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Advanced protection and control IEDs from ABB

Relion. Thinking beyond the box.

Designed to seamlessly consolidate functions, Relion relays are smarter, more flexible and more adaptable. Easy to integrate and with an extensive function library, the Relion family of protection and control delivers advanced functionality and improved performance.

ABB Protective Relay School webinar series
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ABB Protective Relay School Webinar Series

Introduction to protection and control

Roger Hedding

June 03, 2014

Presenter

Roger Hedding

Roger graduated from Marquette University and joined Westinghouse Electric Corp. After receiving a Masters degree in Electrical Engineering from the University of Pittsburgh, Roger became a District Engineer, and eventually moved to Milwaukee where he currently resides.

As a Relay Development Consultant he guides the development of relay products for the North American market. Roger is a IEEE senior member, and Chair of the IEEE Power Systems Relay Committee. Roger has authored or co-authored many papers in power systems protection.

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Learning objectives

- Overview and understanding of the role of relays in protection and control
- Define relay classifications
- Review common relay applications
- Understand relaying philosophy
- Review basic protection principles
- Review of IEEE device function numbers
- Review of IEEE and IEC symbols

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WHAT IS RELAYING

What is a relay?
Definition

- An act of passing something along from one person, group, or station to another
- A supply (as of horses) arranged beforehand for successive relief
- A number of persons who relieve others in some work
- An electrically operated switch that responds to current or voltage in one circuit to switch on and off a current in a second circuit

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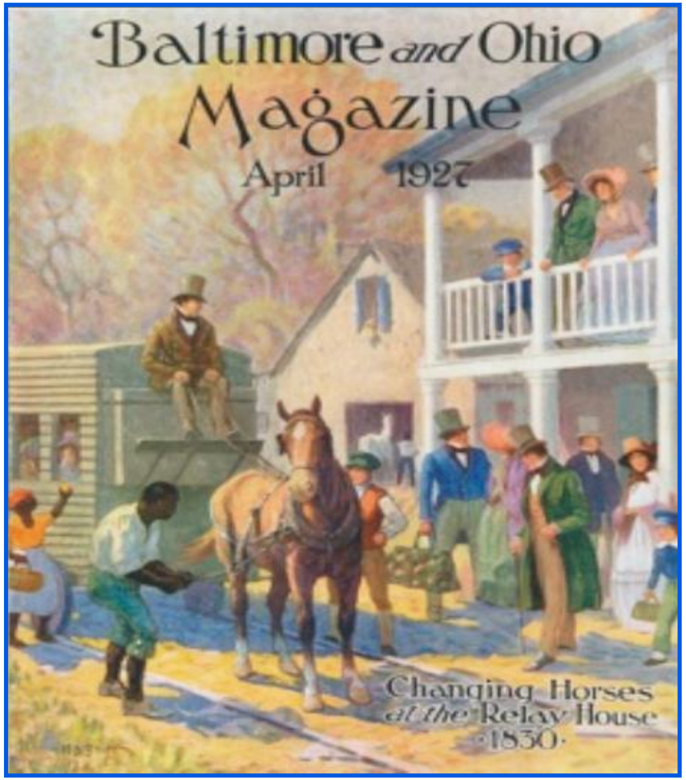
Horses and electromagnetic devices
“Relais”



Relaymaryland.com

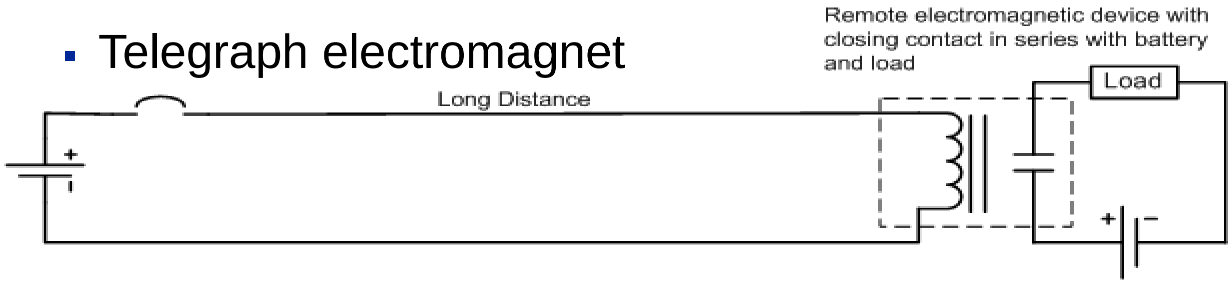
Relay – derived from the French word *“relais”*, which [at that time] meant replacement.

