SNS COLLEGE OF ENGINEERING

Kurumbapalayam (Po), Coimbatore – 641 107

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Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

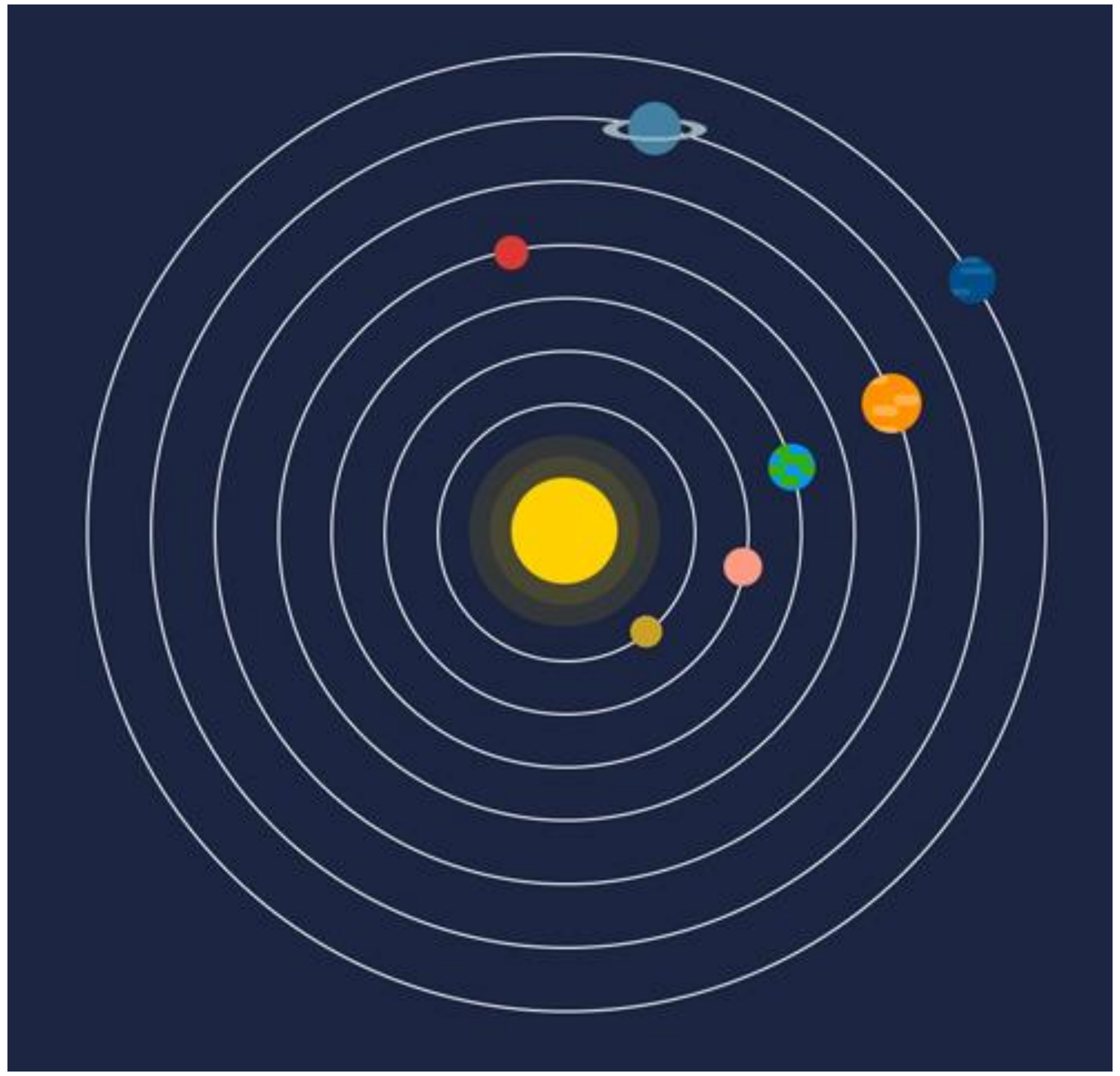
COURSE NAME : 19EE401 SYNCHRONOUS AND INDUCTION MACHINES

