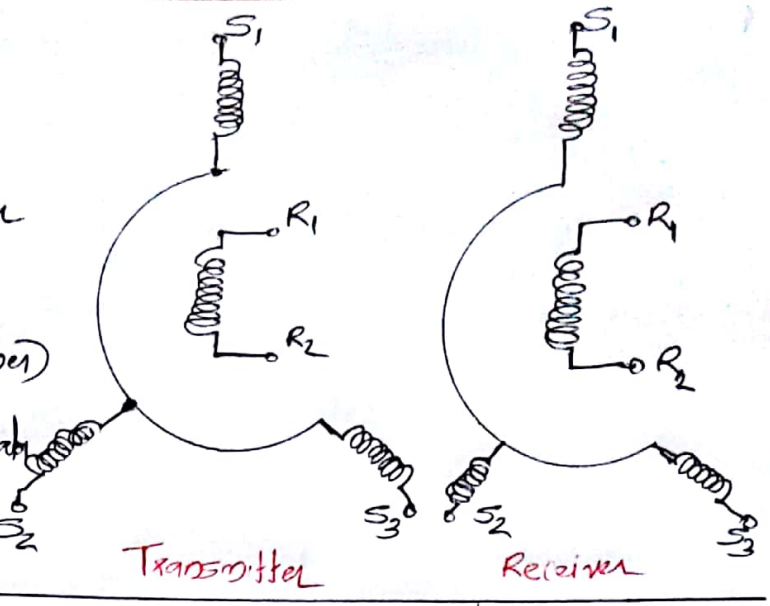
Synchro

* Synchro is an electro mechanical transducer
* It consists of
  1) Transmitter
  2) Receiver (control transformer)
* It's construction is similar to ac generator. It's stator consist of 3 windings star connected.

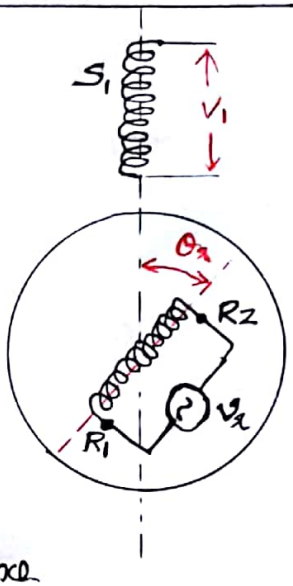


Theory

Suppose we are applying an ac voltage to the rotor. i.e $v_r = V_m \sin \omega t$

Now the current through rotor winding is

$$i_r = I_m \cos \omega t$$



Now the flux linkage in the stator winding (S_1) due to i_r is

$$\lambda_1 = M i_r \cos \theta_r \qquad M \rightarrow \text{mutual inductance}$$

ie flux linkage is maximum when the windings are exactly aligned $[\theta_r = 0]$

Now the induced emf is

$$V_1 = -\frac{d}{dt}\lambda_1 = -\frac{d}{dt}\left[M I_m \cos \omega t \cos \theta_r\right]$$

$$= M I_m \omega \sin \omega t \cos \theta_r + M I_m \omega_r \cos \omega t \sin \theta_r$$

$$= M I_m \omega \cos \theta_r \cos\left(\omega t - \frac{\pi}{2}\right) + M I_m \omega_r \cos\left(\theta_r - \frac{\pi}{2}\right) \cos \omega t$$

(θ_r ↑ wrt t in the first term; θ_r ↑ wrt t in the second term)

Statically induced emf — Max. at $\theta_r = 0$

Rotationally induced emf — Max. at $\theta_r = \frac{\pi}{2}$

Now if S_2 and S_3 are placed 120° apart mechanically then we have

$$V_2 = M I_m \omega \cos\left(\theta_1 - \frac{2\pi}{3}\right) \cos\left(\omega t - \frac{\pi}{2}\right) + M I_m \omega_r \cos\left[\left(\theta_1 - \frac{2\pi}{3}\right) - \frac{\pi}{2}\right] \cos \omega t$$

$$V_3 = M I_m \omega \cos\left(\theta_1 - \frac{4\pi}{3}\right) \cos\left(\omega t - \frac{\pi}{2}\right) + M I_m \omega_r \cos\left[\left(\theta_1 - \frac{4\pi}{3}\right) - \frac{\pi}{2}\right] \cos \omega t$$