- The term “relay "was first applied in 1830 to a team of fresh relief horses that pulled horsed vans (railway cars with wooden wheels) on a wooden railway between Baltimore and Ellicott’s Mills
- The term “relay” also applied to the station where the worked horses were changed for fresh horses to continue the journey without delay.
- In the “old west” stage coaches had relay stations
- In 1860 and 1861 the Pony Express moved mail across the west in “relays”.

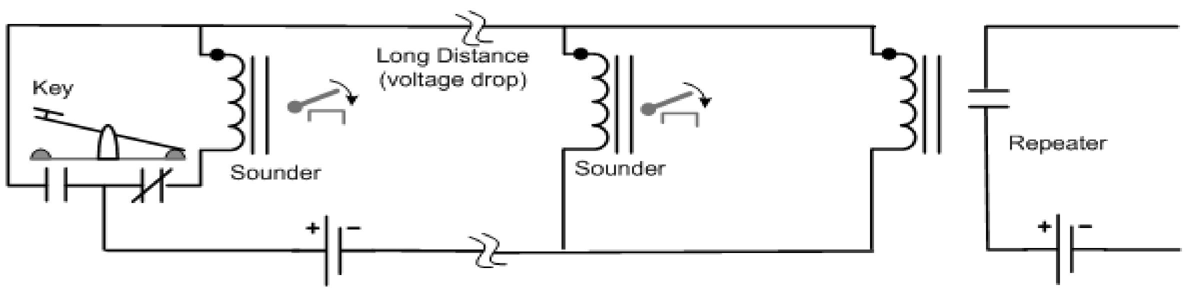
At about the same time. . . electromagnetic technology was evolving.

Electromagnetism
Invention and application in the U. S. 1830 - 1875

- Joseph Henry –
  - Telegraph electromagnet



- Samuel Morse –
  - Sounder, Repeater, and Morse Code



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Relays
Horses and the telegraph

Recognizing the similarity of function between the relay of horses and telegraph repeaters and sounders the telegraph electromagnetic devices became commonly called “relays” by 1870

Thomas Hall Telegraph Relay (1850 - 1860)

The first electrical relays were used in long distance telegraph circuits, repeating the signal coming in from one circuit and re-transmitting it to another.

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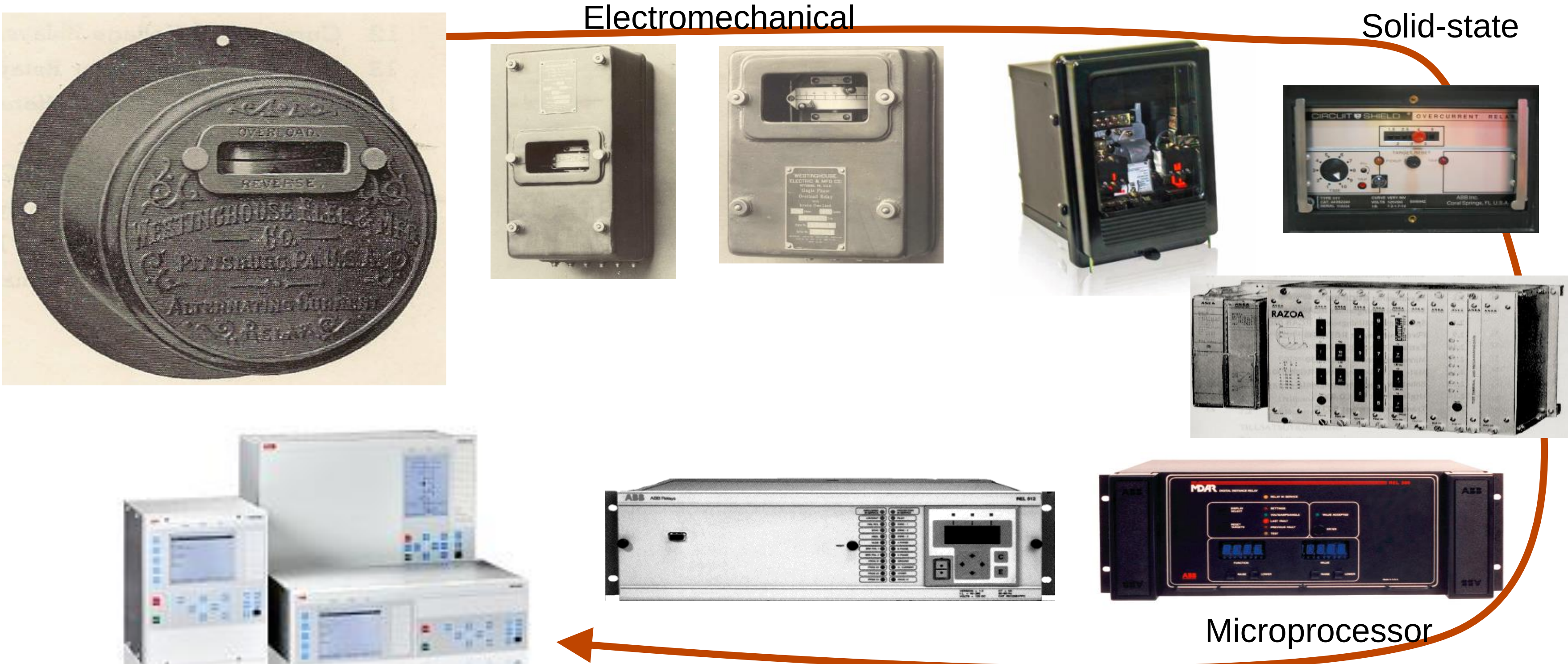
Relays
The electric power system

