SNS COLLEGE OF TECHNOLOGY

(An Autonomous Institution)

COIMBATORE-35

Accredited by NBA-AICTE and Accredited by NAAC – UGC with A+ Grade
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

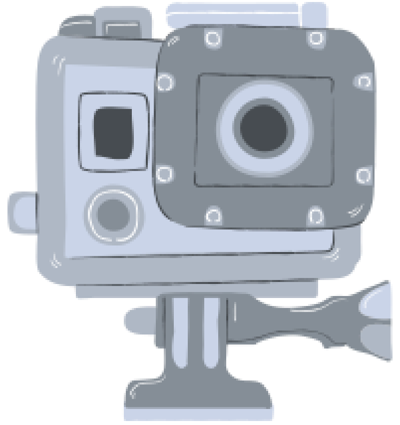
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE NAME: 19EET207/ SYNCHRONOUS AND INDUCTION MACHINES

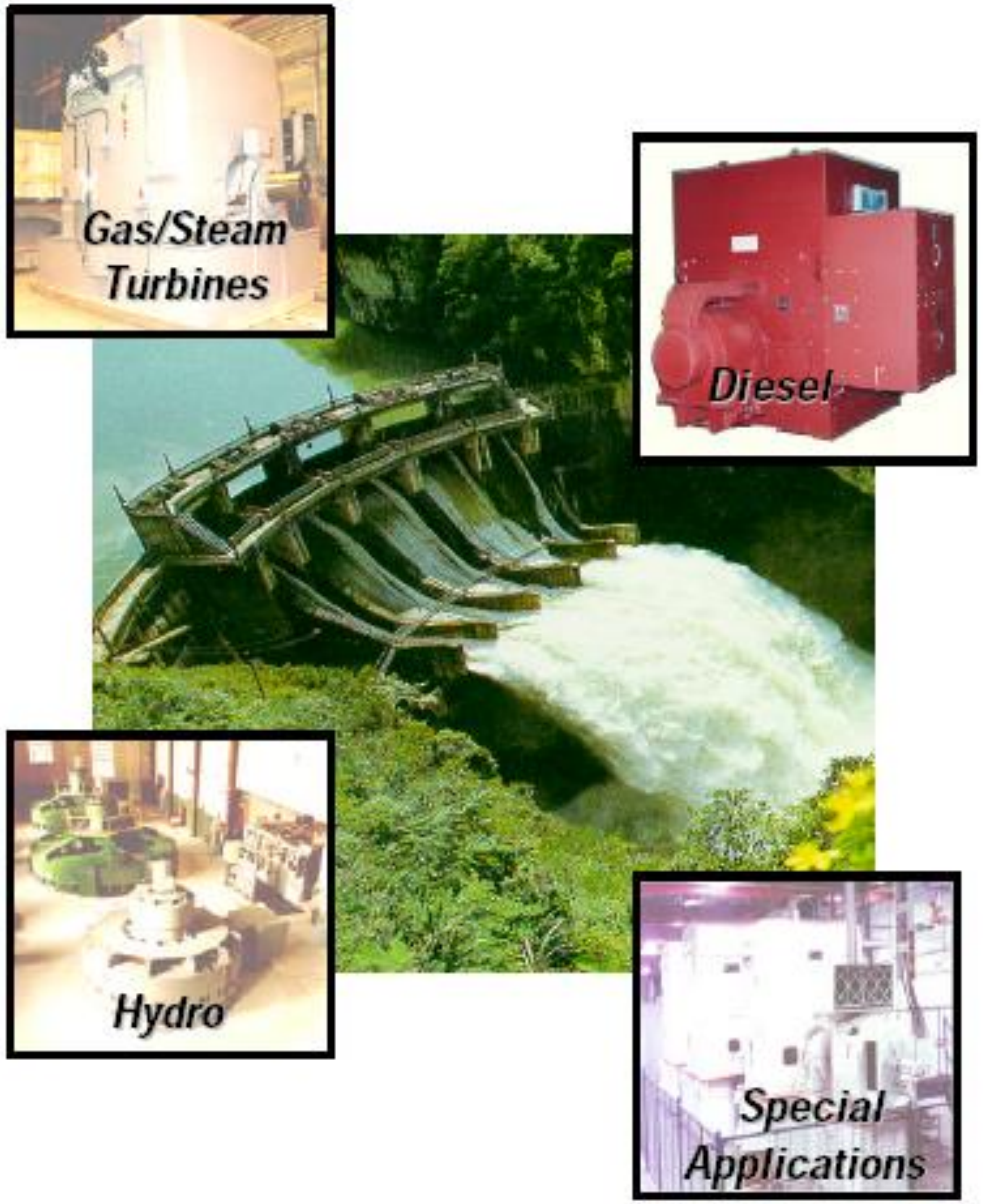
II YEAR / IV SEMESTER

Unit 1 – SYNCHRONOUS GENERATOR

TOPIC 2: EMF EQUATION



GUESS THE TOPIC NAME…



Synchronous Generators

AC Machines

Synchronous Machines

Synchronous Generator

A primary source of **electrical energy**

Synchronous Motor

Used as motors as well as **power factor compensators** (synchronous condensers)

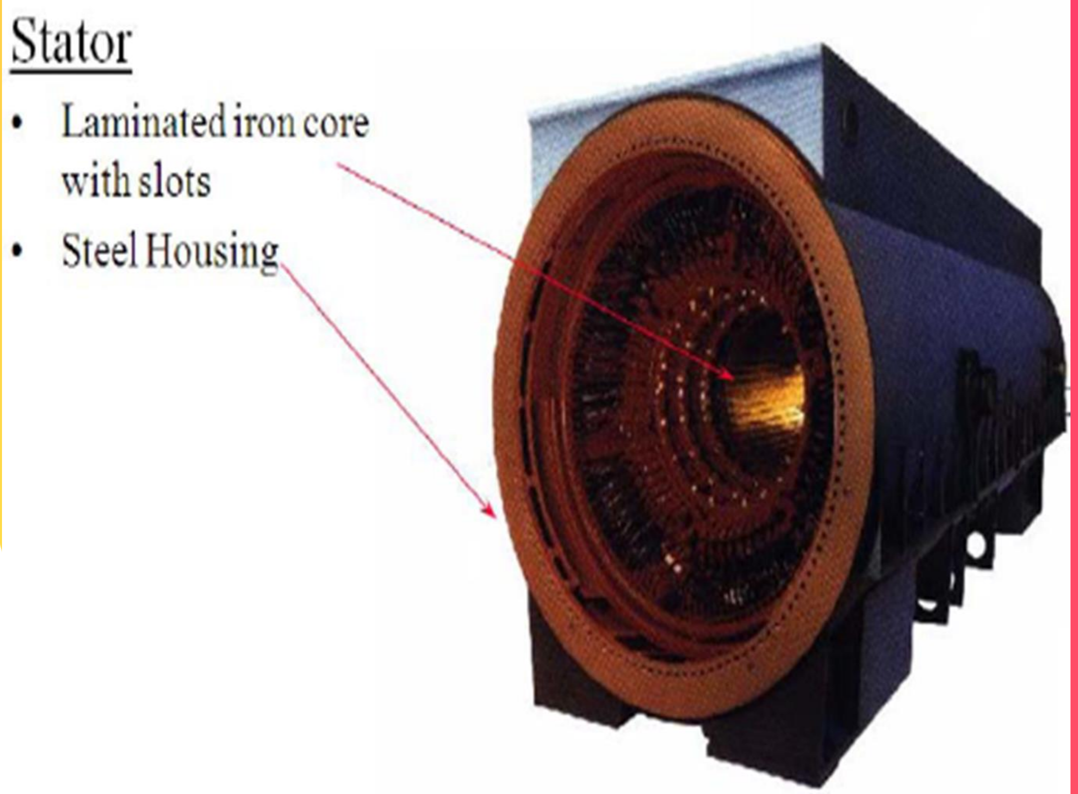
Asynchronous Machines (Induction Machine)

