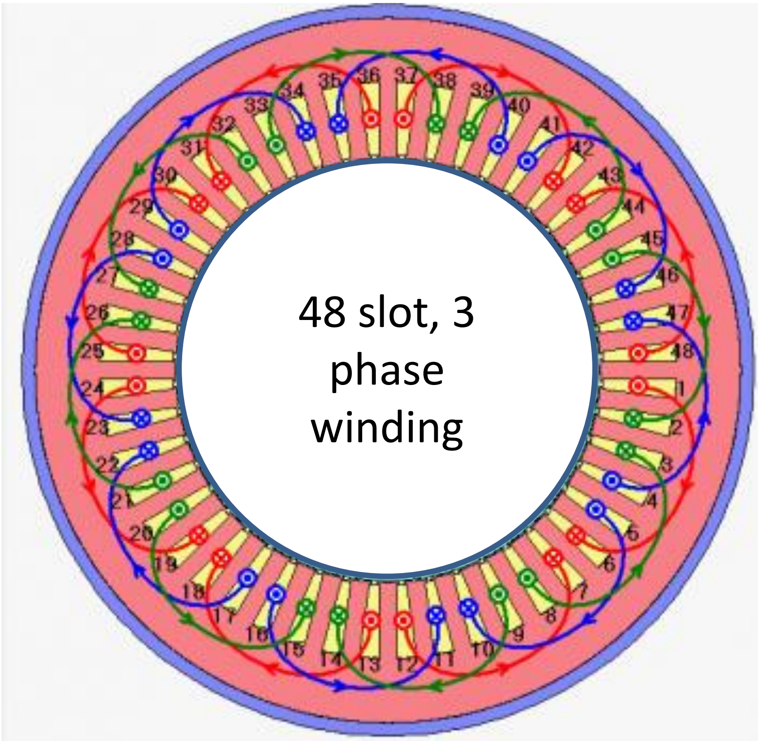
Multi-phase machines

- Whereas the preceding analysis has focussed on a single rotor coil and single stator coil, practical machines contain an array of coils arranged into a series of grouped phases (There are single-phase AC synchronous and induction machines which tend to be limited to lower power applications generally up to 2kW or so)
- The basic principles for the interactions between two coils can be extended to any number of coils and phases
- By far the most common machines are those based on 3 phases stator windings – the exact arrangement will be explored later in this course



Rotating fields with 3 phase windings

Time varying currents in each phase with are phase displaced by 2π/3 (120°)

$$I_A = \widehat{I_p}\sin(\omega t) \qquad I_B = \widehat{I_p}\sin\left(\omega t + \frac{2\pi}{3}\right) \qquad I_c = \widehat{I_p}\sin\left(\omega t - \frac{2\pi}{3}\right)$$

If we consider a **2-pole** machine as an initial case (mech angle = elec angle in a 2 pole machine) then these currents flow in coils that are shifted spatially by 2π/3.

Taking the mmf produced by phase A then:

$$F_{A\theta} = \widehat{F_p}\, sin(\omega t) cos(\theta)$$

N.B θ in this analysis is simply the angular position around the stator bore

We can make use of the trigonometric identity 2*sin u cos v = sin (u+v) + sin (u-v)* to get:

$$F_{A\theta} = \frac{\widehat{F_p}}{2}\big(sin(\omega t + \theta) + sin(\omega t - \theta)\big)$$

and similarly for phases B and C

$$F_{B\theta} = \widehat{F_p}\sin\left(\omega t + \frac{2\pi}{3}\right) cos\left(\theta + \frac{2\pi}{3}\right) = \frac{\widehat{F_p}}{2}\left(sin\left(\omega t + \theta + \frac{4\pi}{3}\right) + sin(\omega t - \theta)\right)$$

$$F_{C\theta} = \widehat{F_p}\sin\left(\omega t - \frac{2\pi}{3}\right) cos\left(\theta - \frac{2\pi}{3}\right) = \frac{\widehat{F_p}}{2}\left(sin\left(\omega t + \theta - \frac{4\pi}{3}\right) + sin(\omega t - \theta)\right)$$