- The electric power system did not begin to be implemented until the 1880s
- The need for protection evolved with the power system and experience from gained from system faults
  - Nothing – service interruption was not important
  - Intentional “weak-links” (thin wires)
  - Fuses
    - Availability
    - Maintenance shortcuts

      “The improper replacement of fuses is one of the deepest rooted evils in the electric industry.” – V. H. Todd, Protective Relays, 1922
  - Electromagnetic operated switches
    - But still no fault location discrimination
- Application of telegraph “relay” technology

Relays
Evolution of technology

The first protective relays began to appear in the early 1900s.



And have evolved to the advanced substation automation systems of today.

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Relays
Definition

- A **relay** is a device that responds to a measured quantity . . . current, voltage, heat, pressure, vibration, etc., from one system and switches a current in another system, usually an electric circuit for the purpose of protection or control.
- **Protective relays** are devices that are used throughout the electric power system to detect abnormal and unsafe conditions and initiate corrective action.

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Classification of relays defined in IEEE C37.90
By function

- **Protective** - Detects intolerable conditions and defective apparatus.
- **Monitoring** - Verify conditions in the protection and/or power system.
- **Reclosing** - Establish closing sequences for a circuit breaker following a protective relay trip.
- **Regulating** - Operates to maintain operating parameters within a defined region.
- **Auxiliary** - Operates in response to other [relay] actions to provide additional functionality
- **Synchronizing** - Assures that proper conditions exist for interconnecting two sections of the power system

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Classification of relays
By input

- Current
- Voltage
- Power
- Frequency
- Temperature
- Pressure
- Flow
- Vibration

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Classification of relays
By performance characteristics

- Overcurrent
- Over/under voltage
- Distance
- Directional
- Inverse time, definite time
- Ground/phase
- High or slow speed
- Current differential
- Phase comparison
- Directional comparison

Classification of relays
By operating principle

- Current balance
- Percentage biased
- Multi-restraint
- Product
- Thermal
- Comparator
- Phase
- Magnitude

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Classification of relays
By technology

- Electromechanical
- Solid state (Static)
- Microprocessor-based (Digital/Numerical)

The protection team
Relays are just one part of a team

- The relay(s)
- The sensors
  - PTs
  - CTs
  - Etc.
- The switch or circuit breaker
- DC power supply (Battery)
- The interconnection

