Feeder Protection

Protection of Feeders

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SAVE ENERGY,SAVE EARTH
Haryana Vidyut Parsaran Nigam

Save Energy
HVPNL

Current Transformer

HVPNL,Haryana

- As we go towards high voltages , it becomes very costly & unsafe to measure the circuit current by putting ammeter in circuit.

- We need a sensing device , which sense the heavy line current and gives a replica Of this current for metering & protection circuits.

- Current Transformer(C.T) performs the task. Transformer is a device used to step up or step-down the circuit voltages & currents.

- No's turns on secondary side of a C.T. are always more than primary no's turns

- So we can say that a C.T. is a Step-Up transformer , which step-up the voltage on secondary side.

- All transformers works on the principle that

Power on primary side = Power on secondary side

$V_p \times I_p = V_s \times I_s$

In case of C.T. $I_s \ll I_p$ so $V_s \gg V_p$

IMPORTANT

"Open circuit secondary of C.T. can generate high voltage on high loads and May prove very harmful. So the secondary circuit of C.T. should never left open."

Current Transformer

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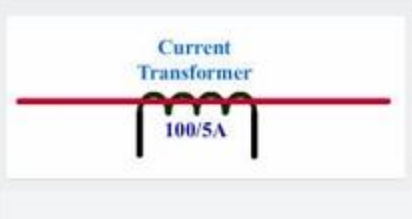
CASE 01

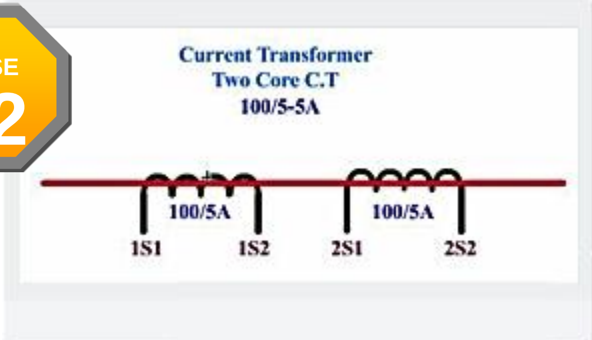
Single Core Single Ratio C.T.



Single core-single ratio current transformer is the simples t one having 2 terminals on secondary side (proba-bly names a s 1S1 & 1S2)

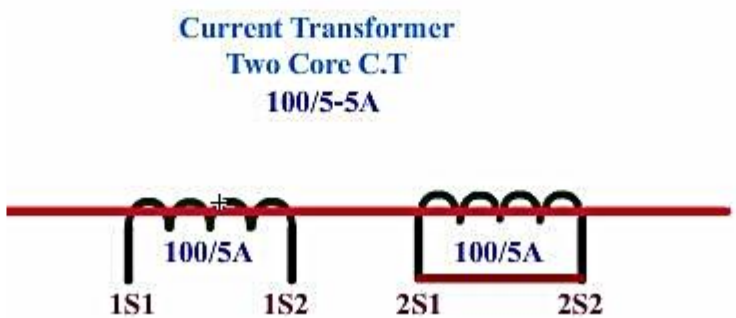
Two Core Single Ratio C.T.

CASE 02



Two core-single ratio current transformer have two cores , one for metering & another for protection. The secondary windings of both the cores are wound on a common primary bar. With the passage of c urrent on primary winding/bar , secondary currents produced in both the windings as per the C.T. rati o.

•In case of a two core C.T. , if one core isn't being used , same should be shorted to avoid any formati on of H.V on secondary side and hazard.



Current Transformer

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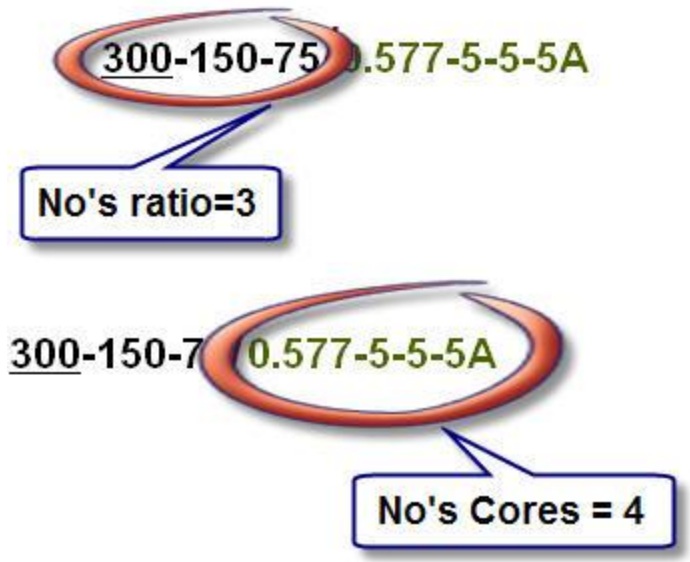
CASE 03

Single Core Double Ratio C.T.

