A.C. Generator/Alternator/Synchronous Generator

* Rotating machines that rotate at a speed fixed by the supply frequency and the number of poles are called synchronous machines.
* In a synchronous machine, the stator carries the armature winding and rotor carries the field winding. The field winding is excited by DC to produce flux in the air gap. It means it is doubly excited machine.
* Alternator is a machine for converting mechanical power from a prime mover to a.c. electric power at a specified voltage and frequency. It rotates at a constant speed called as synchronous speed.
* Synchronous generators are usually of 3-phase type beca-use of the several advantages are used to generate bulk po-wer at thermal, hydro and nuclear power stations.

Speed and Frequency

* One complete cycle of voltage is gererated in an armature coil when a pair of field poles passes over the coil.

$$\frac{N}{60} = n \qquad \frac{P}{2} = p$$

Where, P = total number of field poles.
p = pair of field poles.
N = speed of field poles in r.p.m.
n = speed of field poles in r.p.s.
f = frequency of the generated voltage in Hz.

If, p = number of cycles per revolution
n = Number of revolutions per second.

$$\text{Frequency} = \frac{\text{number of cycles}}{\text{revolutions}} \times \frac{\text{revolutions}}{\text{seconds}}$$

$$f = p \times n \qquad f = \frac{PN}{120}$$

Synchronous Speed

$$N_s = \frac{120f}{p}$$

Number of poles	Synchronous speed N_s in r.p.m.
2	3000
4	1500
6	1000
8	750
10	600
12	500

Stator

* The stator is the stationary part of the machine. It carries the armature winding in which the voltage is generated.
* The rotor produces the main field flux.
* Salient-pole alternators have a large number of poles and operate at lower speed. Salient-pole generator has comparatively a large diameter and a short axial length.
* Non-salient pole rotor machine (cylindrical rotor machine) has its rotor so constructed that it forms smooth cylinder. It has relatively long but small diameter rotor and is used to limit centrifugal forces developed.

ENTRI

* Smooth rotor of a machine makes less windage losses and the operation is less noisy because of uniform air gap.

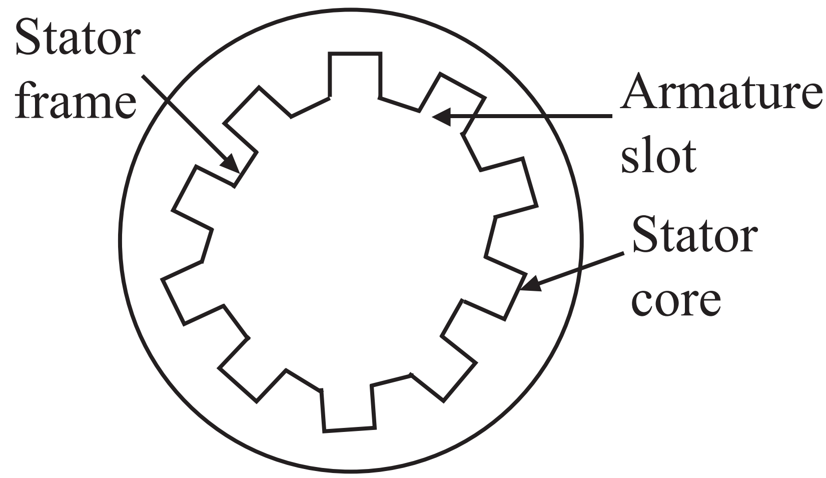


Figure : Alternator stator

E.M.F. Equation of an Alternator

Average value of generated voltage per conductor

$$= \frac{\text{flux cut per revolution in Wb}}{\text{time taken for one revolution in seconds}}$$

E_{av} /conductor = $2f\phi$

E_{av} /phase = $2f\phi Z_p$ $\qquad$ $E_p = 4.44\, f\phi T_p$

ϕ = useful flux per pole in weber (Wb)

P = total number of poles

Z_p = total number of conductors or coil sides in series per phase.

T_p = Total number of coils or turns per phase.

n = Speed of rotation of rotor in revolution per second (r.p.s.)

