
AREVA

Application of Directional Overcurrent and Earthfault Protection

Training Manager

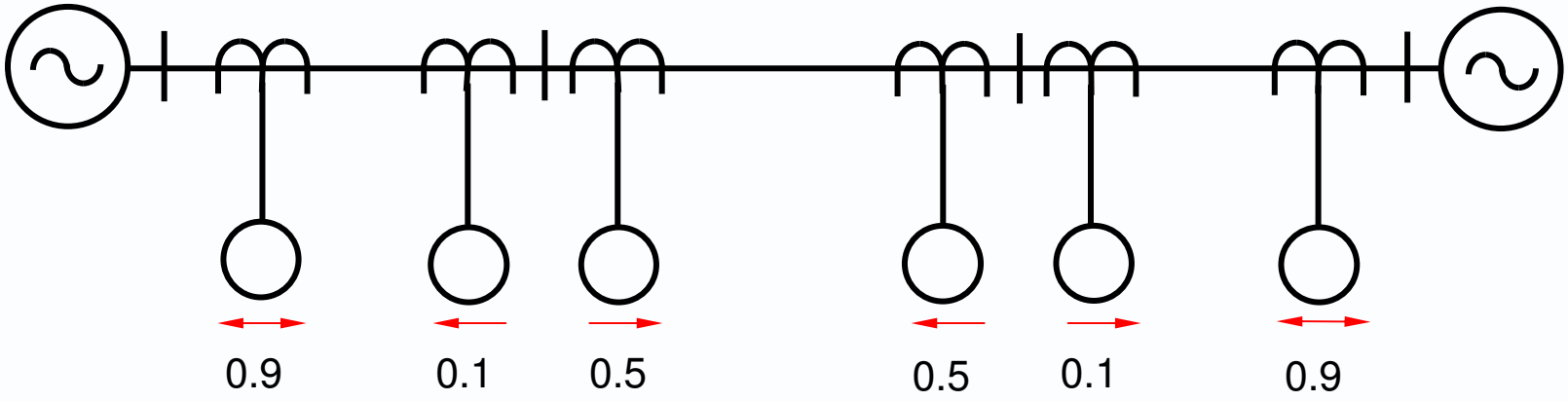
Directional Protection

Need for Directional Control

Generally required if current can flow in both directions through a relay location

e.g. Parallel feeder circuits

Ring Main Circuits



Relays operate for current flow in direction indicated. (Typical operating times shown).

Ring Main Circuit

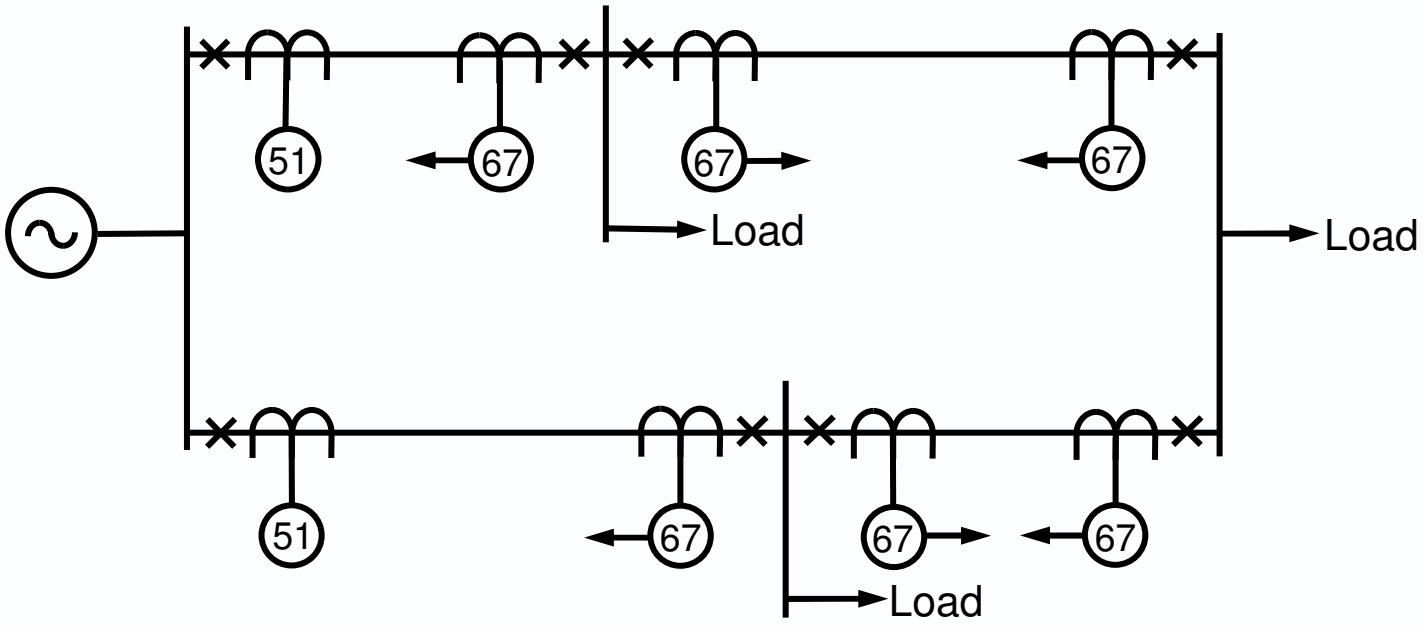
With ring closed :

Both load and fault current may flow in either direction along feeder circuits.

Thus, directional relays are required.

Note: Directional relays look into the feeder.

Need to establish principle for relay.



Ring Main Circuit

Procedure :

1. **Open ring at A**

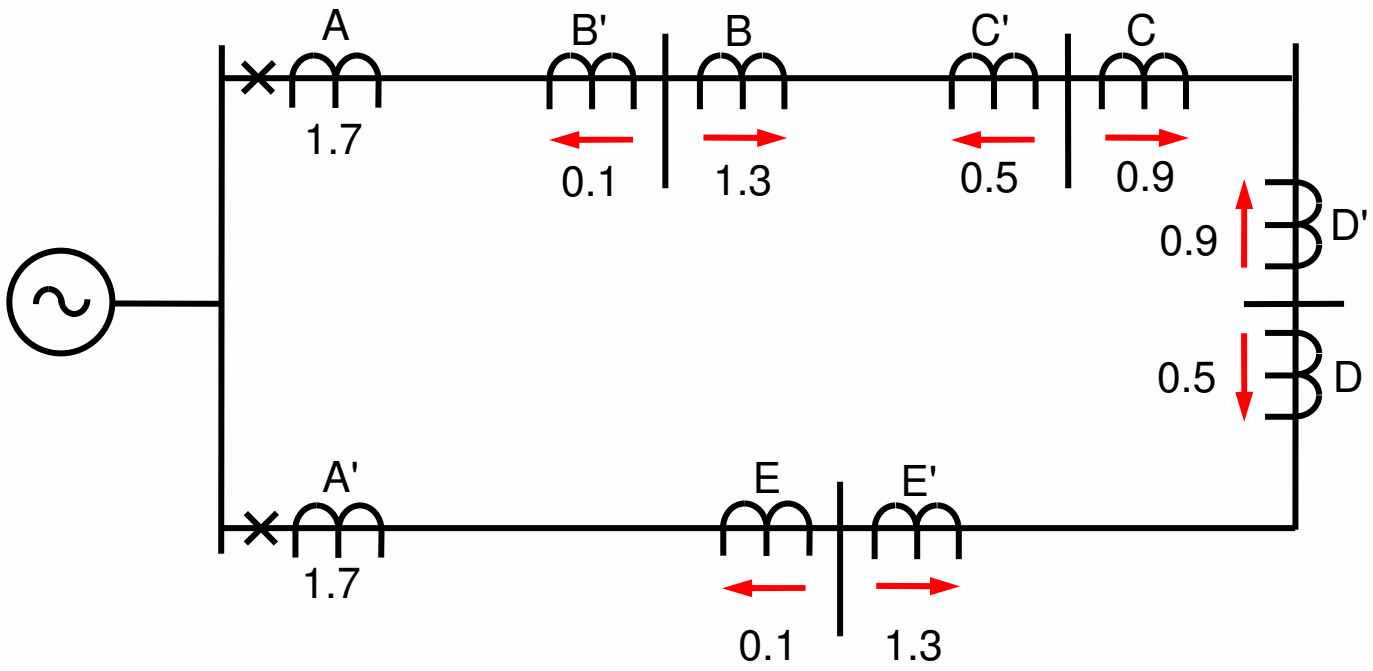
   Grade : A' - E' - D' - C' - B'

2. **Open ring at A'**

   Grade : A - B - C - D - E

Typical operating times shown.

