SYNCRO

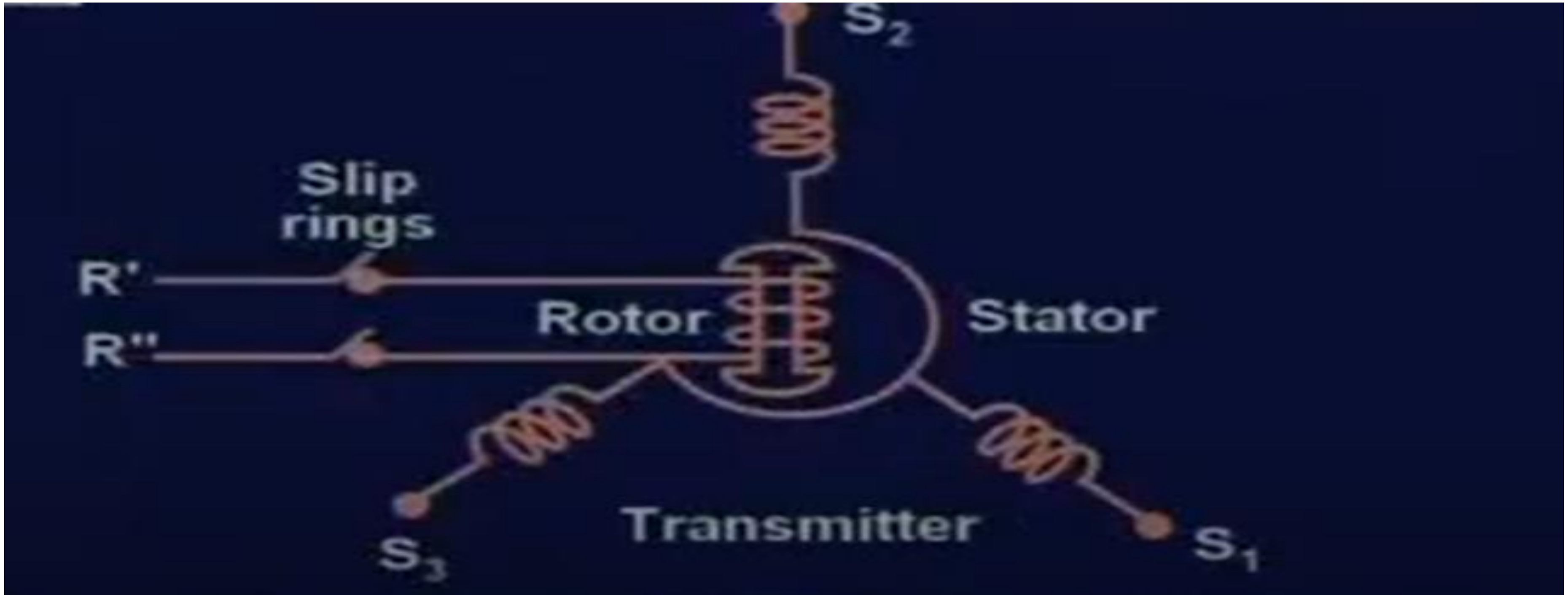
Introduction

- Synchro is an AC electromechanical system which basically makes the angle measurement.
- Synchros for angle measurement are most widely used as components of servo-mechanism where they are used to measure and compare the actual rotational position of a load with its commanded position.

- To perform this operation a synchro pair is used and they are called as transmitter and control transformer.
- The pair is used to detect shaft position error.

Theory

Synchro is a rotating device that operates on the same principle as a transformer and produces a set of voltages, correlated to angular position.



ig. 1 Schematic diagram of Synchro Transmitter

Synchro Transmitter

Stator: Y connected stator similar to a 3-phase induction motor. The rotor is salient pole, dumb bell shaped (To reduce weight of the rotor) with a single winding.

