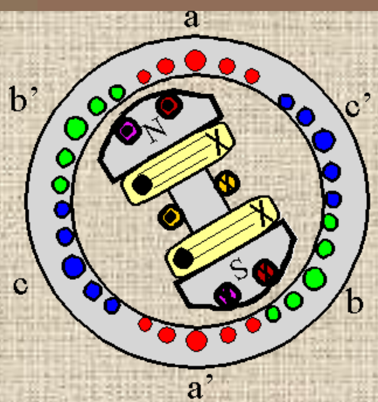
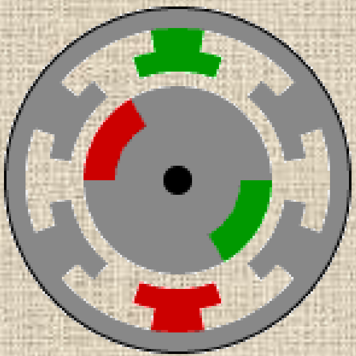
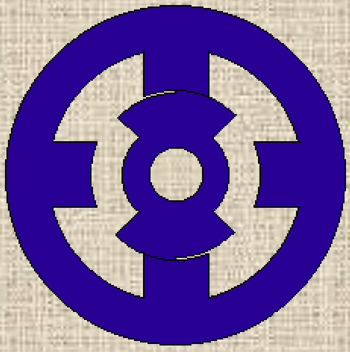
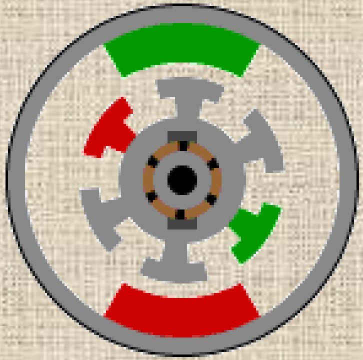
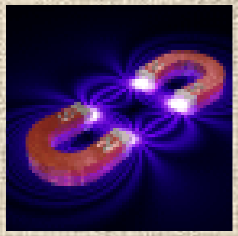
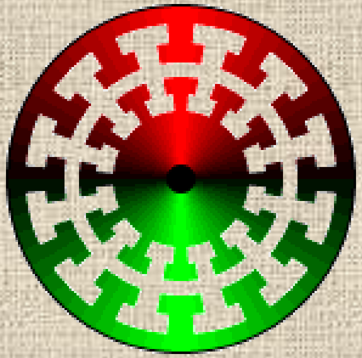


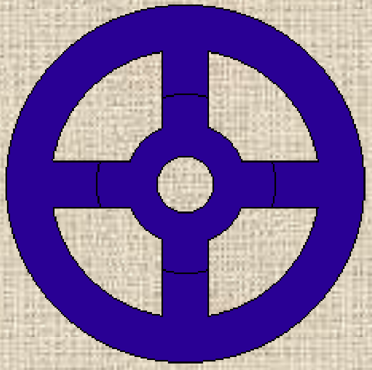
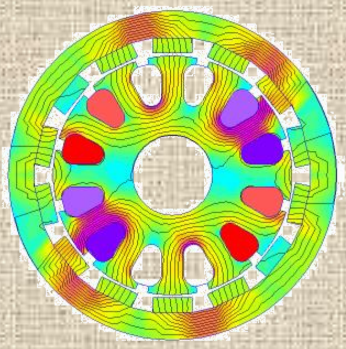
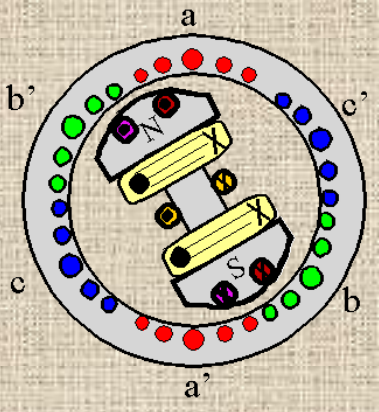