In a single core double ratio C.T. three secondary terminals will be there. To utilize full ratio , connect secondary circuit to 1S1 & 1S3 and to utilize the half ratio , connect secondary terminals to 1S1 & 1S2.

1s1-1s2	50/5A
1s1-1s2	100/5A

How to denote C.T. ratio?



No's sec. terminals/core=No's Ratio+1

i.e. in the given example it is 3+1=4 e.g. 1s1,1s2,1s3,1s4

As it is a 4cores, 3 ratio C.T. , total no's secondary terminals =((no's ratio+1) x no's cores) = (3+1)x4=16No's

Voltage Transformer

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Voltage Transformer & its use

Voltage Transformer or Potential transformer is used to step down the voltage from a higher level (primary side) to low level (secondary side) so that same may be used for metering & protection circuits.

Most of the V.T/P.T are of single ratio/two core types. i.e. 220000/

Ph-Ph primary voltage

$$\frac{\dfrac{220000}{\sqrt{3}}\ V}{\dfrac{110}{\sqrt{3}}\ V}$$

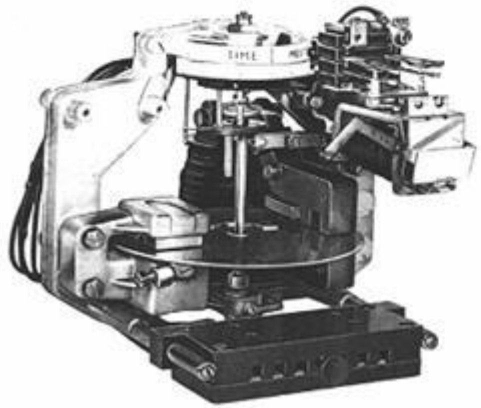
Ph-Ph sec. voltage

Normally we connect the P.Ts on Ph to ground configuration i.e. for a 220KV P.T , Ph-G voltage will be 220000/1.732 = 127020V or 127KV and the secondary voltage will not be 110V but will be 110/1.732=63.3V

Never short the secondary terminals of a PT/VT if not in use as it may lead to damage of the secondary winding of the Instrument transformer

The ferrules of the P.T/Voltage circuits are generally denoted by E (prefix)

Feeder's Protection



1. Fault current sensed by C.T.
2. C.T. secondary circuit fed fault current to Relay.
3. Relay operates.
4. Relay contacts acts as a switch for d.c. tripping circuit.
5. Relay contacts closes the path of d.c. tripping circuit.
6. C.B. trips.
7. Fault cleared.

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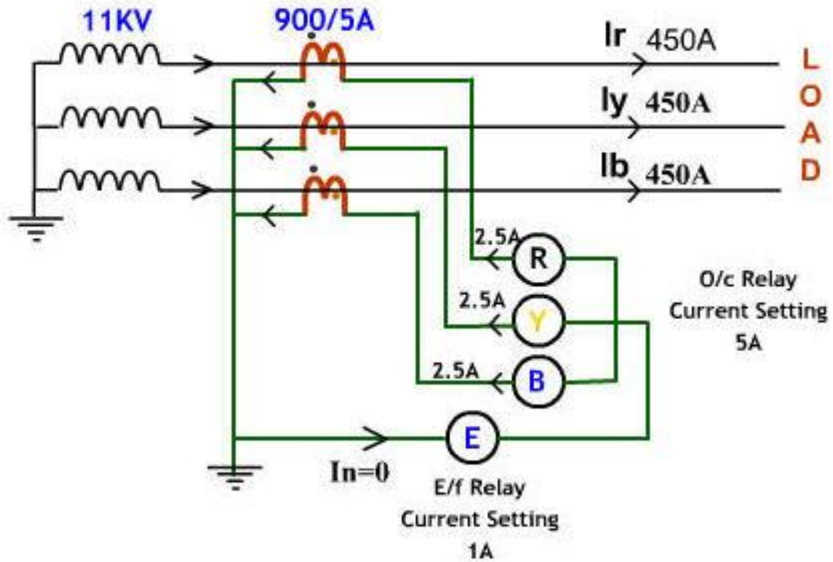
Behavious of Protection circuit in Non-fault condition