Let the voltage applied to the rotor of a synchro transmitter be

$$e_{tr}(t) = E_{tr} \sin\omega t$$

When the rotor is in position shown in Fig. 1 which is defined as the electric zero, the voltage induced across the stator winding between s_2 and the neutral n is maximum and is written as

$$e_{s_{2n}}(t) = KE_{tr} \sin \omega t$$

where K is the constant of proportionality and two other stator voltages can be written as

$$e_{s_{1m}}(t) = KE_{tr} \cos 240^\circ \sin\omega t$$

$$= -0.5\, KE_{tr} \sin\omega t$$

$$e_{s_{3m}}(t) = KE_{tr} \cos 120^\circ \sin\omega t$$

$$= -0.5\, KE_{tr} \sin\omega t$$

Therefore the voltages across the stator winding are

$$e_{s_1s_2} = e_{s_{1n}} - e_{s_{2n}} = -1.5\,KE_{tr}\sin\omega t$$

$$e_{s_2s_3} = e_{s_{2n}} - e_{s_{3n}} = 1.5\,KE_{tr}\sin\omega t$$

$$e_{s_3s_1} = e_{s_{3n}} - e_{s_{1n}} = 0$$

It is to be noted that despite the similarity between the construction of the stator of a synchro and that of a three phase machine, only single phase voltage is induced in the stator.

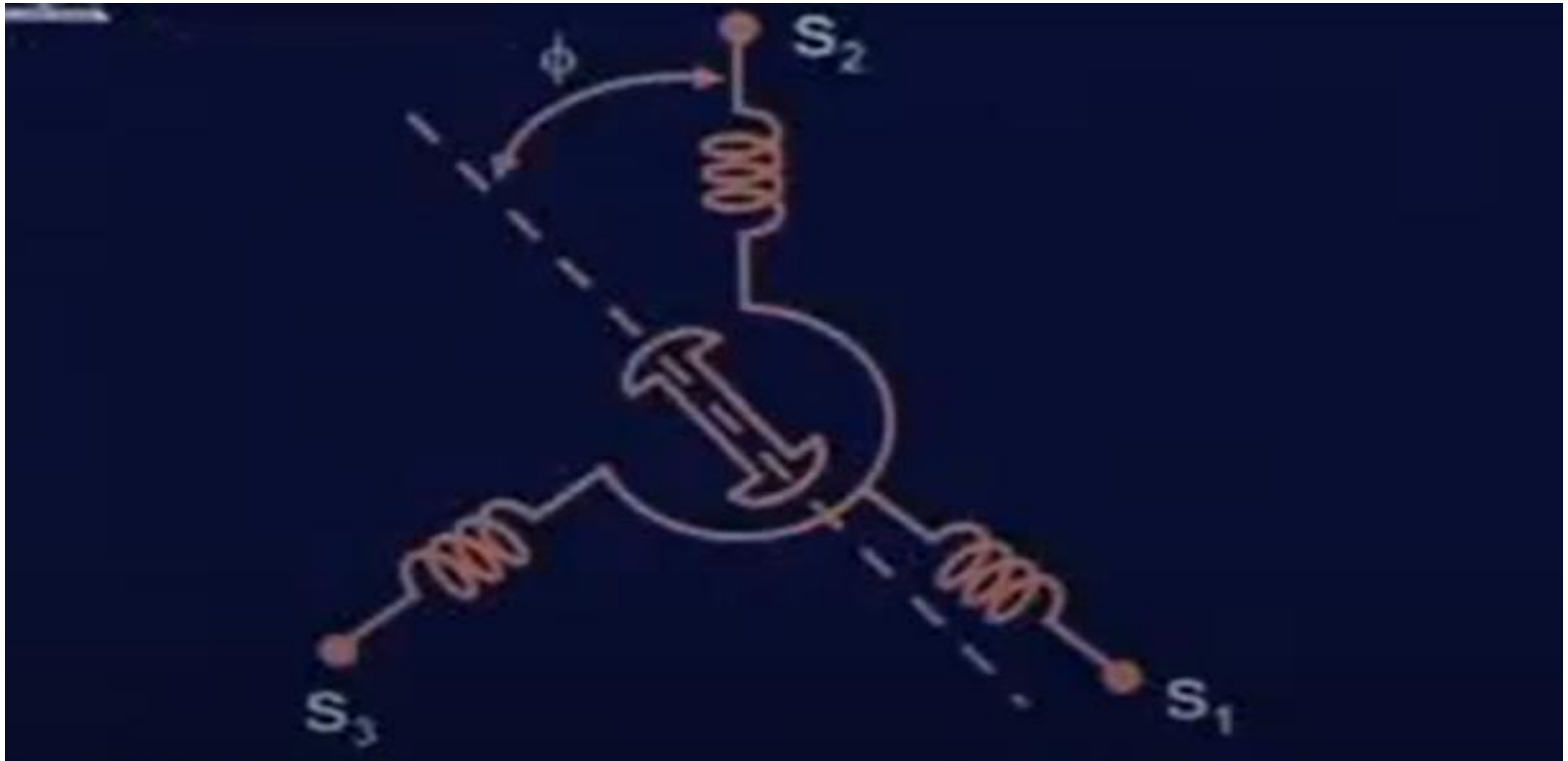


Fig. 2 Rotor is at angle ϕ from electric zero

If now the rotor is rotated to a position as shown in Fig. 2, the voltages in each stator winding will vary as a function of the cosine of the rotor displacement angle ϕ. The voltage magnitudes are