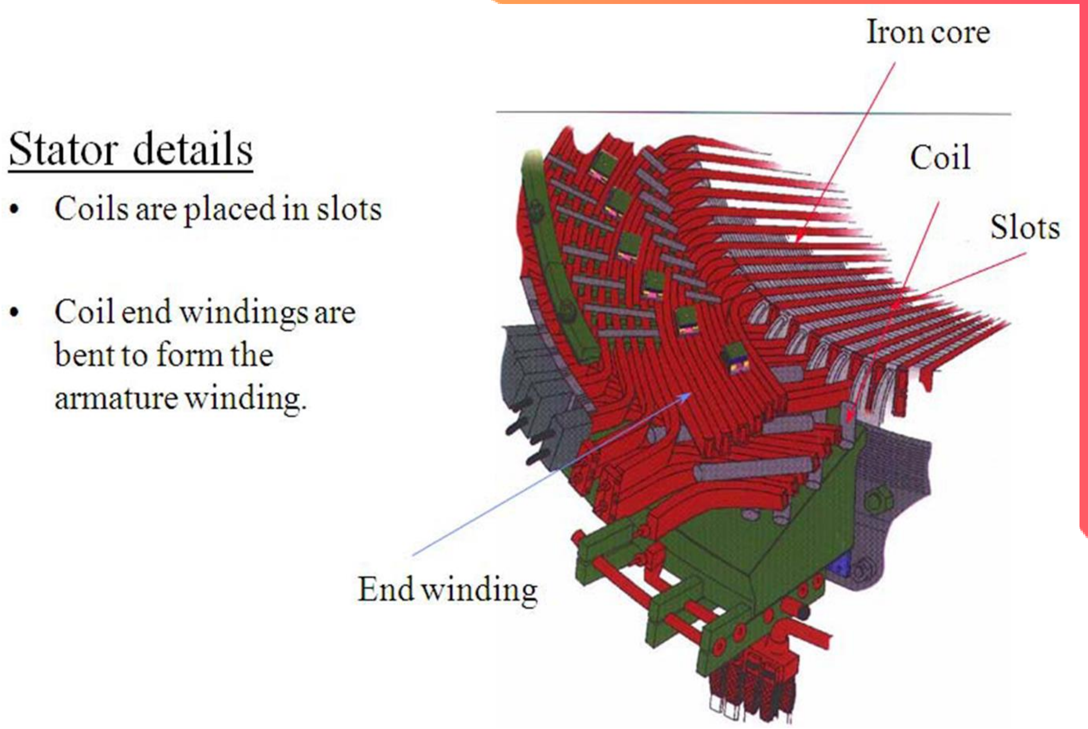
Induction Generator

Due to lack of a separate field excitation, these machines are rarely used as generators.

Induction Motor

Most **widely used electrical motors** in both domestic and industrial applications





Synchronous Generator: Classifications

Types of Synchronous Machine

According to the arrangement of the field and armature windings, synchronous machines may be classified as

- Stationary Armature - Rotating Field (Above 5 kVA)
- Stationary Field – Rotating Armature (Below 5 kVA)

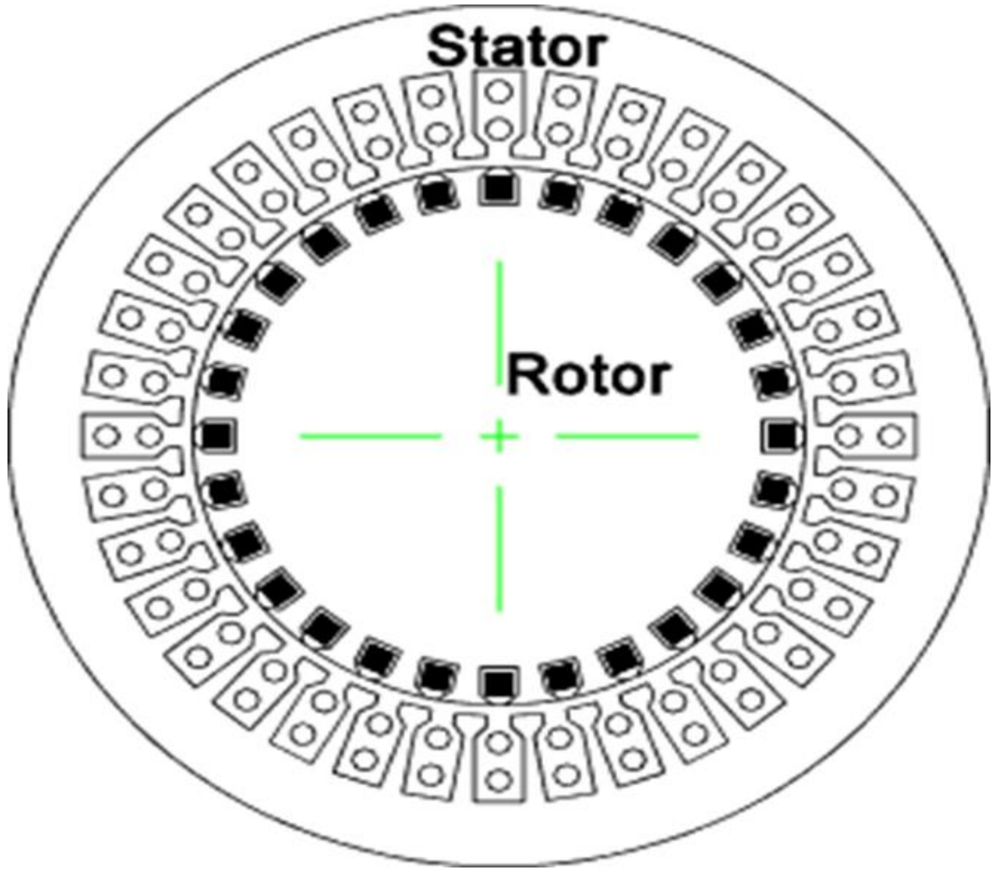
Advantages of stationary armature - rotating field:

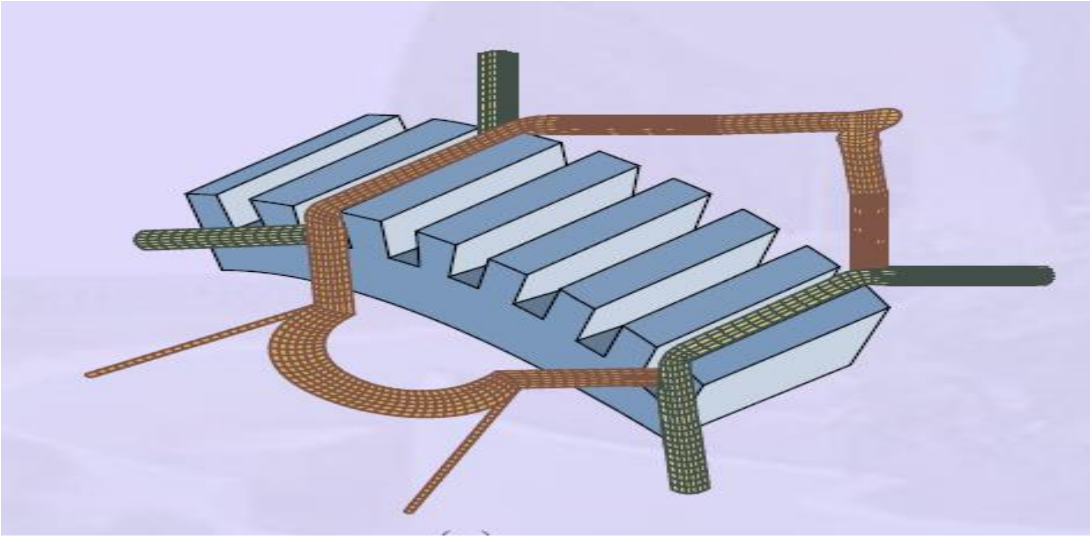
i) The High Voltage ac winding and its insulation not subjected to centrifugal forces.(11kV - 33 kV) (BETTER INSULATION)
ii) Easier to collect large currents from a stationary member.
iii) Rotating field makes overall construction simple.
iv) Problem of sparking at the slip ring can be avoided.
v) Ventilation arrangement for HV can be Improved.
vi) The LV(110 V – 220V) dc excitation easily supplied through slip rings and brushes to the rotor field winding.
vii) Noiseless running is possible.
viii) Air gap length is uniform
ix) Better mechanical balancing of rotor