So Out-of-balance current (I^n) = $I^R\angle 0° + I^Y\angle 120° + I^B\angle 240°$

In case of a balanced system, all phase currents are nearly equal .Let us assume that

$I^R = I^Y = I^B = 450A$

Secondary current=2.5A

$I^n = 2.5\angle 0° + 2.5\angle 120° + 2.5\angle 240°$

$I^n = 2.5\left(Cos\,0° - jSin\,0°\right) + 2.5\left(Cos\,120° - jSin120°\right) + 2.5\left(Cos\,240° - jSin\,240°\right)$

$I^n = 2.5\left(1 - j\,(0)\right) + 2.5\left(-0.5 - j0.866\right) + 2.5\left(-0.5 - (-0.866)j\right)$

$I^n = 2.5 - 1.25 - j2.165 - 1.25 + j2.165$

$I^n = 0$

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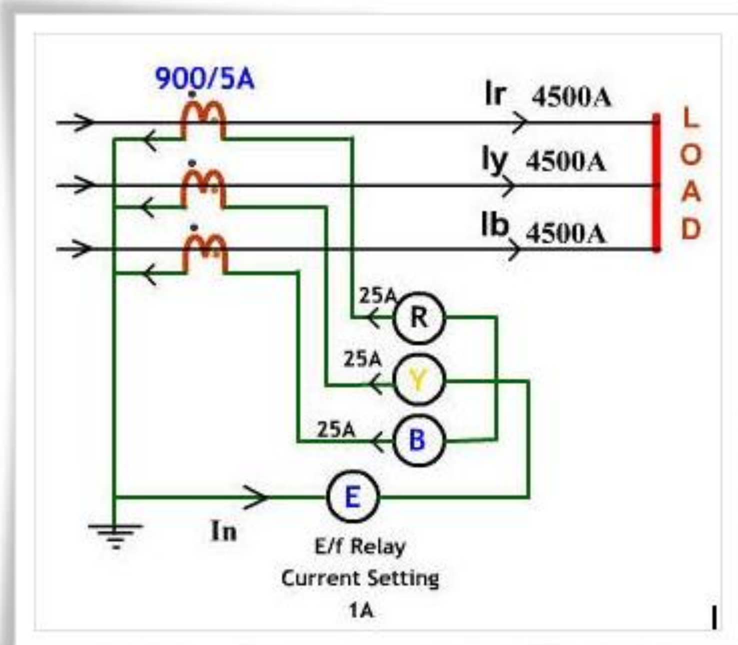
Behavious of Protection circuit in Fault condition



Case1
01

Phase-to-Phase Fault

During a fault of Ph-Ph fault (all phases) , the vector sum o f the fault currents flowing in the secondary circuit of all th e C.Ts.will be Zero. No current will flow through Earth Fau lt Relay. As seen , for a fault current of 4500A,25A (i.e. 5x4 500/900=25) will flow through all the over-current relays. As relays are set at 5A , it will faces 5 times current. Hence the Over-current Relays of all phases trips simultaneously

$$I^n = 25\angle 0° + 25\angle 120° + 25\angle 240°$$

$$I^n = 25\left(Cos\,0° - jSin\,0°\right) + 25\left(Cos\,120° - jSin\,120°\right) + 25\left(Cos\,240° - jSin\,240°\right)$$

$$I^n = 25\,(1 - 0) + 25\left(-0.5 - j0.866\right) + 25\left(-0.5 - j\,(-0.866)\right)$$