$$e_{s_{1n}} = KE_{tr}\cos(\phi - 240^\circ)$$

$$e_{s_{2n}} = KE_{tr}\cos\phi$$

Therefore the voltages across the stator winding are

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$$e_{s_2s_3} = e_{s_{2n}} - e_{s_{3n}} = 1.5\, KE_{tr} \sin\omega t$$

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$$e_{S_{2n}} = KE_{tr}\cos\phi$$

$$e_{S_{3n}}' = KE_{tr}\cos(\phi - 120^\circ)$$

The magnitudes of the stator terminal voltages will be expressed as

$$e_{s_1s_2} = e_{s_{1n}} - e_{s_{2n}} = \sqrt{3}\,KE_{tr}\sin(\phi + 240^\circ)$$

$$e_{s_2s_3} = e_{s_{2n}} - e_{s_{3n}} = \sqrt{3}\,KE_{tr}\sin(\phi + 120^\circ)$$

$$e_{s_3s_1} = e_{s_{3n}} - e_{s_{1n}} = \sqrt{3}\,KE_{tr}\sin\phi$$

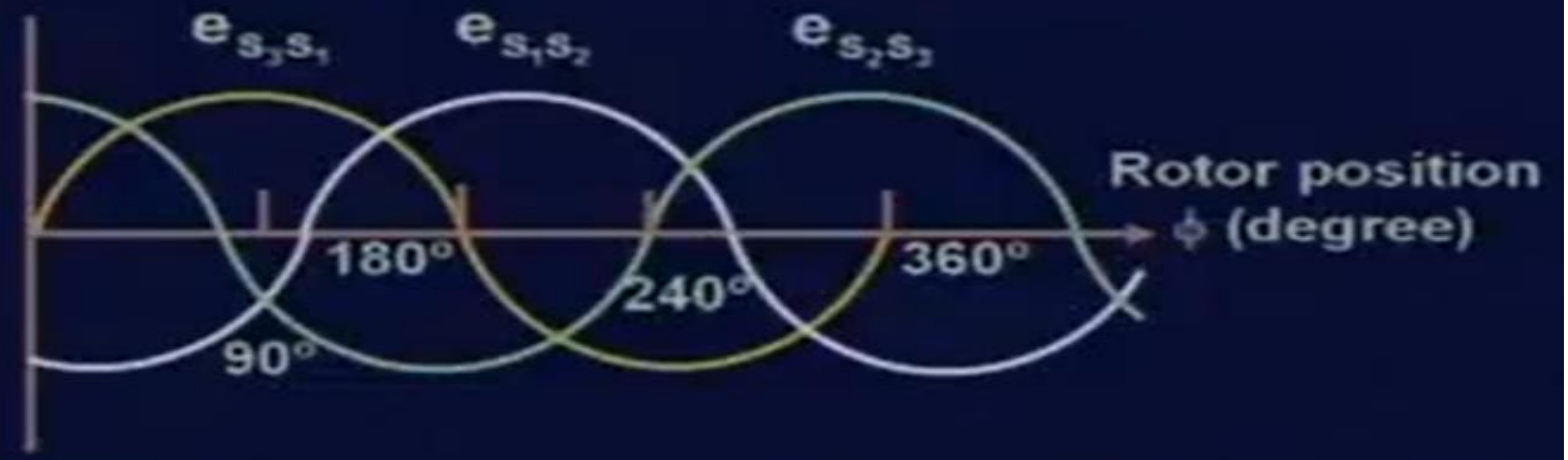


Fig. 3 The plot of stator voltages of a synchro transmitter Vs. ϕ (which is in counter clockwise direction).

Construction of Synchro

- The physical constructions of the transmitter and control transformer are identical except that the transmitter has a salient-pole ("dumbbell" shaped) rotor while the transformer has a cylindrical rotor.
- The construction is similar to that of a wound-rotor induction motor. Figure 4 shows the coil arrangement of the transmitter rotor.

Transmitter - Rotor

Control Transformer – Rotor (there are two null positions of the rotor of control Transformer.

