SNS COLLEGE OF ENGINEERING

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AN AUTONOMOUS INSTITUTION

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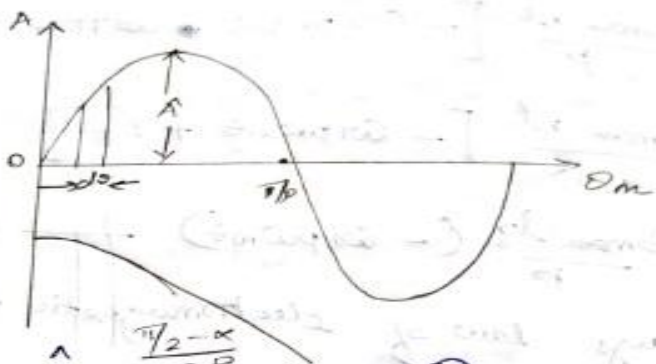
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

UNIT – 2

PERMANENT MAGNET SYNCHRONOUS MOTOR

TORQUE EQUATION

Torque equation of PMSM.



$$A = \hat{A} \sin p\theta \quad \text{--- (1)}$$

A → ampere conductor density

Consider a strip of dθ at an angle θ from reference axis

$$d\theta = \hat{A}\, d\theta$$
$$= \hat{A} \sin p\theta \cdot d\theta \quad \text{--- (2)}$$

$$\text{Ampere conductor/pole} = \int_0^{\pi/p} \hat{A} \sin p\theta \, d\theta$$

$$= -\hat{A} \left[\frac{\cos p\theta}{p} \right]_0^{\pi/p}$$

$$= -\frac{\hat{A}}{p} \left[\cos \pi - \cos 0 \right]$$

$$= \frac{2\hat{A}}{p} \quad \text{--- (3)}$$

Let us consider flux density distribution is placed by an angle of $(\pi/2 - \alpha)$

$$B = B_{max} \sin\left[p\theta + (\pi/2 - \alpha)\right]$$

$$= B_{max} \sin\left[\frac{\pi}{2} + (p\theta - \alpha)\right]$$

$$= B_{max} \cos\left[p\theta - \alpha\right] \quad \because \sin(90+\theta) = \cos\theta$$

$$B = B_{max} \cos\left[p\theta - \alpha\right] \longrightarrow (4)$$

difference in angle $dF = BlA \cdot d\theta$

$$dF = B_{max} \cos\left[p\theta - \alpha\right] \, l \, \underline{A_{max} \sin p\theta} \cdot d\theta \quad (1)$$

$$dF = A_{max} B_{max} \, l \sin p\theta \cdot \cos(p\theta - \alpha) \cdot d\theta \quad (5)$$

$$dT = dF \times r$$

$$dT = A_{max} B_{max} rl \cdot \sin p\theta \cdot \cos(p\theta - \alpha) \cdot d\theta \quad (6)$$

Torque experienced / pole $= T/\text{pole}$

$$= \int_0^{\pi/p} dt$$

$$= \int_0^{\pi/p} A_{max} B_{max} rl \, \underline{\sin p\theta} \cdot \underline{\cos(p\theta - \alpha) \cdot d\theta}$$

$$\sin A \cos B = \frac{1}{2}\left[\sin(A+B) + \sin(A-B)\right]$$

$$= \frac{A_{max} B_{max} r l}{2} \int_0^{\pi/p} [\sin(p\theta + p\theta - \alpha) + \sin(p\theta - p\theta + \alpha)] \cdot d\theta$$

$$= \frac{A_{max} B_{max} r l}{2} \left[-\frac{\cos(2p\theta - \alpha)}{2p} + \theta \cdot \sin\alpha \right]_0^{\pi/p}$$

$$= \frac{A_{max} B_{max} r l}{2} \left[-\frac{\cos 2p\,\pi/p - \alpha}{2p} + \frac{\cos 2p0 - \alpha}{2p} + \frac{\pi}{p} \sin\alpha \right]$$

$$= \frac{A_{max} B_{max} r l}{2} \left[-\frac{\cos(2\pi - \alpha)}{2p} + \frac{\cos(-\alpha)}{2p} + \frac{\pi}{p} \sin\alpha \right]$$

$$T = \frac{A_{max} B_{max} r l}{2} \cdot \frac{\pi}{p} \sin\alpha \quad N\text{-}m$$

$$-\frac{\cos(2\pi - \alpha)}{2p} + \frac{\cos(-\alpha)}{2p} \quad [(\cos - \theta) = \cos\theta$$

$$-\frac{\cos 2\pi}{2p} - \frac{\cos\alpha}{2p} + \frac{\cos(-\alpha)}{2p}$$

$$\cos(2\pi - \theta) = -\cos\theta$$
$$\cos(-\theta) = \cos\theta$$

Total torque = 2P × torque /pole

$$= 2P \times \frac{\pi}{p} \times \frac{ABrl}{2} \sin\alpha$$

$$T = \pi A B r l \sin\alpha \quad N\text{-}m$$