$$I^n = 25 - 12.5 - j21.65 - 12.5 + j21.65$$

$$I^n = 0$$

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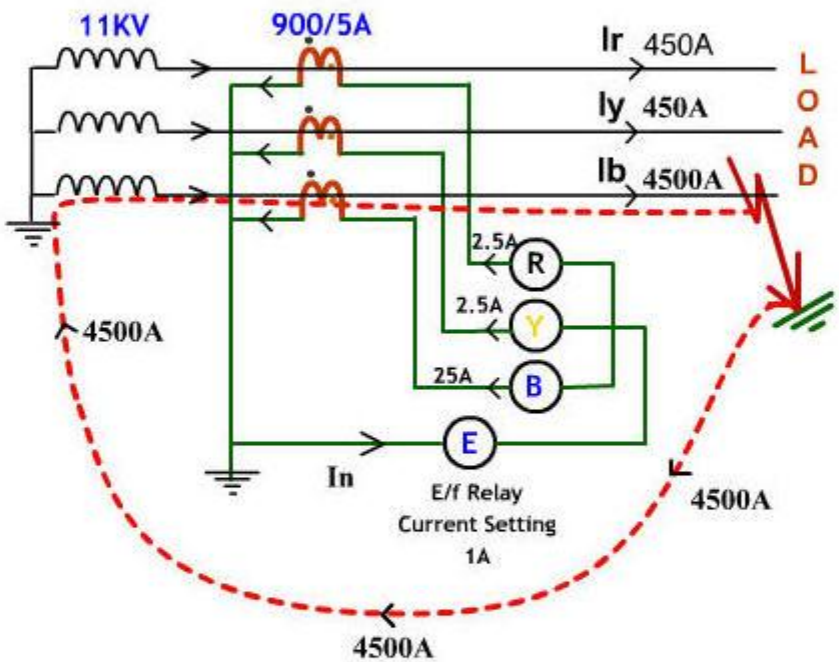
Behaviour of Protection circuit in Fault condition



Ph-G Fault

$$I^{n} = 2.5\angle 0° + 2.5\angle 120° + 25\angle 240°$$

$$I^{n} = 2.5\left(Cos\ 0° - jSin\ 0°\right) + 2.5\left(Cos\ 120° - jSin\ 120°\right) + 25\left(Cos\ 240° - jSin\ 240°\right)$$

$$I^{n} = 2.5\,(1 - 0) + 2.5\left(-0.5 - j0.866\right) + 25\left(-0.5 - j\,(-0.866)\right)$$

$$I^{n} = 2.5 - 1.25 - j2.165 - 12.5 + j23.815$$

$$I^{n} = -11.25 + j21.65$$

$$I^{n} = 24.4A$$

Case1

02

Phase-to-Ground Fault

It observed that during an earth fault as shown , 24th times current (i.e. rated for 1A) will flow through E/f relay & 9 times current(i.e. rated for 5A) flow through the O/c r elay of phase under ground fault , so Earth Fault relay will pickup prior to O/c relay & trip the CB to isolate the fault.

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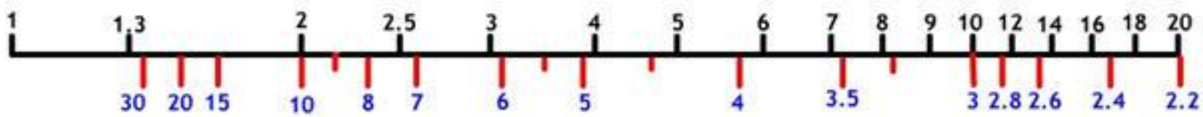
How to calculate the operating time of a Relay during a fault

Plug Setting Multiplier



Time in Seconds

Fig: Logarithmic scale for IDMT relay at TMS=1

I.D.M.T.L

$$t = \frac{0.14}{Ic^{0.02} - 1}$$

Very Inverse

$$t = \frac{13.5}{Ic - 1}$$

Extremely Inverse

$$t = \frac{80}{Ic^{2} - 1}$$

Where
Ic=Current in Amps
t=time

Tip

On every Over current/Earth Fault relay , you will get a s
imilar scale. This scale represents the characteristic of the
relay. The formulas written in side describe the relati
onship between current & time for different characteris
tics.

Task

We have a transmission line having line C.T. of 300/1A.

Relay PSM (Plug Setting Multiplier)		i.e. Current setting of Relay=1A (100%)	
Relay TMS (Time Multiplier Setting)		0.1 (i.e 10% of full sace of 1.0)	
Fault Current	(Assume)	1200A	(Case 1)
Fault Current	(Assume)	1500A	(Case 2)

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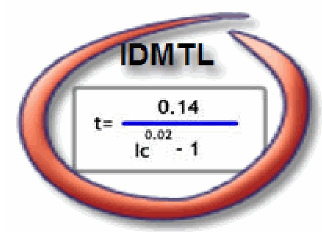
How to calculate the operating time of a Relay during a fault

We can't set an Over current /Earth fault relay operating timings directly as it is dependent on many factors and primarily depends on Fault Current. Being inverse characteristic, if Fault current increase , the operating time of relay decrease. A higher value of TMS will cause long tripping time and lower values of TMS will results in lower tripping time. Sometimes , for same type of faults at a same location , the fault current may change and tripping timing of relays will differ. The fault current is dependent on the Fault MVA level, Distance of fault from Generators, No's generators operating in Grid etc.