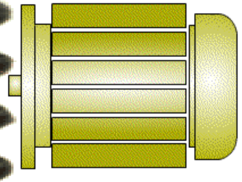
EE552 ELECTRICAL MACHINES III

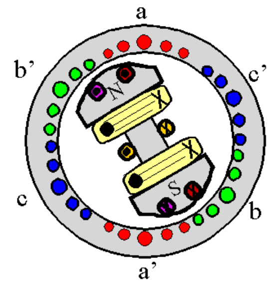
LECTURE 9





LECTURE NOTES

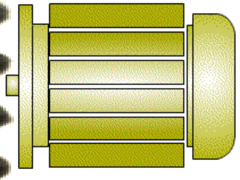


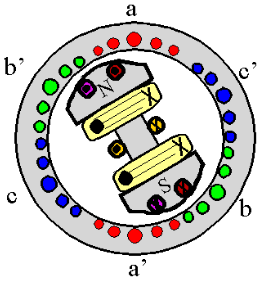
ELECTRICAL MACHINES III

EE552

SPRING 2018

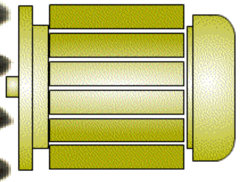
Dr : MUSTAFA AL-REFAI



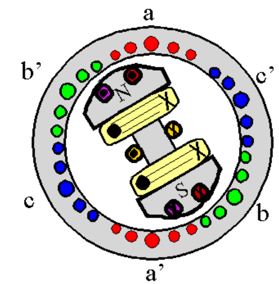


LECTURE 9

SYNCHRONOUS GENERATOR

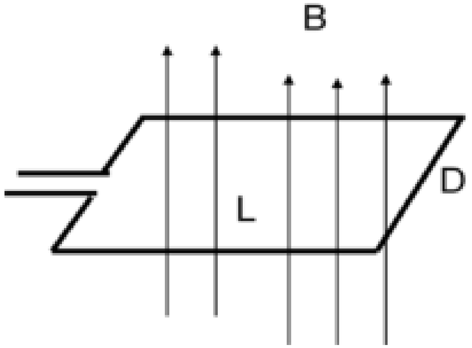


EMF Equation Of An Alternator



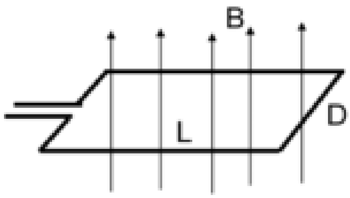
Electromotive Force (EMF) Equation

- A wire loop is rotated in a magnetic field.
  - N is the number of turns in the loop
  - L is the length of the loop
  - D is the width of the loop
  - B is the magnetic flux density
  - n is the number of revolutions per seconds



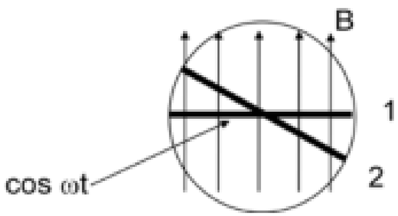
- A wire loop is rotated in a magnetic field.

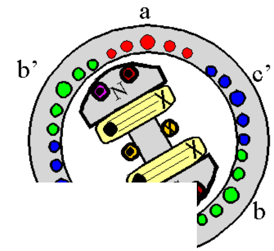
- The magnetic flux through the loop changes by the position



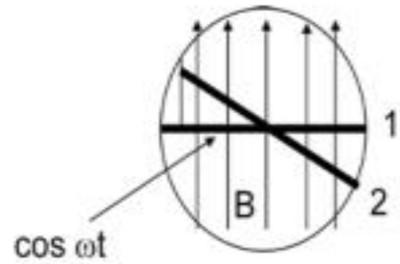
$$\Phi(t) = B\,D\,L\cos(\omega\,t)$$

$$\omega = 2\pi n$$





- Position 1 all flux links with the loop
- Position 2 the flux linkage reduced
- The change of flux linkage induces a voltage in the loop



$$E(t) = N\frac{d\Phi(t)}{dt} = N\,B\,D\,L\frac{d[\cos(\omega t)]}{dt} = N\,B\,D\,L\,\omega\,\sin(\omega t)$$