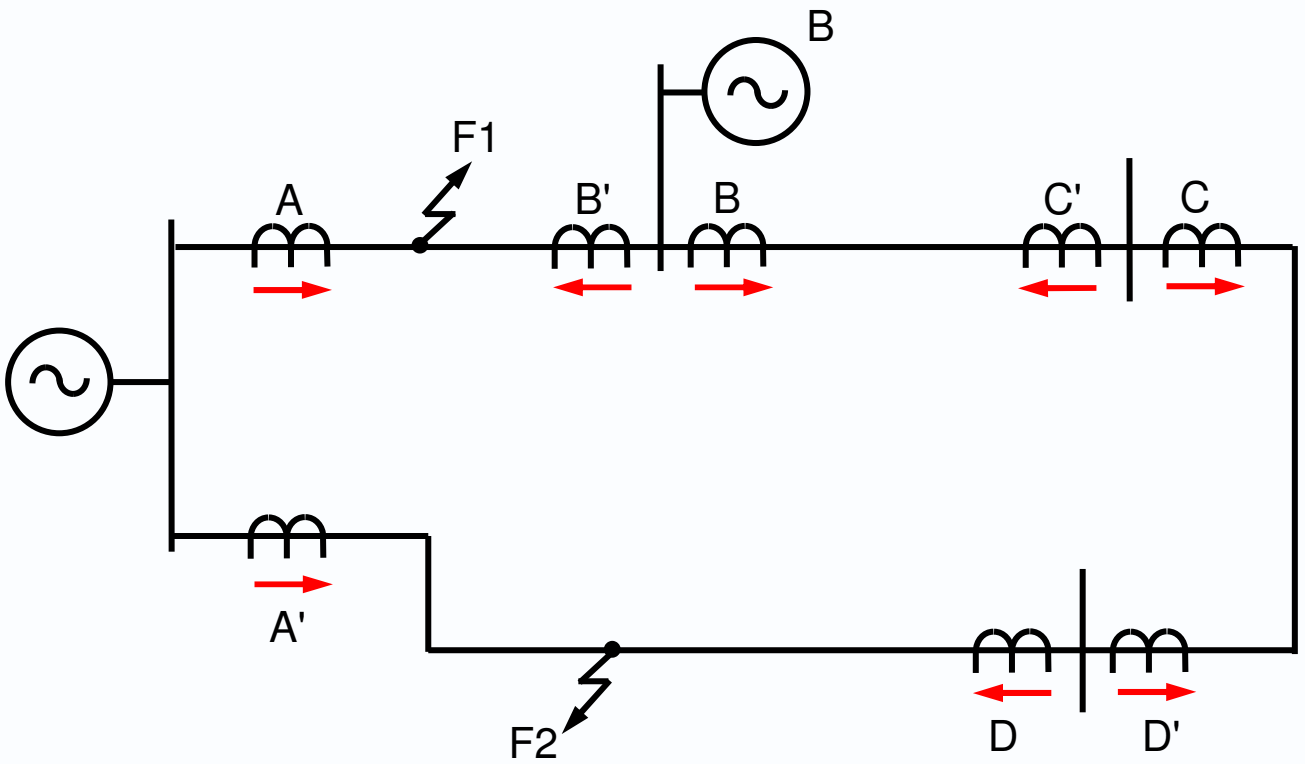
Note : Relays B, C, D', E' may be non-directional.



Ring System with Two Sources

Discrimination between all relays is not possible due to different requirements under different ring operating conditions.

For F1 :- B' must operate before A'
For F2 :- B' must operate after A'
} **Not Compatible**



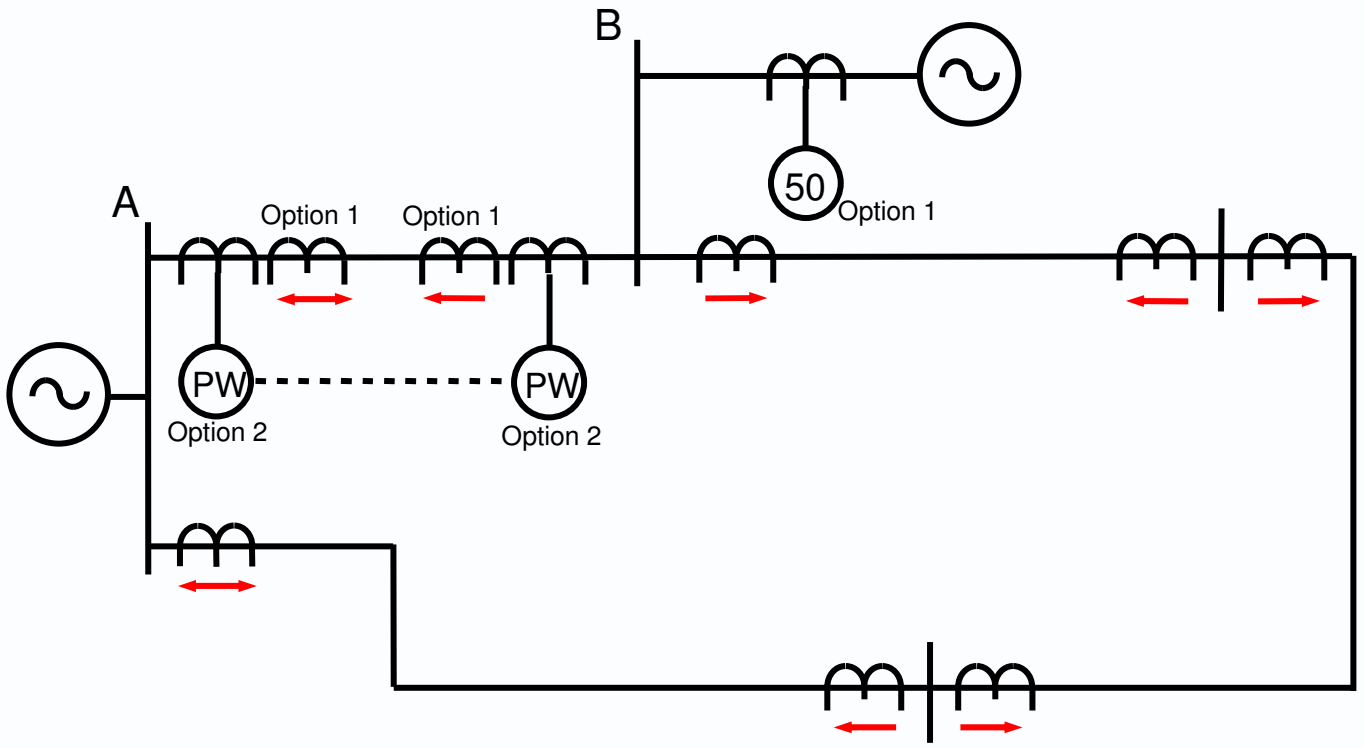
Ring System with Two Sources

Option 1

Trip least important source instantaneously then treat as normal ring main.

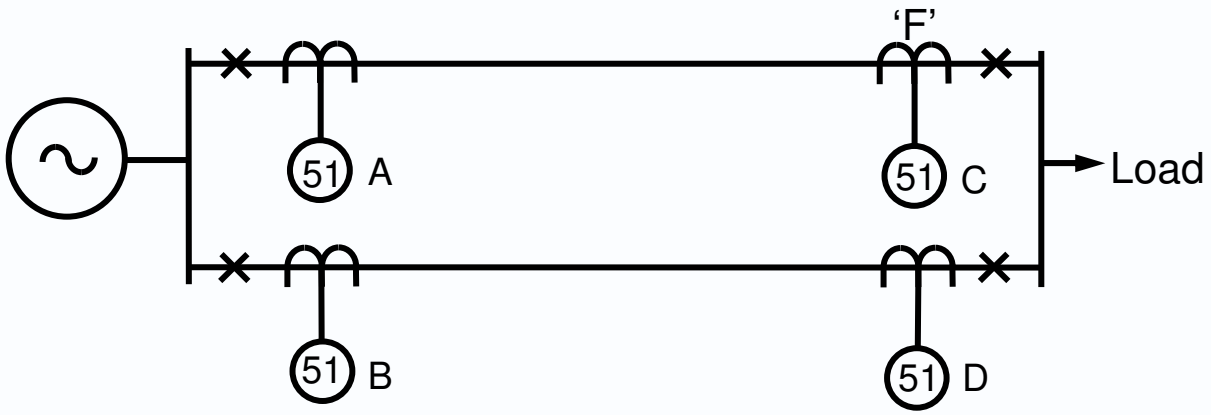
Option 2

Fit pilot wire protection to circuit A - B and consider as common source busbar.



Parallel Feeders

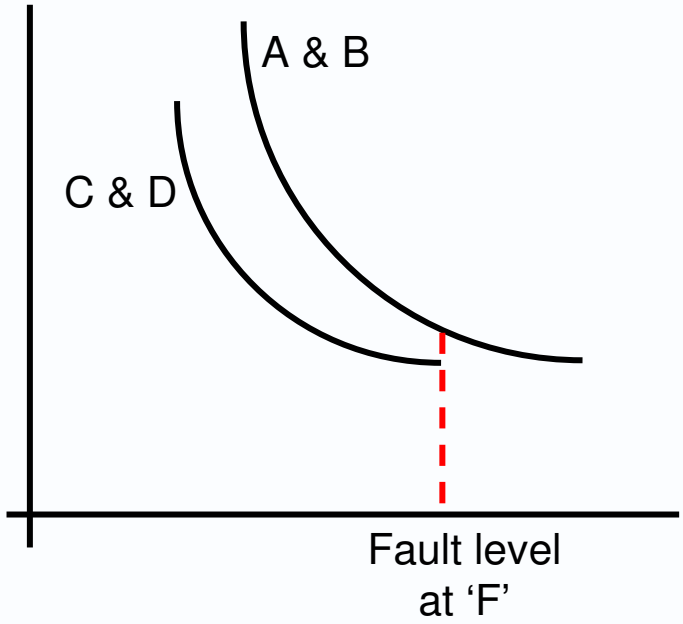
Non-Directional Relays :-



"Conventional Grading" :-

Grade 'A' with 'C'