Case 01

Fault Current = 1200A , C.T.Ratio = 300/1A , Relay Rating = 1A ,

Plug Setting Multiplier = 100%



C.T. Secondary Current = 1200x1/300=4Amp

$$\text{Operating Time} = \frac{0.14}{4^{0.02} - 1} = 4.97s$$

We can also see from the characteristic scale that at 4 times current operating time will be 4.97s.

Now if we set a TMS of 0.1 i.e. 10% , the time taken by relay to trip = 4.97x0.1=0.497s or 497ms

If we set TMS at 0.05 then relay will take 4.97x0.05=0.248s or 248ms to trip.

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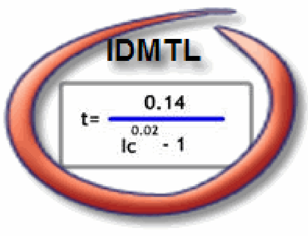
How to calculate the operating time of a Relay during a fault

Case 02

Fault Current = 1500A , C.T.Ratio = 300/1A , Relay Rating = 1A ,

Plug Setting Multiplier = 100%



C.T. Secondary Current = 1500x1/300=5Amp

$$\text{Operating Time} = \frac{0.14}{5^{0.02} - 1} = 4.27s$$

If set a TMS of 0.1 i.e. at 10% ,so time taken by relay to trip = 4.27x0.1=0.427s or 427ms

If we set TMS at 0.05 i.e. at 5% ,then relay will take 4.27x0.05=0.213s or 213ms to trip.

Tip

So we can easily interpret that the operation time taken by the relay is largely depends on fault current. On the other hand, the fault current may not be same at every time for a fixed location & for an identical type of fault. Fault current depends on following parameters also;

- Short circuit power of in feed
- Line Impedance
- Arc resistance
- Type of Earthing
- Treating of Star point
- Voltage level.

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Important

Causes of Earthfault Relay Malfunctions

Tip

Over-current protection is very appealing and attractive because of its inherent simplicity. However, it has some major drawbacks which causes it to mal-operate. In LV systems, however, mal-operation of relays can be tolerated. The only consideration in LV systems is the continuity of supply to the consumers.

In EHV systems , mal-operations cannot be tolerated. This is because EHV lines are part of an interconnected grid. Any mal-operation on these systems jeopardizes the stability of the electric grid.

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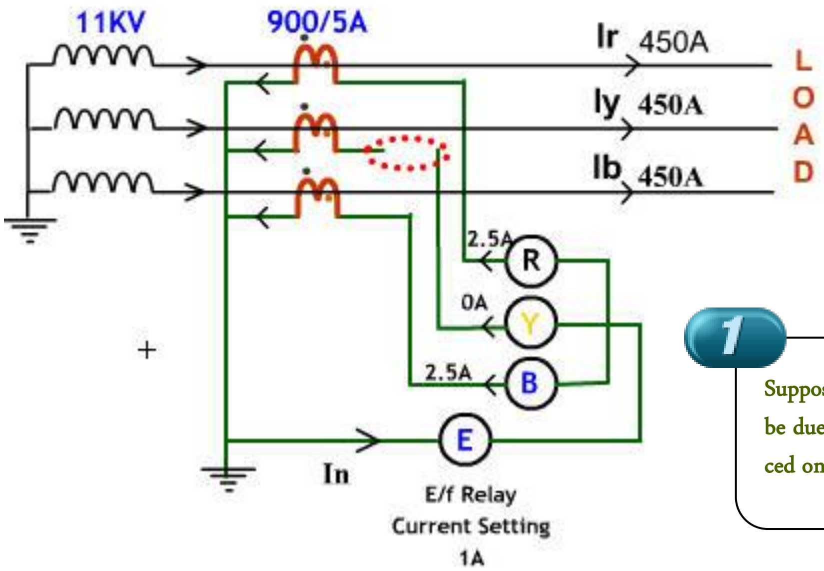
Open-circuit of C.T. secondary

Case 01



Tip

During normal operation of the power system, if secondary circuit of one of the C.T. gets open circuit , it will lead to mal-operation of Earth Fault Relay (even without any earth fault)

1

Suppose a condition, when "Y" phase C.T's secondary gets opened due to any reason (may be due to continuous sparking, sulphation , looseness etc). & Load is running balanced on all the phases.

2

Let's calculate the Out-of-balance current I_n which will flow through Earth Fault Relay.