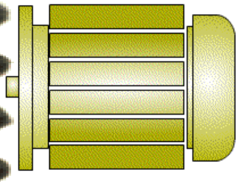
- The induced voltage is an ac voltage
- The voltage is sinusoidal
- The rms value of the induced voltage loop is:

$$E_{rms} = \frac{N\,B\,D\,L\,\omega}{\sqrt{2}}$$

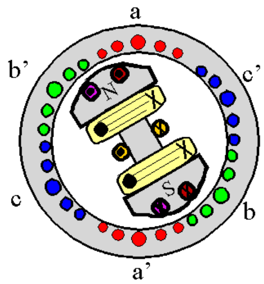
The r.m.s value of the generated emf in a full pitched coil is

$$E = \frac{E_{max}}{\sqrt{2}}\ , \quad \text{where } E_{max} = \omega_r N\emptyset = 2\pi f N\emptyset \quad [\emptyset = BDL]$$

$$\therefore \quad E = \frac{E_{max}}{\sqrt{2}} = \sqrt{2}\ \pi f N\emptyset = 4.44 f N\emptyset$$



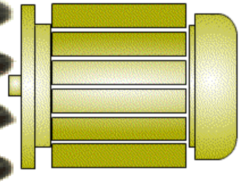
Fractional pitch winding



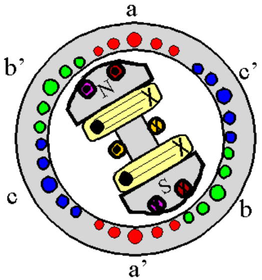
Advantages: cu saving, reduce harmonics

Pitch factor = emf generated in fractional pitch winding/emf generated in full pitch winding

Pitch factor, $K_p = \cos\beta/2$

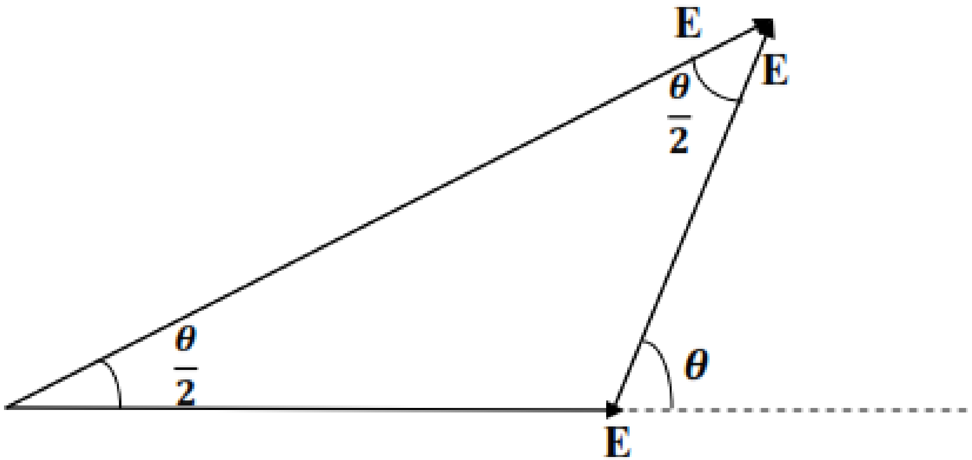


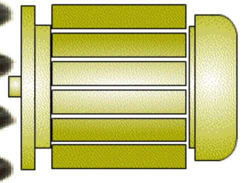
Pitch Factor or Coil Pitch cont…



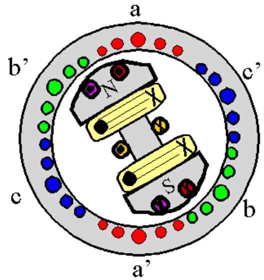
The ratio of phasor (vector) sum of induced emfs per coil to the arithmetic sum of induced emfs per coil is known as ***pitch factor (Kp)*** or ***coil span factor (Kc)*** which is always less than unity.

