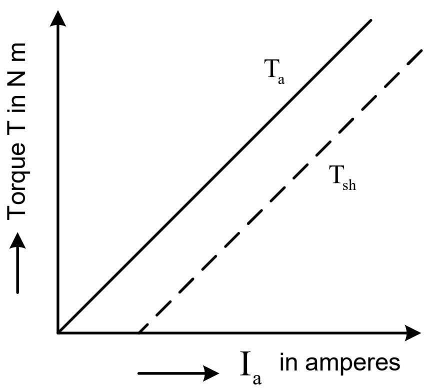

Figure 9: DC series motor

2. Speed Vs Armature current characteristic (N/Ia)

   In a DC Motor E_b is

   $$E_b = \frac{\phi ZNP}{60A}$$
   $$N \propto \frac{E_b}{\phi}$$

   Remaining $P,\ Z,\ A$ are constant, and also for DC shunt motor ϕ is constant.

   $$E_b = V - I_a R_a$$
   $$N \propto V - I_a R_a$$

   From the above equation as armature current I_a increases the voltage drop $I_a R_a$ increases and the speed decreases.

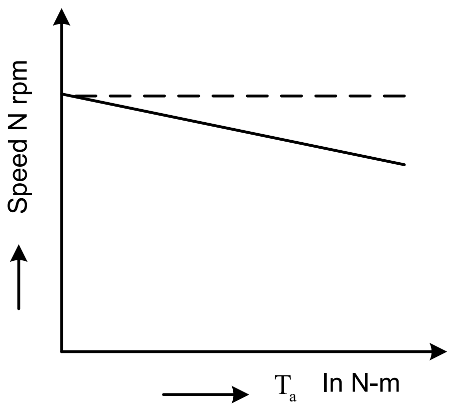

Figure 10: DC series motor

3. Speed Vs Torque characteristic (N/Ta)

   In a DC Motor T is

   $$T = \frac{1}{2\pi} \frac{PZ\phi I_a}{A}$$
   $$T \propto I_a$$

   Remaining $P,\ Z,\ A\ \phi$ are constant. From the above equation Torque T is proportional to armature current I_a.

   $$E_b = \frac{\phi ZNP}{60A}$$
   $$N \propto \frac{E_b}{\phi}$$

   Remaining $P,\ Z,\ A$ are constant, and also for DC shunt motor ϕ is constant.

   $$E_b = V - I_a R_a$$
   $$N \propto V - I_a R_a$$

   From the above equation as armature current I_a increases the voltage drop $I_a R_a$ increases and the speed decreases.

   $$N \propto T$$

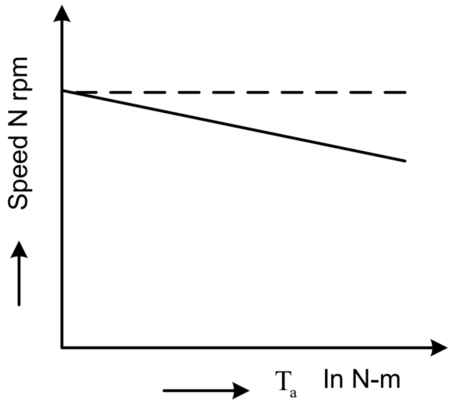

Figure 11: DC series motor

DC Series Motor Characteristics:

1. **Torque Vs Armature current characteristic (Ta/Ia)**

   In a DC Motor T is

$$T = \frac{1}{2\pi}\frac{PZ\phi I_a}{A}$$
$$T \propto \phi I_a$$

Remaining $P,\ Z,\ A\ \phi$ are constant.

$$\phi \propto I_a$$

$$T \propto I_a^2$$

After saturation the flux get constant and hence

$$T \propto I_a$$

Hence the curve is parabola is upto saturation point.

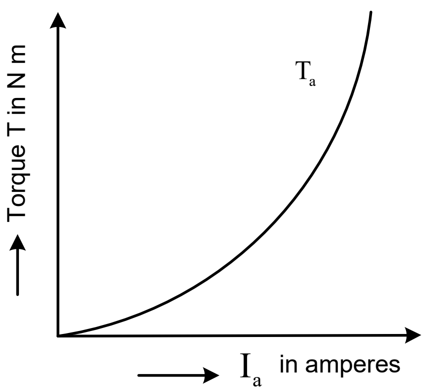

Figure 12: DC series motor

2. Speed Vs Armature current characteristic (N/Ia)

   In a DC Motor E_b is

$$E_b = \frac{\phi ZNP}{60A}$$
$$N \propto \frac{E_b}{\phi}$$

Remaining $P,\ Z,\ A$ are constant, and also for DC shunt motor ϕ is constant.

$$E_b = V - I_a(R_a + R_{se})$$
$$N \propto \frac{V - I_a(R_a + R_{se})}{\phi}$$

$$N \propto \frac{1}{\phi}$$

and

$$\phi \propto I_a$$

Hence

$$N \propto \frac{1}{I_a}$$

From the above equation it is observed that speed N is inversely proportional to armature current I_a .

