UNIT - IV

STATIC RELAYS

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SYLLABUS (UNIT – IV)

- Static relays - amplitude & phase comparators, duality between amplitude & phase comparators, circulating current amplitude comparators, coincidence type phase comparator, block spike phase comparator, integrating phase comparator, Hall effect sine phase comparator, Design of directional relay, reactance relay, mho relay, impedance relay, quadrilateral characteristics relay using cosine phase comparator and amplitude comparator.

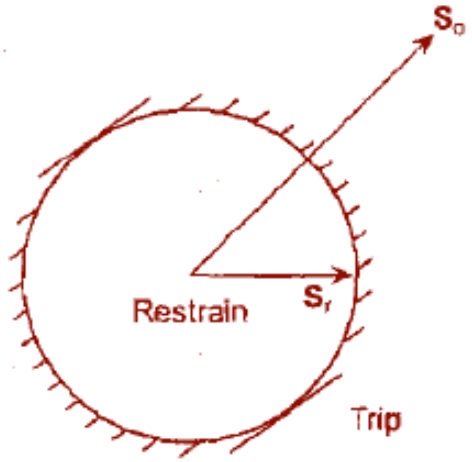
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Amplitude Comparator

- The amplitude comparator has two inputs, So and *Sr and a trip output. Both the inputs* are phasor. The input phasor *So is called the operating quantity and the input phasor Sr is called the restraining quantity. The amplitude comparator follows the simple law*

$$\text{If} \quad |S_o| > |S_r| \quad \text{then trip; else restrain}$$





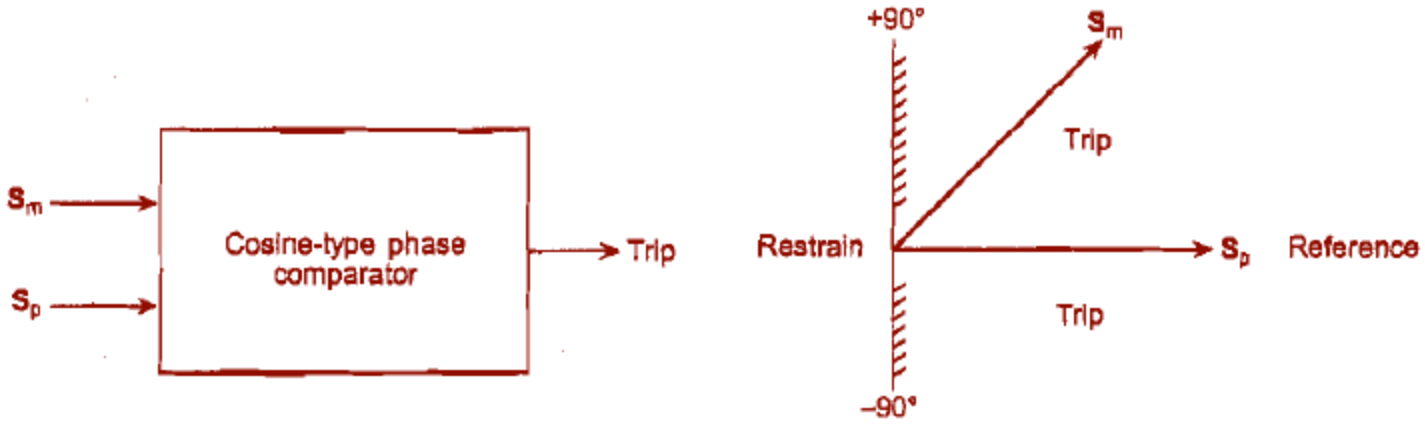
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PHASE COMPARATOR

- The phase comparator are two types
  - 1) **The Cosine-type Phase Comparator**
  - 2) **The Sine-type Phase Comparator.**

- **The Cosine – Type Phase Comparator**
- The cosine-type phase comparator has two phasor Sp and **Sm, at its input and has a trip** output. The input-phasor, designated as Sp is the *polarizing or reference input. The* input-phasor, designated as Sm is called the *measured input. The cosine-type phase* comparator follows the trip law:

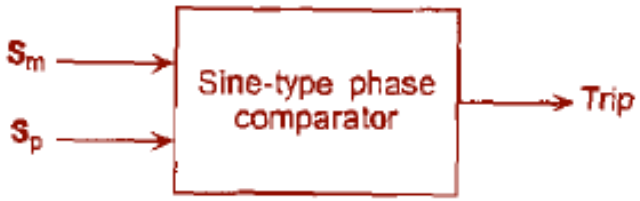
$$\text{If } -90° < \text{Arg}\,(S_m/S_p) < +90° \text{ then trip; else restrain}$$