The mmf at any value of θ and time t is therefore given by:

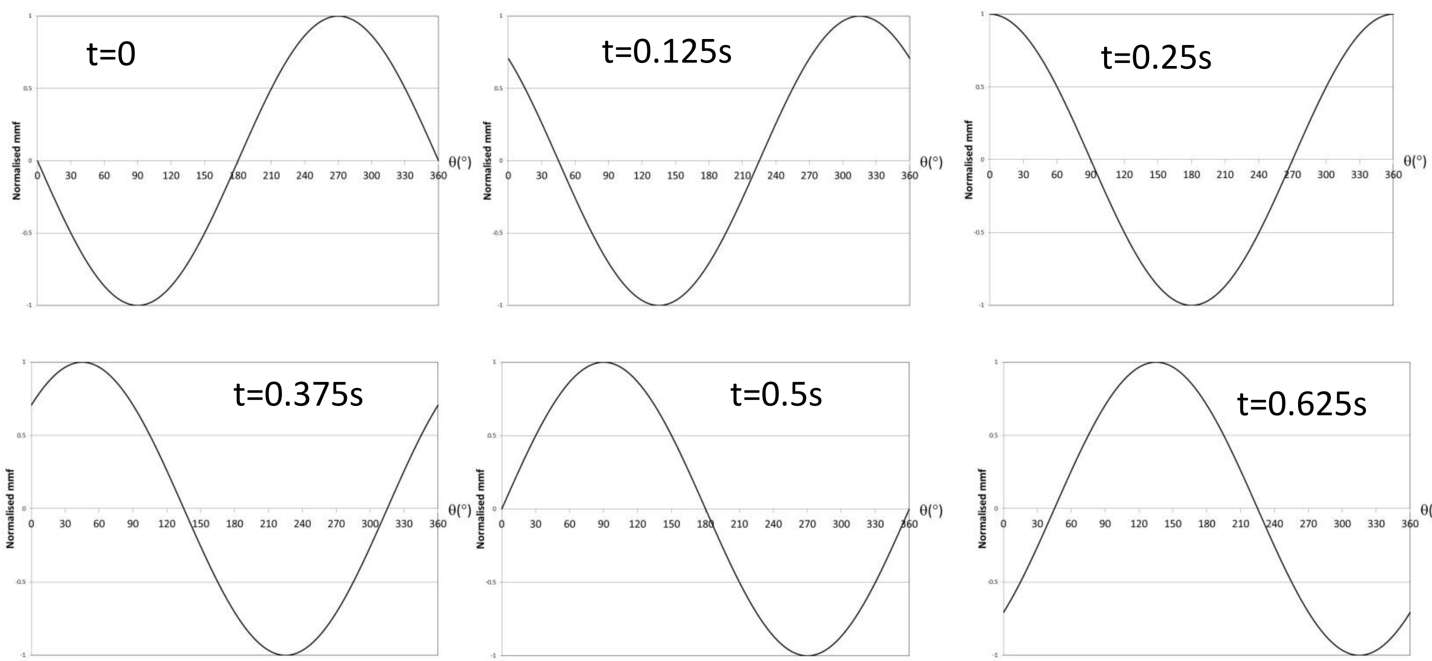
$$F(\theta, t) = \frac{\widehat{F_p}}{2}\left(3\, sin(\omega t - \theta) + sin(\omega t + \theta) + sin\left(\omega t + \theta + \frac{4\pi}{3}\right) sin\left(\omega t + \theta - \frac{4\pi}{3}\right)\right)$$

It can be shown from trigonometry that

$$sin(\omega t+\theta)+sin\left(\omega t+\theta+\frac{4\pi}{3}\right)sin\left(\omega t+\theta-\frac{4\pi}{3}\right)=0$$

Hence: $F(\theta,t)=\dfrac{3\widehat{F_p}}{2}sin(\omega t-\theta)$

If we plot the mmf as a function of θ at different instants of time for 1Hz time variation we get:



As will be seen from the time variation, this function produces a rotating field