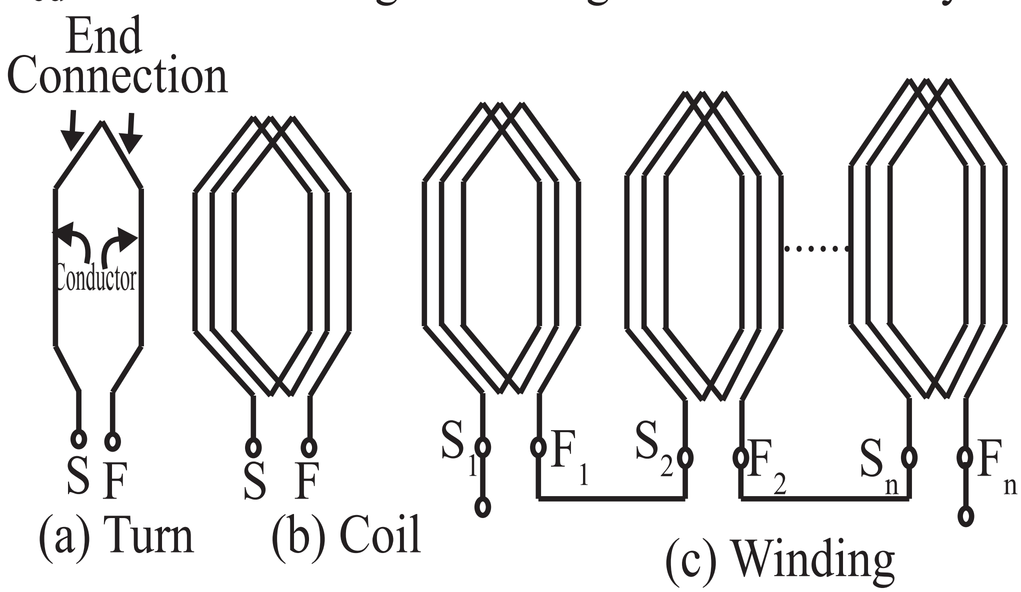
f = frequency of generated voltage (Hz)

Armature Winding

$$\theta_{ed} = \frac{P}{2}\theta_{md}$$

where, θ_{md} = mechanical degrees or angular measure in space.

θ_{ed} = electrical degrees or angular measure in cycles.



$$\text{One pole pitch} = 180^0_{ed} = \frac{360^0_{md}}{P}$$

Chording factor,

$$K_C = \frac{\text{actual voltage generation in the coil}}{\text{voltage generation in the coil of span } 180^0 \text{ electrical}}$$

$$K_C = \cos\frac{\alpha}{2}$$

For full-pitch coil, $\alpha = 0^0$ and $K_C = 1$

For short pitch coil $K_C < 1$.

. Advantages of short pitching (chording)

(i) Shortens the ends of the winding saving in the conductor material.

(ii) Reduces effect of distorting , waveform of the generated voltage is improved sine wave.

Distribution Factor (Breadth factor), k_d

$$k_d = \frac{\text{phasor of coil voltages per phase}}{\text{arithmetic sum of coil voltages per phase}}$$

m = slots per pole per phase, that is slots per phase belt.

$$m = \frac{\text{slots}}{\text{poles} \times \text{phases}}$$

β = angular displacement between ajdacent slots in electrical degrees

$$\beta = \frac{180^o}{\text{slots} \times \text{pole}} = \frac{180^o \times \text{poles}}{\text{slots}}$$

$$k_d = \frac{\sin m\beta/2}{m \sin\beta/2}$$

Actual generated voltage per phase

$$E_p = 4.44\, k_c k_d f\phi T_p$$

Effective turns per phase $T_{ep} = k_c k_d T_p$

Winding factor, $k_w = k_c k_d$

Voltage Regulation

* In case of a synchronous generator, it is the rise in voltage at the terminals when the load is reduced from full-load rated value to zero, speed and field current remaining constant.
* Voltage regulation depends upon the power factor of the load.

Per unit voltage regulation $= \frac{|E_a| - |V|}{|V|}$

Percent voltage regulation $= \frac{|E_a| - |V|}{|V|} \times 100$

where, $E_a|$ = magnitude of generated voltage per phase

$|V|$ magnitude of rated terminal voltage per phase.