THE SINE-TYPE PHASE COMPARATOR

- The sine-type phase comparator has two phasor Sp and Sm at its input and has a trip output. The input phasor, designated as *Sm is the polarizing or reference input. The input* phasor, designated as S,, is called the measured input. The sine-type phase comparator follows the trip law:

$$\text{If } 0° < \text{Arg } (S_m/S_p) < 180° \text{ then trip; else restrain}$$





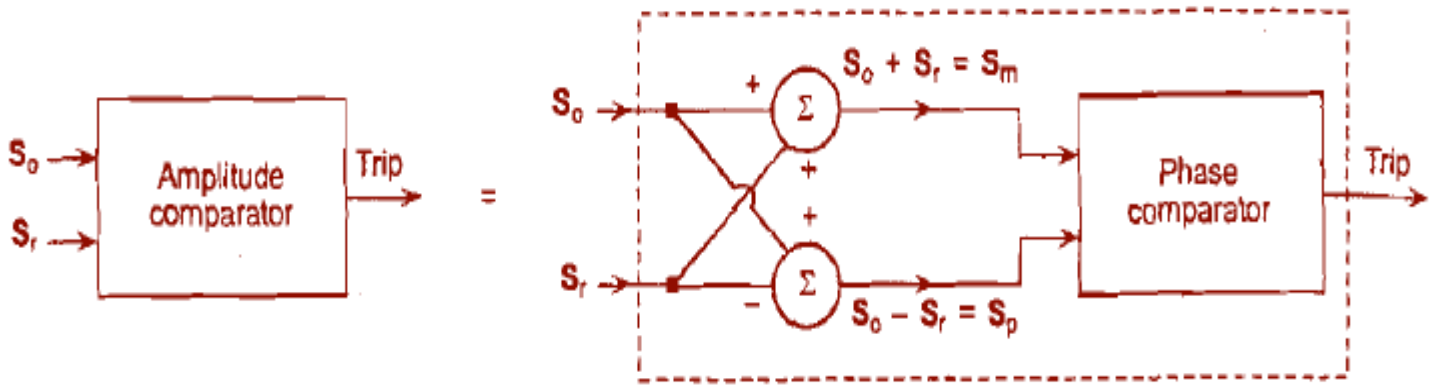
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Duality Between Amplitude and Phase Comparators

- There is a relationship of duality between the amplitude and phase comparators. If the inputs of an amplitude comparator are modified according to the theorem of duality then they become suitable as inputs for a phase comparator and vice versa. In the discussion that follows, unless otherwise explicitly specified, we mean cosine comparator when we mention phase comparator. Let So and *Sr be the original inputs to an amplitude* comparator. If we derive Sm and Sp from So and Sr such that

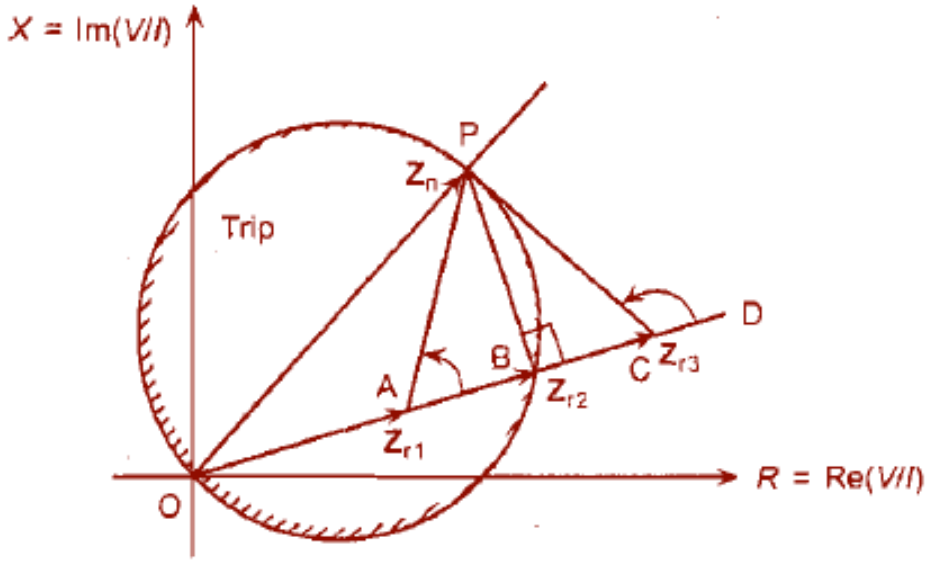
$$S_m = (S_o + S_r) \quad \text{and} \quad S_p = (S_o - S_r)$$