Synchronous Generator

Stationary Armature - Rotating Field

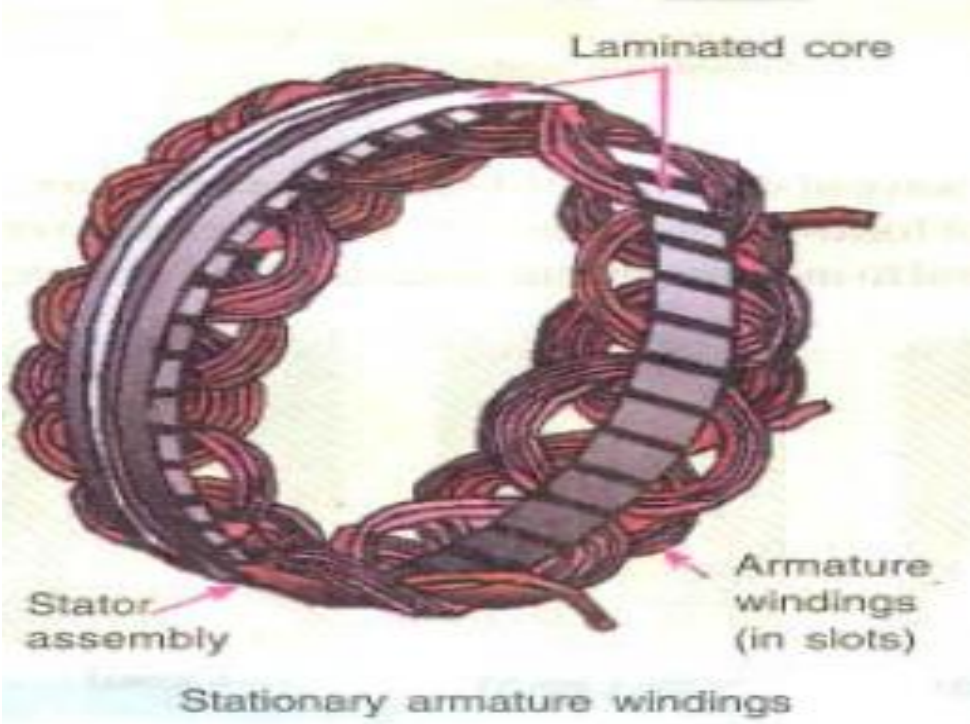
An alternator has 3 phase winding on the stator and DC field winding on the rotor.





STATOR

Stationary part of the machine.
It is built up of Sheet-Steel Lamination Core (Stampings) with slots to hold the armature Conductor

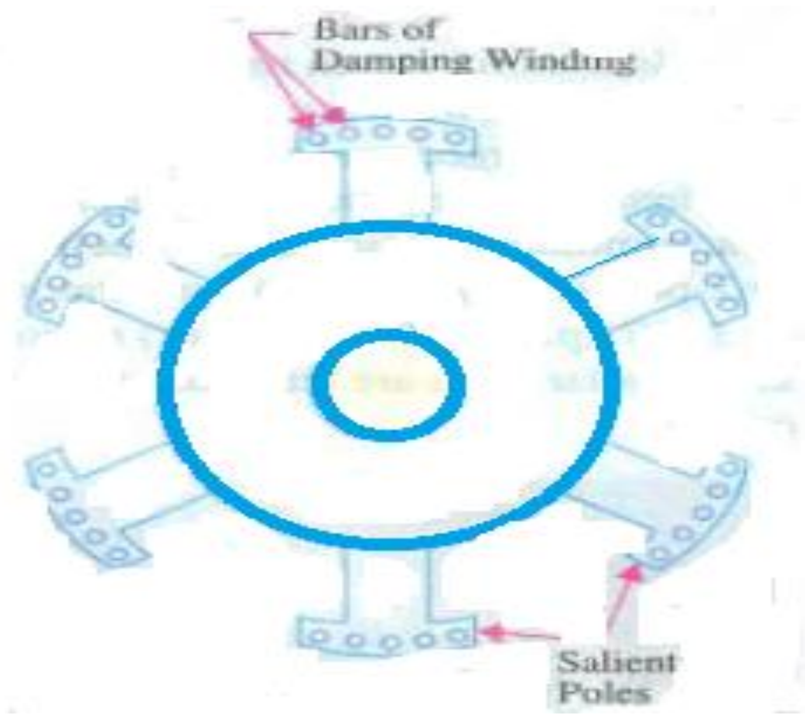


Rotors

ROTOR:

There are two types of rotor

i) Salient Pole type {Projected Poles}
ii) Non - Salient Pole type {Non – Projected Poles}
Smooth Cylindrical Type



DAMPER WINDING

- Pole faces are provided with damper winding
- Damper winding is useful in preventing Hunting
- EMF generated will be sinusoidal
- Copper Bar

Rotors

ROTOR:

There are two types of rotor

II) NON SALIENT POLE TYPE

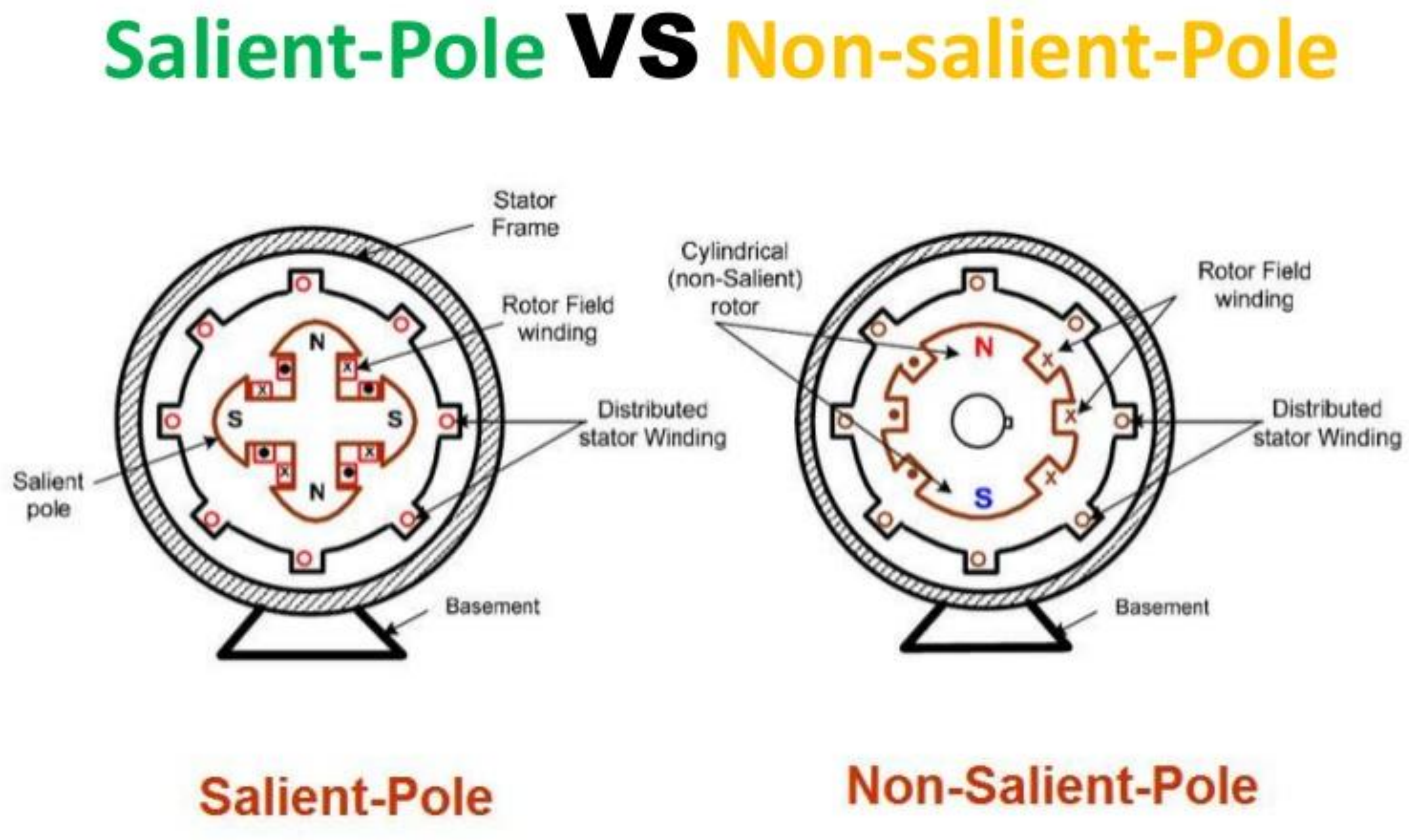
Smooth cylindrical rotor or TURBO ALTERNATOR field winding used in high speed alternators driven by steam turbines .

Features

Smaller diameter and larger axial length compared to salient pole type machines, of the same rating.

Less Windage loss.

Speed 1200 RPM to 3000 RPM.. Better Balancing..

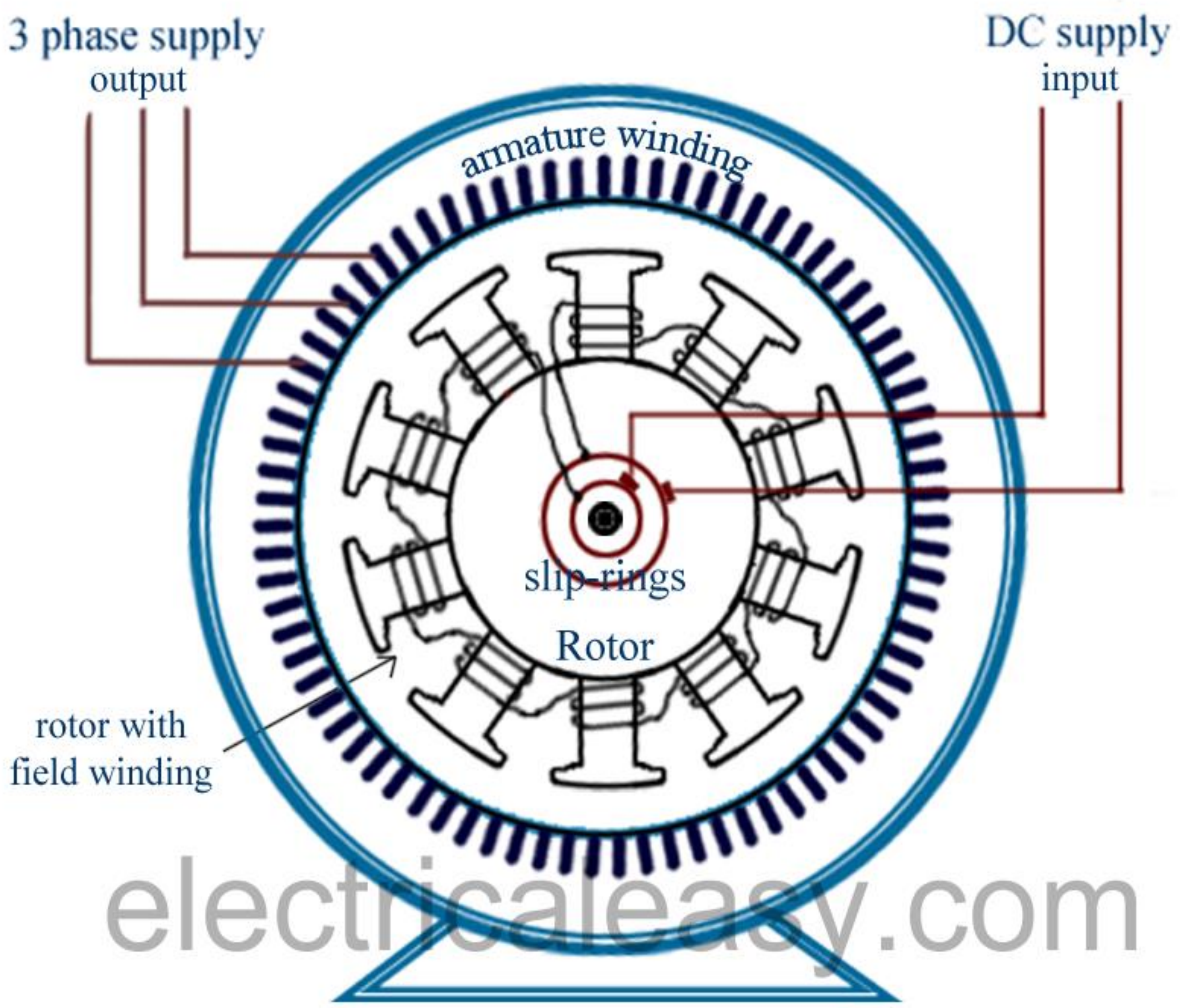


Working Principle

The rotor of the generator is driven by a prime-mover

A dc current is flowing in the rotor winding which produces a rotating magnetic field within the machine

The rotating magnetic field induces a three-phase voltage in the stator winding of the generator



EMF Equation of an Alternator

Let

Φ = Flux per pole, Wb

P = Number of Poles

Ns = Synchronous Speed in RMP

Z = Total Number of Conductors or coil sides in series / Phase

Z = 2T

T = Number of coils or Turns per phase

Tph = Turns in series per phase

= (No. of slots * No. of cond. per slot) / (2 x 3)

Zph = Conductor per phase

Zph = Z / 3. No. of phase 3

Kc or Kp = Pitch factor or coil span factor

Kd = Distribution factor

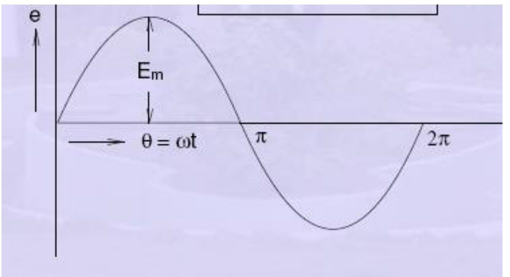
Kp = Cos (α / 2)

$$K_d = \frac{\sin(m\beta/2)}{m \sin(\beta/2)}$$

Consider single conductor placed in a Slot

Average E.M.F. induced in a conductor $e_{avg} = \frac{\text{Flux cut in one revolution}}{\text{Time taken for one revolution}}$