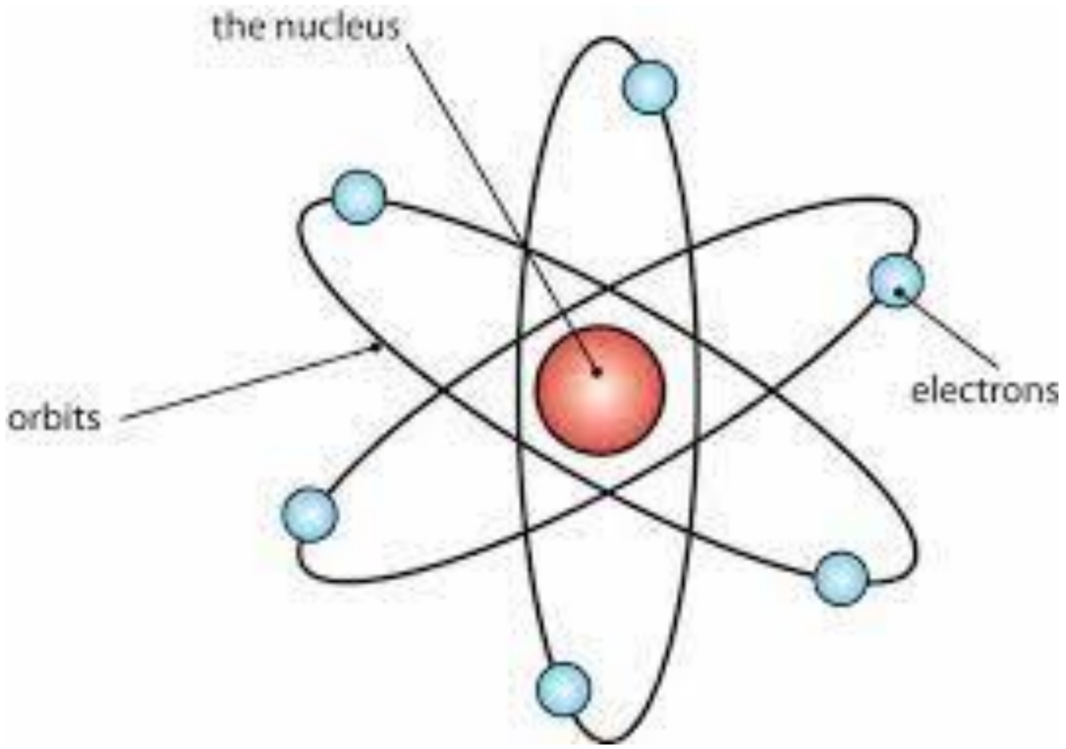
II YEAR /IV SEMESTER

Unit 3: INDUCTION MOTOR

Topic 1 : Rotating Magnetic Field

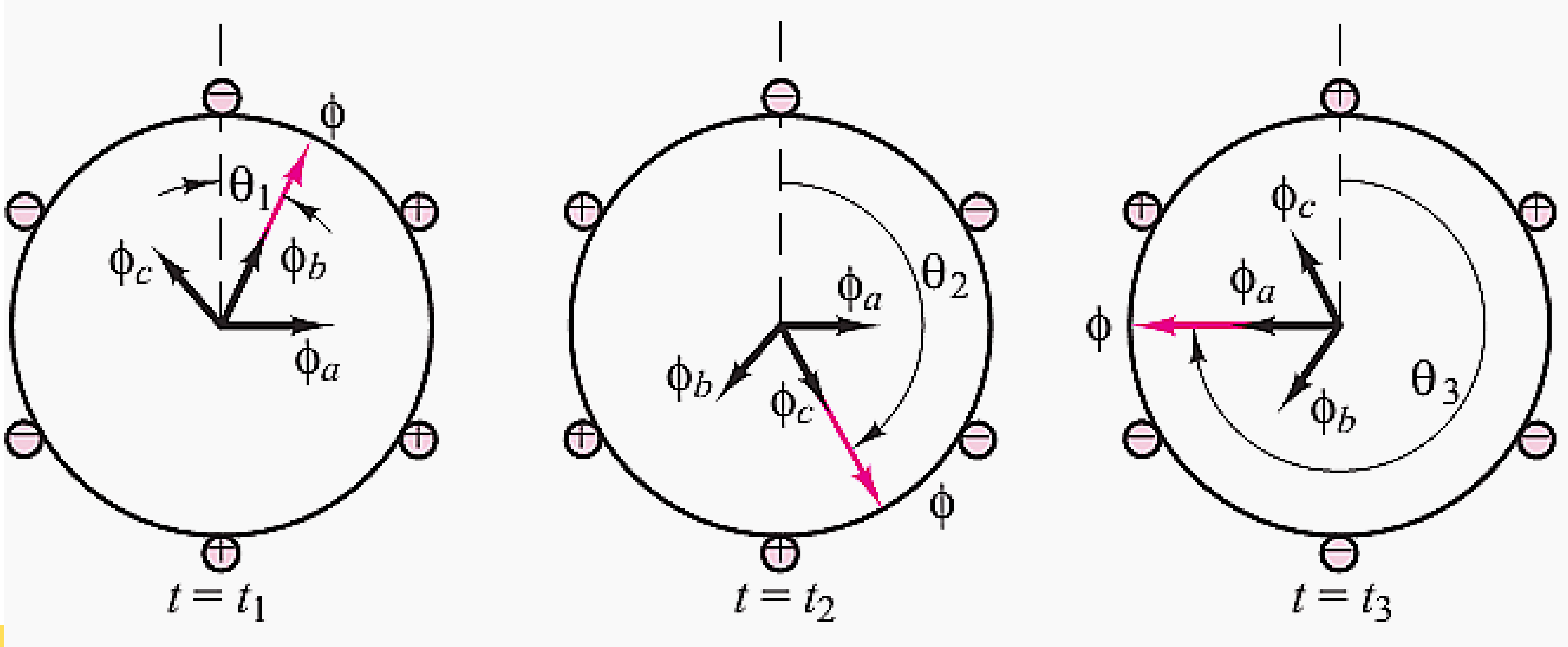
What is Common ?