- and feed these to a phase comparator, then the output of the phase comparator would be exactly the same as that of the original amplitude comparator



Synthesis of Mho Relay Using Static Phase Comparator

- Figure shows the synthesis of a mho relay using a phase comparator. The mho relay to be synthesized has a setting of *!Z! < On The characteristic to be synthesized is thus* a circle with diameter as phasor Zn Now, let the impedance seen by the relay be Zrl represented by point A in Figure Since the impedance phasor lies within the trip region, the relay must issue the trip output. It can be easily seen from the figure that the phasor (Zn - Zrl), represented by line AP leads the phasor Zrl by an angle which is definitely less than 90º. The figure shows that as the impedance seen by the relay moves towards the boundary between the trip and restrain regions, the angle between (Zn – Zr) and Zr moves towards 90º. When the phasor representing the impedance seen by the relay, lies on the boundary, this angle is exactly 90º (for example, the angle between PB and OB = 90º). For all impedances lying outside the trip region, i.e. in the restraining region, the angle between (Zn - Zr) and Zr is always greater than 90º (for example, the angle between CP and CD). Similar analysis shows that even if the impedance seen by the relay is on the other I side of Z, as shown in Figure as long as it is in the trip region, the angle between (Zn - Zr) and Zr is always greater than -90º. The angle hits 90º for boundary conditions.



$OA = |Z_{r1}| \rightarrow$ Trip $\qquad AP = |Z_n - Z_{r1}|$

$OB = |Z_{r2}| \rightarrow$ Threshold $\qquad BP = |Z_n - Z_{r2}|$

$OC = |Z_{r3}| \rightarrow$ Restrain $\qquad CP = |Z_n - Z_{r3}|$

$$\text{Arg}\frac{|Z_n - Z_{r1}|}{|Z_{r1}|} = \angle BAP < 90° \rightarrow \text{Trip}$$

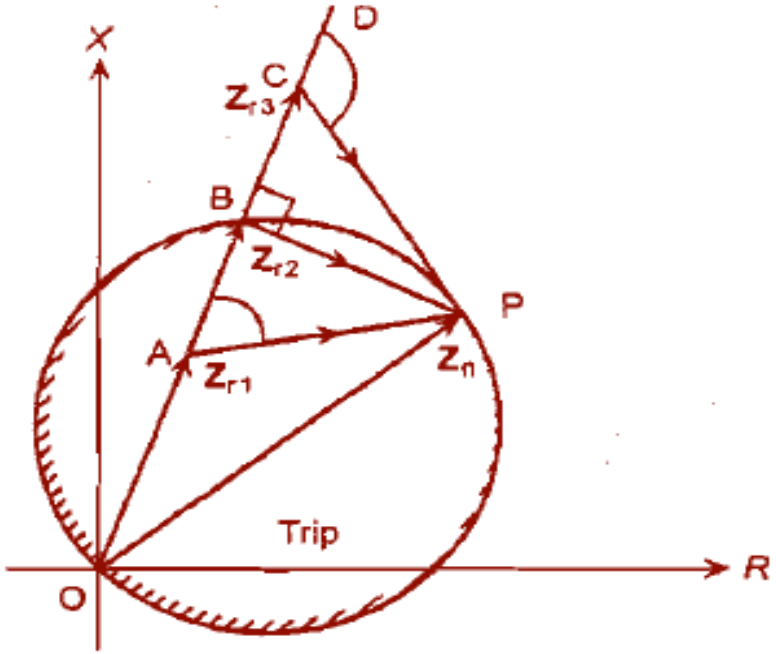
$$\text{Arg}\frac{|Z_n - Z_{r2}|}{|Z_{r2}|} = \angle CBP = 90° \rightarrow \text{Threshold}$$

$$\text{Arg}\frac{|Z_n - Z_{r3}|}{|Z_{r3}|} = \angle DCP > 90° \rightarrow \text{Restrain}$$

Trip law:

$$\text{If} \quad \text{Arg}\frac{|Z_n - Z_r|}{|Z_r|} < 90°; \quad \text{then trip}$$

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$OA = |Z_{r1}| \rightarrow$ Trip