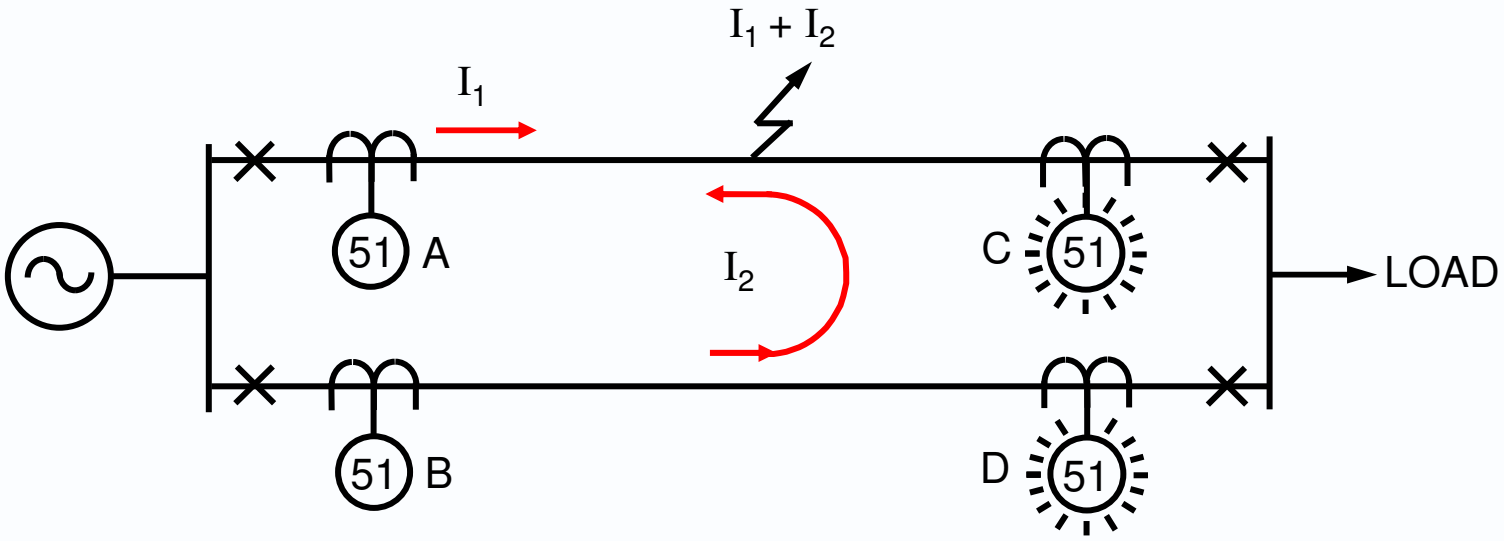
and Grade 'B' with 'D'



Relays 'A' and 'B' have the same setting.

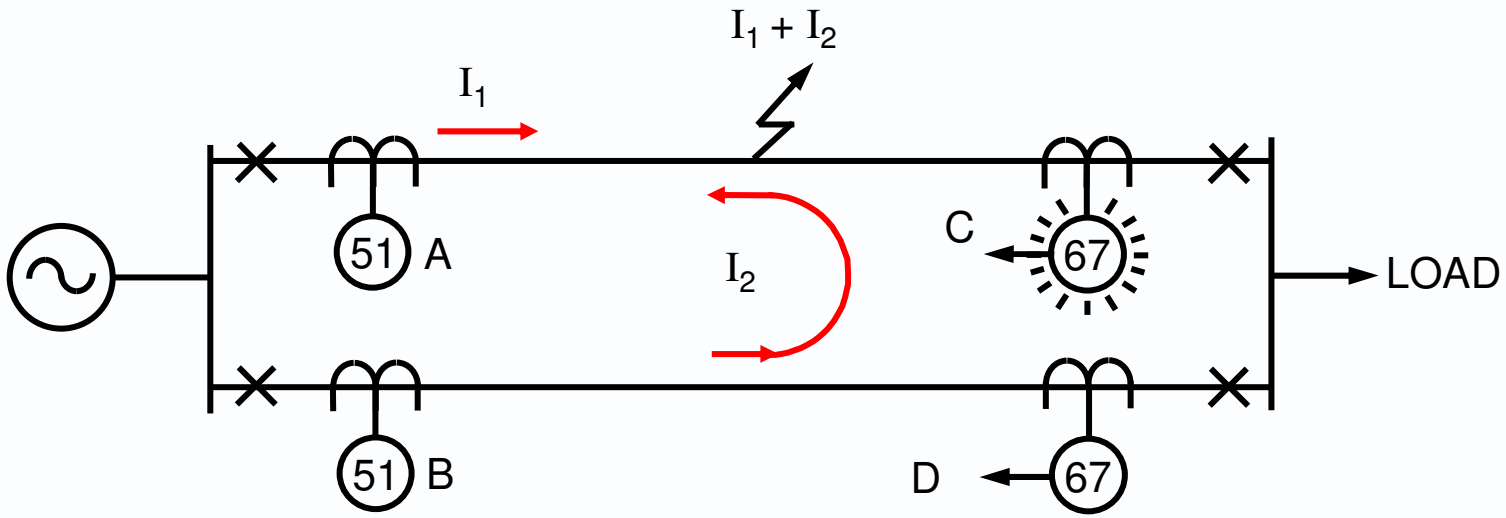
Parallel Feeders

Consider fault on one feeder :-



Relays 'C' and 'D' see the same fault current (I_2). As 'C' and 'D' have similar settings both feeders will be tipped.

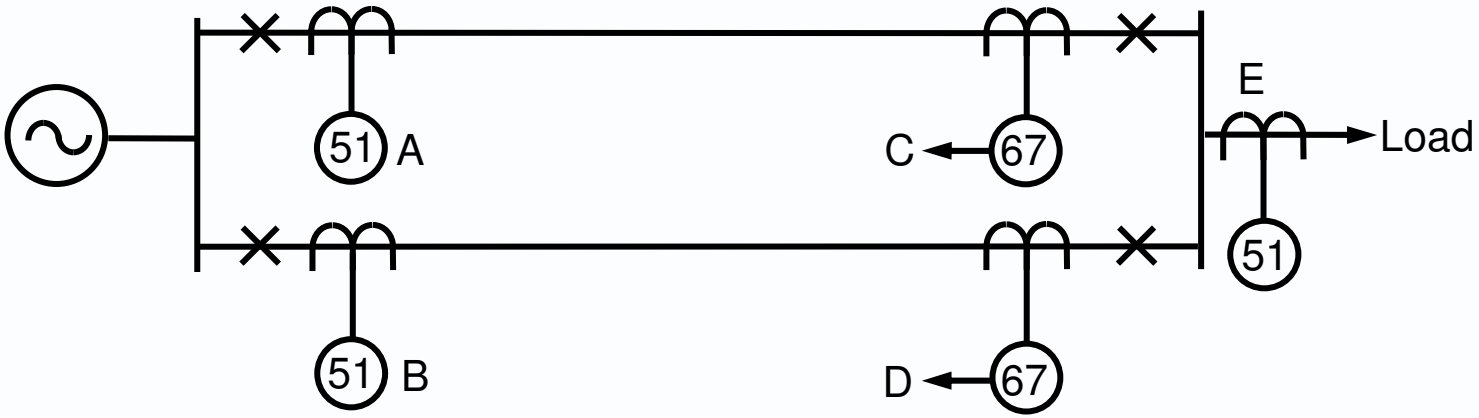
Solution:- Directional Control at ‘C’ and ‘D’



Relay ‘D’ does not operate due to current flow in the reverse direction.

Parallel Feeders

Setting philosophy for directional relays



Load current always flows in 'non-operate' direction.

Any current flow in 'operate' direction is indicative of a fault condition.

Thus Relays 'C' and 'D' may be set :-

- **Sensitive (typically 50% load)**
- **Fast operating time (i.e. TMS=0.1)**

Parallel Feeders

Usually, relays are set :-

- **50% full load current (note thermal rating)**
- **Minimum T.M.S. (0.1)**

Grading procedure :-

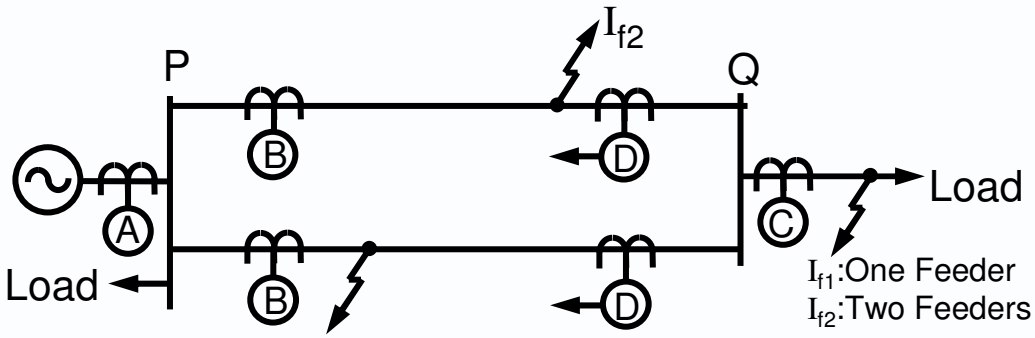
1. **Grade 'A' (and 'B') with 'E' assuming one feeder in service.**
2. **Grade 'A' with 'D' (and 'B' with 'C') assuming both feeders in service.**

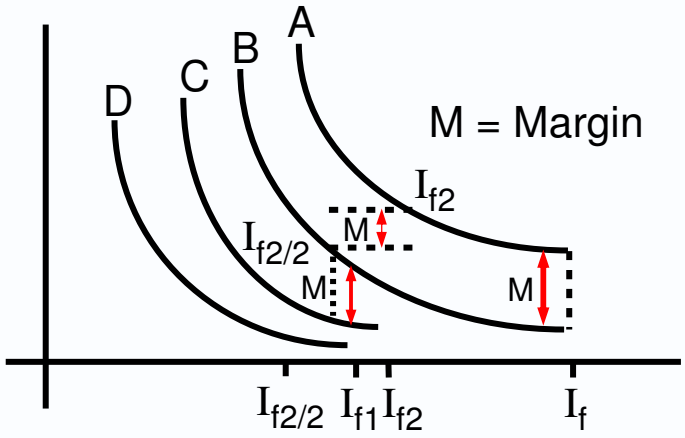
Parallel Feeders - Application Note

Grade B with C at If1

Grade B with D at If2 (in practice)

Grade A with B at If - but check that sufficient margin exists for bus fault at Q when relay A sees total fault current If2, but relay B sees only If2/2.





Establishing Direction

Establishing Direction:- Polarising Quantity

The DIRECTION of Alternating Current may only be determined with respect to a COMMON REFERENCE.

In relaying terms, the REFERENCE is called the POLARISING QUANTITY.