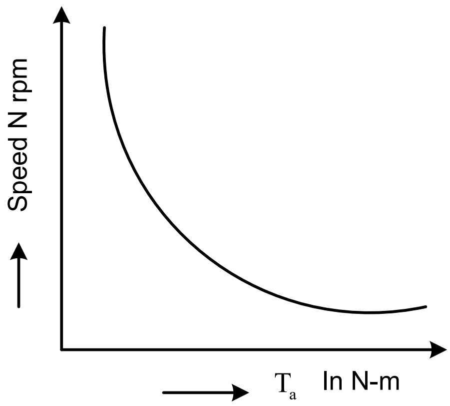

Figure 13: DC series motor

3. Speed Vs Torque characteristic (N/Ta)

   In a DC Motor T is

$$T = \frac{1}{2\pi}\frac{PZ\phi I_a}{A}$$
$$T \propto \phi I_a$$

Remaining $P,\ Z,\ A$ are constant.

Flux ϕ is proportional to armature current I_a. Hence

$$T \propto I_a^2$$

or

$$I_a \propto \sqrt{T}$$

or

$$N \propto \frac{1}{\sqrt{T}}$$

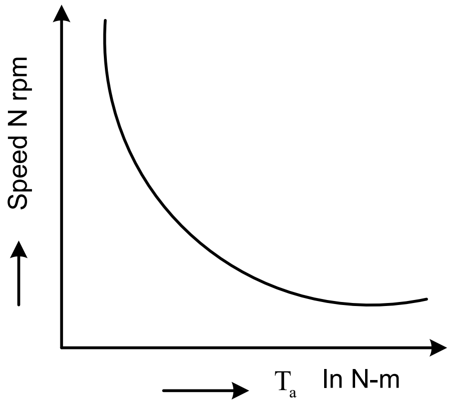

Figure 14: DC series motor

0.6 Problems on DC Motor

The field current in shunt DC machine is 2A and the line current is 20A at 200 V. Calculate the (i) generated emf when working as generator (ii) torque i N-m when running at 1500 rpm as motor. Take the armature resistance as 0.5 Ω.

Solution:

Armature current

$$I_a = I_L + I_{sh} = 20 + 2 = 22A$$

$$\begin{aligned} E_g &= V + I_a R_a \\ &= 200 + 822 \times 0.5 \\ &= 211V \end{aligned}$$

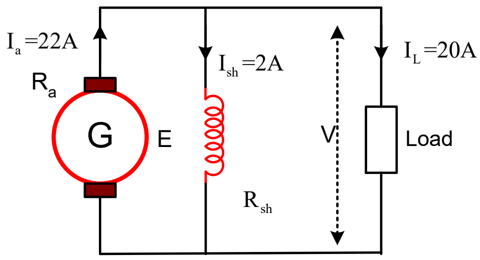

Figure 15

As a motor
Armature current

$$I_a = I_L - I_{sh} = 20 - 2 = 18A$$

$$\begin{aligned} E_b &= V - I_a R_a \\ &= 200 - 18 \times 0.5 \\ &= 191V \end{aligned}$$

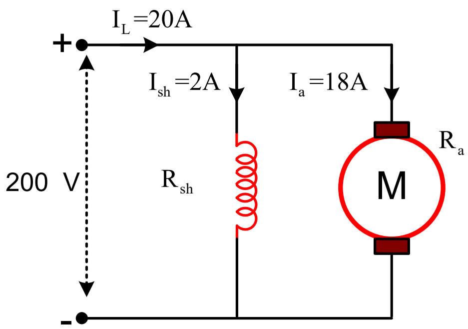

Figure 16

$$\begin{aligned} T &= \frac{1}{2\pi}\frac{E_b I_a}{N/60} \\ &= \frac{1}{2\pi}\frac{191 \times 18}{1500/60} \\ &= 21.9\ N - m \end{aligned}$$

A shunt DC machine connected to 250 V supply, has an armature resistance of 0.02 Ω and the field resistance of 100 Ω. Find the ratio of the speed of the machine as a generator to the speed as a motor, the line current in each case being 80 A.