Case 1

when we are applying a dc input at rotor (i.e $\omega = 0$), we have

$$V_1 = M I_m \omega_r \cos\left(\theta_r - \frac{\pi}{2}\right) = M I_m \omega_r \sin(\omega_r t)$$

$$V_2 = M I_m \omega_r \sin\left(\omega_r t - \frac{2\pi}{3}\right)$$

$$V_3 = M I_m \omega_r \sin\left(\omega_r t - \frac{4\pi}{3}\right)$$

ie we have an AC generator here. [induced emf V_1, V_2, V_3 are 120° shifted in time axis

Case 2

when we are applying an AC input at rotor & holding the rotor at one position without rotating (i.e $\omega_r = 0$) we have

$$V_1 = M I_m \omega \cos\theta_r \cos\left(\omega t - \frac{\pi}{2}\right) = \underbrace{M I_m \omega \cos\theta_r}_{K_1} \sin\omega t = K_1 \sin\omega t$$

$$V_2 = M I_m \omega \cos\left(\theta_r - \frac{2\pi}{3}\right) \cos\left(\omega t - \frac{\pi}{2}\right)$$

$$V_3 = M I_m \omega \cos\left(\theta_r - \frac{4\pi}{3}\right) \cos\left(\omega t - \frac{\pi}{2}\right)$$

Here we have some variable ac transformer here [induced emf V_1, V_2, V_3 are in phase with input signal

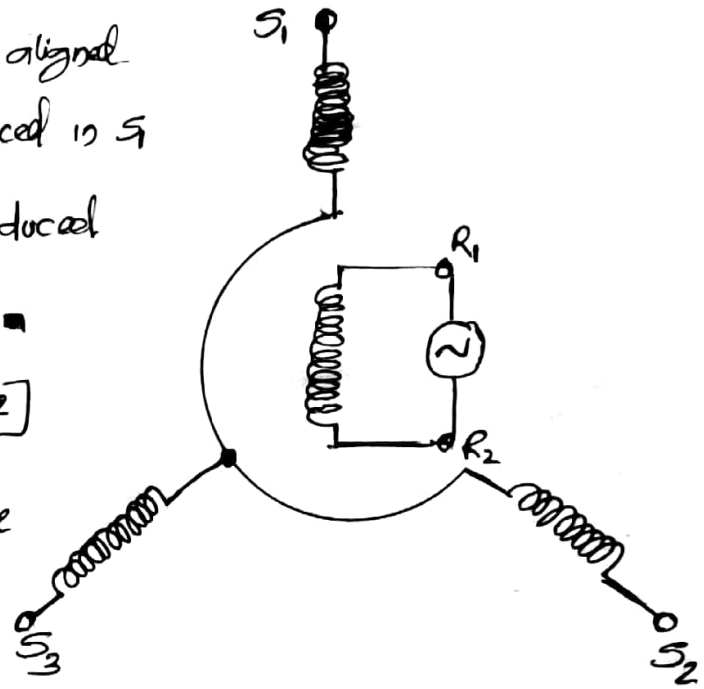
* In syncros we are using case 2 as working principle

* when we are applying an ac input at rotor and rotating the rotor using a prime mover, then the induced emf will be sum of statically induced emf & rotationally induced emf

Electrical zero of transmitter

When we are applying an ac input to the synchro transmitter rotor and holding the rotor at one position then the voltage induced in stator contains only statically induced emf [since $\omega_r = 0$]

* Suppose the rotor is exactly aligned with S_1. Then voltage induced in S_1 will be maximum & voltage induced in S_2 & S_3 will be exactly same [in magnitude & phase]