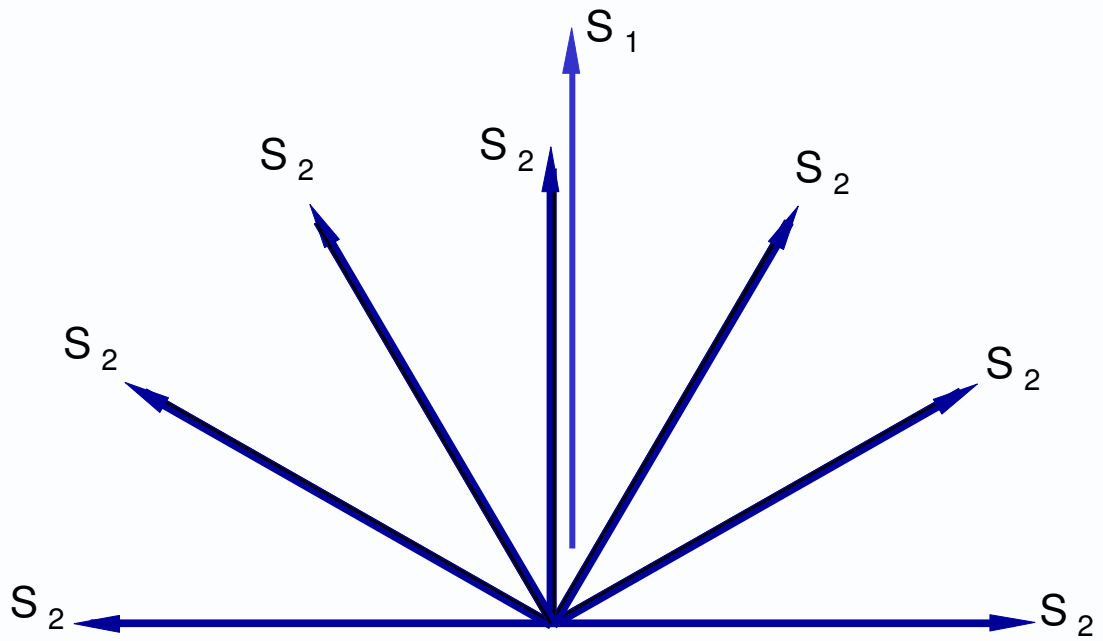
The most convenient reference quantity is POLARISING VOLTAGE taken from the Power System Voltages.

Directional Decision by Phase Comparison (1)

S_1 = Reference Direction = Polarising Signal = V_{POL}

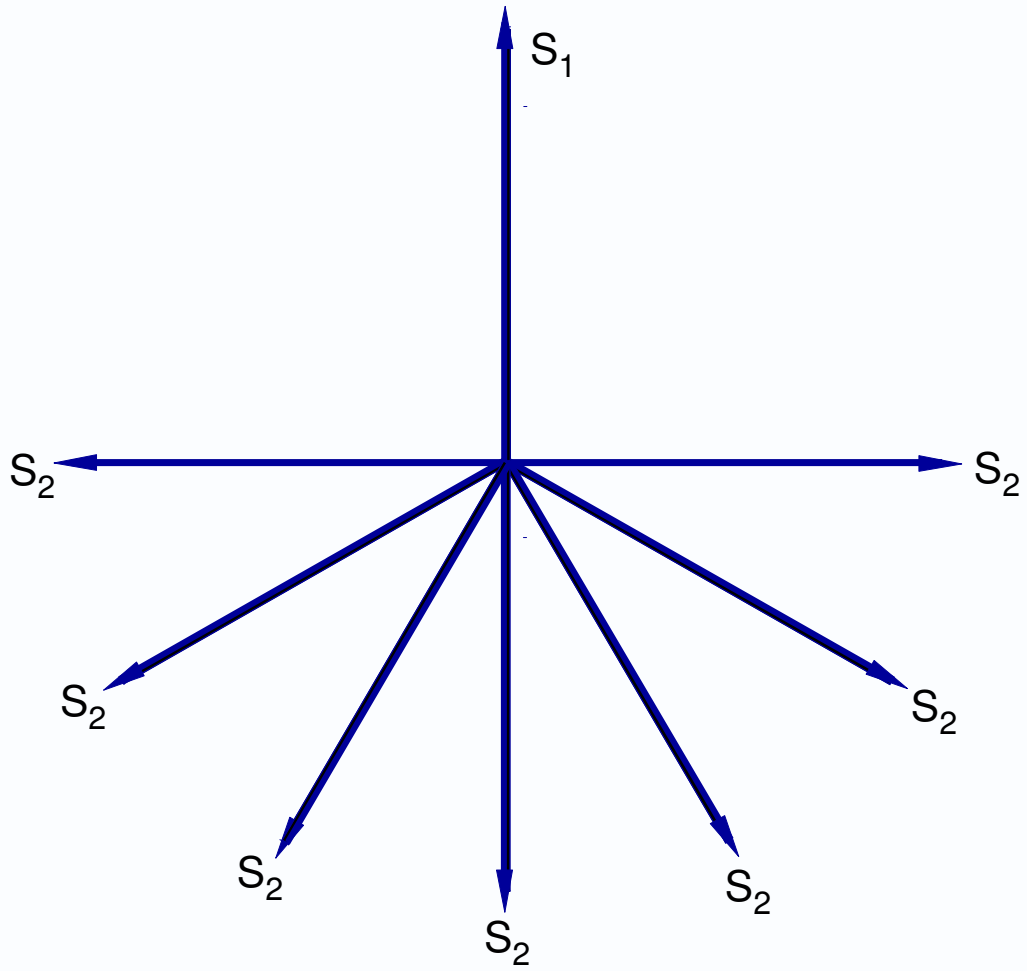
S_2 = Current Signal = I

OPERATION when S_2 is within ±90° of S_1 :-



Directional Decision by Phase Comparison (2)