Rotating Magnetic Field

The **rotating magnetic field** can be defined as the field or flux having **constant amplitude** but whose axis is **continuously rotating** in a plane with a certain speed.



Production of Rotating Magnetic Field

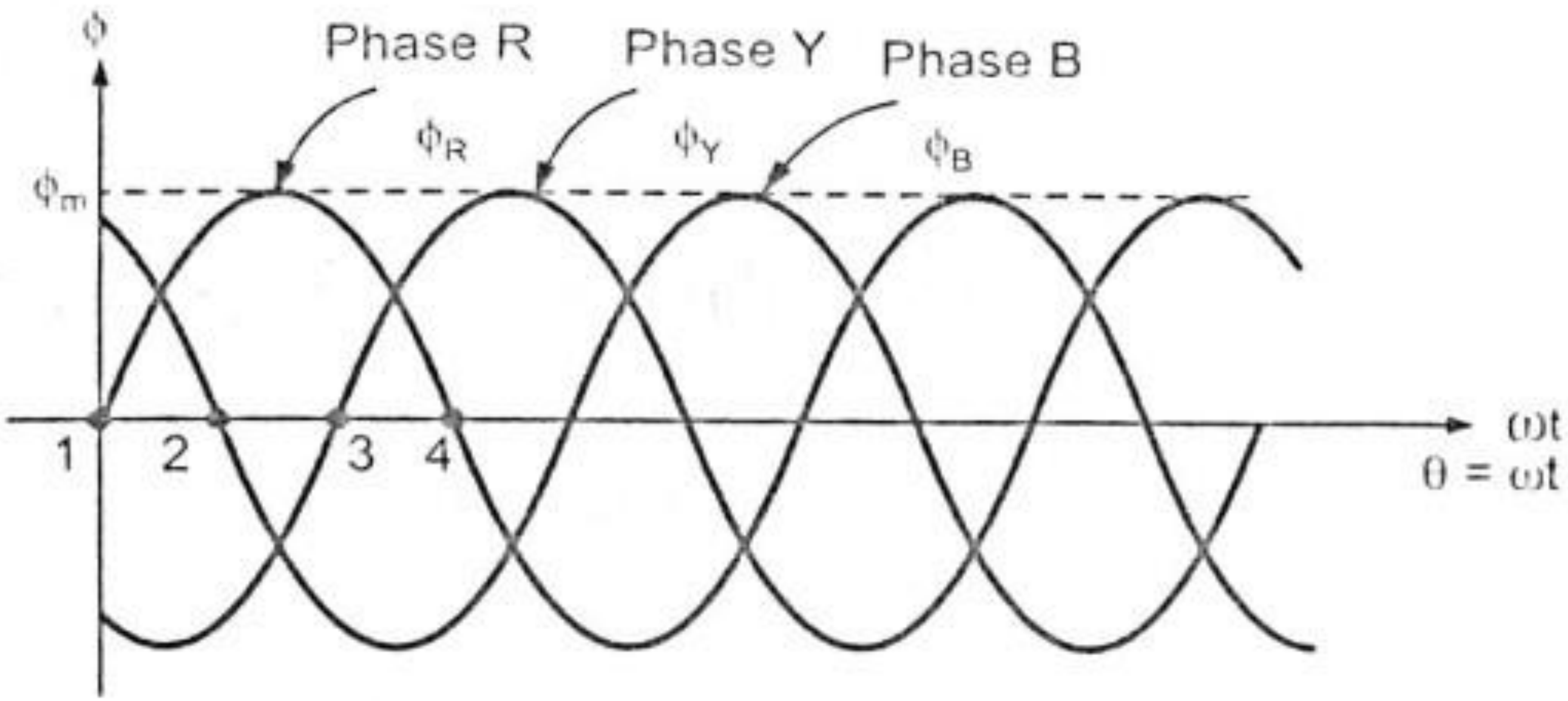
- Stator of a three phase induction motor consists of three phase winding, connected in star or delta.
- The three phase windings are displaced from each other by 120^o (means electrically 120^o apart from each other)
- The windings are supplied by a balanced 3 phase a.c. supply