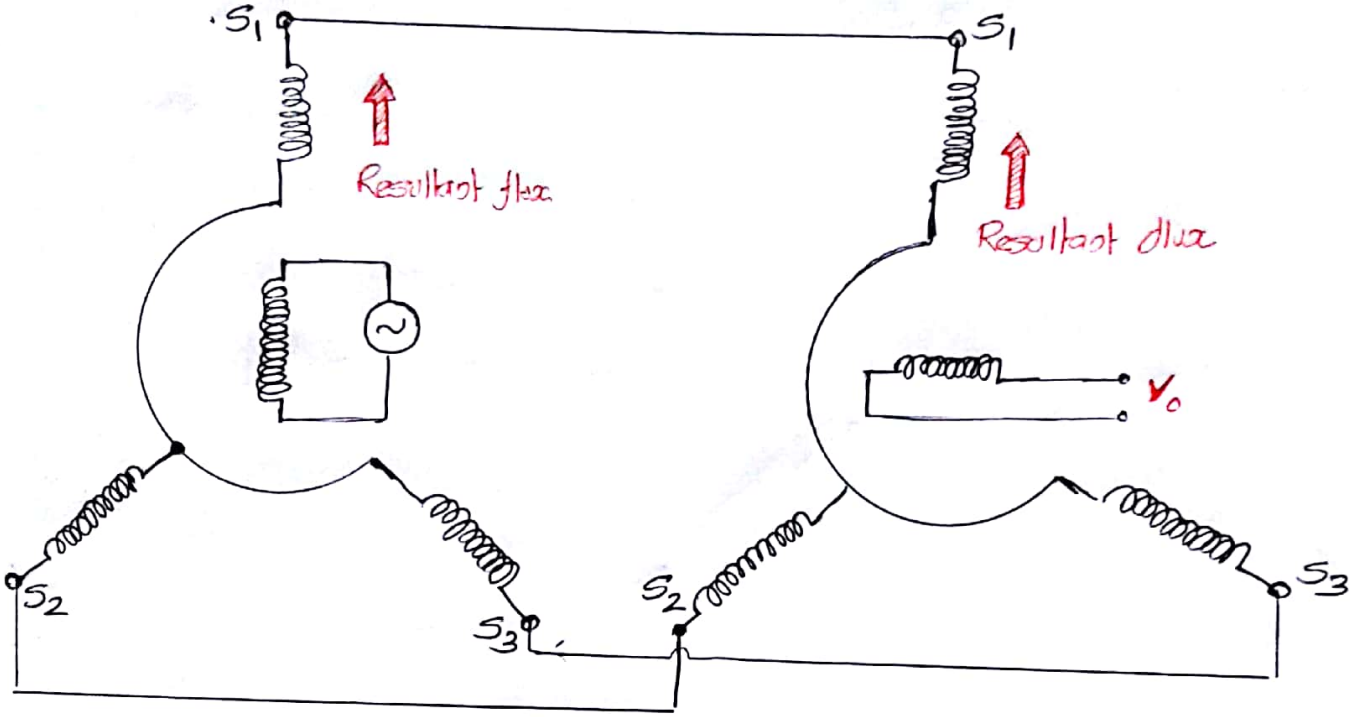


Then if we measure the voltage b/w S_2 & S_3 we get a zero voltage. $V_{23} = 0$

* This angle is known as the electrical zero of transmitter
* We can measure either the voltage b/w S_1-S_2, S_2-S_3, S_3-S_1 for finding electrical zero. In each cases the electrical zero will be differed by 120°
* Electrical zero is used as a reference

Electrical zero of receiver

* Here we are applying an ac input to the transmitter rotor
* S_1, S_2, S_3 of the transmitter stator is connected to the S_1, S_2, S_3 of receiver stator



* When the rotor is exactly aligned to one stator winding in the transmitter (ie S_1 in figure), the voltage induced in that winding will be maximum.
* Now when S_1 of the transmitter is connected to the receiver current starts flowing in the circuit. And in this position the maximum current flows in S_1 and hence resultant stator flux will be as shown in figure.
* Now when the rotor of receiver is aligned with S_1 maximum voltage will be induced.
* When rotor is 90° out of phase [as in figure] induced voltage $V_0 = 0$ This position is known as electrical zero of receiver.
* If we start moving transmitter rotor from this balance condition corresponding voltage can be observed in V_0