RESTRAINT when S_2 lags S_1 by between 90° and 270° :-



Polarising Voltage for 'A' Phase Overcurrent Relay

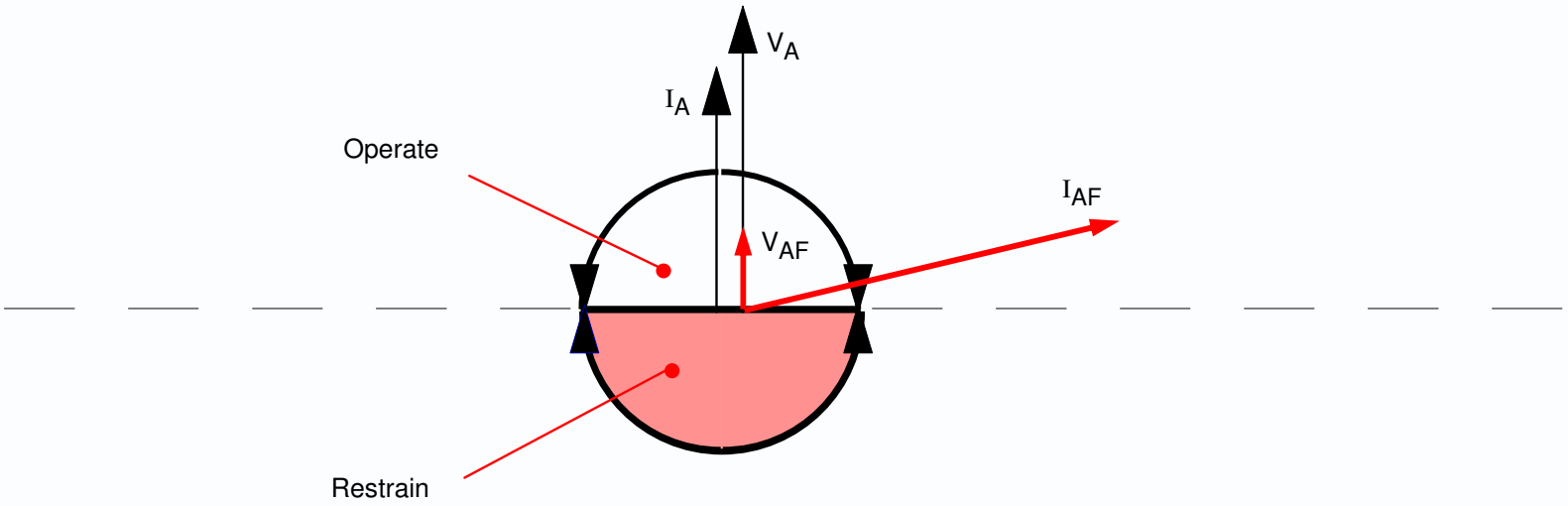
OPERATE SIGNAL = I_A

POLARISING SIGNAL :- Which voltage to use ?
Selectable from

V_A
V_B
V_C
V_{A-B}
V_{B-C}
V_{C-A}

Directional Relay

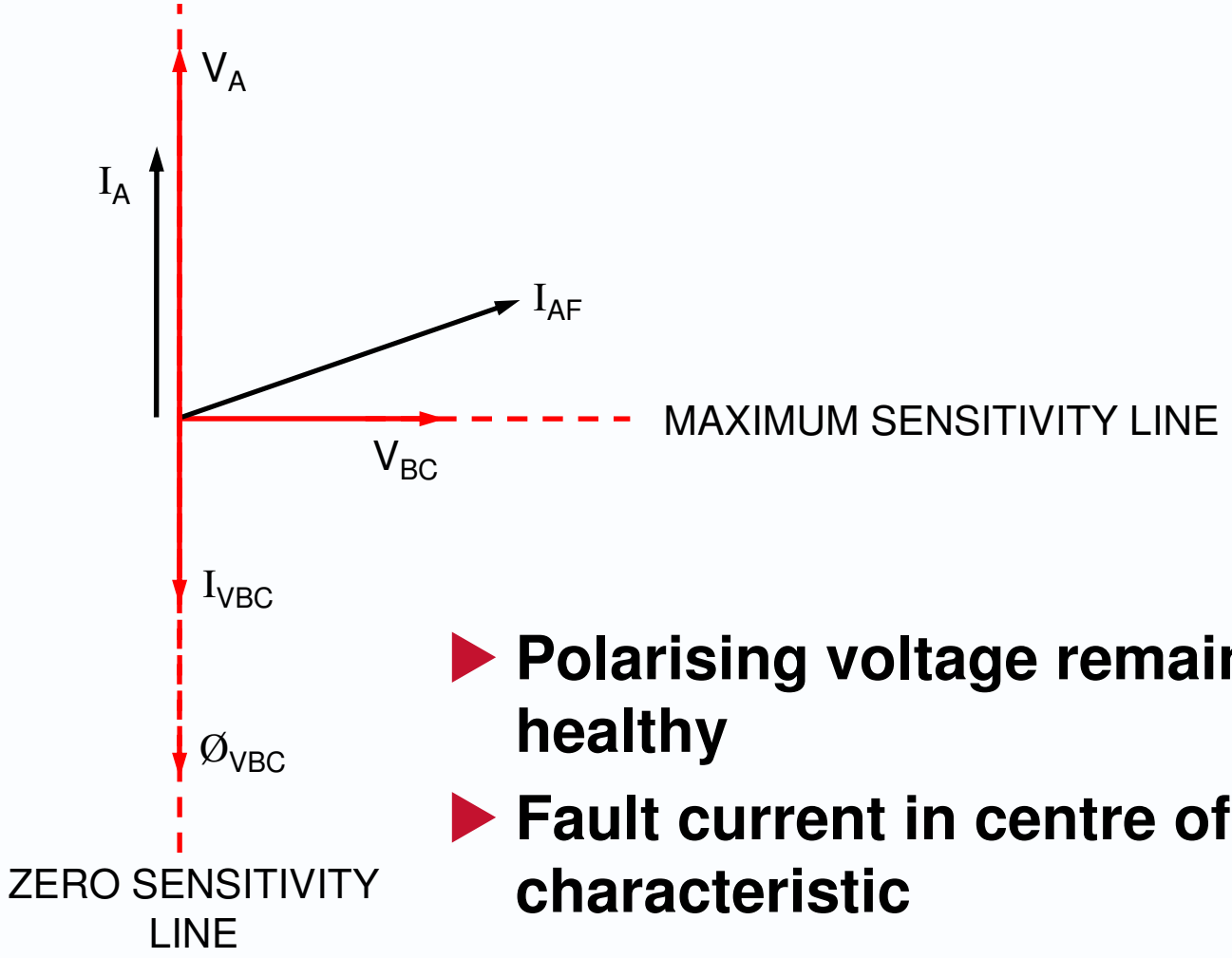
Applied Voltage : V_A
Applied Current : I_A



Question :
- is this connection suitable for a typical power system ?

Polarising Voltage

Applied Voltage : V_{BC}
Applied Current : I_A

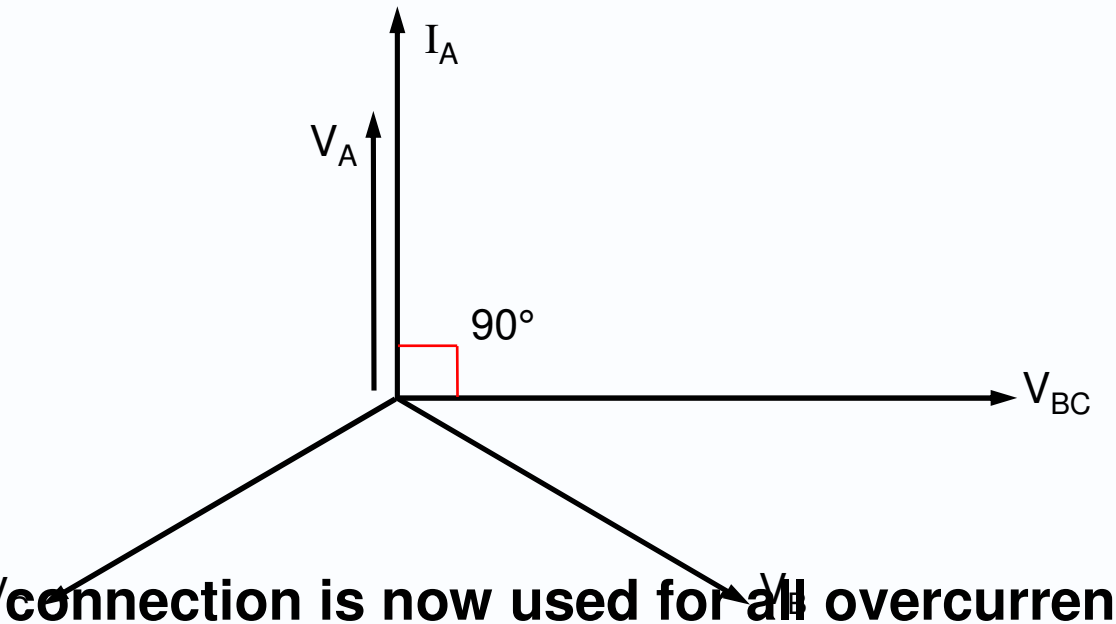


- **Polarising voltage remains healthy**
- **Fault current in centre of characteristic**

Relay Connection Angle

The angle between the current applied to the relay and the voltage applied to the relay at system unity power factor

e.g. 90° (Quadrature) Connection : I_A and V_{BC}

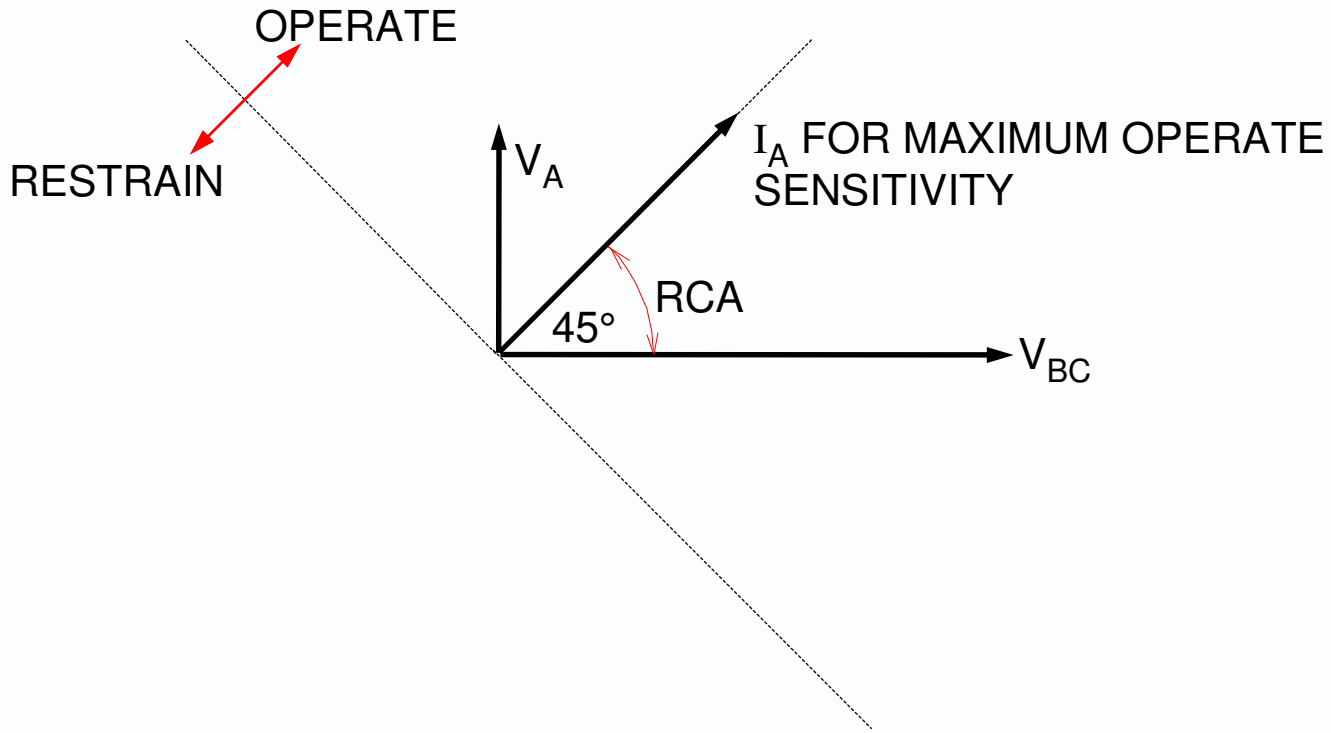


The 90° connection is now used for all overcurrent relays. 30° and 60° connections were also used in the past, but no longer, as the 90° connection gives better performance.

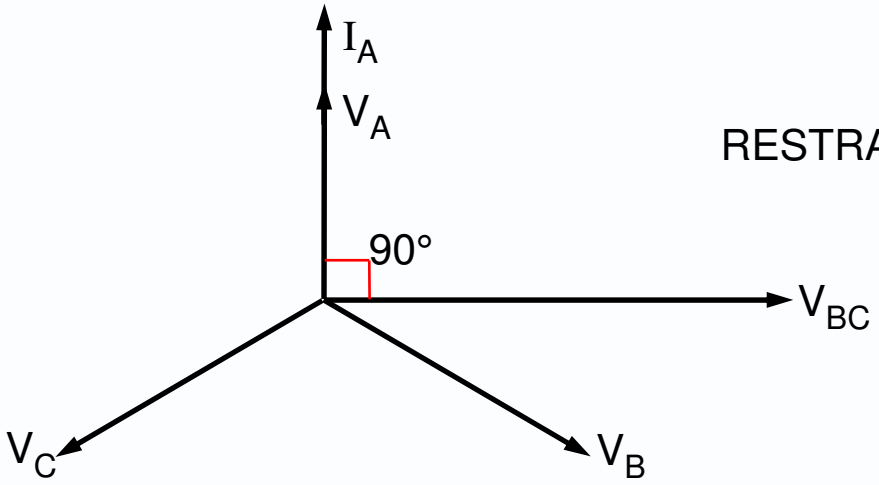
Relay Characteristic Angle (R.C.A.) for Electronic Relays