Fig. 4 Synchro Rotors

- Rotation of the rotor changes the mutual inductance between the rotor coil and the stator coils.
- For a given stator coil, the open-circuit output voltage is sinusoidal in time and varies in amplitude with rotor position, also sinusoidally, as shown in Fig. 3.
- The three voltage signals from the stator coils uniquely define the angular position of the rotor.

- When these three voltages are applied to the stator coils of a control transformer, they produce a resultant magnetomotive force aligned in the same direction as that of the transmitter rotor.
- The rotor of the transformer acts as a "search coil" in detecting the direction of its stator field.
- If the axis of this coil is aligned with the field, the maximum voltage is induced into the transformer rotor coil.

- If the axis is perpendicular to the field, zero voltage is induced, giving the null position mentioned above.
- The output voltage amplitude actually varies sinusoidally with the misalignment angle, but for small angles the sine and the angle are nearly equal, giving a linear output.

- The control transformer stator winding is similar to that of transmitter.
- Rotor of control transformer is cylindrically shaped to make density of magnetic flux same at all positions of the rotor, otherwise output voltage will be the function of the position of control transformer rotor it self.

Error Detector

The function of an error detector is to convert the difference of two shaft positions into an electrical signal.

Therefore a single synchro transmitter is apparently inadequate.

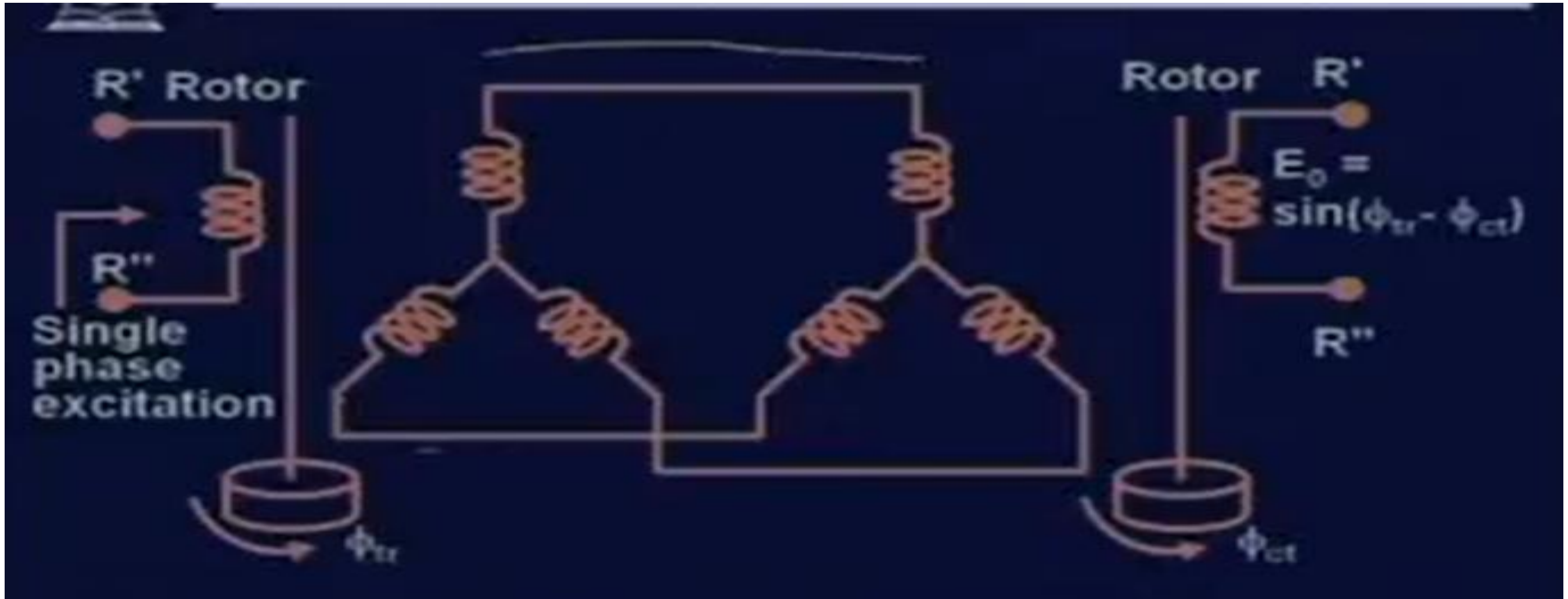


Fig. 5 Synchro error detector

- A synchro error detector is made of two synchros or a synchro pair i.e. one transmitter and one control transformer.
- For small angular deviations between the rotor position a proportional voltage is developed at the rotor terminals of the control transformer.