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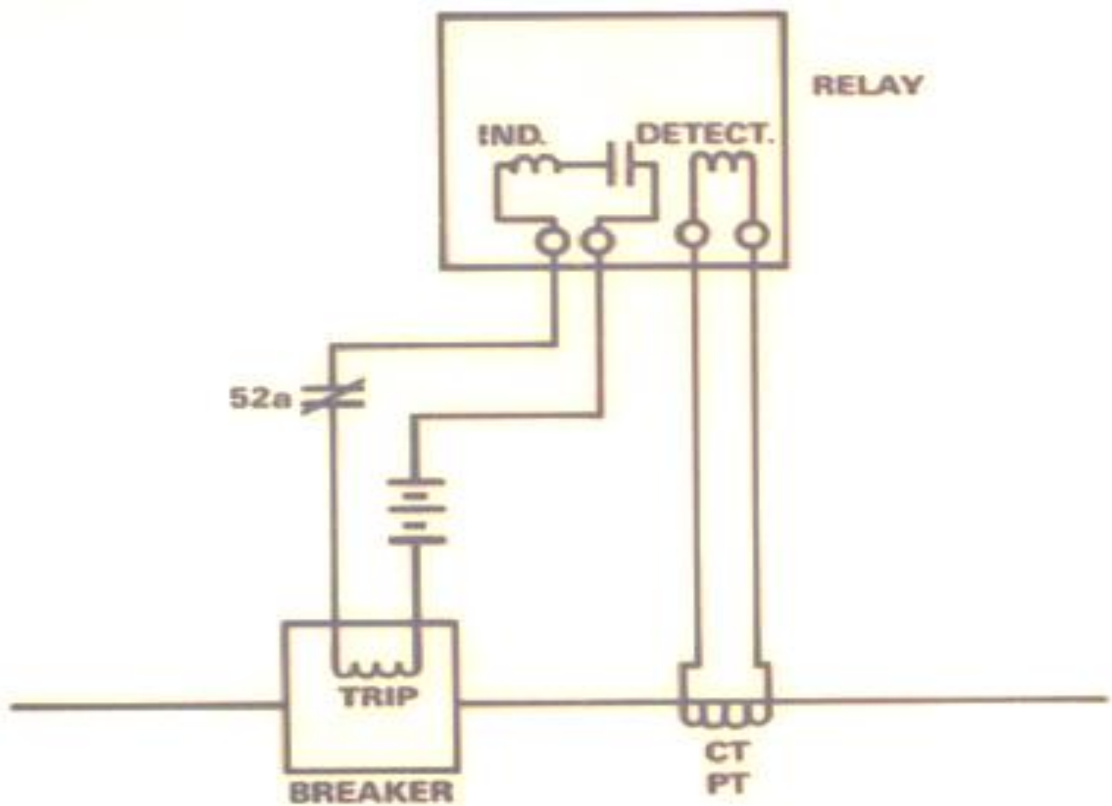
The protection team



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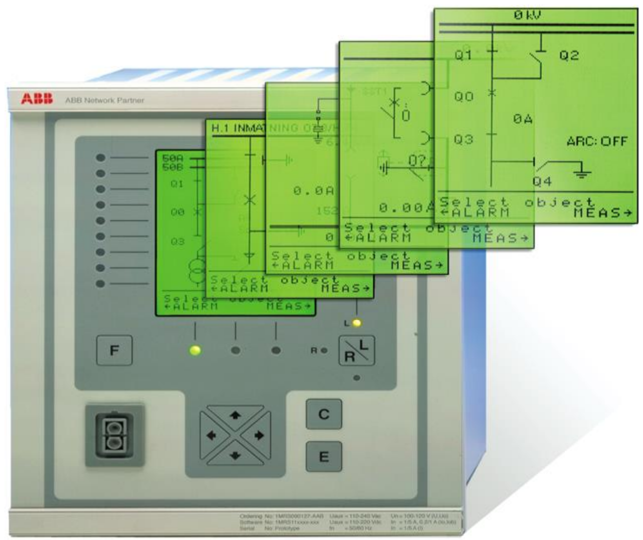
Principles of relay application



- Selectivity
- Reliability
- Speed – based on need
- Simplicity
- Economics

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Reliability

DEPENDABILITY | **SECURITY**

The certainty of correct operation in response to system trouble.

The ability of the system to avoid undesired operations with or without faults.