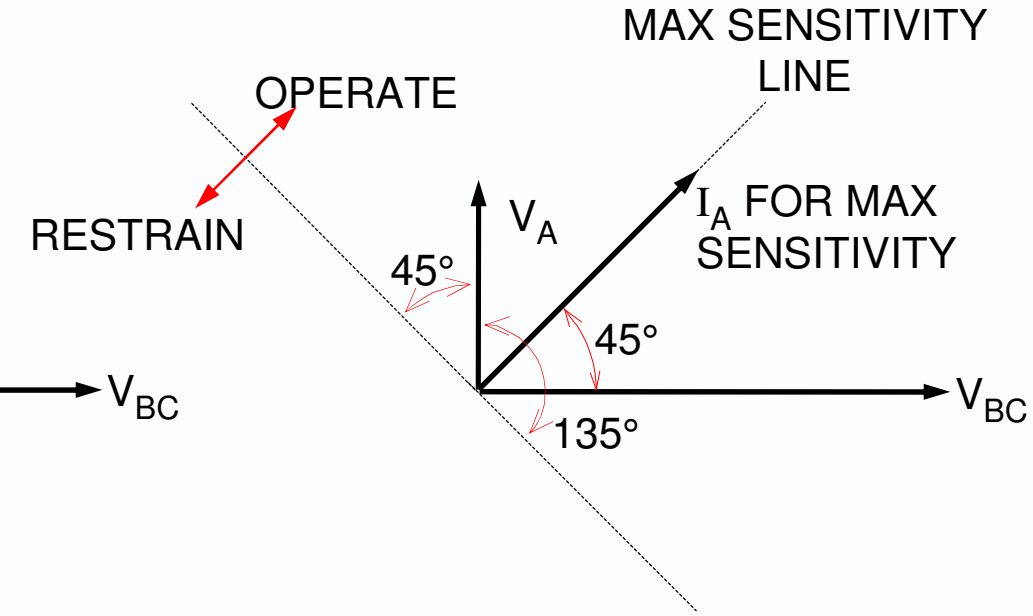
The angle by which the current applied to the relay must be displaced from the voltage applied to the relay to produce maximum operational sensitivity

e.g. 45°



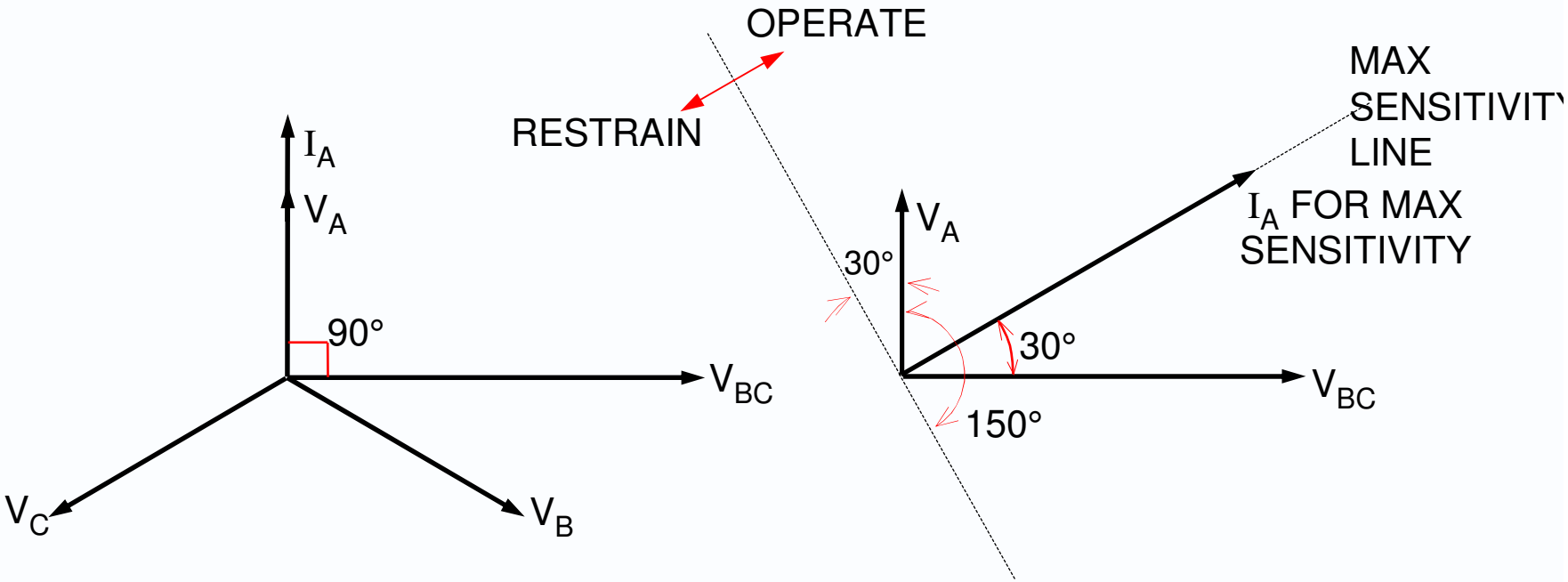
90° Connection - 45° R.C.A.





RELAY	CURRENT	VOLTAGE
A	I_A	V_{BC}
B	I_B	V_{CA}
C	I_C	V_{AB}

90° Connection - 30° R.C.A.



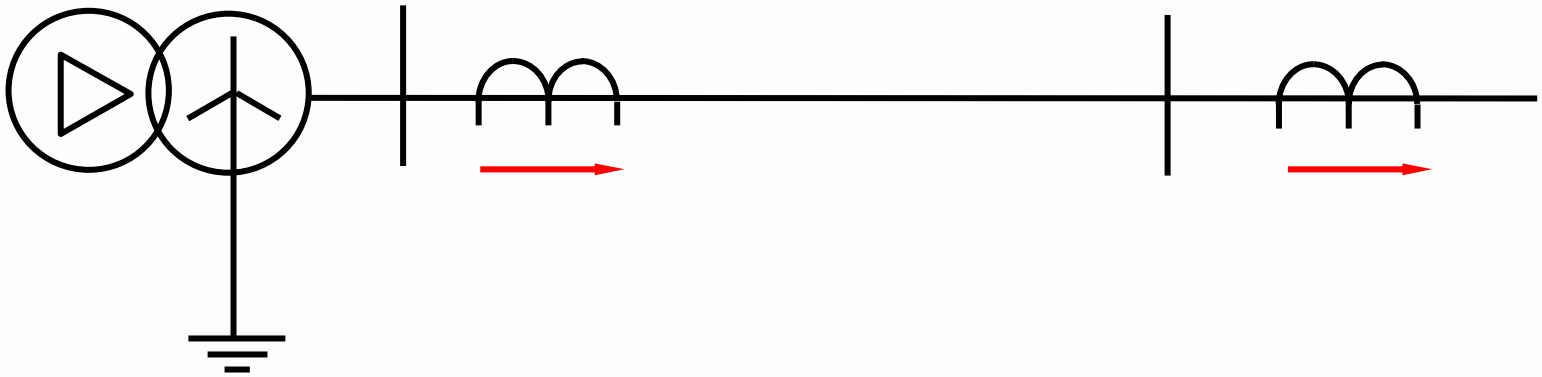
RELAY	CURRENT	VOLTAGE
A	I_A	V_{BC}
B	I_B	V_{CA}
C	I_C	V_{AB}

Selection of R.C.A. (1)

Overcurrent Relays

90° connection 30° RCA (lead)

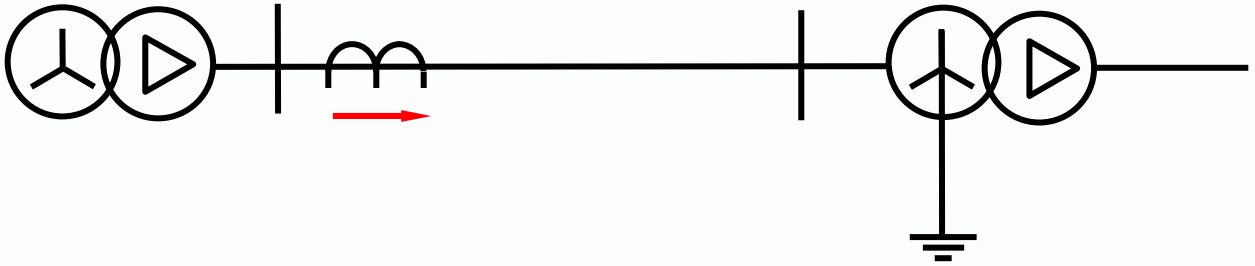
Plain feeder, zero sequence source behind relay



Selection of R.C.A. (2)

90° connection 45° RCA (lead)