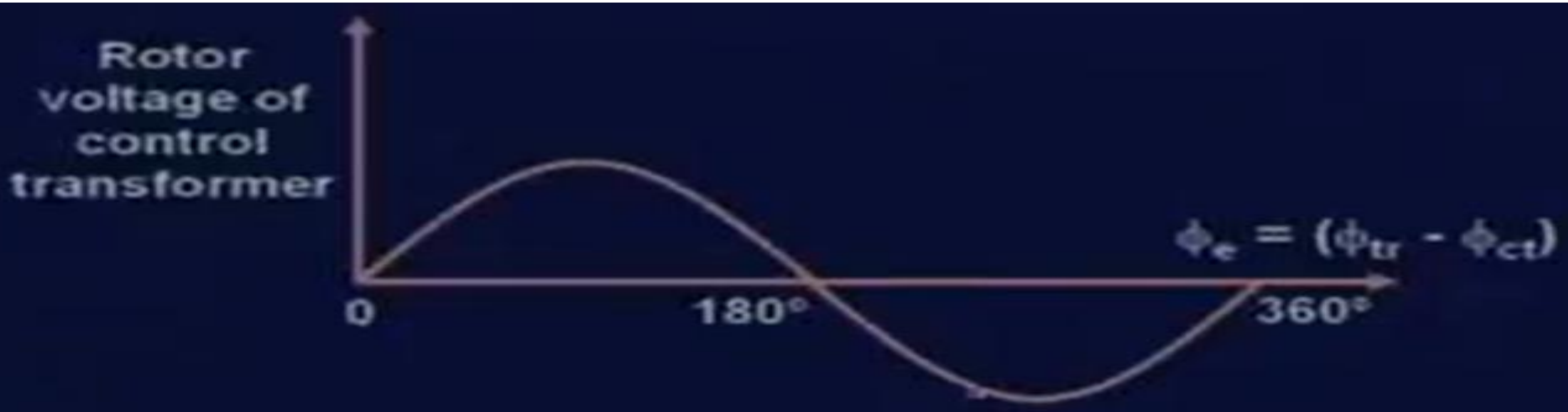


Fig. 6 Rotor voltage of control transformer plotted as a function of the difference of rotor position

- Synchro error detector is a nonlinear device but for small angular deviations of upto 15° in the vicinity of null positions, the rotor voltage of control transformer is approximately proportional to the difference between the positions of the rotors of the transmitter and the control transformer

Mathematically $K_s = \dfrac{E}{\phi_{tr} - \phi_{ct}} = \dfrac{E}{\phi_e}$ (For small deviation)

Where, E = Error voltage,

ϕ_{tr} = Shaft position of rotor of synchro transmitter in degree

ϕ_{ct} = Shaft position of rotor of control transformer in degree

ϕ_{e} = Error in shaft position in degree

K_s = Sensitivity of error detector, volts/degree

- For typical control transformer, sensitivities lie between 100 to 500 mV/degree. Synchro accuracy is usually specified in terms of minutes of error.
- A synchro having ± 10 minutes accuracy will produce the correct stator voltages for a given angle with no more than ± 10 minute error in angle.

- Apart from their use as a displacement transducer, such synchro pairs are commonly used to transmit angular displacement information over some distance, for instance to transmit gyro compass measurements in an aircraft to remote meters.
- They are also used for load positioning, allowing a load connected to the control transformer rotor shaft to be controlled remotely by turning the transmitter rotor.