$I_n = \text{Vector sum of currents of CT secondary of all phases}$

$I_n = 2.5\angle 0° + I_y + 2.5\angle 240°$

As $I_y = 0$ due to open circuit of C.T. secondary

So

$$I_n = 2.5\left(Cos\,0° - jSin\,0°\right) + 2.5\left(Cos\,240° - jSin\,240°\right)$$

$$I_n = 2.5\left(1 - j0\right) + 2.5\left(-0.5 - j\left(-0.866\right)\right)$$

$$I_n = 2.5 - 1.25 + j2.165 = 1.25 + j2.165$$

$$\mathbf{I_n = 2.5A}$$

3

2.5A current in Earth fault relay will definitely cause the tripping of Earth Fault relay set at 1A.

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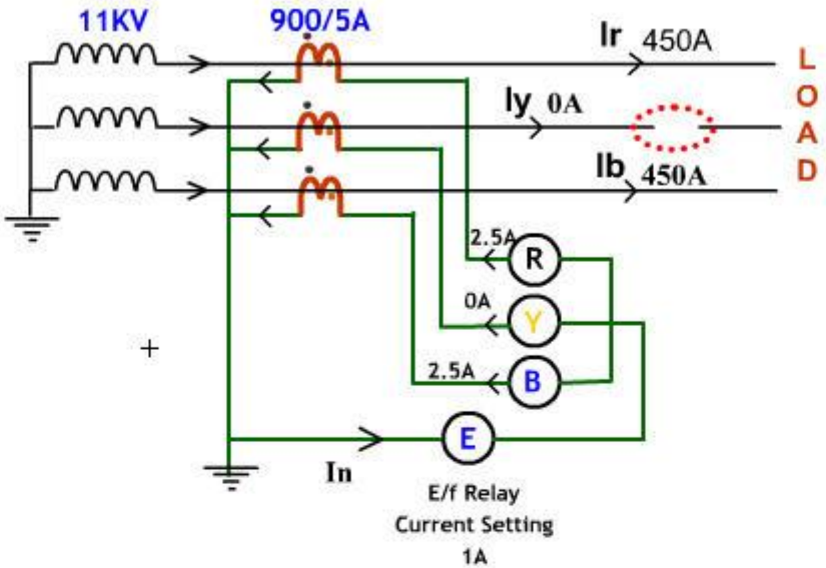
Broken Jumper

Case 02



1

If a jumper of any phase of transmission line gets ope ned (but doesn't drop to ground & make Earth fault) , the loa d current through that phase drop to zero(0) and we will get out-of-balance current of 2.5A. So we will get an Earth Faul t Relay operation without actual Earth Fault.

2

Let's calculate the Out-of-balance current I_n which will flow through Earth Fault Relay.

$\mathrm{I_n}$ = Vector sum of currents of CT secondary of all phases

$$\mathrm{I_n} = 2.5\angle 0° + I_y + 2.5\angle 240°$$

As $\mathrm{I_y} = 0$

So

$$\mathrm{I_n} = 2.5\left(\cos 0° - j\sin 0°\right) + 2.5\left(\cos 240° - j\sin 240°\right)$$

$$\mathrm{I_n} = 2.5\left(1 - j0\right) + 2.5\left(-0.5 - j\left(-0.866\right)\right)$$

$$\mathrm{I_n} = 2.5 - 1.25 + j2.165 = 1.25 + j2.165$$

$$\mathbf{I_n = 2.5A}$$

3

2.5A current in Earth fault relay wil l definitely cause the tripping of Ea rth Fault relay set at 1A without occura nce of a real Earth fault.

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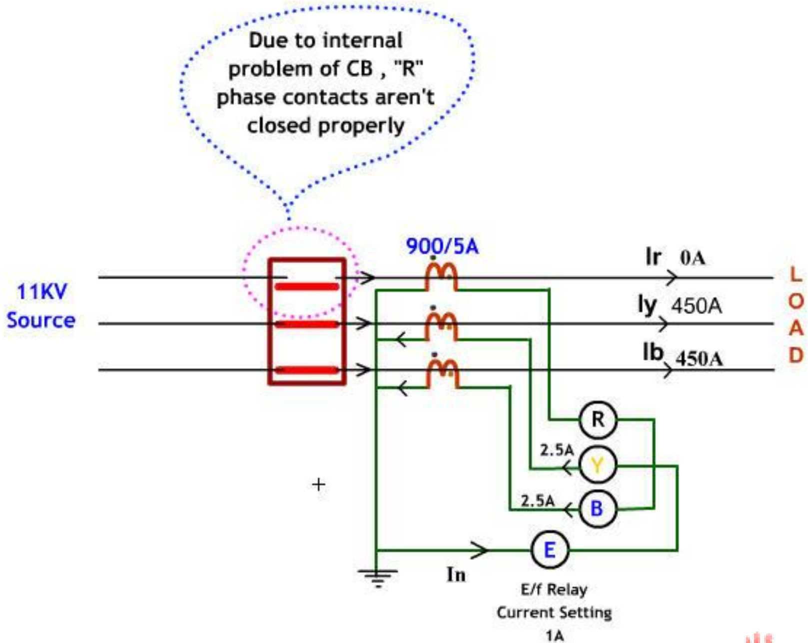
Opening of a limb of Circuit breaker