Solution:

Shunt current

$$I_{sh} = \frac{V}{R_{sh}} = \frac{250}{100} = 2.5A$$

Armature current

$$I_a = I_L + I_{sh} = 80 + 2.5 = 82.5A$$

$$\begin{aligned} E_g &= V + I_a R_a \\ &= 250 + 82.5 \times 0.12 \\ &= 259.9V \end{aligned}$$

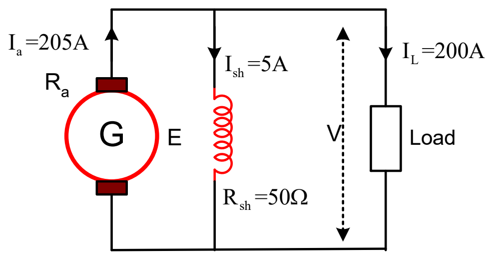

Figure 17

As a motor
Shunt current

$$I_{sh} = \frac{V}{R_{sh}} = \frac{250}{100} = 2.5A$$

Armature current

$$I_a = I_L - I_{sh} = 80 - 2.5 = 77.5A$$

$$\begin{aligned} E_b &= V - I_a R_a \\ &= 250 - 77.5 \times 0.12 \\ &= 240.7V \end{aligned}$$

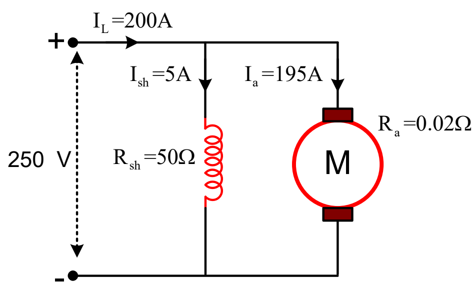

Figure 18

$$\frac{N_g}{N_m} = \frac{E_g}{E_m} = \frac{259.9}{240.7} = 1.08$$

3 c) A shunt generator delivers 50 kW at 250 V and runs at 400 rpm. The armature and field resistances are 0.02 Ω and 50 Ω respectively. Calculate the speed of the machine running as a shunt motor and taking 50 kW input at 250 V. Allow 1 V per brush for contact drop.

Solution:

$$I_L = \frac{P}{V} = \frac{50 \times 10^3}{250} = 200A$$

Shunt current

$$I_{sh} = \frac{V}{R_{sh}} = \frac{250}{50} = 5A$$

Armature current

$$I_a = I_L + I_{sh} = 200 + 5 = 205A$$

$$\begin{aligned} E_g &= V + I_a R_a + drops \\ &= 250 + 205 \times 0.02 + 2 \times 1 \\ &= 256.1V \end{aligned}$$

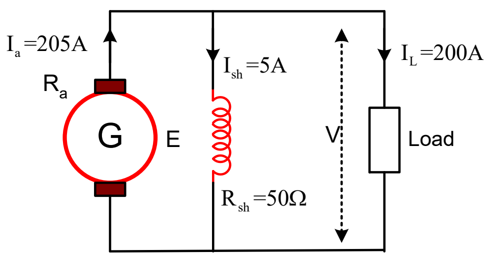

Figure 19

As a motor

$$I_L = \frac{P}{V} = \frac{50 \times 10^3}{250} = 200A$$

Shunt current

$$I_{sh} = \frac{V}{R_{sh}} = \frac{250}{50} = 5A$$

Armature current

$$I_a = I_L - I_{sh} = 200 - 5 = 195A$$

$$\begin{aligned} E_b &= V - I_a R_a \\ &= 250 - 195 \times 0.02 - 2 \times 1 \\ &= 244.1V \end{aligned}$$

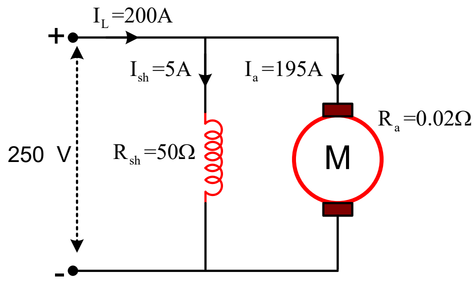

Figure 20

$$\begin{aligned} \frac{N_g}{N_m} &= \frac{E_g}{E_m} \\ N_m &= \frac{E_m}{E_g} N_g = \frac{244.1}{256.1} \times 400 \\ &= 381.26\ rpm \end{aligned}$$

2015-Jan 4 c) A 4 pole DC shunt motor takes 22 A from 220 V supply. The armature and field resistances are 0.5 Ω and 100 Ω respectively. The armature is lap connected with 200 conductors. If the flux per pole 20 mWb, Calculate the speed and gross torque.