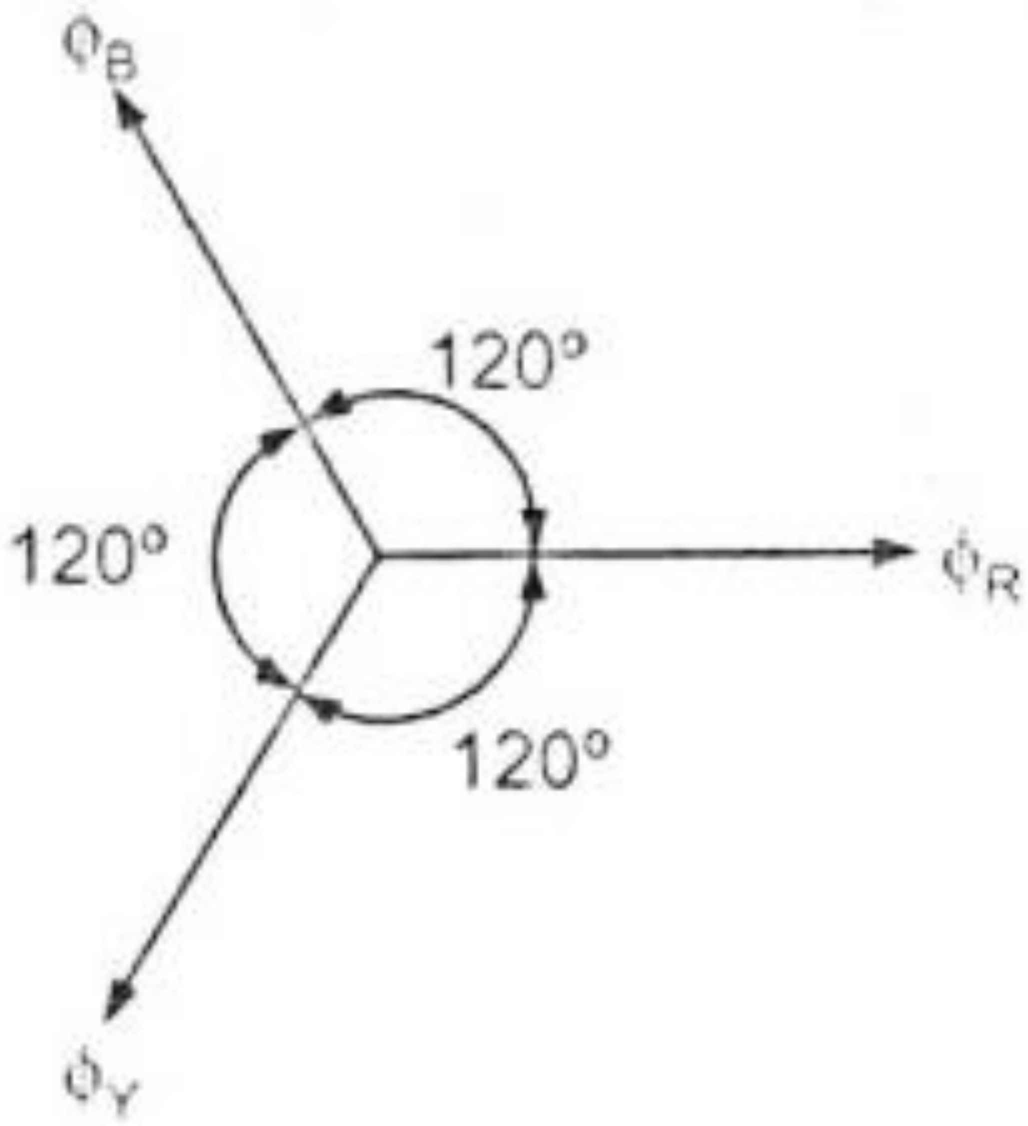
Production of Rotating Magnetic Field

$$\phi_R = \phi_m \sin(\omega t) = \phi_m \sin(\theta)$$

$$\phi_Y = \phi_m \sin(\omega t - 120^\circ) = \phi_m \sin(\theta - 120^\circ)$$

$$\phi_B = \phi_m \sin(\omega t - 240^\circ) = \phi_m \sin(\theta - 240^\circ)$$





Production of Rotating Magnetic Field

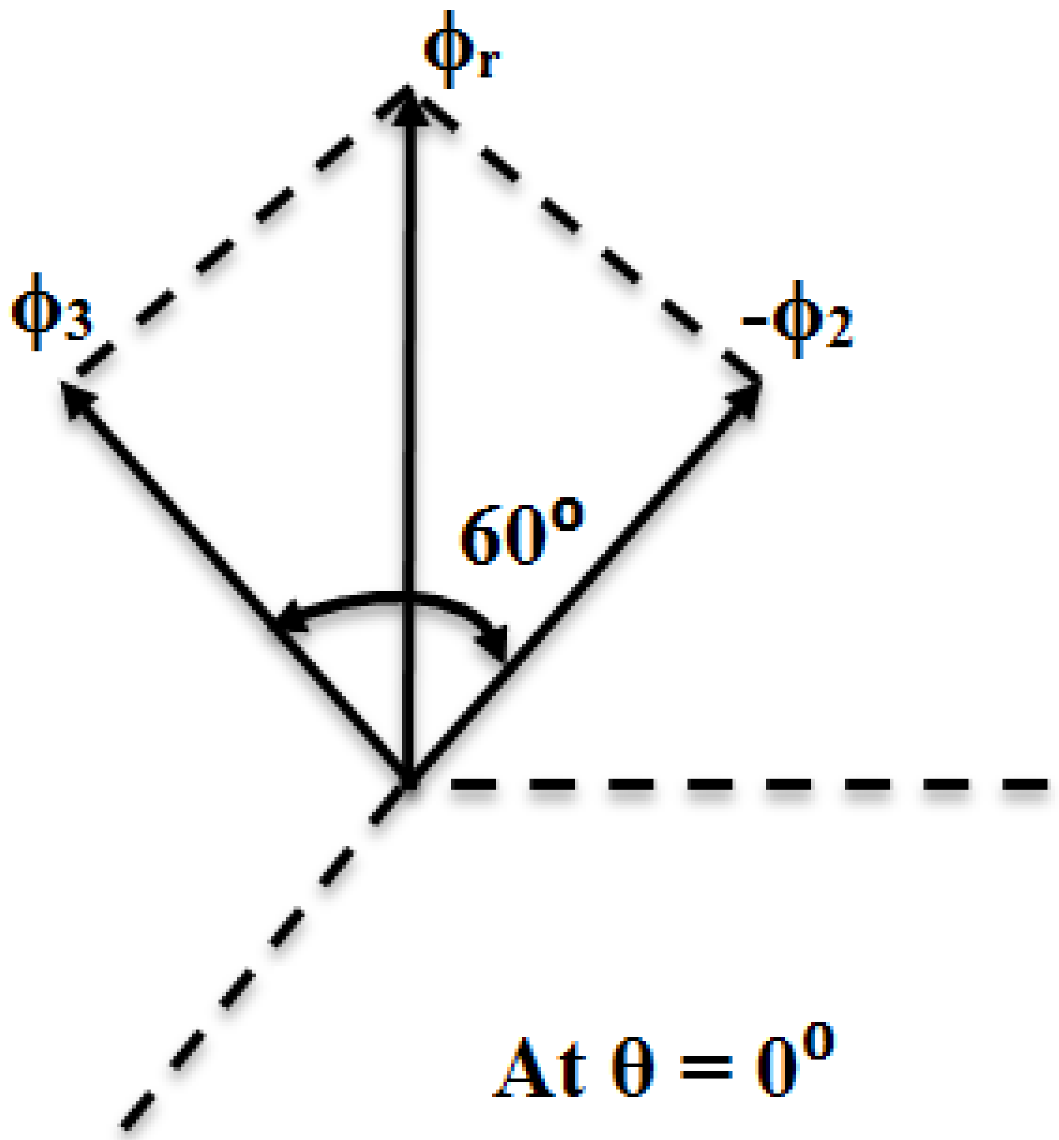
When θ = 0^0 (At point 0) :

At point 0 on the waveform i.e, at 0^0, the value of Φ_1 is.

$$\phi_1 = \phi_m \sin 0^\circ = 0$$

$$\phi_2 = \phi_m \sin(0^\circ - 120^\circ) = \frac{-\sqrt{3}}{2}\phi_m$$

$$\phi_3 = \phi_m \sin(0^\circ - 240^\circ) = \frac{\sqrt{3}}{2}\phi_m$$



Production of Rotating Magnetic Field

$$\phi_r = \sqrt{(-\phi_2)^2 + (\phi_3)^2 + 2(-\phi_2)(\phi_3)\cos 60^\circ}$$

120°

$$\phi_r = \sqrt{{\phi_2}^2 + {\phi_3}^2 - 2\,\phi_2\,\phi_3 \cos 60^\circ}$$

$$\phi_r = \sqrt{\left(\frac{-\sqrt{3}}{2}\phi_m\right)^2 + \left(\frac{\sqrt{3}}{2}\phi_m\right)^2 - 2\left(\frac{-\sqrt{3}}{2}\phi_m\right)\left(\frac{\sqrt{3}}{2}\phi_m\right)\cos 60^\circ}$$

$$\phi_r = 1.5\,\phi_m$$

Production of Rotating Magnetic Field

When θ = 60⁰ (At point 1) :

