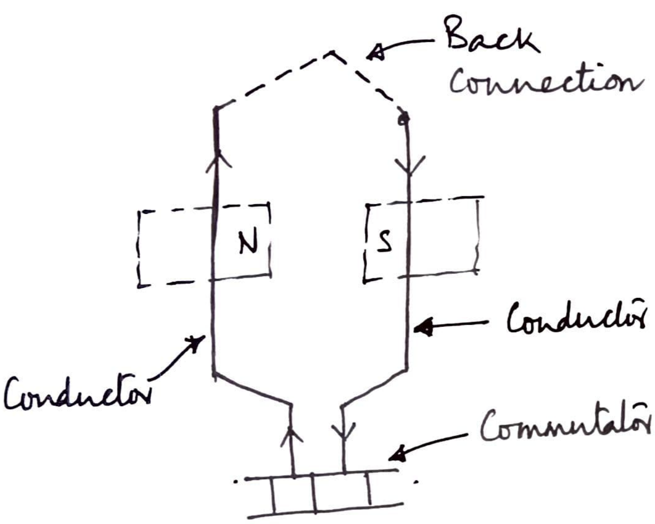
Armature winding of DC m/c

* A dc machine generally employs winding distributed in slots over the circumference of the armature core. (the rotor). Each conductor lies at right angles to the magnetic flux and to the direction of its movement. Thus the induced emf in the conductor is given by

$$e = Blv \text{ volts}$$

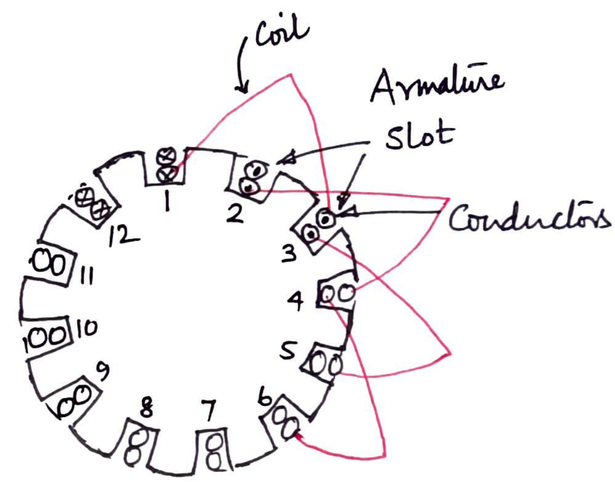
where B = magnetic flux density in Wb/m^2
l = length of the conductor in meter.
v = velocity (in m/s) of the conductor.

The armature conductors are connected to form coils.



Single-turn coil

1 coil = 2 conductors

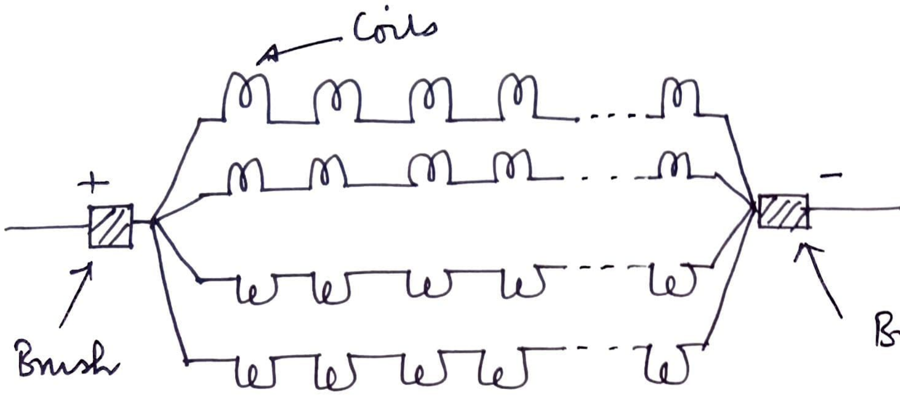


* Two types of armature windings are (a) Lap wdg
(b) Wave wdg.

The different armature coils in a dc armature winding must be connected in series with each other by means of end connections in a manner so that the generated voltages of the respective coils will aid each other in the production of the terminal emf of the winding.

e.g.

For a dc m/c with 4 poles we can configure the following ckts by connecting conductors.