Solution:

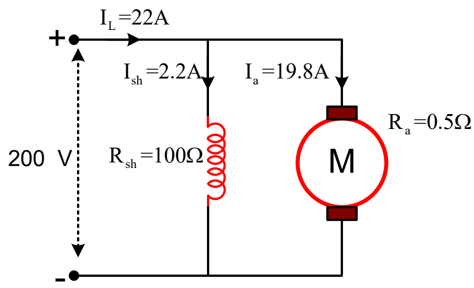

Figure 21

Shunt current

$$I_{sh} = \frac{V}{R_{sh}} = \frac{220}{100} = 2.2A$$

Armature current

$$I_a = I_L - I_{sh} = 22 - 2.2 = 19.8A$$

$$E_b = V - I_a R_a = 220 - 19.8 \times 0.5 = 210.1V$$

$$\begin{aligned} E_b &= \frac{\phi ZNP}{60A} \\ N &= \frac{E_b 60A}{\phi ZP} \\ &= \frac{210.1 \times 60 \times 4}{20 \times 10^{-3} \times 300 \times 4} \\ &= 525.25\ rpm \end{aligned}$$

$$\begin{aligned} T &= \frac{1}{2\pi}\frac{\phi ZPI_a}{A} \\ &= \frac{1}{2\pi}\frac{20\times10^{-3}\times300\times19.8\times4}{4} \\ &= 18.89\ N-m \end{aligned}$$

2015-Jan 4 c) A 200 V lap wound DC shunt motor has 800 conductors on its armature. The resistance of the armature winding is 0.5 Ω and that of field winding is 200 Ω. The motor takes a current of 21 A, the flux per pole is 30 mWb. Find the speed and torque developed in the motor.

Solution:

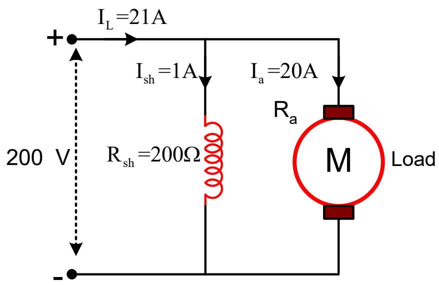

Figure 22

Shunt current

$$I_{sh} = \frac{V}{R_{sh}} = \frac{200}{200} = 1A$$

Armature current

$$I_a = I_L - I_{sh} = 21 - 1 = 20A$$

$$E_b = V - I_aR_a = 200 - 20\times0.5 = 190V$$

$$\begin{aligned} E_b &= \frac{\phi ZNP}{60A} \\ N &= \frac{E_b60A}{\phi ZP} \\ &= \frac{190\times60\times4}{30\times10^{-3}\times800\times4} \\ &= 475rpm \end{aligned}$$

$$\begin{aligned} T &= \frac{1}{2\pi}\frac{\phi ZPI_a}{A} \\ &= \frac{1}{2\pi}\frac{30\times10^{-3}\times800\times20\times4}{4} \\ &= 76.32\ N-m \end{aligned}$$

A 220 V series motor is taking a current of 40 amperes. The resistance of armature is 0.5 Ω and resistance of series field is 0.25 Ω. Calculate: i) voltage at the brushes ii) back emf iii) power wasted in armature iv) power wasted in field.

Solution:

i) voltage at the brushes

$$\begin{aligned} &= V - I(R_a) \\ &= 220 - 40(0.25) \\ &= 210V \end{aligned}$$

ii) back emf

$$\begin{aligned} E_b &= V - I(R_a + R_s) \\ &= 220 - 40(0.25 + 0.5) \\ &= 190V \end{aligned}$$

iii) power wasted in armature

$$\begin{aligned} &= I^2 \times R_a \\ &= 40^2 \times 0.5 \\ &= 800W \end{aligned}$$

iv) power wasted in field.

$$\begin{aligned} &= I^2 \times R_a \\ &= 40^2 \times 0.25 \\ &= 400W \end{aligned}$$

2020 Jan 8 b) A 6 pole lap connected DC series motor with 864 conductors, takes a current of 110 A at 480V. The armature resistance and field resistance are 0.18 Ω and 0.02 Ω respectively. The flux per pole is 50 mwb. Calculate: i) The speed ii) The gross torque.