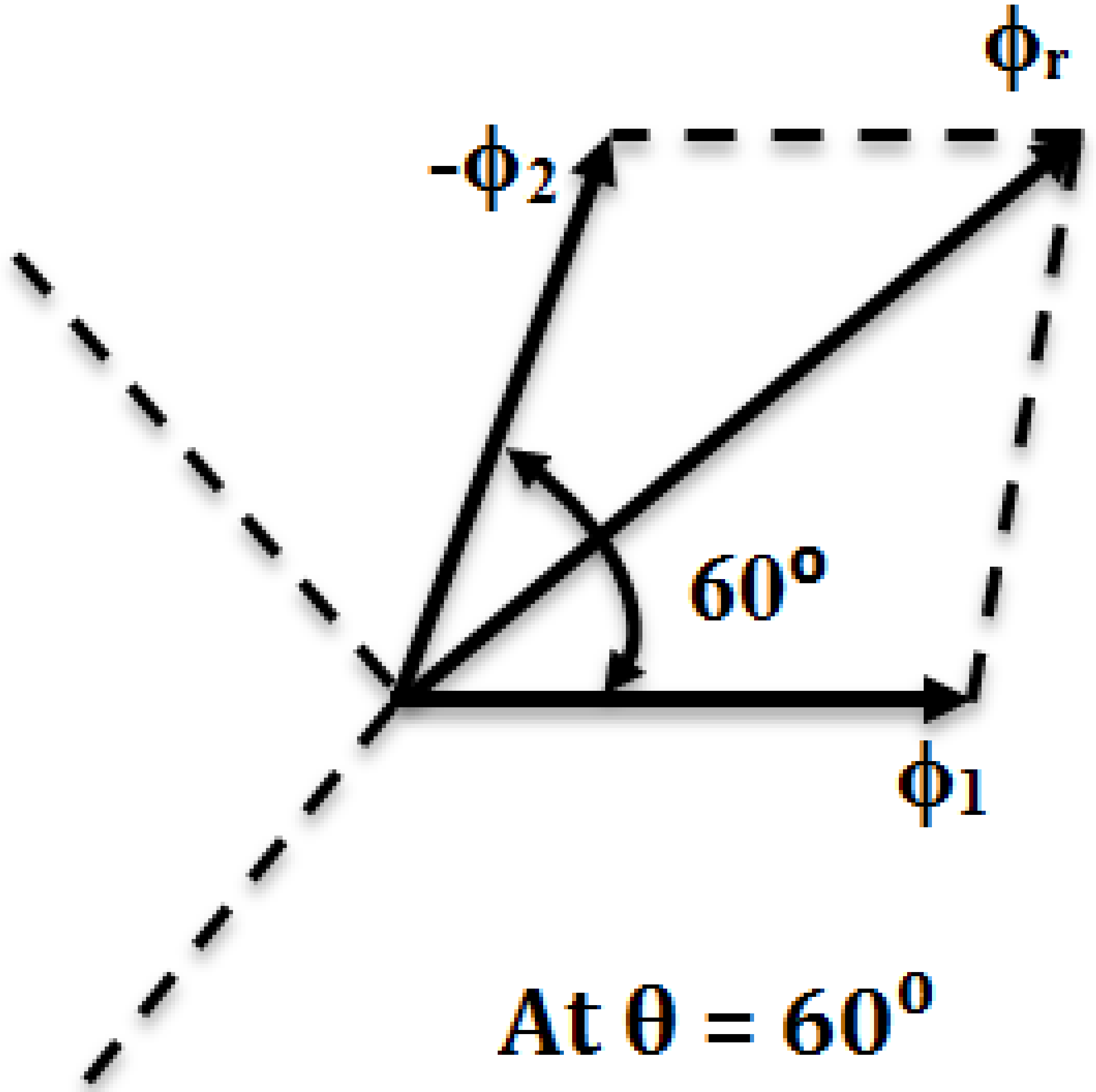
At point 1 on the waveform i.e, at 60^0, the value of Φ_1 is

$$\phi_1 = \phi_m \sin 60^\circ = \frac{\sqrt{3}}{2}\phi_m$$

$$\phi_2 = \phi_m \sin(60^\circ - 120^\circ) = \frac{-\sqrt{3}}{2}\phi_m$$

$$\phi_3 = \phi_m \sin(60^\circ - 240^\circ) = 0$$

120°



At θ = 60^0

Production of Rotating Magnetic Field

$$\phi_r = \sqrt{(\phi_1)^2 + (-\phi_2)^2 + 2(\phi_1)(-\phi_2)\cos 60^\circ}$$ 120°