Let the coil have a pitch short by angle *θ* electrical space degrees from full pitch and induced emf in each coil side be *E*,





Pitch Factor or Coil Pitch cont…



- If the coil would have been full pitched, then total induced emf in the coil would have been *2E*.
- when the coil is short pitched by θ electrical space degrees the resultant induced emf, E_R in the coil is phasor sum of two voltages, θ apart

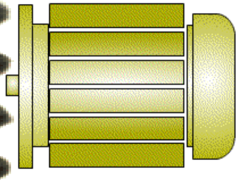
$$E_R = 2E\cos\frac{\theta}{2}$$

$$\text{Pitch factor,}\quad K_p = \frac{\textit{Phasor sum of coil side emfs}}{\textit{Arithmetic sum of coil side emfs}} = \frac{2E\cos\frac{\theta}{2}}{2E} = \cos\frac{\theta}{2}$$

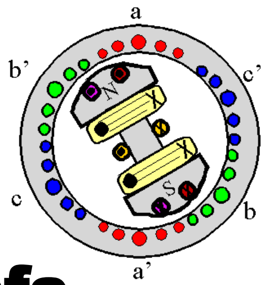
Example. The coil span for the stator winding of an alternator is 120°. Find the chording factor of the winding.

Solution: Chording angle, $\theta = 180^o - coil\ span = 180^o - 120^o = 60^o$

Chording factor, $K_p = \cos\frac{\theta}{2} = \cos\frac{60^o}{2} = 0.866$



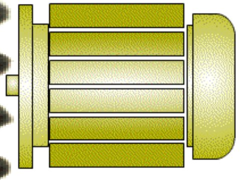
Distribution Factor



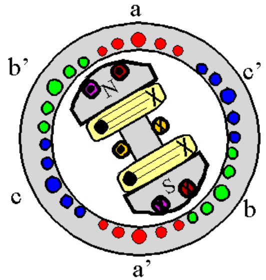
The ratio of the phasor sum of the emfs induced in all the coils distributed in a number of slots under one pole to the arithmetic sum of the emfs induced(or to the resultant of emfs induced in all coils concentrated in one slot under one pole) is known as breadth factor (kb) or distribution factor (kd)

$$K_d = \frac{EMF\ induced\ in\ distributed\ winding}{EMF\ induced\ if\ the\ winding\ would\ have\ been\ concentrated}$$

$$= \frac{Phasor\ \ sum\ \ of\ \ component\ \ \ emfs}{Arithmetic\ \ sum\ \ of\ \ component\ \ \ emfs}$$



