Simplex lap winding :-

(i) The total no. of brushes is equal to the total no. of poles.

(ii) The no. of parallel paths is equal to the no. of poles.

(iii) The e.m.f. between the positive and negative brushes is equal to the e.m.f. generated in any one of the parallel paths.

Simplex wave winding :-

(i) Only two brushes are necessary.

(ii) The no. of parallel paths is equal to two.

(iii) The generator e.m.f. is equal to the e.m.f. induced in any one of the two parallel paths.

* E.m.f. equation of a d.c. generator :-

Let, P = No. of poles

ϕ = Flux per pole in Wb.

N = Speed of rotation in r.p.m.

Z = Total no. of armature conductors

A = No. of parallel paths in armature

(= 2 for wave winding and

= P for lap winding).

Time taken by the armature for one revolution

$= \frac{1}{N}$ minute $= \frac{60}{N}$ sec.

Hence, the time taken by each armature conductor to move through one pole pitch,

$$t = \frac{60}{N} \times \frac{1}{P} \text{ sec.}$$

During this period, the conductor cuts all the flux ϕ produced by the pole and the average e.m.f. induced per conductor $= \frac{\phi}{t}$ volts

$$= \frac{\phi}{60} \times NP \text{ volts.}$$

1. The e.m.f. of the D.c. generator, (iii)

$E_1 =$ (e.m.f. induced per conductor) $\times$ (No. of conductors per parallel path)

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

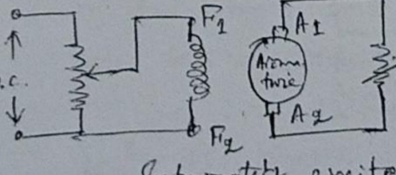
$$\therefore \boxed{E_1 = \frac{\phi Z N P}{A \times 60} \text{ volts.}}$$

Types of generators:-

Generators are usually classified according to the way in which their fields are excited.
(1) Separately excited generators and (2) Self excited generators.

(1) In Separately excited generators, the field winding is connected to an independent source of d.c. supply of suitable voltage and power capacity. This method of excitation is not commonly used, as it involves an additional d.c. source.

(2) Self-excited generators are those whose field magnets are energised by the currents produced by the generators themselves.



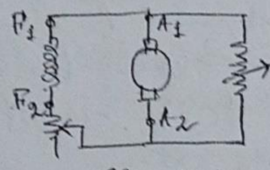
Separately excited generator.

There are three types of self-excited generators—
(i) Shunt wound (ii) Series wound (iii) Compound wound.

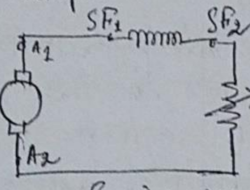
(i) Shunt wound:- The field circuit is connected in parallel with the armature and the external load circuit, so the field current is supplied by the armature. In order to reduce the power loss ~~(ii) Series wound:-~~ in the field circuit, the shunt field consists of large no. of turns of small cross section. Thus, it has a high field resistance and reduced field loss.

(ii) <u>Series wound</u>:— The field windings are connected in series with the armature and the load circuit and hence, they carry the load current. Therefore, the conductors of field windings must be of large cross-section with lesser no. of turns. Series field resistance becomes very low.

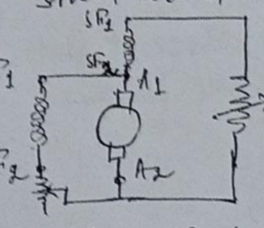
(iii) <u>Compound wound</u>:— The generator is provided with both series field as well as shunt field and can be either short shunt or long shunt. In a compound generator, the shunt field is stronger than series field. When series field aids the shunt field, generator is said to be cumulatively compounded. On the other hand, if series field opposes the shunt field, the generator is said to be differentially compounded.



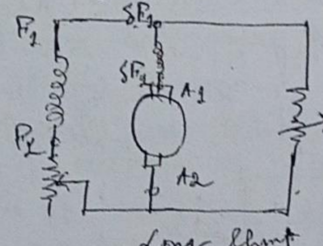
Shunt wound



Series wound



Short shunt



Long shunt

<u>Losses in d.c. generator</u>:—

The various losses occurring in a d.c. generator can be subdivided as follows—

(1) <u>Copper losses</u>:— Copper losses are—

(i) Armature copper loss $= I_a^2 R_a$ where,

R_a = resistance of armature winding.