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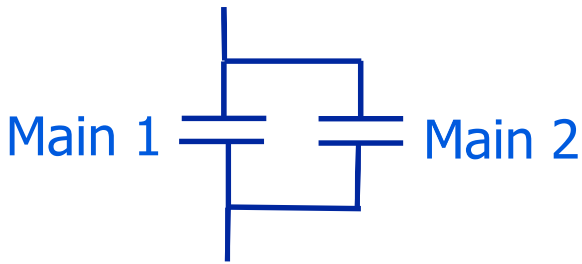
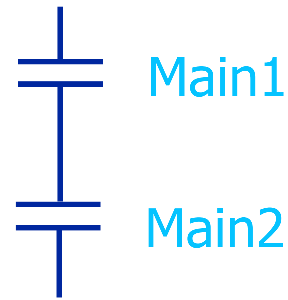
Reliability

DEPENDABILITY



The certainty of operation in response to system trouble

SECURITY



The ability of the system to avoid misoperation with or without faults

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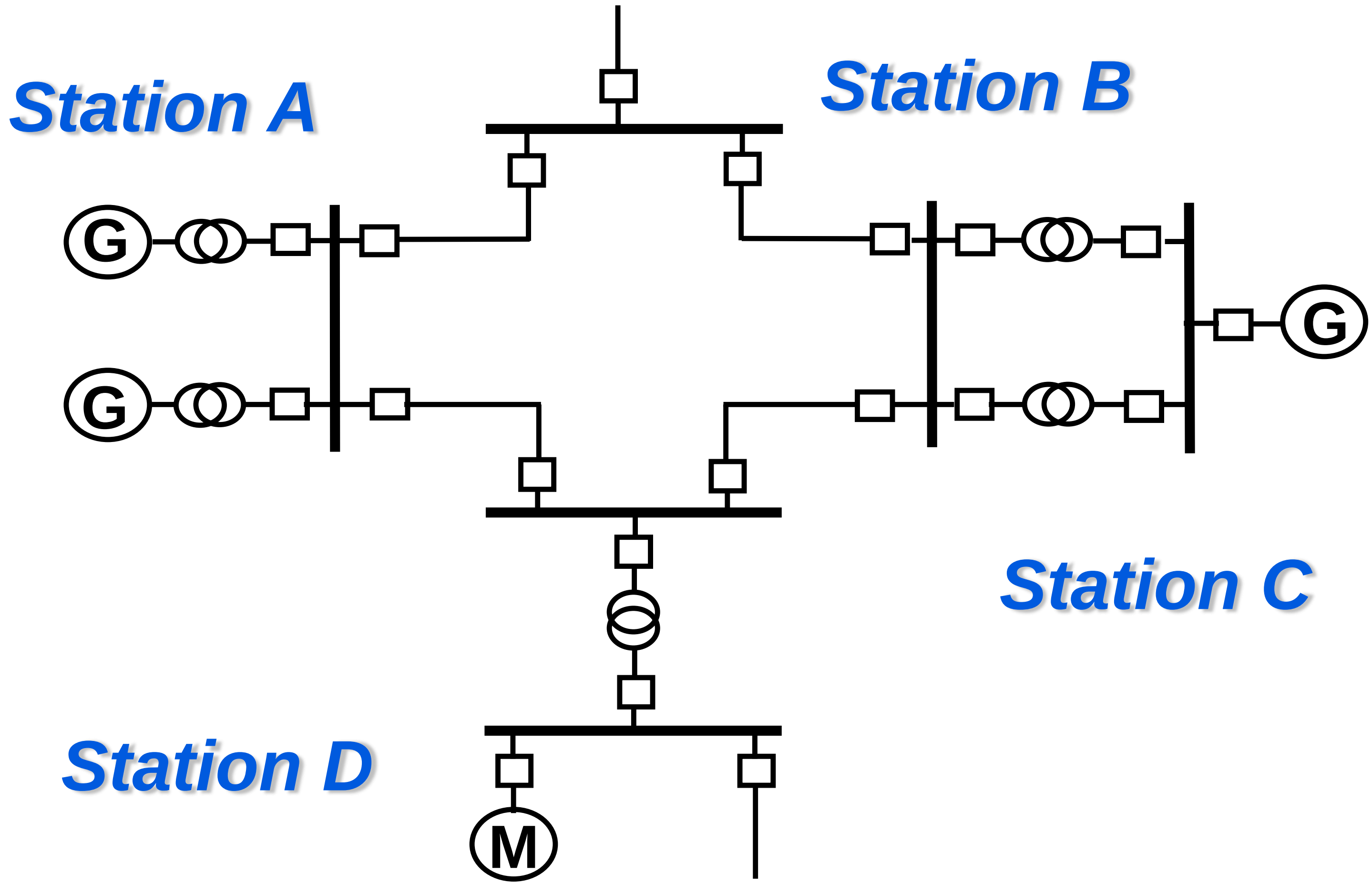
General relaying philosophy
“Zone protection”