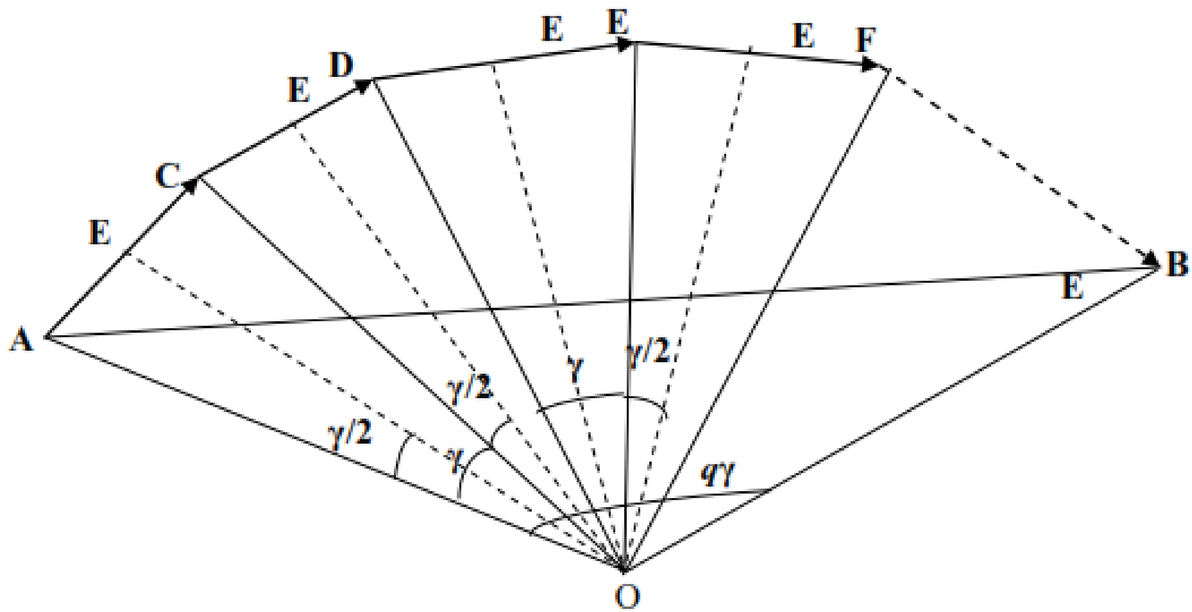
Distribution Factor cont..

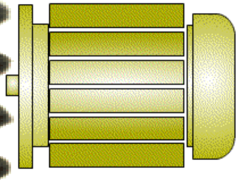


- The distribution factor is always less than unity.

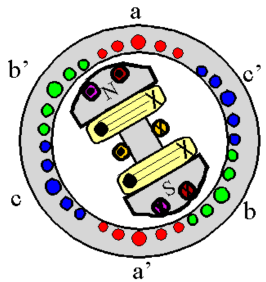
- Let no. of slots per pole = Q and no. of slots per pole per phase = q
  Induced emf in each coil side = E_c
  Angular displacement between the slots, $\gamma = \frac{180^o}{Q}$

- The emf induced in different coils of one phase under one pole are represented by side AC, CD, DE, EF… Which are equal in magnitude (say each equal E_c) and differ in phase (say by γ^o) from each other.





Distribution Factor cont..



If bisectors are drawn on AC, CD, DE, EF… they would meet at common point *(O)*. The point *O* would be the circum center of the circle having AC, CD, DE, EF…as the chords and representing the emfs induced in the coils in different slots.

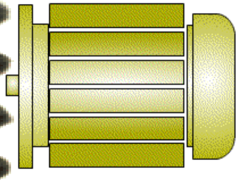
EMF induced in each coil side, $E_c = AC = 2OA \sin\frac{\gamma}{2}$

$$Arithmetic\ sum = q \times 2 \times OA \sin\frac{\gamma}{2}$$

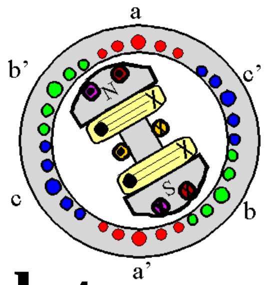
$\therefore$ The resultant emf, $E_R = AB = 2 \times OA \sin\frac{AOB}{2} = 2 \times OA \sin\frac{q\gamma}{2}$

& distribution factor, $k_d = \dfrac{Phasor\ \ sum\ \ of\ \ components\ \ emfs}{Arithmetic\ \ sum\ \ of\ \ components\ \ emfs}$

$$= \frac{2 \times OA \sin\frac{q\gamma}{2}}{q \times 2 \times OA \sin\frac{\gamma}{2}} = \frac{\mathbf{\sin\frac{q\gamma}{2}}}{\mathbf{q \sin\frac{\gamma}{2}}}$$



Example.



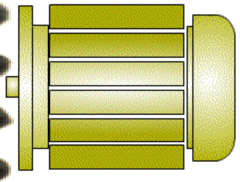
Calculate the distribution factor for a 36-slots, 4-pole, single layer 3-phase winding.