This loss is about 30 to 40% of full load losses.

(ii) <u>Field copper loss</u>:— In the case of shunt generators, it is practically constant and equal to $I_{sh}^2 R_{sh}$ (or VI_{sh}). In the case of series generator, it is equal to $I_{se}^2 R_{se}$ where, R_{se} = the resistance of the series field windings.

This loss is about 20 to 30% of full load losses.

(ii) The loss due to brush contact resistance. It is usually included in the armature copper loss.

(2) Magnetic losses (also known as iron or core losses) :-

(i) Hysteresis loss, $W_h \propto B_{max}^{1.6} f$ and

(ii) Eddy current loss, $W_e \propto B_{max}^2 f^2$.

These losses are practically constant for shunt and compound wound generators, because field current is approximately constant.

Both these losses total up to about 20 to 30% of full load losses.

(3) Mechanical losses :- These consist of —

(i) friction loss at bearings and commutators

(ii) air friction or windage loss of rotating armature.

These are about 10 to 20% of full load losses.

Stray losses :- Usually, magnetic and mechanical losses are collectively known as stray losses. These are also known as rotational losses.

Constant losses :- Field cu-loss is constant for shunt and compound generators. Hence, stray losses and shunt cu-loss are constant in their case. These losses are together known as Constant losses (W_c).

Hence, for shunt and compound generators,

Total loss = Armature cu-loss + W_c

$= I_a^2 R_a + W_c = (I + I_{sh})^2 R_a + W_c$.

$I_a^2 R_a$ is known as Variable loss.

∴ Total loss = variable loss + constant losses, W_c.

Efficiency :- *

(i) Mechanical efficiency, $\eta_m = \dfrac{\text{Electrical power developed}}{\text{Mechanical power input}}$

$= \dfrac{E_g I_a}{\text{Mechanical power input}}$

(ii) Electrical efficiency, $\eta_e = \dfrac{\text{Electrical power output}}{\text{Electrical power developed}} = \dfrac{VI}{E_g I_a}$.

(iii) Overall or Commercial efficiency,

$\eta_c = \dfrac{\text{Electrical power output}}{\text{Mechanical power input}} = \dfrac{VI}{\text{Mechanical power input}}$

$\therefore$ Overall efficiency, $\eta = \eta_m \times \eta_e$.

In case of a generator,

electrical power developed, P_e = Mechanical power input, P_i — mechanical losses — Core losses.

= Electrical power output, P_o + Ohmic losses.

In case of a motor,

mechanical power developed, P_m

= Electrical power input, P_i — Ohmic losses.

Mechanical power output, P_o

= Mechanical power developed, P_m — Mechanical losses — Core losses.

Maximum efficiency :-

Let, generator output = VI.

generator input = output + losses

$$= VI + I_a^2 R_a + W_c$$

$$= VI + (I + I_{sh})^2 R_a + W_c.$$

If I_{sh} is negligible as compared to load current, then $I_a = I$ (approx).

$$\therefore \eta = \frac{\text{output}}{\text{input}} = \frac{VI}{VI + I_a^2 R_a + W_c}$$

$$= \frac{VI}{VI + I^2 R_a + W_c} = \frac{1}{1 + \left(\frac{IR_a}{V} + \frac{W_c}{VI}\right)}.$$

Efficiency is maximum when denominator is minimum.

i.e., when $\frac{d}{dI}\left[\frac{IR_a}{V} + \frac{W_c}{VI}\right] = 0$

$$\Rightarrow \frac{R_a}{V} - \frac{W_c}{VI^2} = 0$$

$$\Rightarrow I^2 R_a = W_c.$$

Generator efficiency is maximum when variable loss = constant loss.

$\therefore$ Load current corresponding to maximum efficiency is given by $I^2 R_a = W_c \Rightarrow I = \sqrt{\frac{W_c}{R_a}}$.