Special Considerations for Distribution Feeder Protection Coordination

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INTRODUCTION

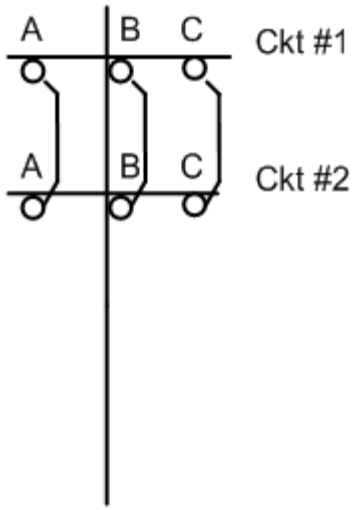
Depending on application, certain onerous conditions require special considerations for proper feeder relay coordination.

Some applications requiring special consideration include:

- Multiple circuits sharing same structures
- Networks
- Single-pole tripping
- Fast bus tripping schemes

Multiple Distribution Circuits Sharing Same Set of Structures

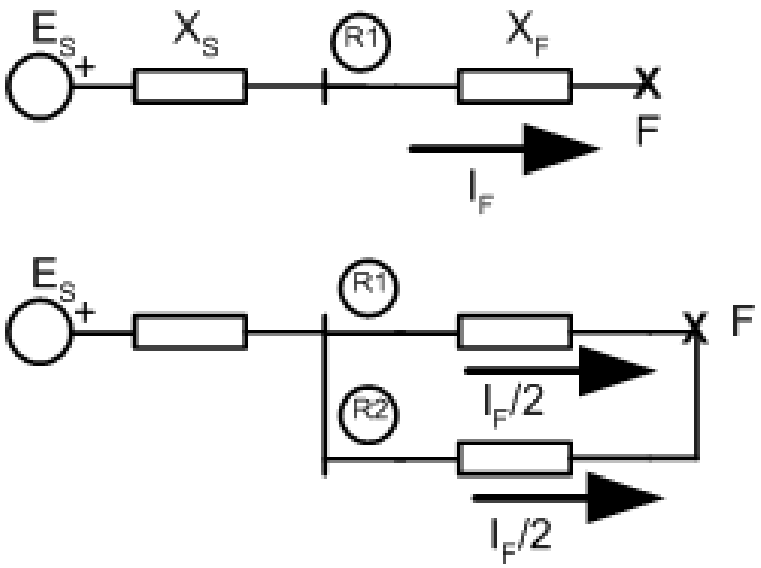
Here is an example of multiple distribution circuits sharing same set of structures:



A tree limb falling across outer phase pair of overhead circuits causes a fault to occur. This is one example of a cross-country fault (CCF).

Multiple Distribution Circuits Sharing Same Set of Structures (Single Line Short Circuit Diagram)

Example:



$X_F = Z_1/2$

Where:

E_S = system voltage (100 volt secondary line-to-ground)

X_F = total feeder reactance up to the point of fault ($Z_1/2$)

I_F = total fault current flowing in the feeder

Multiple Distribution Circuits Sharing Same Set of Structures

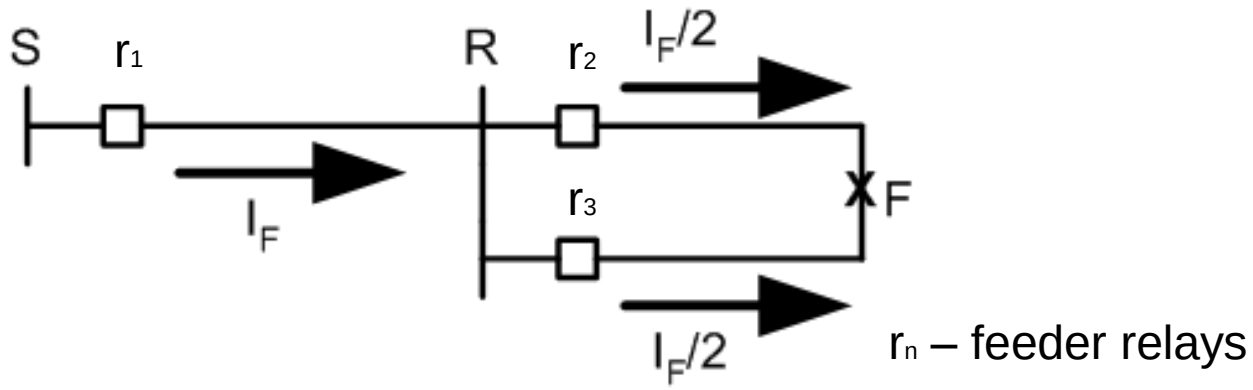
Table shows fault current magnitude for:

- A single feeder (I_F)
- Cross-country fault involving both feeders (I_F')

X_S	I_F	I_F'	I_F/I_F' (ratio)
1 Ω	9.1 amps	8.33 amps	1.1
2 Ω	8.33 amps	7.1 amps	1.2
5 Ω	6.67 amps	5 amps	1.3
10 Ω	5 amps	3.33 amps	1.5
15 Ω	4 amps	2.5 amps	1.6

- X_F is held constant
- X_S (system equivalent reactance) varies

Multiple Distribution Circuits Sharing Same Set of Structures

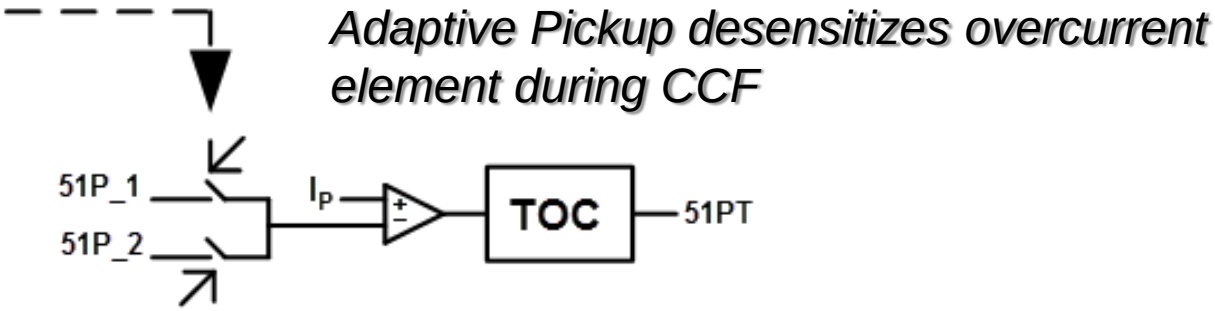


Fault current magnitude *in the feeder* for cross-country fault decreases as source impedance increases.

This can cause mis-coordination between local feeder overcurrent protection and upstream protection.

Multiple Distribution Circuits Sharing Same Set of Structures

- Peer-to-peer communication allows relays to share status in real-time
- Program two feeder relays at substation R as follows:
  - If both simultaneously detect a fault, then they automatically can adjust pickup settings to maintain coordination.



- 51P_1 = normal pickup setting for the phase time overcurrent element
- 51P_2 = lower pickup setting (only used when cross-country fault detected)
- I_P = maximum phase current
- TOC = time overcurrent characteristic
- 51PT = output

Single-pole Tripping

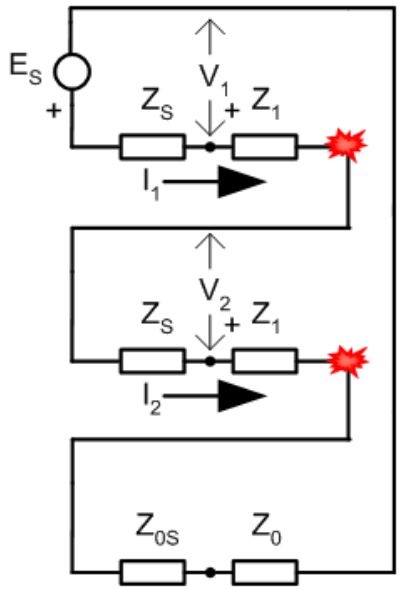
Single-pole tripping:

- Popular for some three-phase distribution circuits because most load is single phase (e.g., residential areas)

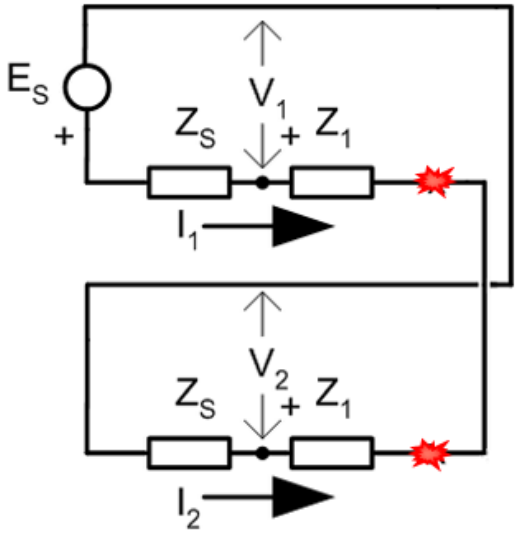
- *Special consideration required because of unbalance during a single phase trip*
- The open pole can adversely affect:
  - Directional elements
  - Ground overcurrent protection

- Angular relationships (V_1 vs. I_1 & V_2 vs. I_2)
  - Single-phase-to-ground fault
  - Phase-to-phase fault

- Fault location is in forward direction with respect to feeder relay



Phase-to-Ground

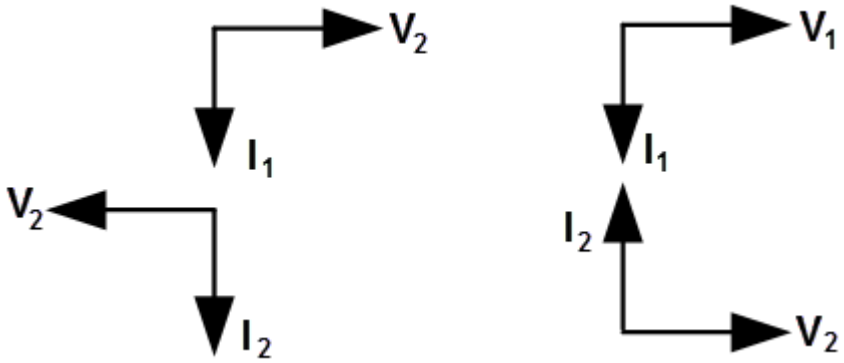


Phase-to-Phase

Single-pole Tripping

Symmetrical component voltage and current relationships

- During an open pole, relationship between V_2 and I_2 could be same or close to phase-to-phase-to ground fault in forward direction
- Unwanted tripping can occur during heavy load due to unbalance current (I_2 > pickup)

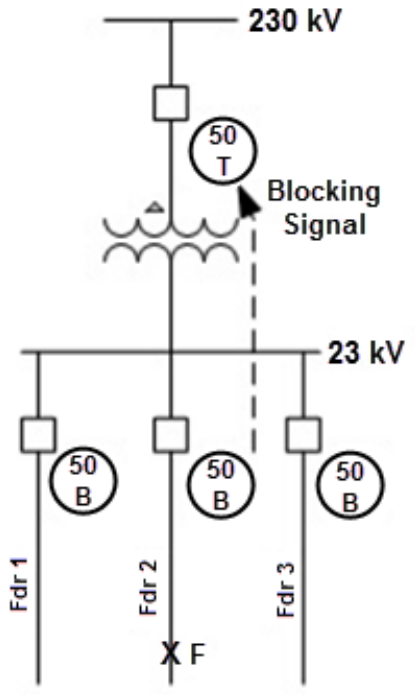


Single-pole Tripping

Single-pole tripping can lead to heavy inrush current following reclose:

- Appears as ground fault current
- Special steps required to avoid nuisance tripping (e.g., hot load pickup detection)

Fast Bus Tripping Schemes

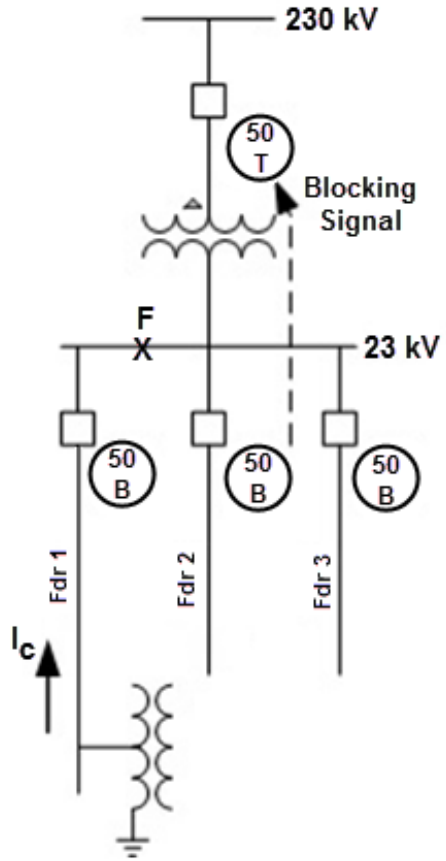


- Applied for bus work in distribution systems
- Works on basic principle of directional comparison blocking scheme
- ***Many special considerations required*** to ensure reliability and security to avoid unwanted trips during external fault

Fast Bus Tripping Schemes

Directional Supervision

- This arrangement uses directional elements to supervise overcurrent elements
- If bus ground occurs, feeder relay overcurrent element does not block due to forward-looking directional element:
  - ➢ Quickly clears bus ground fault



Fast Bus Tripping Schemes

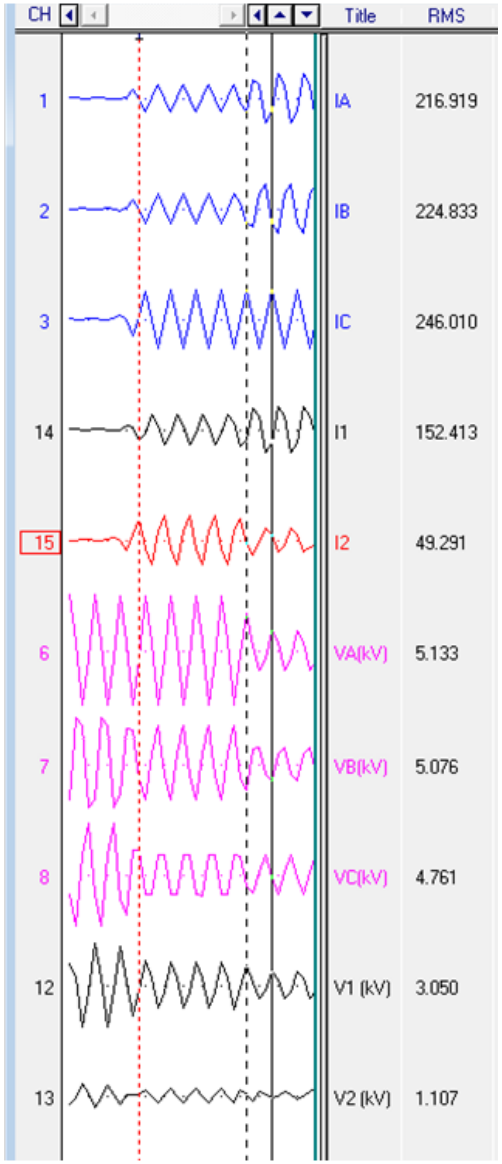
Modern numerical feeder relays use multiple polarizing quantities:

- negative-sequence voltage
- zero-sequence voltage

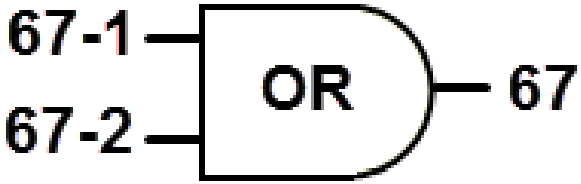
Feeder overcurrent elements supervised by directional elements that can operate for any fault type

Only one active directional element at any time causes momentary dropout of blocking signal during an evolving fault

Graphic shows phase-to-phase fault that evolves into three-phase fault



Fast Bus Tripping Schemes

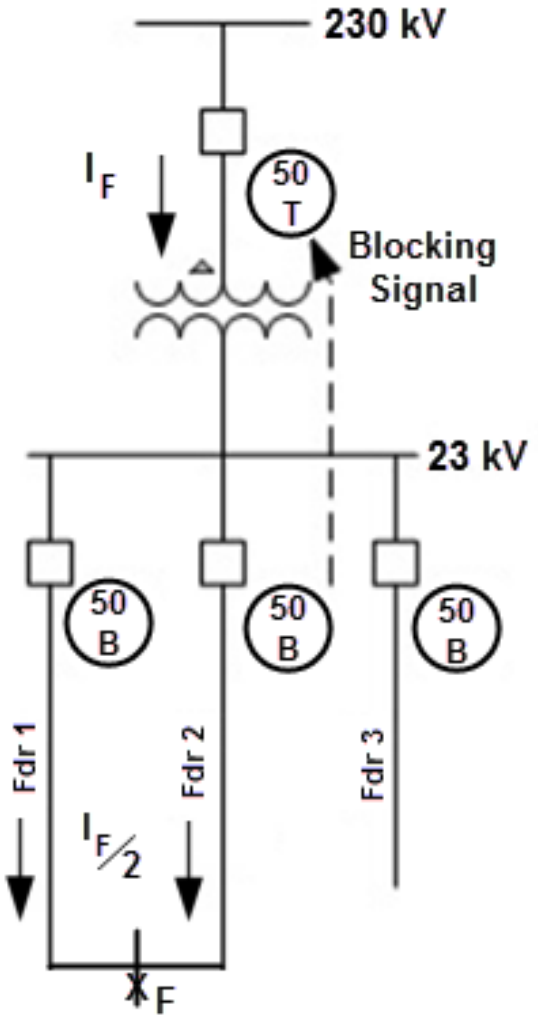


- Fault evolving into third phase causes negative-sequence voltage and current measured by feeder to drop to zero
- If supervisory directional element requires at least one processing interval to switch from negative-sequence to positive-sequence voltage:
  - The blocking signal drops out
  - An unwanted bus trip can occur during an external fault.
- If both positive- and negative-sequence directional elements are active:
  - Protection scheme will remain stable
  - Will ride through transition

Fast Bus Tripping Schemes

Overcurrent Pickup Protection

- Looped feeders as shown require 50T pickup setting to be properly coordinated versus 50B
- Feeder relays see less fault current due to distribution requiring greater sensitivity of 50B pickup
- Incorrect setting of 50B causes unwanted tripping due to remote faults



Conclusions

Certain onerous distribution system conditions require special considerations for proper feeder relay coordination.

Applications requiring special consideration include:

- Multiple circuits sharing same structures: cross-country faults require special feeder relay coordination because fault current magnitude decreases as source impedance increases
- Single-pole tripping in three-phase distribution systems must account for system unbalance due to effect of open pole on directional elements and ground overcurrent protection
- Fast bus tripping schemes are applied to distribution substations bus work and operate on basic principle of directional comparison-blocking scheme

Questions?

Special Considerations for Distribution Feeder Protection Coordination

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