Solution:

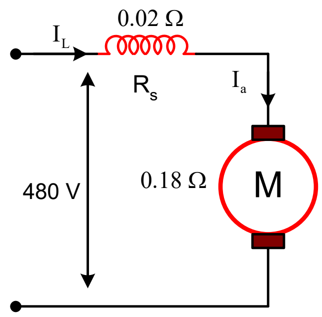

Figure 23

$$\begin{aligned} E_b &= V - I_a(R_a + R_s) \\ &= 480 - 110(0.18 + 0.02) \\ &= 458V \end{aligned}$$

$$\begin{aligned} E_b &= \frac{\phi ZNP}{60A} \\ N &= \frac{E_b60A}{\phi ZP} \\ &= \frac{458\times60\times6}{50\times10^{-3}\times864\times6} \\ &= 636\ rpm \end{aligned}$$

$$
\begin{aligned}
P &= E_b I_a = 458 \times 110 \\
&= 50380\ W
\end{aligned}
$$

$$
\begin{aligned}
T &= \frac{1}{2\pi}\frac{PZ\phi I_a}{A} \\
&= \frac{1}{2\pi}\frac{6 \times 864 \times 50 \times 10^{-3} \times 110}{6} \\
&= 7560.3\ N-m
\end{aligned}
$$

2019 June 7 b) A 4 pole 230 V DC series wave connected armature with 1254 conductors with flux/pole of 22 mWb, takes 50A for motoring. The armature and series filed coil resistances are 0.3Ω and 0.2Ω respectively. Calculate the speed and torque developed in Watts.

Solution:

i) For lap wound connection. The emf generated in the armature is

$$
\begin{aligned}
E &= V + I_a(R_a + R_{sc}) \\
&= 230 + 50(0.3 + 0.2) \\
&= 255V
\end{aligned}
$$

$$
\begin{aligned}
E &= \frac{\phi ZNP}{60A} \\
N &= \frac{E60A}{\phi ZNP60A} \\
&= \frac{E60A}{\phi ZNP60A} \\
255 &= \frac{22 \times 10^{-3} \times 1254 \times N}{60} \times \frac{4}{2} \\
N &= 277rpm
\end{aligned}
$$

$$
\begin{aligned}
T_a &= 0.159 \times \phi I_a Z \times \frac{P}{A} \\
&= 0.159 \times 22 \times 10^{-3} \times 50 \times 1254 \times \frac{4}{2} \\
&= 438.6Nm
\end{aligned}
$$

2019 Jan 7 c) A four pole motor is fed at 440 V and takes an armature current of 50 A. The resistance of the armature circuit is 0.28 Ω. The armature winding is wave connected with 888 conductors and useful flux per poer is 0.023 wb. Calculate the back emf and speed.

Solution:

$$
\begin{aligned}
E_b &= V - I_a(R_a + R_s) \\
&= 440 - 50(0.28) \\
&= 426V
\end{aligned}
$$

$$
\begin{aligned}
E_b &= \frac{\phi ZNP}{60A} \\
N &= \frac{E_b 60A}{\phi ZP} \\
&= \frac{426 \times 60 \times 4}{0.023 \times 888 \times 4} \\
&= 1251.46\ rpm
\end{aligned}
$$

2019 June 7 b) A 4 pole 230 V DC series wave connected armature with 1254 conductors, with flux per pole of 22 mWb, takes 50 A for motoring. The armature and series field coil resistances are 0.3 Ω and 0.2 Ω respectively. Calculate the speed and torque developed in watts.