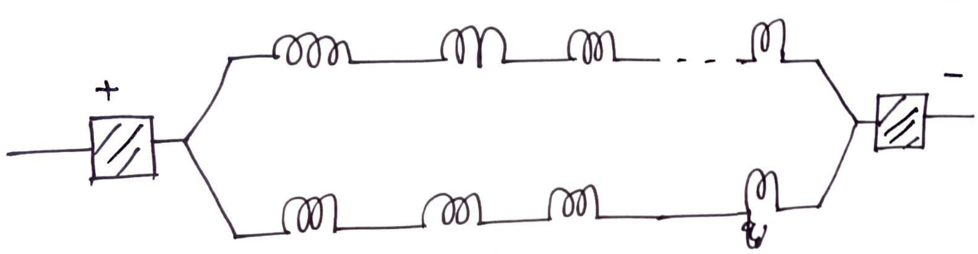
For the 4-pole m/c we are configuring 4 parallel paths

$A = 4$

So for lap winding connection, the no of parallel paths = no of poles $\boxed{A = P}$

No of conductors/path $= \frac{Z}{P}$

Z = total conductors



Here we are configuring 2 parallel paths only by using all conductors

So, for wave winding connection, the no of parallel paths = 2 (always) $\boxed{A = 2}$

* EMF generated = EMF per parallel path
  = average emf per conductor $\times \frac{Z}{P}$

* Total armature current, $I_a = P \times$ current per parallel path

* Armature resistance : R_a (total)

$$R_a = \frac{\rho l Z}{a A^2}$$

ρ : resistivity

l : length of cond.

a : x-sectional area.

Z : no of cond

A : no of parallel paths

$A = P$ for lap wdg

$= 2$ for wave wdg

EMF equation :-

Let ϕ = flux/pole in Wb.

N = speed of armature in rpm.

Flux cut by one conductor in one revolution of the armature

$$d\phi = P\phi \text{ webers.}$$

Time taken to complete one revolution

$$dt = \frac{60}{N} \text{ second.}$$

$$\text{emf generated/conductor} = \frac{d\phi}{dt} = \frac{P\phi}{60/N} = \frac{P\phi N}{60} \ (V)$$

emf generated, E_g = emf per parallel path

= (emf/conductor) × No of conductors in series per parallel path

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

$$\therefore \boxed{E_g = \frac{P\phi Z N}{60A}}$$

where A = 2 for wave wdg

A = P for lap wdg.

If a dc m/c works like a generator then it generates E_g and called generated emf. But if it works like a motor then it is called back emf (E_b).

Here, for a given DC m/c, P, Z and A are const.

$$\therefore E_g \propto \phi N$$

Ex. A 6-pole lap wound dc generator has 600 conductors on its armature. The flux per pole is 0.02 Wb. Calculate (i) the speed at which the generator must be run to generate 300 V (ii) What would be the speed if the generator were wave wound?

Sol^n (i) Lap wound : $E_g = \dfrac{P \phi Z N}{60A}$

$$\Rightarrow N = \frac{E_g \times 60A}{P \phi Z}$$

$$= \frac{300 \times 60 \times 6}{6 \times 0.02 \times 600}$$

$$= 1500 \text{ rpm}$$

(ii) Wave wound : $N = \dfrac{300 \times 60 \times 2}{6 \times 0.02 \times 600}$

$$= 500 \text{ rpm}$$

Ex. An 8-pole, lap wound armature rotated at 350 rpm is required to generate 260V. The useful flux per pole is 0.05 Wb. If the armature has 120 slots, calculate the number of conductors per slot.

Sol^n. $E_g = \dfrac{P \phi Z N}{60A} \Rightarrow Z = \dfrac{E_g \times 60A}{P \phi N} = \dfrac{260 \times 60 \times 8}{8 \times 0.05 \times 350} = 890$

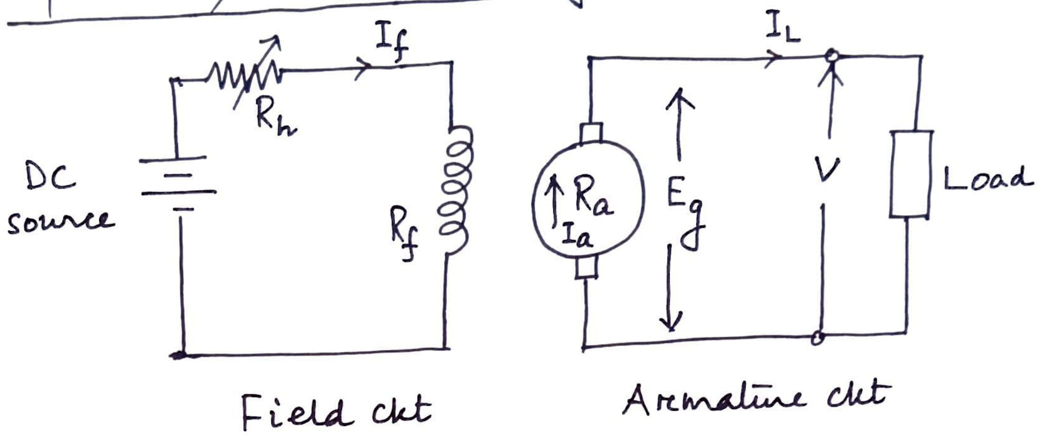
No of conductors/slot $= \dfrac{890}{120} = 7.41 \approx 8$ (value must be an even no)