Case 03



1

During Closing of the circuit breaker , if due to any reason , any phase contacts aren't closed properly , same may lead to drop the current & voltage on that phase to zero. This condition cause a out-of-balance current of 2.5A (as calculated in previous examples) and will cause the mal-operation of earth Fault Relay .i.e. the Earth fault relay will trip without actual Earth fault.

2

2.5A current in Earth fault relay will definitely cause the tripping of Earth Fault relay set at 1A without occurrence of a real Earth fault.

Important

3

So it is concluded that opening of a current circuit both on primary & secondary side of a C.T. may cause the out-of-balance current in Earth fault relay

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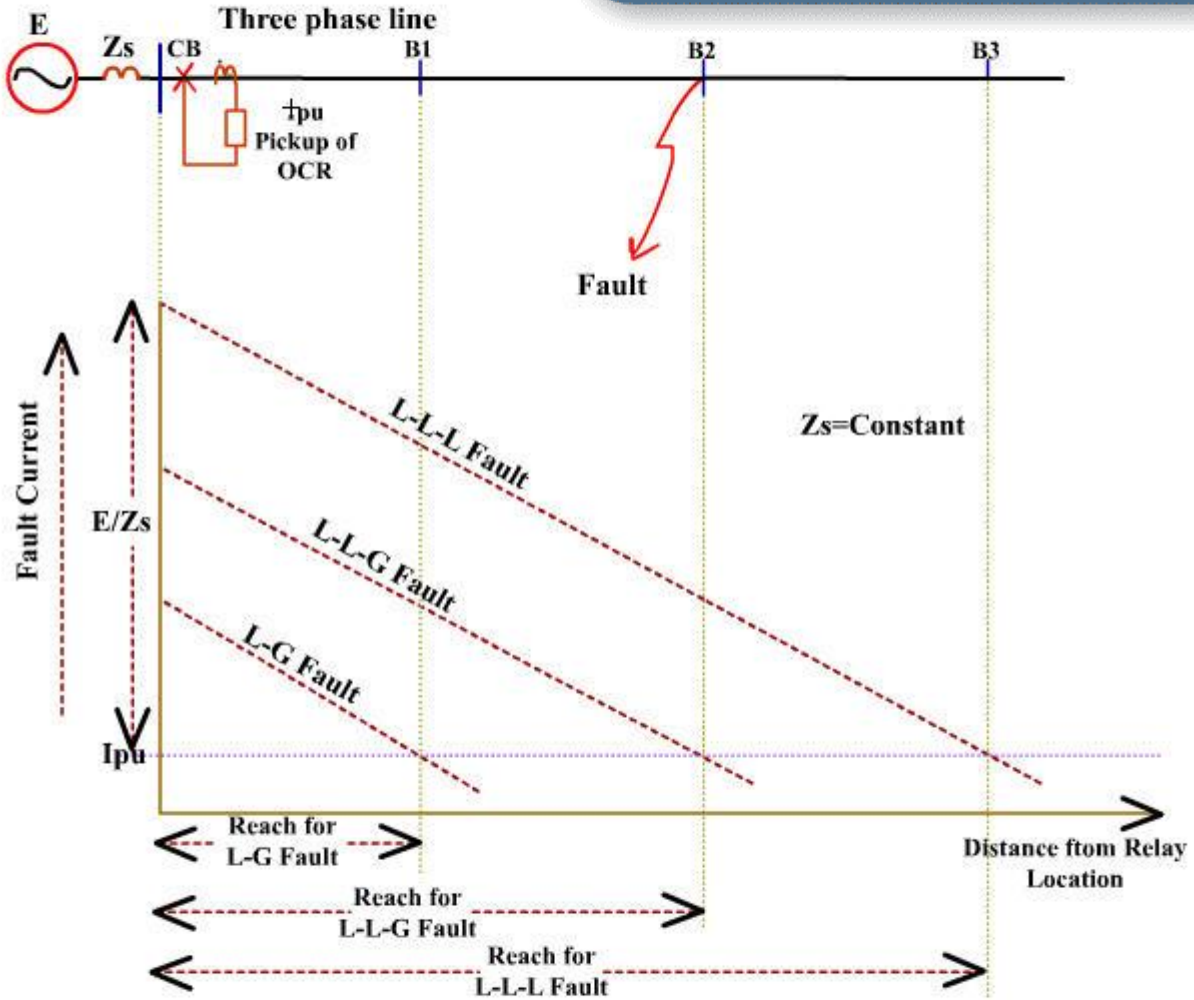
Effect of type of fault on the reach of over-current relay