$OB = |Z_{r2}| \rightarrow$ Threshold

$OC = |Z_{r3}| \rightarrow$ Restrain

$AP = |Z_n - Z_{r1}|$

$BP = |Z_n - Z_{r2}|$

$CP = |Z_n - Z_{r3}|$

$$\text{Arg}\ \frac{|Z_n - Z_{r1}|}{|Z_{r1}|} = \angle PAB > -90° \rightarrow \text{Trip}$$

$$\text{Arg}\ \frac{|Z_n - Z_{r2}|}{|Z_{r2}|} = \angle PBC = 90° \rightarrow \text{Threshold}$$

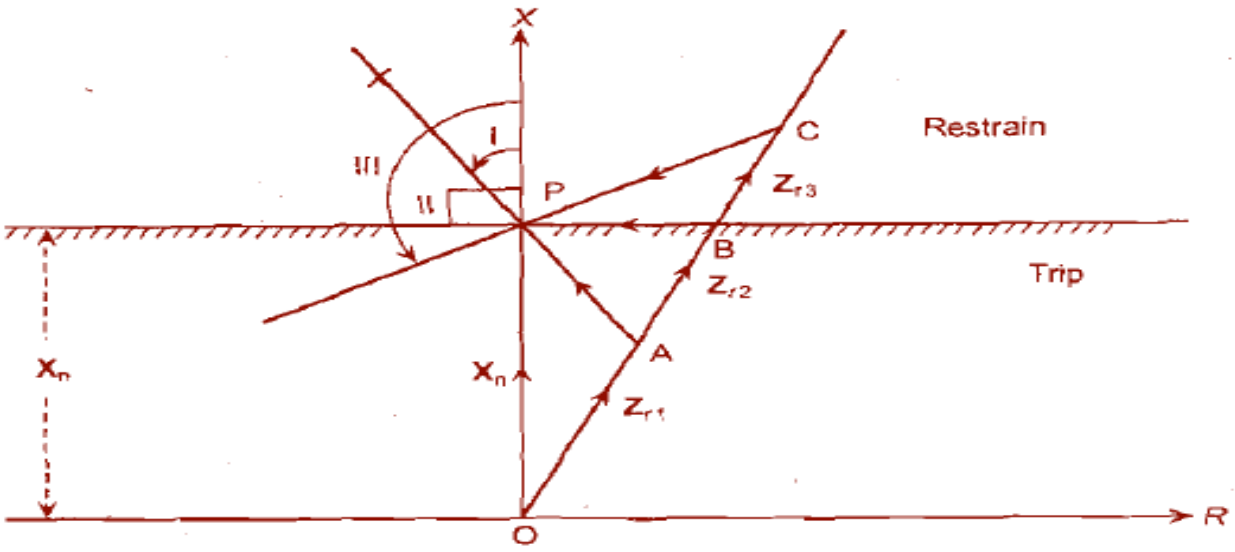
$$\text{Arg}\ \frac{|Z_n - Z_{r3}|}{|Z_{r3}|} = \angle PCD < -90° \rightarrow \text{Restrain}$$

Trip law:

$$\text{If}\quad \text{Arg}\ \frac{|Z_n - Z_r|}{|Z_r|} > -90°; \quad \text{then trip}$$

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Synthesis of Reactance Relay Using Cosine-type Phase Comparator



$OP = |X_n| =$ Setting

$OA = |Z_{r1}| \rightarrow$ Trip $\qquad AP = |X_n - Z_{r1}|$

$OB = |Z_{r2}| \rightarrow$ Threshold $\qquad BP = |X_n - Z_{r2}|$

$OC = |Z_{r3}| \rightarrow$ Restrain $\qquad CP = |X_n - Z_{r3}|$

$$\text{Arg}\frac{|X_n - Z_{r1}|}{|X_n|} = \angle OPA = \angle I < 90° \rightarrow \text{Trip}$$

$$\text{Arg}\frac{|X_n - Z_{r2}|}{|X_n|} = \angle OPB = \angle II = 90° \rightarrow \text{Threshold}$$

$$\text{Arg}\frac{|X_n - Z_{r3}|}{|X_n|} = \angle OPC = \angle III > 90° \rightarrow \text{Restrain}$$