Ex. The armature of a 6-pole, 600 rpm lap-wound generator has 90 slots. If each coil has 4 turns, calculate the flux per pole required to generate an emf of 288 volts.

Sol^n. $\phi = 0.04$ Wb.

Equivalent circuit diagram

1. Separately excited DC generator



R_f = field wdg resistance
R_h = variable resistance.
I_f = field current
R_a = armature resistance.
I_a = armature current
E_g = generated emf
I_L = load current
V = terminal voltage of the generator.

Here, $I_a = I_L$

$$V = E_g - I_a R_a$$

Electric power developed $= E_g I_a$

Power delivered to the load $= E_g I_a - I_a^2 R_a$

$$= (E_g - I_a R_a) I_a = V I_a = V I_L$$

The field magnet wdg is excited by an independent external DC source separately.

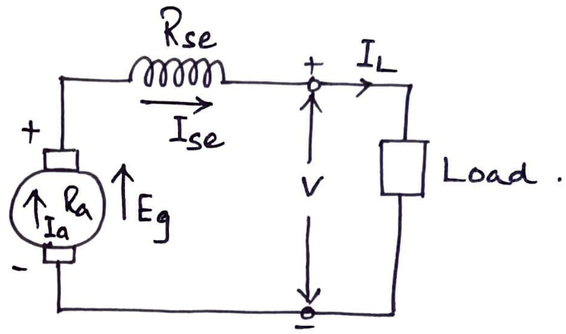
The voltage output depends upon the speed of the rotation of armature and field current.

2. Self-excited DC generator

A dc generator whose field magnet winding is supplied current from the output of the generator itself is called a self-excited generator.

Three types of self-excited DC generators are (a) Series generator (b) Shunt generator (c) Compound gen.

(a) Series generator



R_{se} = series field wdg

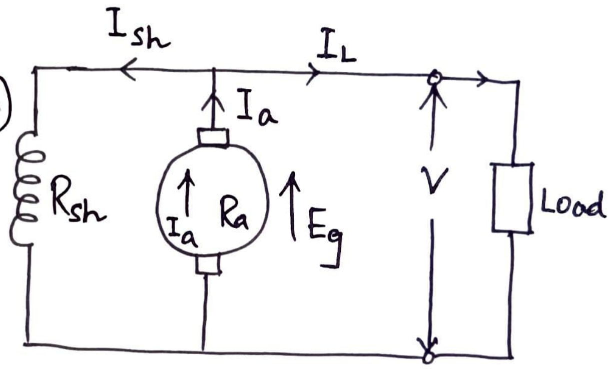
$I_a = I_{se} = I_L = I$ (say)

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

$P_a = E_g I_a$

$P_L = E_g I_a - I_a^2(R_a + R_{se}) = V I_a = V I_L$

(b) Shunt generator



R_{sh} = shunt field resistance (high)

I_{sh} = shunt field current

$= \dfrac{V}{R_{sh}}$

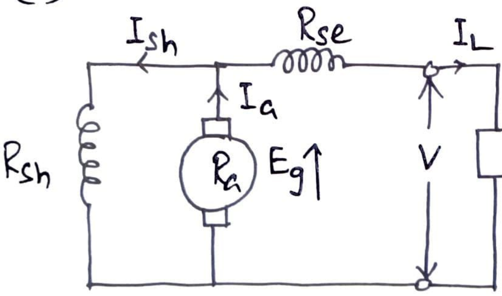
$I_a = I_{sh} + I_L$

$V = E_g - I_a R_a$

$P_a = E_g I_a$ & $P_L = V I_L$

(c) Compound generator

(i) Short shunt



(ii) Long shunt