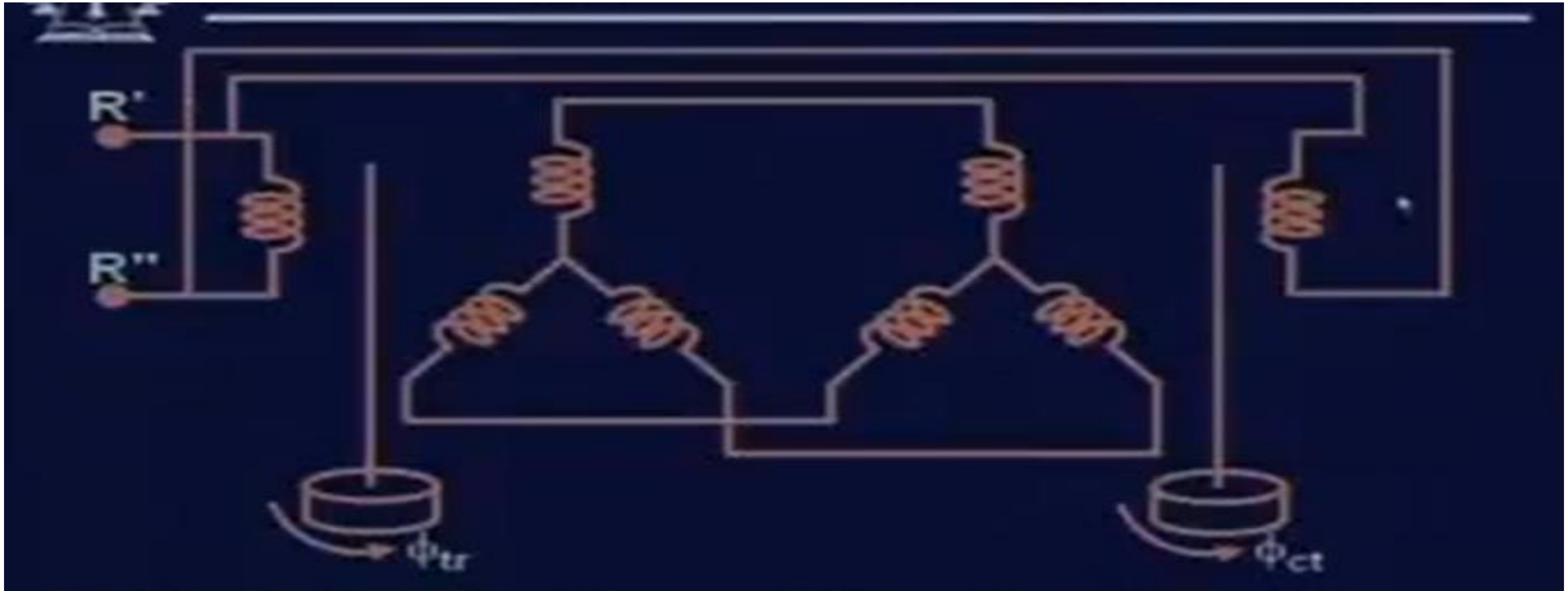


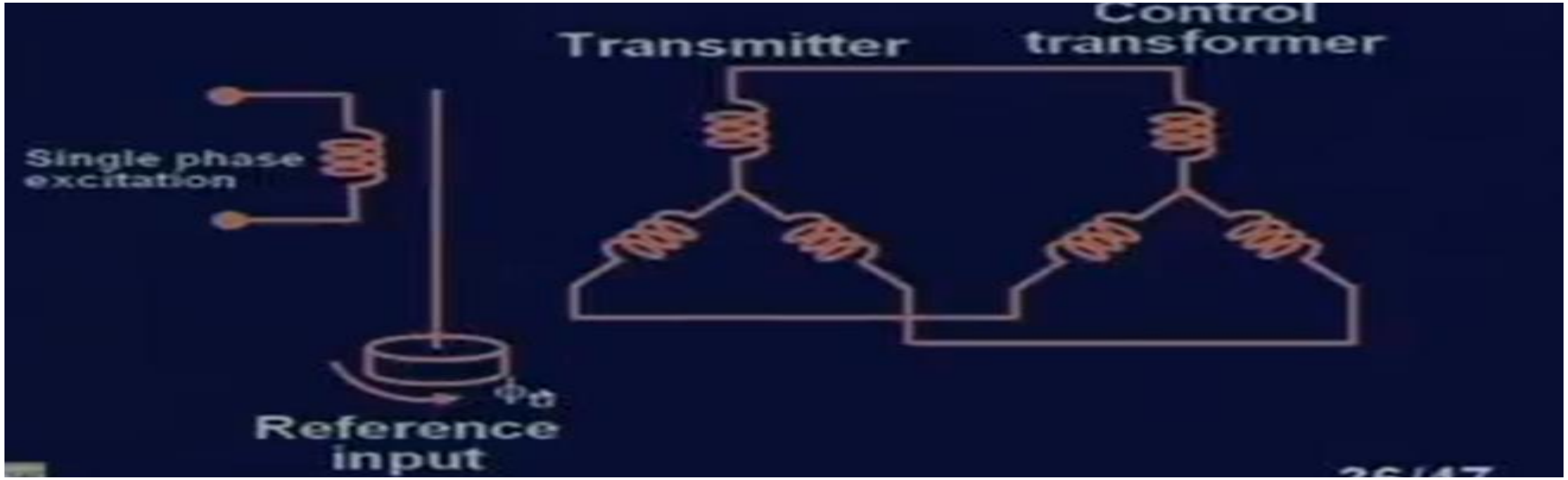
Fig. 7 Synchro Transmitter – Receiver Pair

- For these applications, the transformer rotor is free to rotate and is also damped to prevent oscillatory motions.
- In the simplest arrangement, a common sinusoidal excitation voltage is applied to both rotors.
- If the transmitter rotor is turned, this causes an imbalance in the magnetic flux patterns and results in a torque on the transformer rotor which tends to bring it into line with the transmitter rotor.