Solution: No. of slots per pole, $Q = \frac{36}{4} = 9$

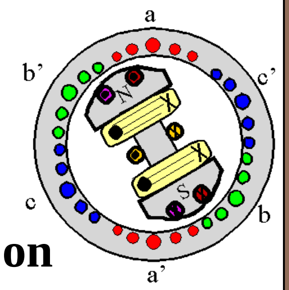
No. of slots per pole per phase, $q = \frac{Q}{Number\ \ of\ phases} = \frac{9}{3} = 3$

Angular displacement between the slots, $\gamma = \frac{180^o}{Q} = \frac{180^o}{9} = 20^o$

Distribution factor, $K_d = \frac{\sin\frac{q\gamma}{2}}{q\sin\frac{\gamma}{2}} = \frac{\sin\frac{3\times 20^o}{2}}{3\sin\frac{20^o}{2}} = \frac{1}{3}\frac{\sin 30^o}{\sin 10^o} = 0.96$



Example1



A 3-phase, 8-pole, 750 r.p.m. star-connected alternator has 72 slots on the armature. Each slot has 12 conductors and winding is short chorded by 2 slots. Find the induced emf between lines, given the flux per pole is 0.06 Wb.

Solution:

Flux per pole, $\emptyset = 0.06\ Wb$

$$f = \frac{pn}{60} = \frac{4 \times 750}{60} = 50\ Hz$$

Number of conductors connected in series per phase,

$$Z_s = \frac{Number\ \ of\ \ conductors\ \ per\ \ slot\ \times number\ \ of\ \ slots}{Num\,ber\ \ of\ \ phases}$$

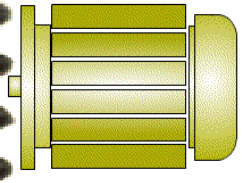
$$= \frac{12 \times 72}{3} = 288$$

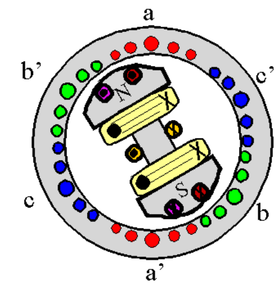
Number of turns per phase, $T = \frac{Z_s}{2} = \frac{288}{2} = 144$

Number of slots per pole, $Q = \frac{72}{8} = 9$

Number of slots per pole per phase, $q = \frac{Q}{3} = \frac{9}{3} = 3$

Angular displacement between the slots, $\gamma = \frac{180^o}{Q} = \frac{180^o}{9} = 20^o$





$$\text{Distribution factor, } K_d = \frac{\sin\frac{q\gamma}{2}}{q\sin\frac{\gamma}{2}} = \frac{\sin\frac{3\times 20^o}{2}}{3\sin\frac{20^o}{2}} = \frac{1}{3}\frac{\sin 30^o}{\sin 10^o} = 0.96$$

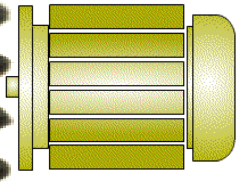
$$\text{Chording angle, } \theta = 180^o \times \frac{2}{9} = 40^o$$

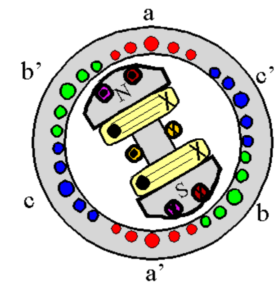
$$\text{Pitch factor, } K_p = \cos\frac{\theta}{2} = \cos\frac{40^o}{2} = \cos 20^o = 0.94$$

$$\text{Induced emf between lines, } E_L = \sqrt{3} \times 4.44 \times K_d \times K_p \times \emptyset \times f \times T$$

$$= \sqrt{3} \times 4.44 \times 0.96 \times 0.94 \times 0.06 \times 50 \times 144 = 2998\ V$$


PresenterMedia

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END OF LECTURE 9