Average E.M.F. induced in a conductor $= \frac{d\phi}{dt}$



Total Flux cut in one revolution $(d\Phi) = \Phi P$

Time taken for one revolution (dt) $= \frac{60}{Ns}$ Seconds

Average E.M.F. induced in a conductor $= \frac{d\phi}{dt} = \frac{\phi P}{60/Ns}$

$$= \frac{\phi P N s}{60}$$

We know that $f = \frac{PNs}{120}$ OR $Ns = \frac{120 f}{P}$

$$= \frac{\phi P \, 120 f}{60 \, P}$$

$$= 2f\phi \text{ Volts}$$

If there are Z conductors connected / phase, then

Average E.M.F. / Phase = 2f Ø Z volts

We know that Z = 2T

Average E.M.F. / Phase = 2f Ø 2T volts

= 4f Ø T volts

$$\text{Form factor} = \frac{\text{RMS Value}}{\text{Average value}}$$

RMS value of E.M.F. / Phase = 1.11 x 4f Ø T volts

RMS value of E.M.F. / Phase = 4.44 f Ø T volts

EMF_{RMS} = 4.44f Ø T

RMS = Form factor x Average Value

= 1.11x Average Value

The above equation is true only if the winding is concentrated in one slot.
The winding for each phase under each pole is Distributed so we have to consider Kp and Kd

Actual available Voltage / Phase = 4.44 f Ø T Kp Kd volts

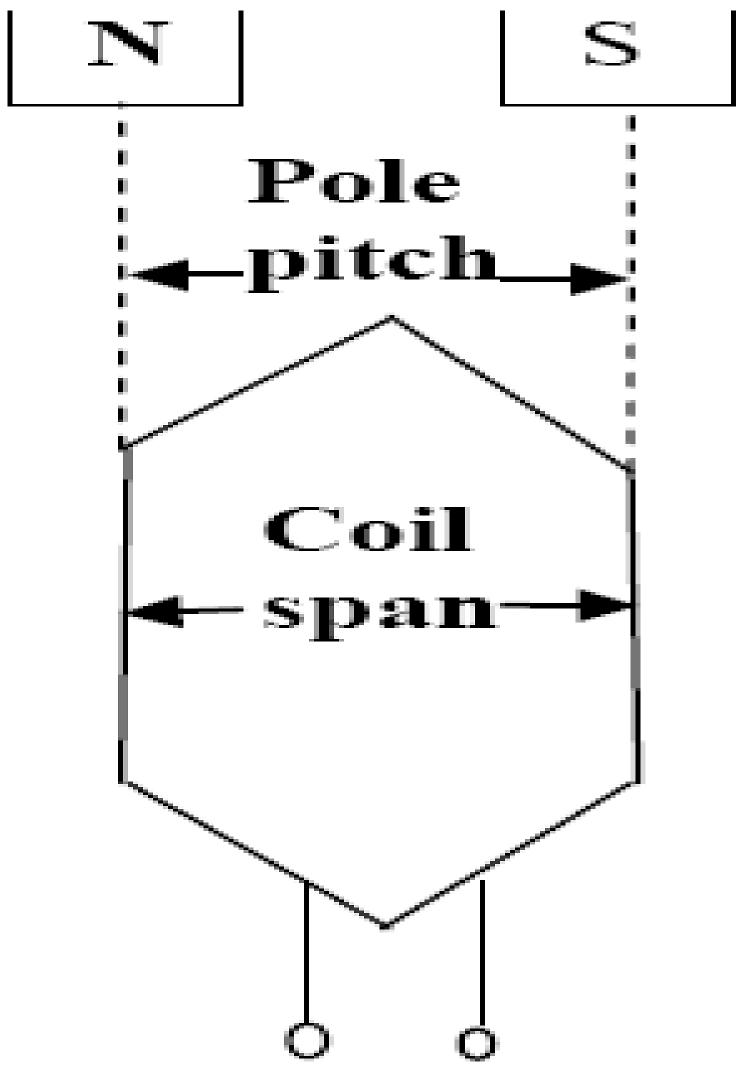
$$\textit{Star Connected Line Voltage} = \sqrt{3} \ x \ \textit{Phase Voltage}$$

POLE – PITCH

It is the distance between the centres of pole faces of two adjacent poles is called pole pitch.

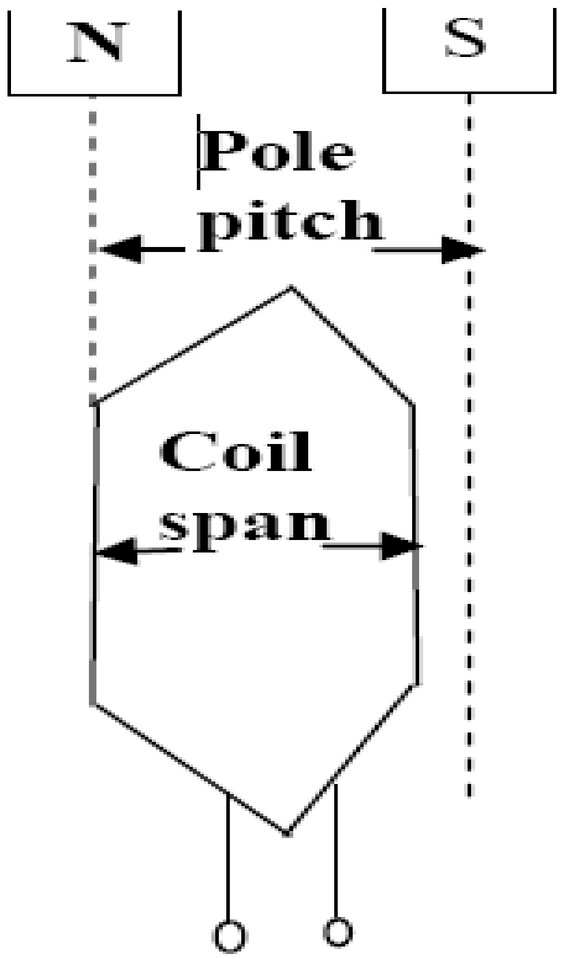
$$\text{Pole Pitch} = \frac{\text{Total number of Slots in the Armature}}{\text{Number of Poles}}$$

Pole pitch = 180 Phase angle



COIL :

A coil consists of two coil sides.
Placed in two separate slots



SLOT PITCH:

It is the phase angle between two adjustment slots

COIL SPAN OR COIL PITCH

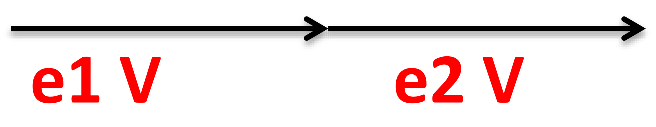
It is the distance between two coil sides of a coil