$$\phi_r = \sqrt{{\phi_1}^2 + {\phi_2}^2 - 2\,\phi_1\,\phi_2 \cos 60^\circ}$$

$$\phi_r = 1.5\,\phi_m$$

Production of Rotating Magnetic Field

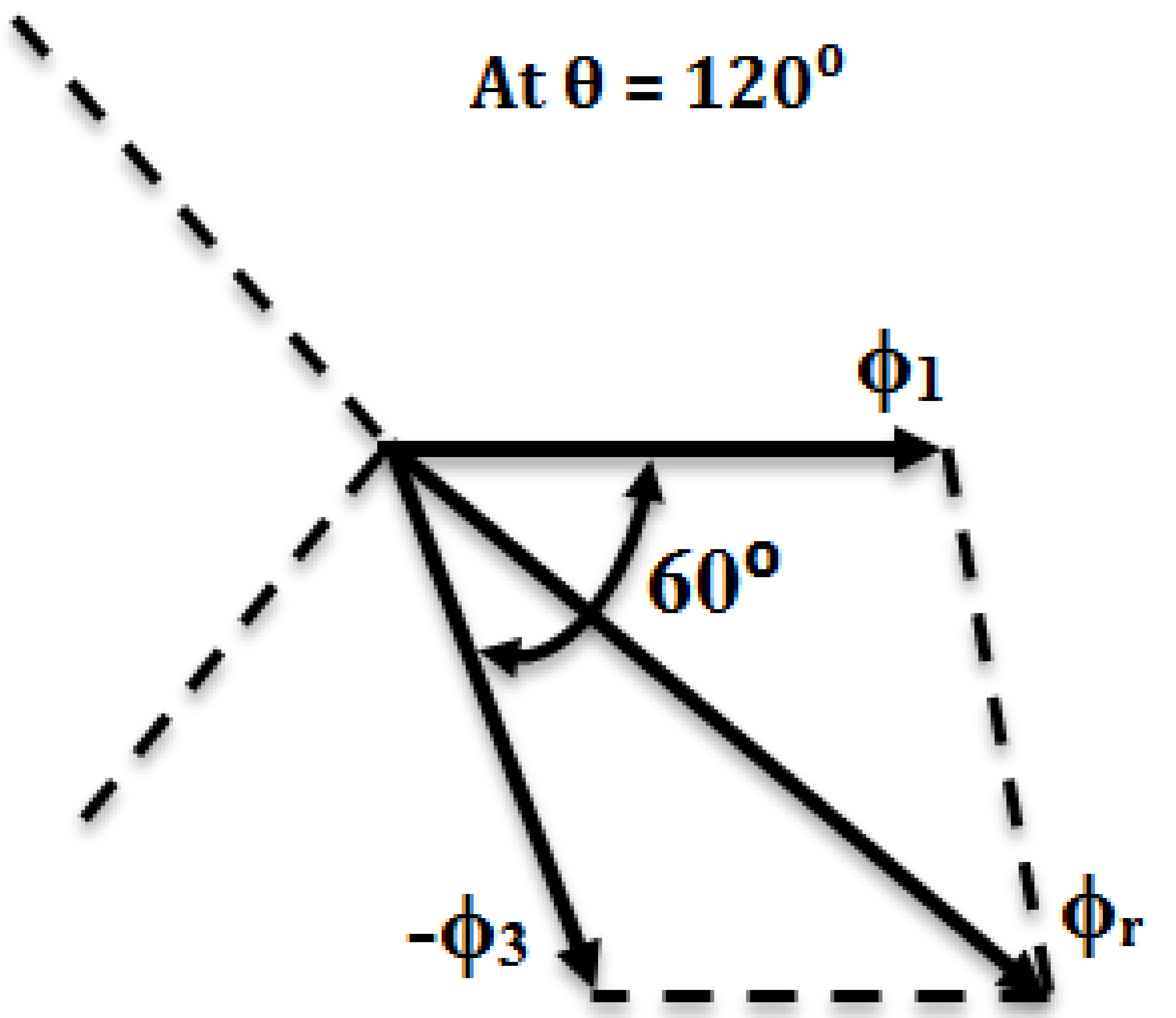
When θ = 120^0 (At point 2) :