Solution:

$$
\begin{aligned}
E_b &= V - I_a(R_a + R_s) \\
&= 230 - 50(0.3 + 0.2) \\
&= 205V
\end{aligned}
$$

$$
\begin{aligned}
E_b &= \frac{\phi ZNP}{60A} \\
N &= \frac{E_b 60A}{\phi ZP} \\
&= \frac{205 \times 60 \times 2}{22 \times 10^{-3} \times 1254 \times 4} \\
&= 223\ rpm
\end{aligned}
$$

$$
\begin{aligned}
T &= \frac{1}{2\pi}\frac{PZ\phi I_a}{A} \\
&= \frac{1}{2\pi}\frac{4 \times 1254 \times 50 \times 10^{-3} \times 50}{2} \\
&= 997.9\ N-m
\end{aligned}
$$

2019 Jan 4 b (17 scheme)) A 4 pole DC shunt motor takes 22A from 220 supply. The armature and field resistances are 0.5Ω and 100 Ω respectively. The armature is lap connected with 300 conductors. If the flux per pole is 20 mWb. Calculate i) speed ii) Torque

Solution:

$$
\begin{aligned}
E_b &= V - I_a(R_a) \\
&= 220 - 22(0.5) \\
&= 209V
\end{aligned}
$$

$$
\begin{aligned}
E_b &= \frac{\phi ZNP}{60A} \\
N &= \frac{E_b 60A}{\phi ZP} \\
&= \frac{209 \times 60 \times 4}{20 \times 10^{-3} \times 300 \times 4} \\
&= 2090\ rpm
\end{aligned}
$$

$$
\begin{aligned}
T &= \frac{1}{2\pi}\frac{PZ\phi I_a}{A} \\
&= \frac{1}{2\pi}\frac{4 \times 300 \times 20 \times 10^{-3} \times 22}{4} \\
&= 21\ N-m
\end{aligned}
$$

2019 June 4 b (17 scheme)) A 4 pole 220 V lap connected DC shunt motor has 36 slot, each slot containing 16 conductors. If draws a current of 40 A from supply. The armature and field resistances are 0.5Ω and 100 Ω respectively. The armature is with 300 conductors. If the flux per pole is 20 mWb. Calculate i) speed ii) Torque

Solution:

$$
\begin{aligned}
E_g &= \frac{\phi ZN}{60} \times \frac{P}{A} \\
&= \frac{40 \times 10^{-3} \times 960 \times 400}{60} \times \frac{8}{8} \\
&= 256
\end{aligned}
$$

When wave connected

$$
\begin{aligned}
E_g &= \frac{\phi ZNP}{120} \\
N &= \frac{120 \times E_g}{\phi ZP} \\
N &= \frac{120 \times 256}{40 \times 10^{-3} \times 960 \times 8} \\
&= 100\ rpm
\end{aligned}
$$

2019 Dec 4 b (17 scheme)) An 8 pole DC generator has 500 armature conductors, and useful flux/ple of 0.065Wb. What will be the emf generated if it is lap connected and runs at 1000 rpm. At what speed it must be driven to produce the same emf if it is wave connected.

Solution:

When lap connected:

$$
\begin{aligned}
E_g &= \frac{\phi ZNP}{60A} \\
&= \frac{0.065 \times 500 \times 1000 \times 8}{60 \times 8} \\
&= 541.67
\end{aligned}
$$

When wave connected

$$
\begin{aligned}
E_g &= \frac{\phi ZNP}{120} \\
N &= \frac{120 \times E_g}{\phi ZP} \\
N &= \frac{120 \times 541.67}{0.065 \times 500 \times 8} \\
&= 250\ rpm
\end{aligned}
$$

2018 Dec 4 c (15 scheme)) An 8 pole lap connected armature has 40 slots with 12 conductors per slot, generate a voltage of 500 V. Determine the speed at which it is running if the flux pole is 50 mWb.

Solution:

When lap connected:

$$
\begin{aligned}
E_g &= \frac{\phi ZNP}{60A} \\
N &= \frac{60 \times A \times E_g}{\phi ZP} \\
&= \frac{60 \times 8 \times 500}{50 \times 10^{-3} \times 40 \times 12 \times 8} \\
&= 1250\ rpm
\end{aligned}
$$

2019 Dec 4 c (15 scheme)) A 4 pole 1500 rpm DC generator has lap wound armature having 24 slots with 10 conductors per slot. If the flux per pole is 0.04 wb. Calculate the emf generated in the armature. What would be the generated emf if the winding is wave connected.

Solution:

When lap connected:

$$
\begin{aligned}
E_g &= \frac{\phi ZNP}{60A} \\
&= \frac{0.04 \times 24 \times 10 \times 1500 \times 4}{60 \times 4} \\
&= 240V
\end{aligned}
$$

When wave connected

$$
\begin{aligned}
E_g &= \frac{\phi ZNP}{120} \\
&= \frac{0.04 \times 24 \times 10 \times 1500 \times 4}{60 \times 2} \\
&= 480V
\end{aligned}
$$