Limitation

- The use of a synchro transmitter-receiver pair is limited to relatively low torque loads and overall accuracy is determined by the friction of the rotor of control transformer and load bearing.
- In ordinary application, such as driving an indicator pointer at a remote location, the receiver shaft will follow the transmitter shaft with less than 1° error.

- It is necessary to incorporate the synchro pair within a servomechanism, where the output voltage induced in the control transformer rotor winding is amplified and applied to a servomotor which drives the transformer rotor shaft until it is aligned with the transmitter shaft.


Transmitter
Control
transformer
Single phase
excitation
Reference
input

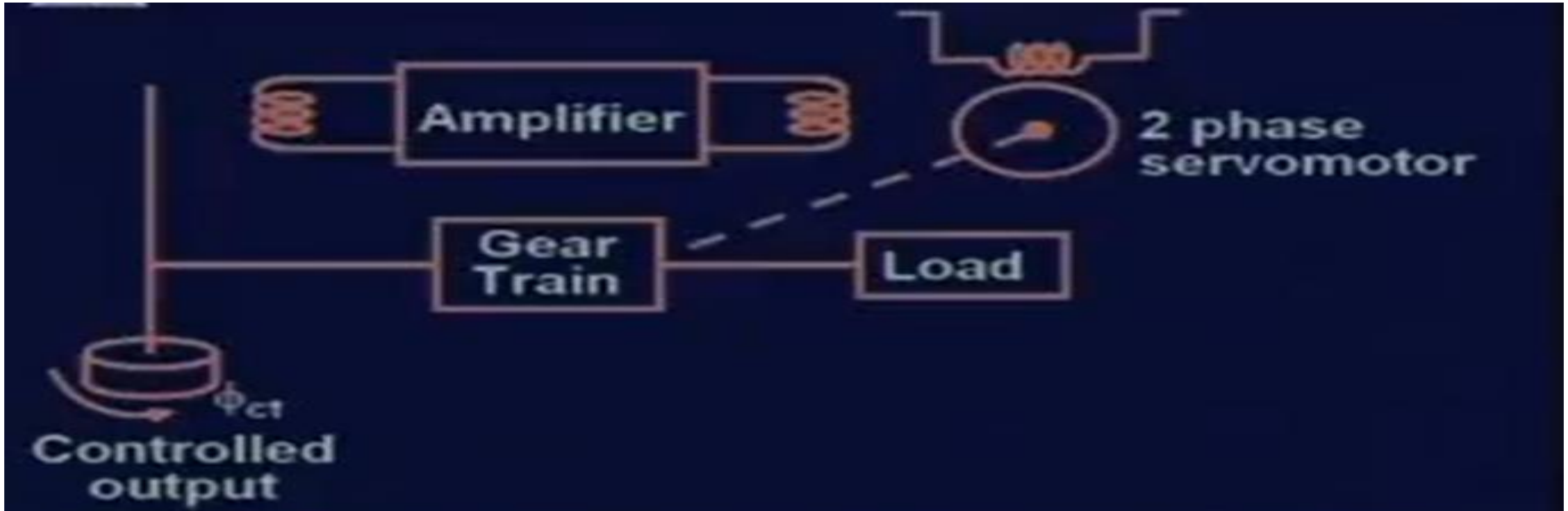


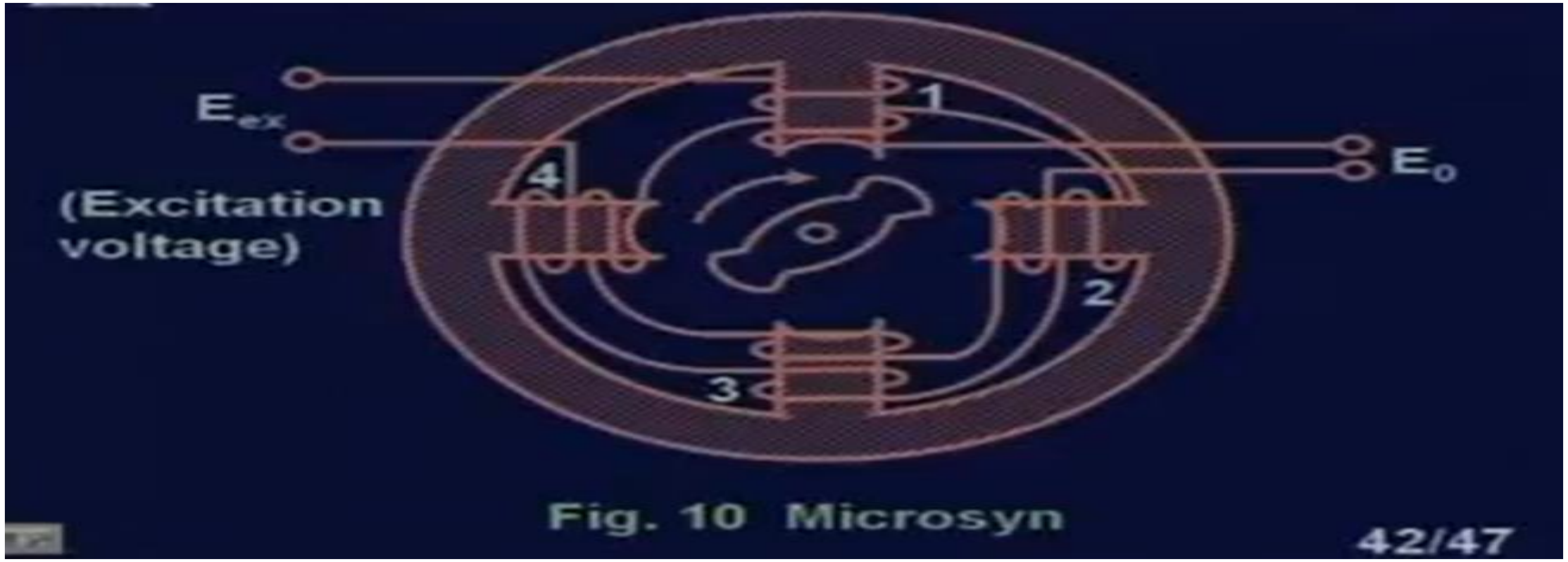
Fig. 8 A.C control system employing synchro as an error detector

Fig. 9 Block diagram of A.C. control system.

- K_s (the sensitivity of the error detector) has opposite signs at two null positions.
- In the closed loop systems there exists only one true null position, the other one corresponds to an unstable operating point.
- When the synchro positions are close to the true null and the rotor of control transformer lags behind the rotor of the transmitter, a positive error voltage will cause the servo motor to turn in the proper direction to correct this lag.