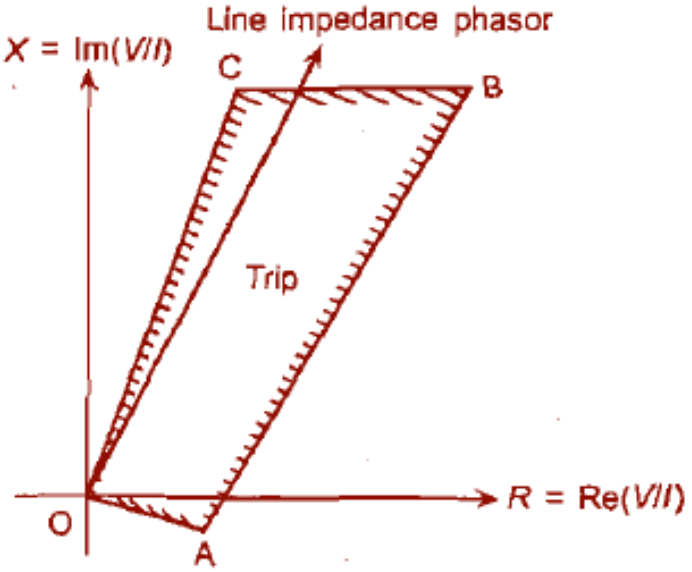
Trip law:

$$\text{If} \quad \text{Arg}\frac{X_n - Z_r}{X_n} < 90°; \quad \text{then trip}$$

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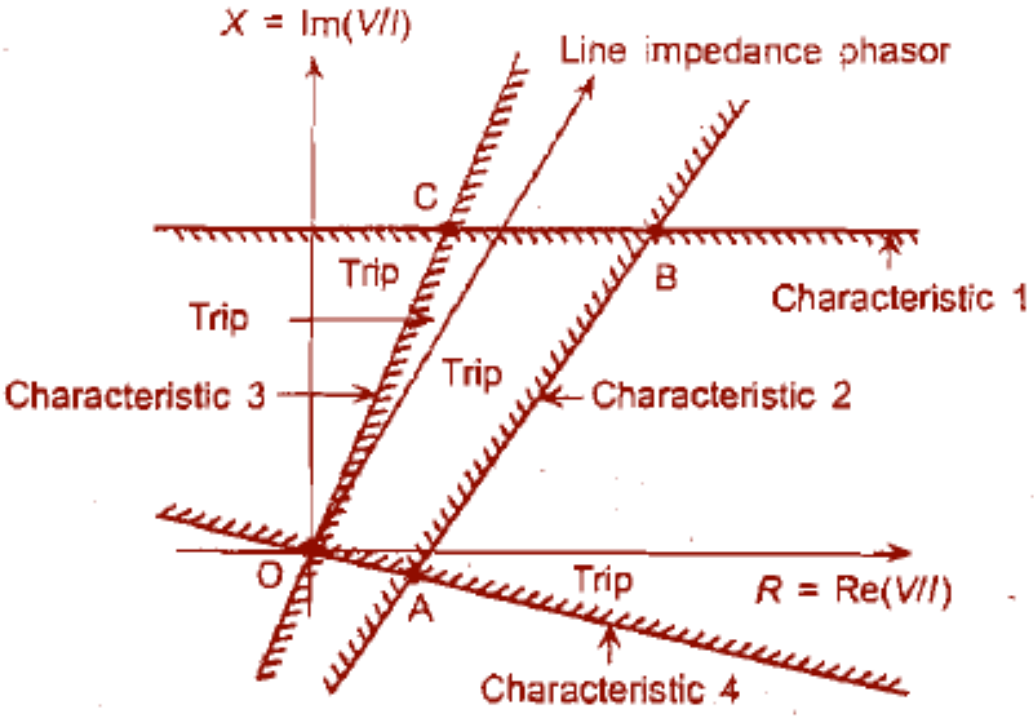
SYNTHESIS OF QUADRILATERAL DISTANCE RELAY

- The fault characteristic of a transmission line is a quadrilateral because of the arcing fault resistance. All the conventional distance relays, such as simple impedance, reactance and mho, encompass much more area on the ***R-X diagram than this quadrilateral. An*** ideal distance relay should have a characteristic which snugly fits around the quadrilateral. Such a relay, called a **quadrilateral relay, whose characteristic is shown** *in Figure*



- Such a characteristic can be synthesized by AND compounding the trip outputs of four different two-input relays We need to synthesize the following characteristics:

1. : Reactance relay with setting of ***Xn1***
2. : Angle-impedance relay with setting of **Zn2**
3. Directional relay with MTA of *-82*
4. Directional relay with MTA of ***81***



Characteristic	*Polarizing qty.*	*Measured qty.*
Reactance	$IX_{n1} - V$	IX_{n1}
Angle impedance	$IZ_{n2} - V$	IZ_{n2}
Directional with MTA = θ_1	$V \angle -\theta_1$	I
Directional with MTA = $-\theta_2$	$V \angle \theta_2$	I

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