At point 2 on the waveform i.e, at 120^0, the value of Φ_1 is,

$$\phi_1 = \phi_m \sin 120^\circ = \frac{\sqrt{3}}{2}\phi_m$$

$$\phi_2 = \phi_m \sin(120^\circ - 120^\circ) = 0$$

$$\phi_3 = \phi_m \sin(120^\circ - 240^\circ) = \frac{-\sqrt{3}}{2}\phi_m$$



Production of Rotating Magnetic Field

$$\phi_r = \sqrt{(\phi_1)^2 + (-\phi_3)^2 + 2(\phi_1)(-\phi_3)\cos 60^\circ}$$

120°

$$\phi_r = \sqrt{\phi_1{}^2 + \phi_3{}^2 - 2\,\phi_1\,\phi_3 \cos 60^\circ}$$

$$\phi_r = 1.5\,\phi_m$$

Production of Rotating Magnetic Field

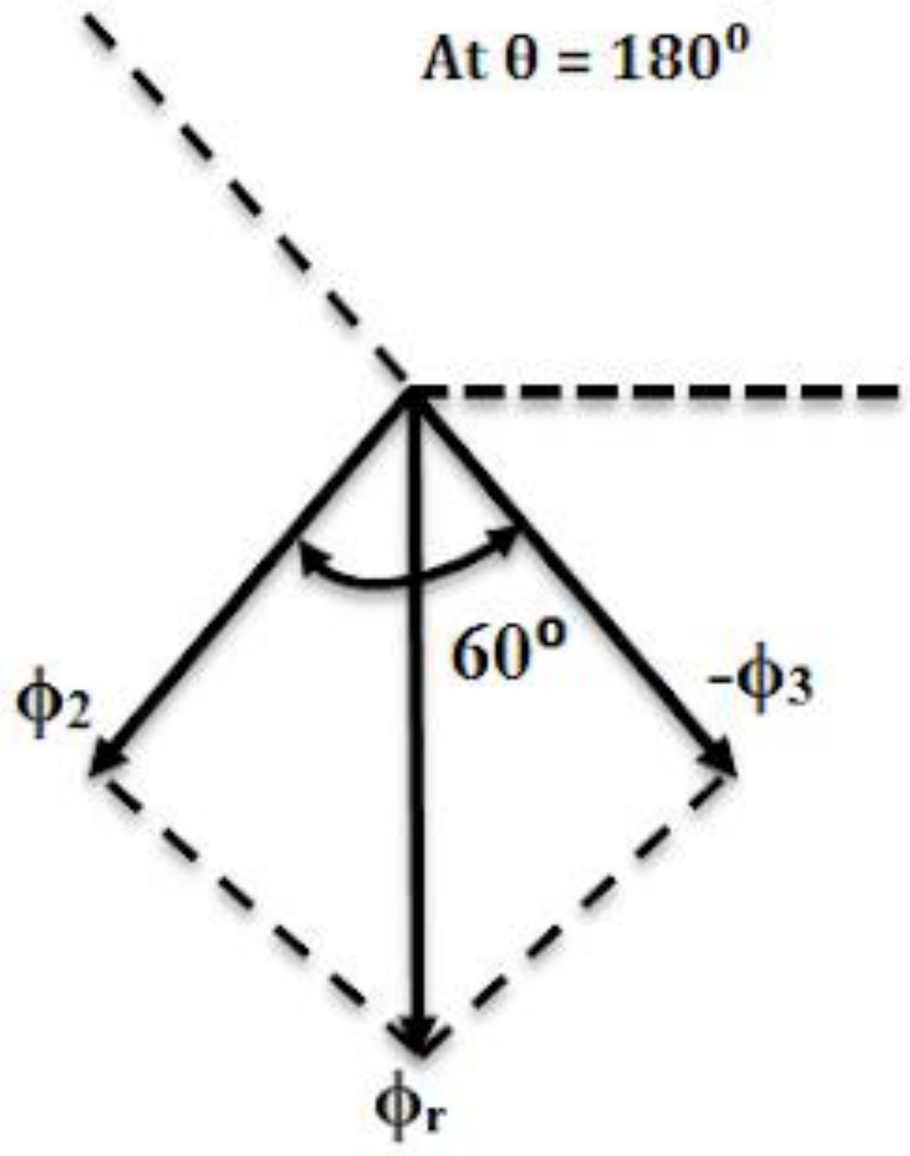
When θ = 180^0 (At point 3) :

At point 3 on the waveform i.e, at 180^0, the value of Φ_1 is,

$$\phi_1 = \phi_m \sin 180^\circ = 0$$

$$\phi_2 = \phi_m \sin(180^\circ - 120^\circ) = \frac{\sqrt{3}}{2}\phi_m$$

$$\phi_3 = \phi_m \sin(180^\circ - 240^\circ) = \frac{-\sqrt{3}}{2}\phi_m$$



Production of Rotating Magnetic Field

$$\phi_r = \sqrt{(\phi_2)^2 + (-\phi_3)^2 + 2(\phi_2)(-\phi_3)\cos 60^\circ}$$

120°

$$\phi_r = \sqrt{{\phi_2}^2 + {\phi_3}^2 - 2\,\phi_2\,\phi_3\cos 60^\circ}$$

$$\phi_r = 1.5\,\phi_m$$

Synchronous Speed

In general, for P poles, the rotating field makes one revolution in P/2 cycles of current.

120°

120°

$$\text{Cycles of Current per second} = (P/2) * (\text{revolutions per second})$$

Since revolutions per second is equal to the revolutions per minute (Ns) divided by 60 and the number of cycles per second is the frequency f,

$$\text{Cycles of Current per second} = (P/2) * (N_s/60)$$

The speed of the rotating magnetic field is known as synchronous speed.

Conclusion

- Magnitude of the net flux remains same, but it can be seen that it has further rotated through 60° from its previous position in clockwise direction.
- The resultant flux rotates at the synchronous speed, N_s is given by $N_s = 120f/P$ rpm
- The direction of magnetic field can be varied by changing the phase sequence of three phase supply.
- Minimum of two phases is essential for RMF to set up.

Assessment 1

1. Who invented the rotating magnetic field?
   (a) Walter Bailey (b) Nikola Tesla
   (c) Dennis Ritchie (d) Adam Osborne
2. The magnitude of rotating flux ____________ at all instants of time.
   (a) Changes (b) pulsates (c) constants (d) zero
3. The speed at which rotating magnetic field revolves is called
   (a) Synchronous Speed (b) Induction Speed (c) Relative Speed (d) Rotating Speed

References

1. https://hackaday.com/2020/11/12/rotating-magnetic-fields-explained/
2. Kothari, D.P., Nagrath, I.J., "Electric Machines", McGraw Hill Publishing Company Ltd, 5th Edition, 2017.
3. Murugesh Kumar, K., "Induction and Synchronous machines", Vikas Publishing House Private Ltd, 2016.

Thank You