- If the synchros are operating close to the position which is not true null, for the same lag between ϕ_{tr} and ϕ_{ct} the error voltage is negative and the servo motor will rotate in the direction that will increase the lag.
- The larger the lag in the rotor position of control transformer higher will be the magnitude of the error voltage.

MICROSYN



- As shown in Fig. 10 the rotor is connected to the input shaft. When input shaft is in null position where voltage induced in coils 1 and 3 (which aid each other) are just balanced by those of coils 2 and 4 (which also aid each other but oppose 1 and 3).
- If now the shaft rotates in clockwise direction (as shown in Fig. 10) from null position reluctance of coils 1 and 3 increases and the reluctance of coils 2 and 4 decreases.

- As a consequence induced voltage in coils 1 and 3 decreases and that of coils 2 and 4 increases.
- Therefore a net output voltage (E_0) will be available from microsyn.
- Now if the shaft moves in opposite direction microsyn gives output voltage of same amplitude with 180° phase shift.

Specifications.

- Excitation voltage $\Rightarrow$ 5 to 50 V.
- Excitation frequency $\Rightarrow$ 50 Hz to 5 KHz.
- Sensitivity $\Rightarrow$ 0.2 to 5V/degree.
- Nonlinearity $\Rightarrow$ 0.5 % of full scale for $\pm$ 7° of rotation.
  1 % of full scale for $\pm$ 10° of rotation.

Advantages

- Very small angular displacement can be measured.
- No slip rings are required for rotor excitation in contrast with synchro.

- IIT K – Prof A Barua - Department of electrical – Lecture number 30 – Synchro