Plain or Transformer Feeder :- Zero Sequence Source in Front of Relay



Transformer Feeder :- Delta/Star Transformer in Front of Relay

Directional Earthfault Protection

Directional Earth Fault

Requirements are similar to directional overcurrent

i.e. need operating signal
and polarising signal

Operating Signal

obtained from residual connection of line CT's
i.e. $I_{op} = 3I_o$

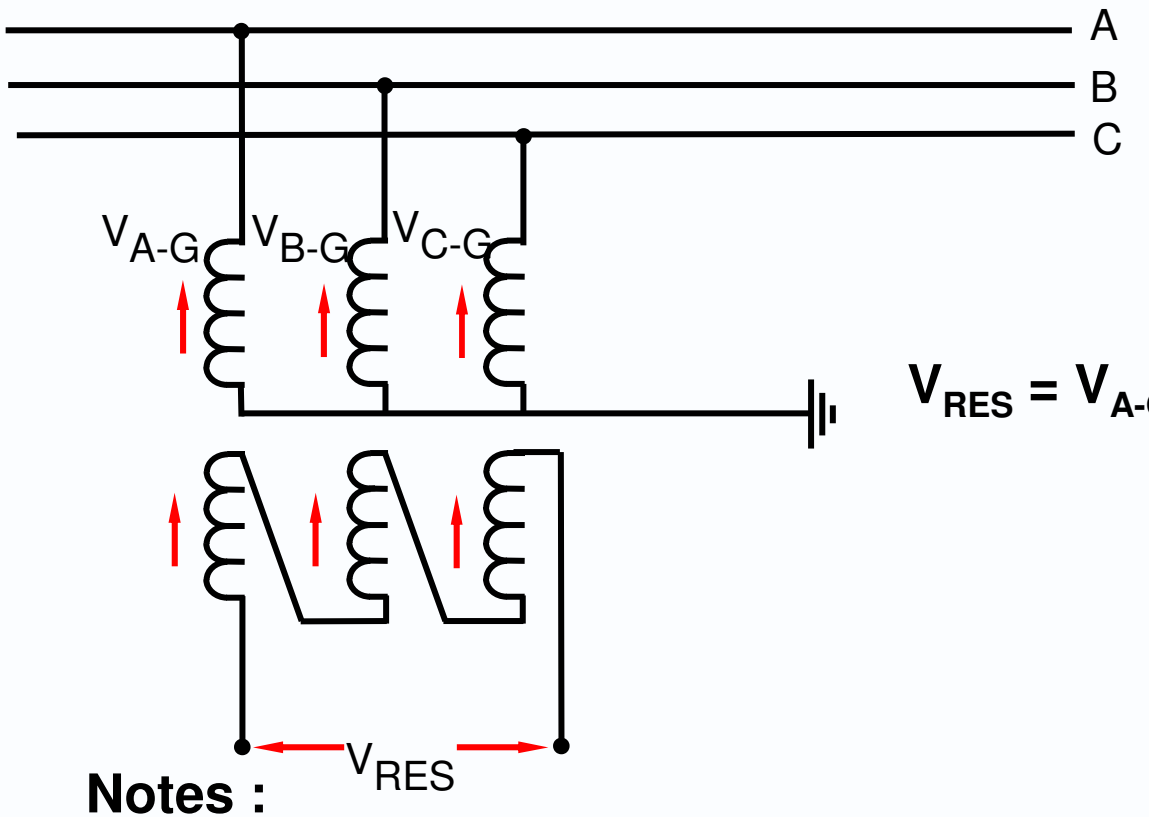
Polarising Signal

The use of either phase-neutral or phase-phase voltage as the reference becomes inappropriate for the comparison with residual current.

Most appropriate polarising signal is the residual voltage.

Residual Voltage

May be obtained from 'broken' delta V.T. secondary.



$$V_{RES} = V_{A-G} + V_{B-G} + V_{C-G} = 3V_0$$

Notes :

1. **VT primary must be earthed.**
2. **VT must be of the '5 limb' construction (or 3 x single phase units)**

Directional Earth Fault Relays

Relay Characteristic Angle

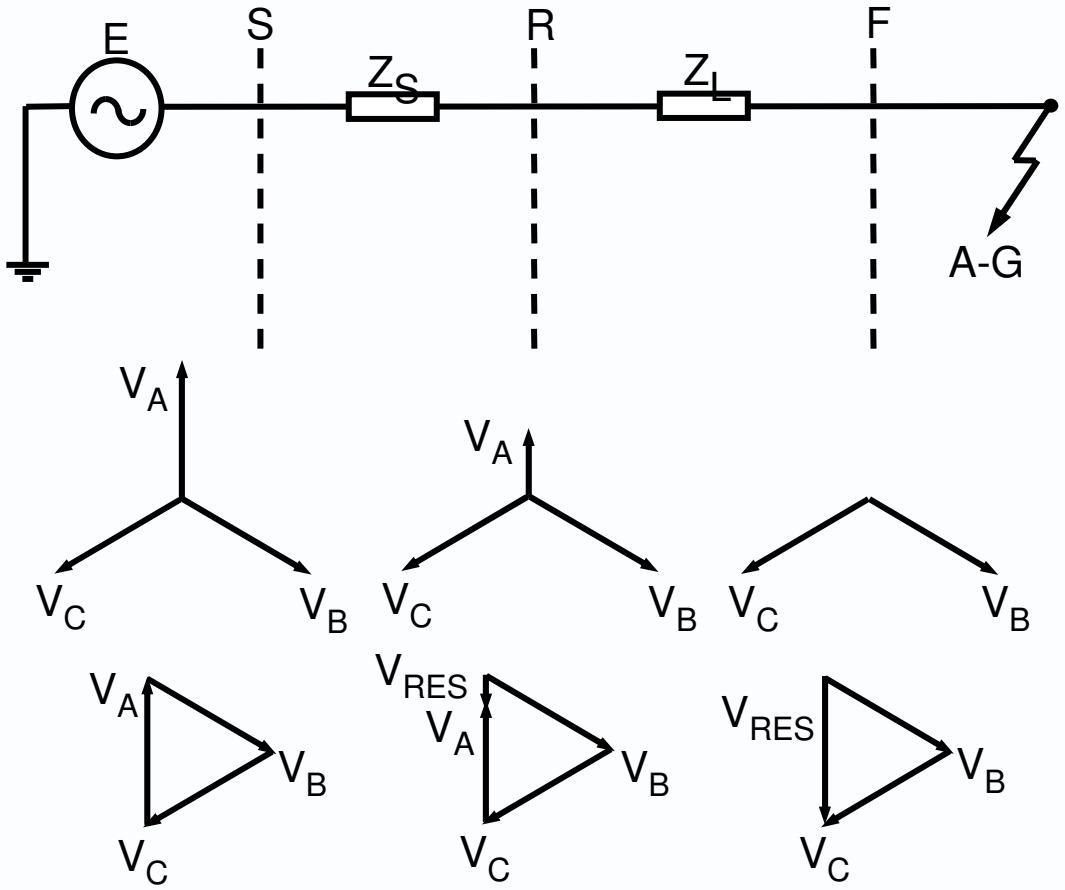
0 - Resistance earthed systems

45 (I lags V) - Distribution systems (solidly earthed)

60 (I lags V) - Transmission systems (solidly earthed)

Residual Voltage

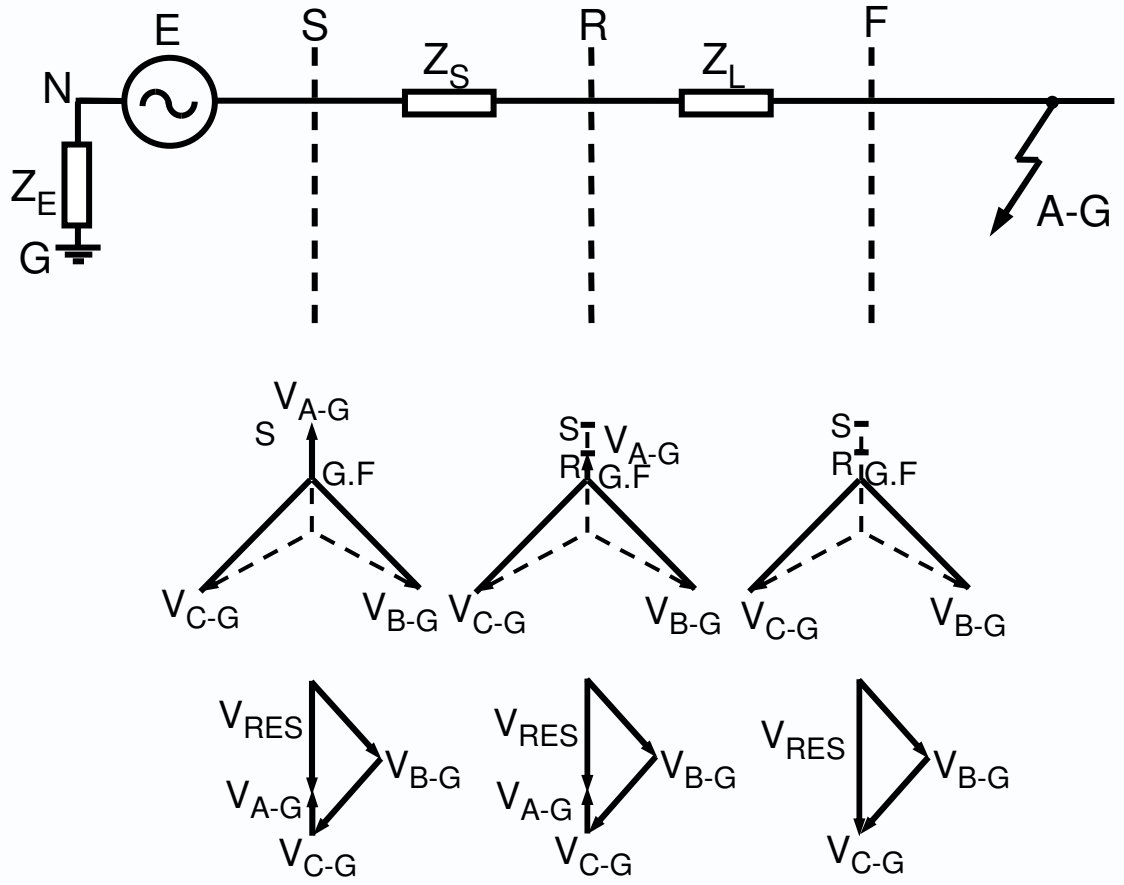
Solidly Earthed System



Residual Voltage at R (relaying point) is dependant upon Z_S / Z_L ratio.