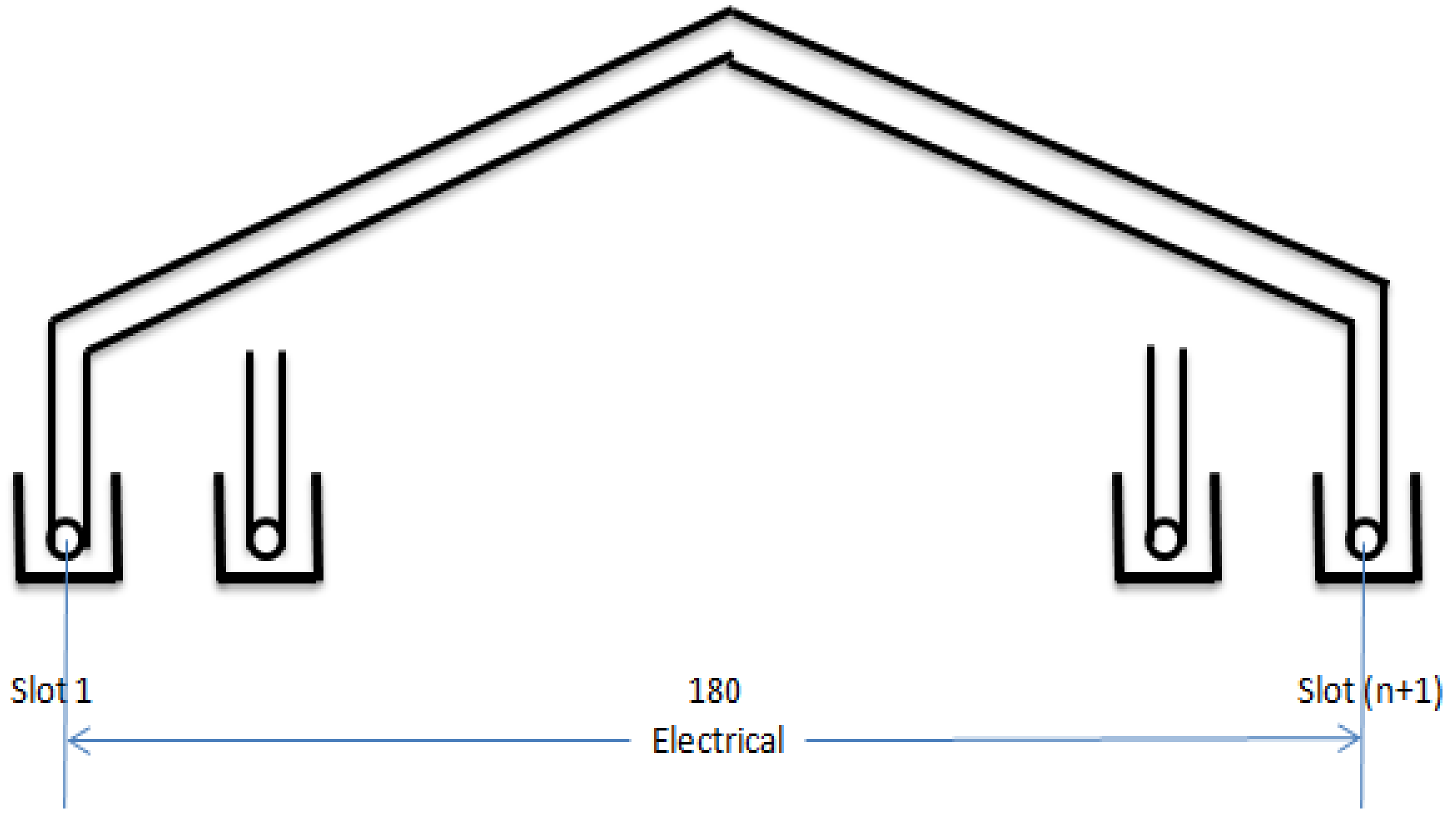
Full Pitch and Short Pitch Winding

Full Pitch Winding

If the coil span is equal to pole pitch then the winding is called Full Pitch Winding

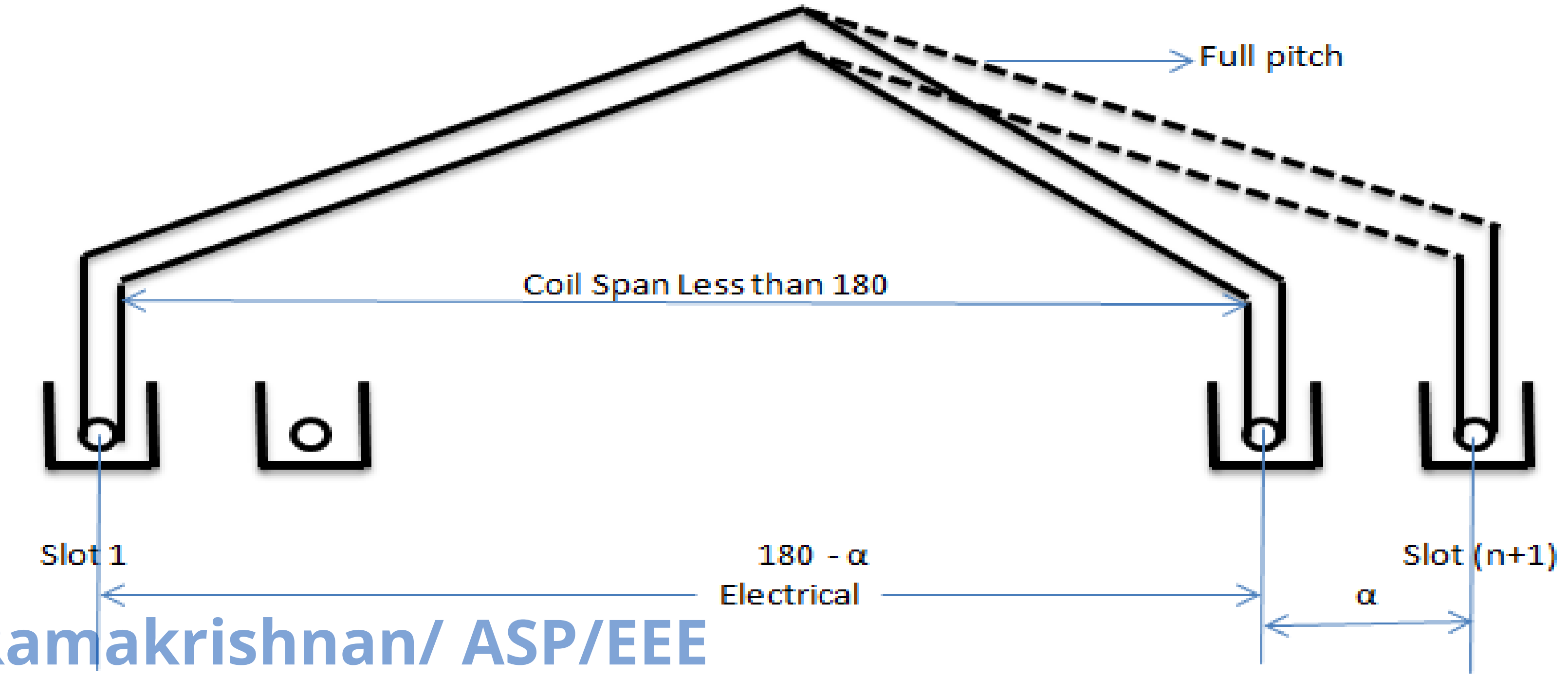
Coil Span = Pole Pitch

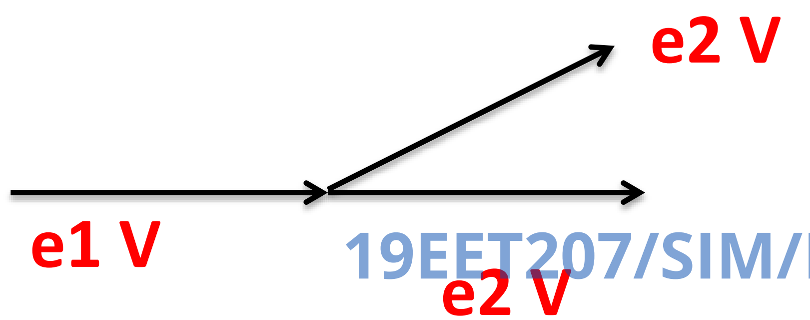




Short Pitch Winding

If the coil span is less than Pole Pitch is called Short pitch winding





Advantages of Short Chorded winding or Chorded Pitch Winding

1. Copper is saved
2. Mechanical strength of the coil is increased
3. Induced EMF in improved

Slot Angle : The angular displacement between any two adjacent poles in electrical degree