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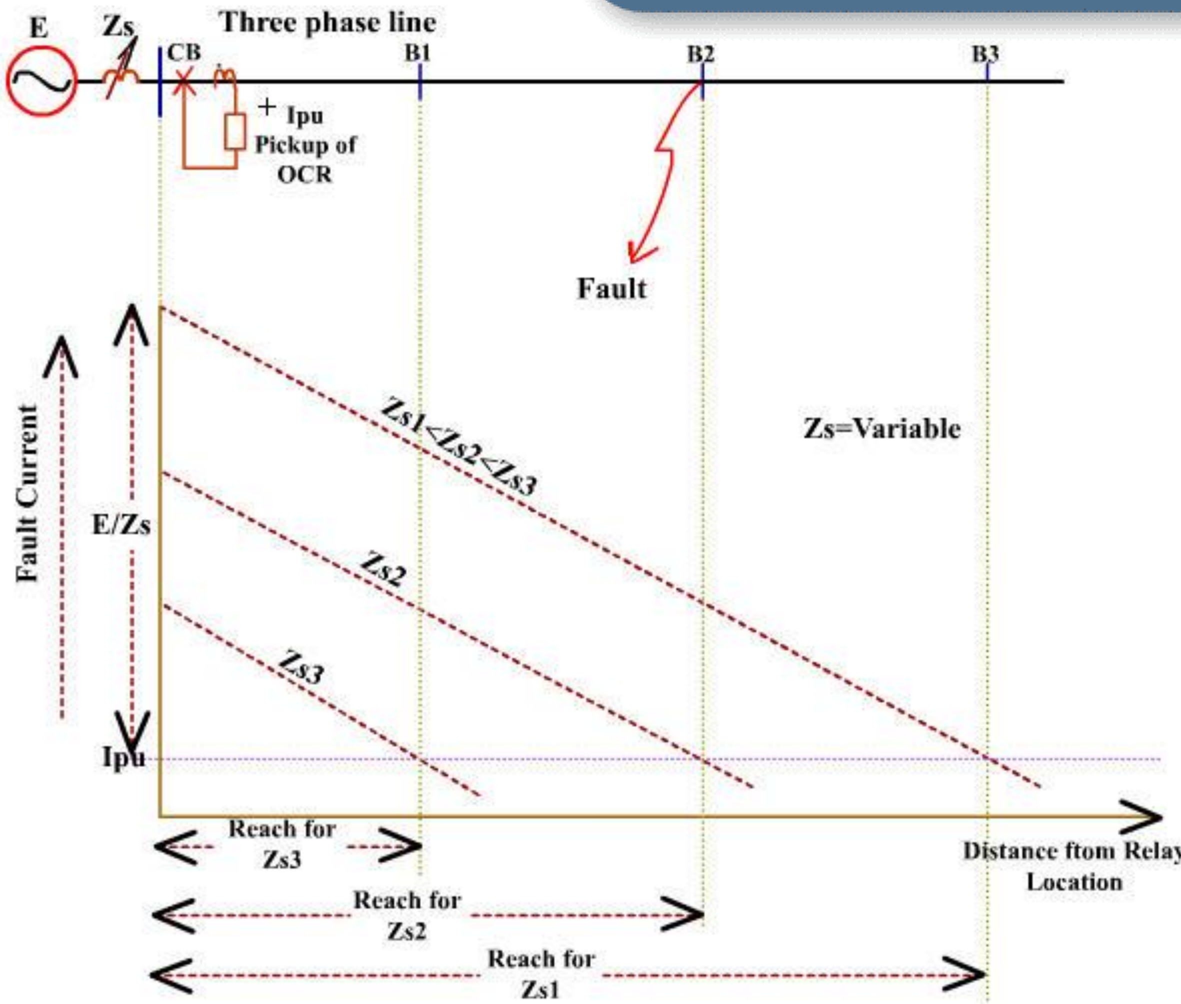
Effect of source impedance on the reach of over-current relay



THANK YOU !!

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