Residual Voltage

Resistance Earthed System

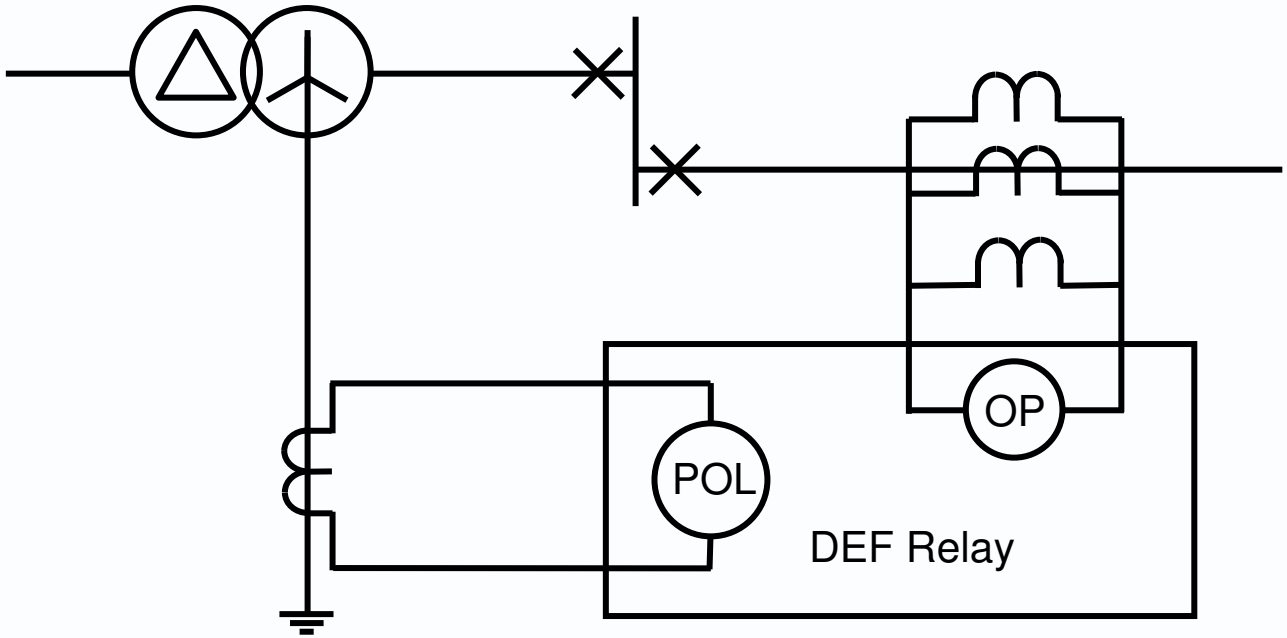


Current Polarising

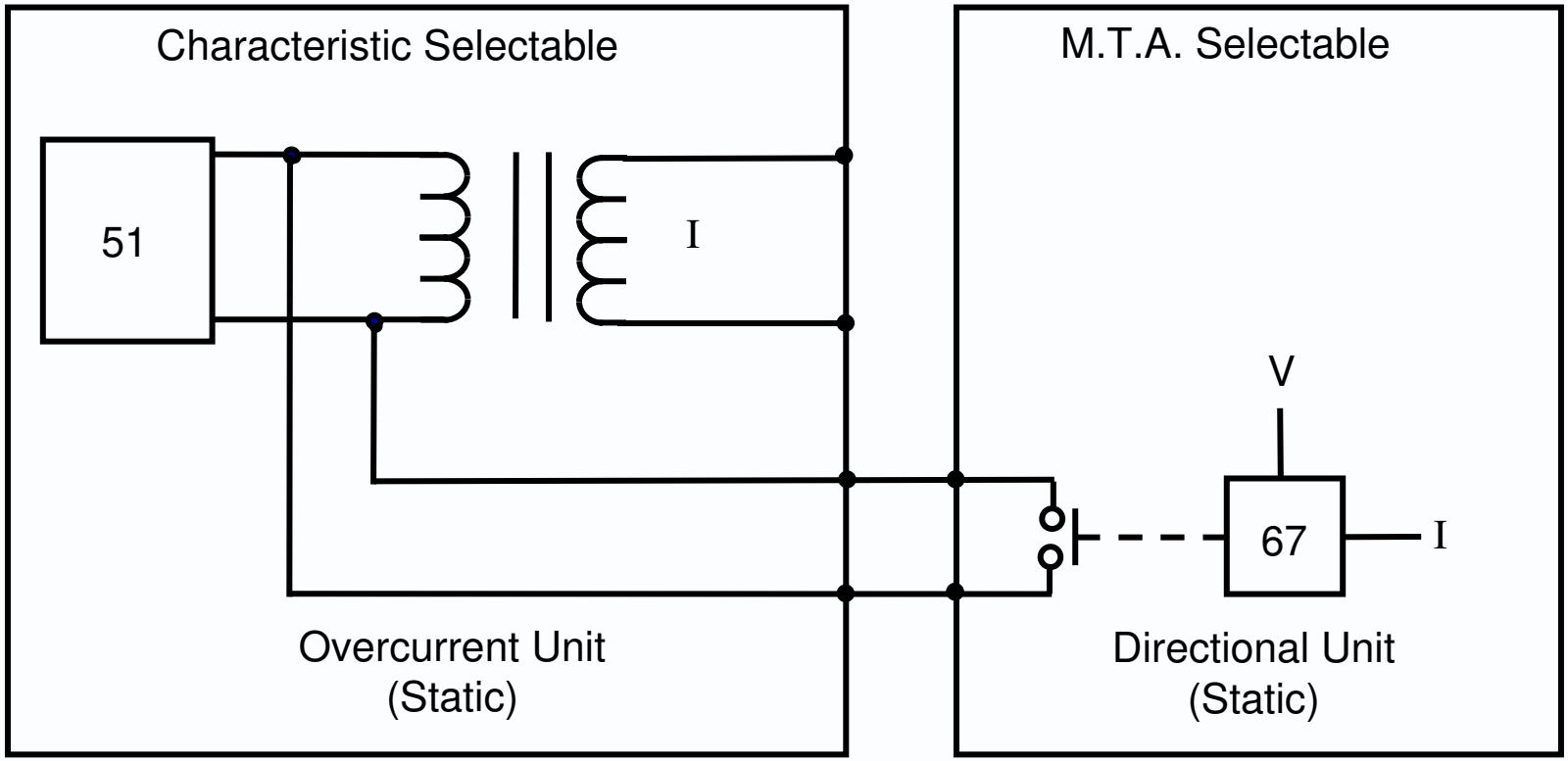
A solidly earthed, high fault level (low source impedance) system may result in a small value of residual voltage at the relaying point. If residual voltage is too low to provide a reliable polarising signal then a current polarising signal may be used as an alternative.

The current polarising signal may be derived from a CT located in a suitable system neutral to earth connection.

e.g.

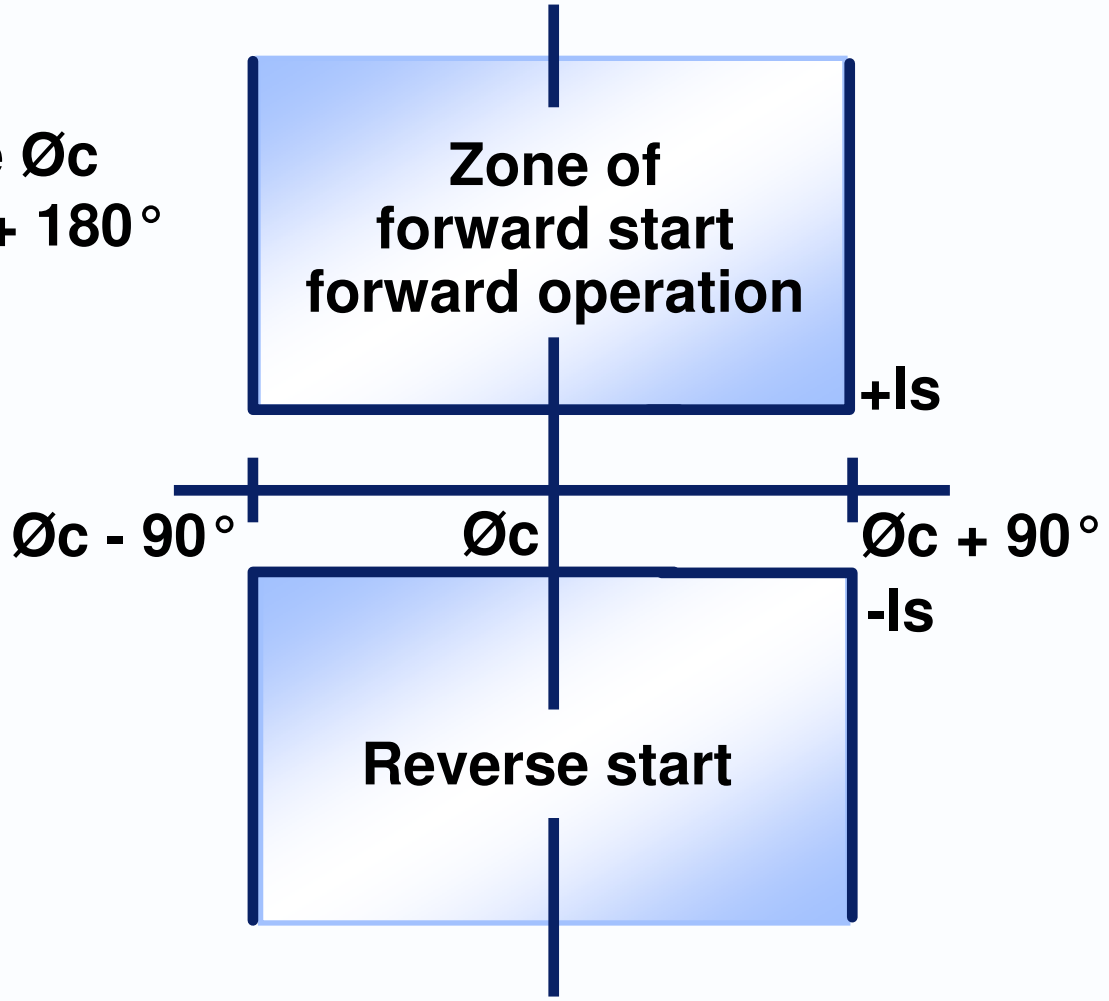


Static Relay (METI + MCGG)



Numerical Relay Directional Characteristic

Characteristic angle Øc
Øc = -180° --- 0° --- + 180°
in 1° steps



Polarising thresholds
Vp > 0.6V
Vop > 0.6 to 80V
in 0.2V steps
for example