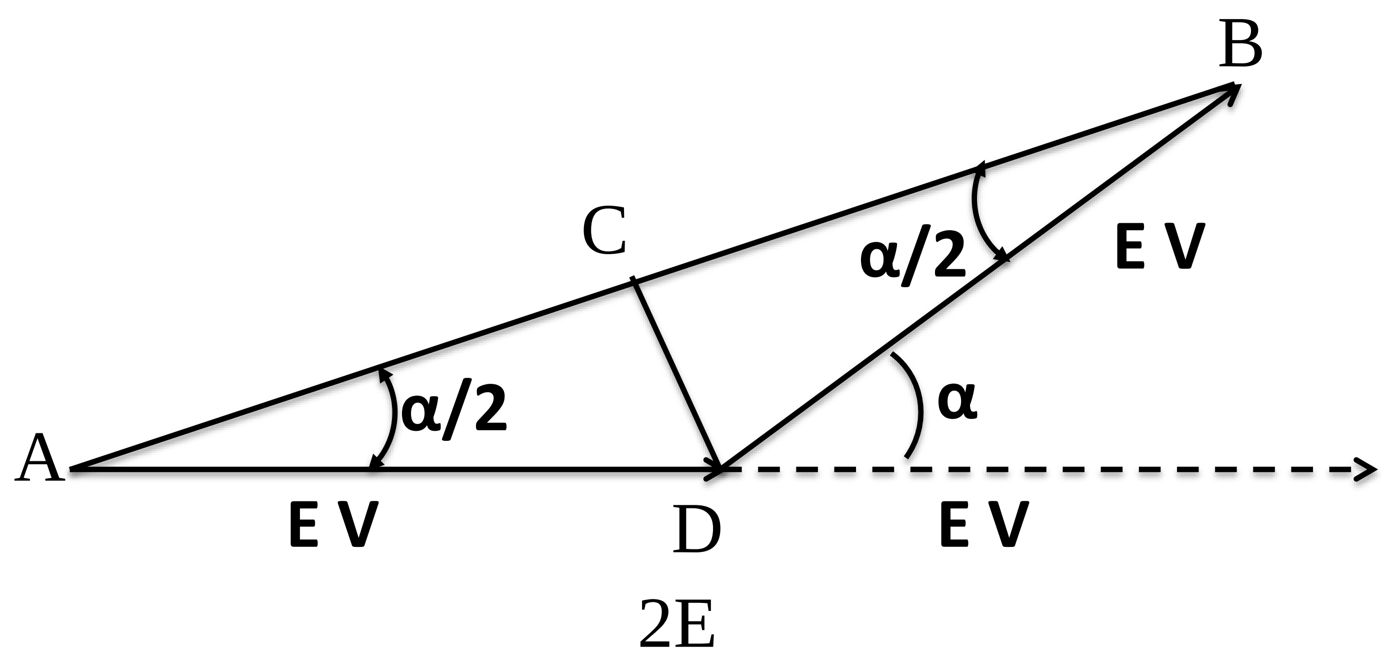
$$\text{Slot angle } (\beta) = \frac{180}{(\text{Number of slots / Pole})}$$

PITCH FACTOR OR COIL SPAN FACTOR OR SHORT CHORDED FACTOR
Kp OR Kc

Pitch factor is defined as the ratio EMF induced in the Short pitch winding to the EMF induced in the full pitch winding

$$\text{Pitch Factor (Kp)} = \frac{\text{EMF induced in the Short pitch winding}}{\text{EMF induced in the Full pitch winding}}$$

$$\textbf{Pitch Factor (Kp)} = \frac{\textbf{Vector sum of induced EMF per coil}}{\textbf{Arithmetic sum of induced EMF per coil}}$$



Vector Sum EMF = AB

= AC + CB

$$Kp = \frac{AC + CB}{AD + DB}$$

$$Kp = \frac{AD\ Cos\ (\alpha/2) \ + DB\ Cos\ (\alpha/2)}{AD + DB}$$

AD = BD

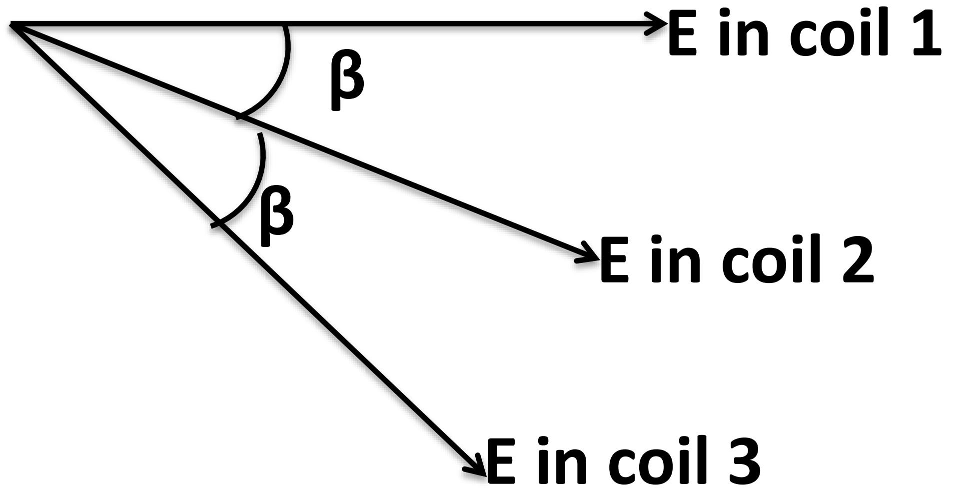
$$Kp = \frac{2\ AD\ Cos\ (\alpha/2)}{2\ AD}$$

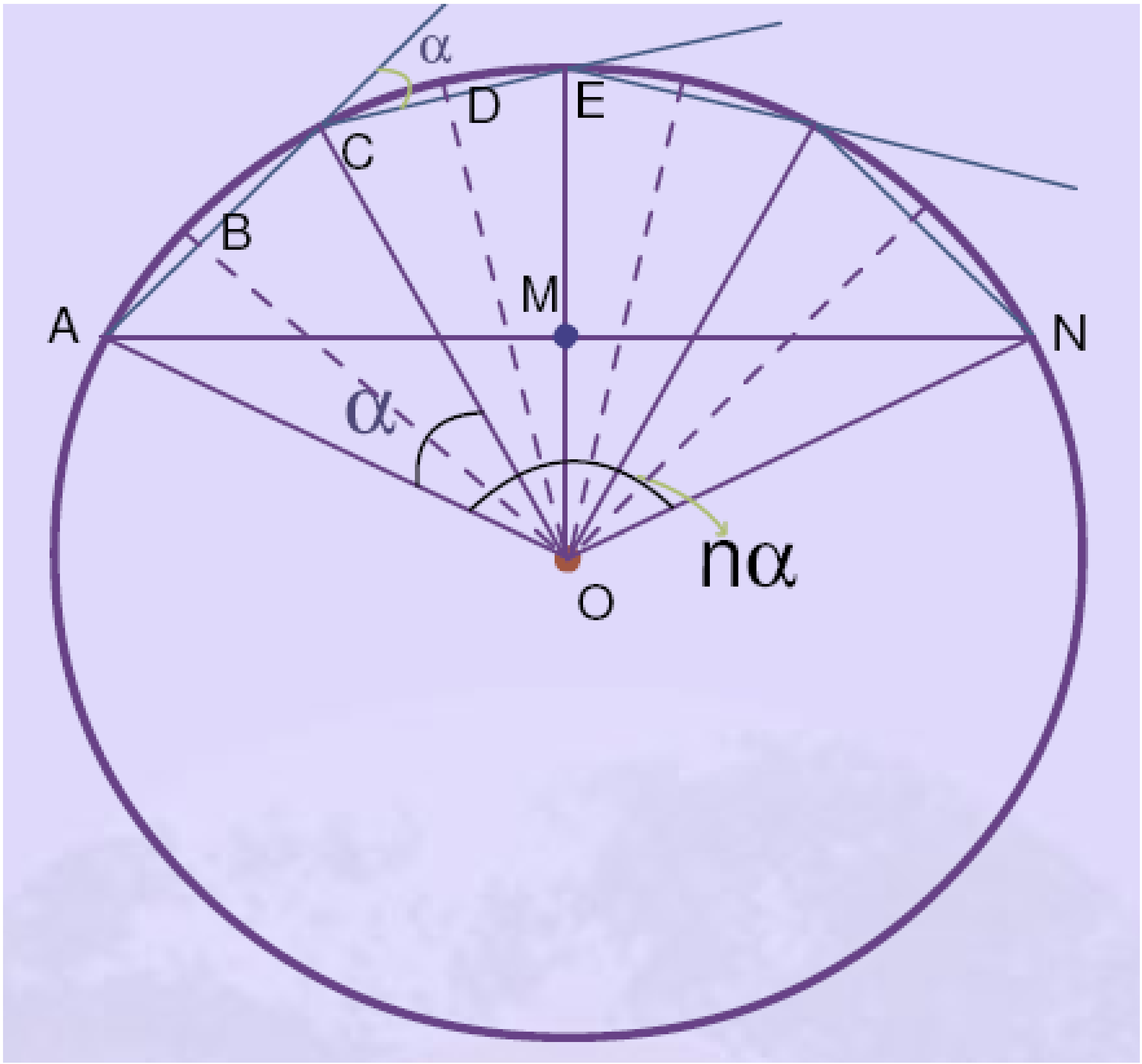
Kp = Cos (α / 2)

DISTRIBUTION FACTOR OR BREATH FACTOR (Kd)

$$\text{Distribution Factor (Kd)} = \frac{\text{EMF induced in the Distributrd winding}}{\text{EMF induced in the Concentrated winding}}$$

$$\textbf{Distribution Factor (Kd)} = \frac{\textbf{Vector sum of EMF per coil}}{\textbf{Arithmetic sum of EMF per coil}}$$





Distribution Factor (Kd)= $\frac{\text{Vector Sum of emf induced}}{\text{Arithmetic sum of emf induced}}$

Arithmetic Sum of EMF = AB + BC + CD

From Vector diagram AB = Ax + xB

= r Sin (β/2) + r Sin (β/2)

AB = 2 r Sin (β/2)

AB = BC = CD = 2 r Sin (β/2)

Arithmetic Sum of EMF = 3 x (2 r Sin (β/2))

If there are **'m'** slots for distribution, then

Arithmetic Sum /phase of the EMF = m x (2 r Sin (β/2))

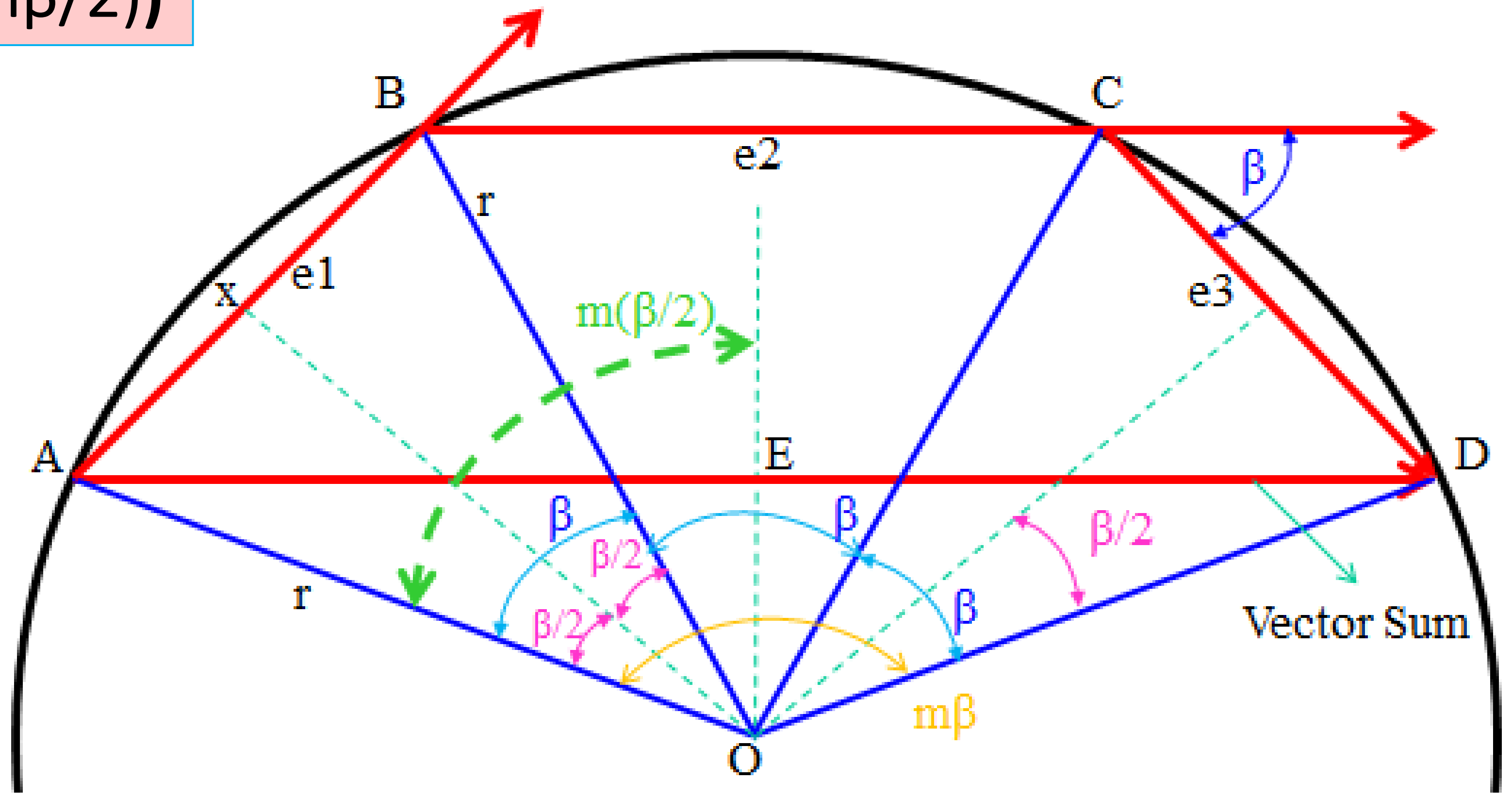
Vector Sum of EMF AD = AE + ED

Vector Sum of EMF AE = ED = r Sin (mβ/2)

Vector Sum of EMF = 2r x (Sin (mβ/2)**)**

$$Kd = \frac{2r \times (\sin(m\beta/2))}{m \times (2 r \sin(\beta/2))}$$

$$Kd = \frac{\sin(m\beta/2)}{m \sin(\beta/2)}$$



SUMMARY

Review on Construction, Working principle of Synchronous Generators, EMF equation

KEEP
LEARNING..

Thank u

SEE YOU IN NEXT CLASS