- Generator
- Transformer
- Bus
- Transmission Lines
- Motors

Zones of protection



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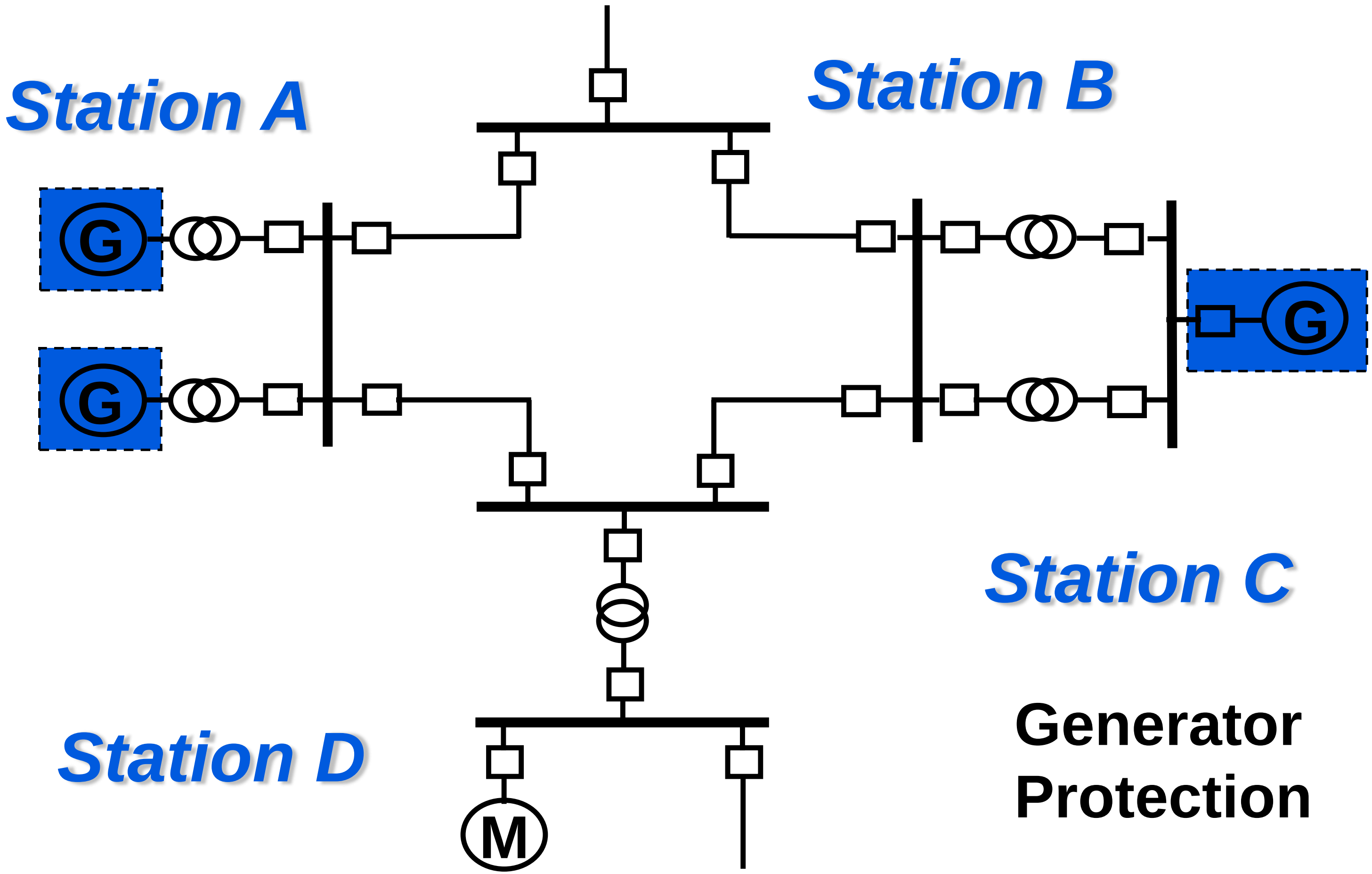
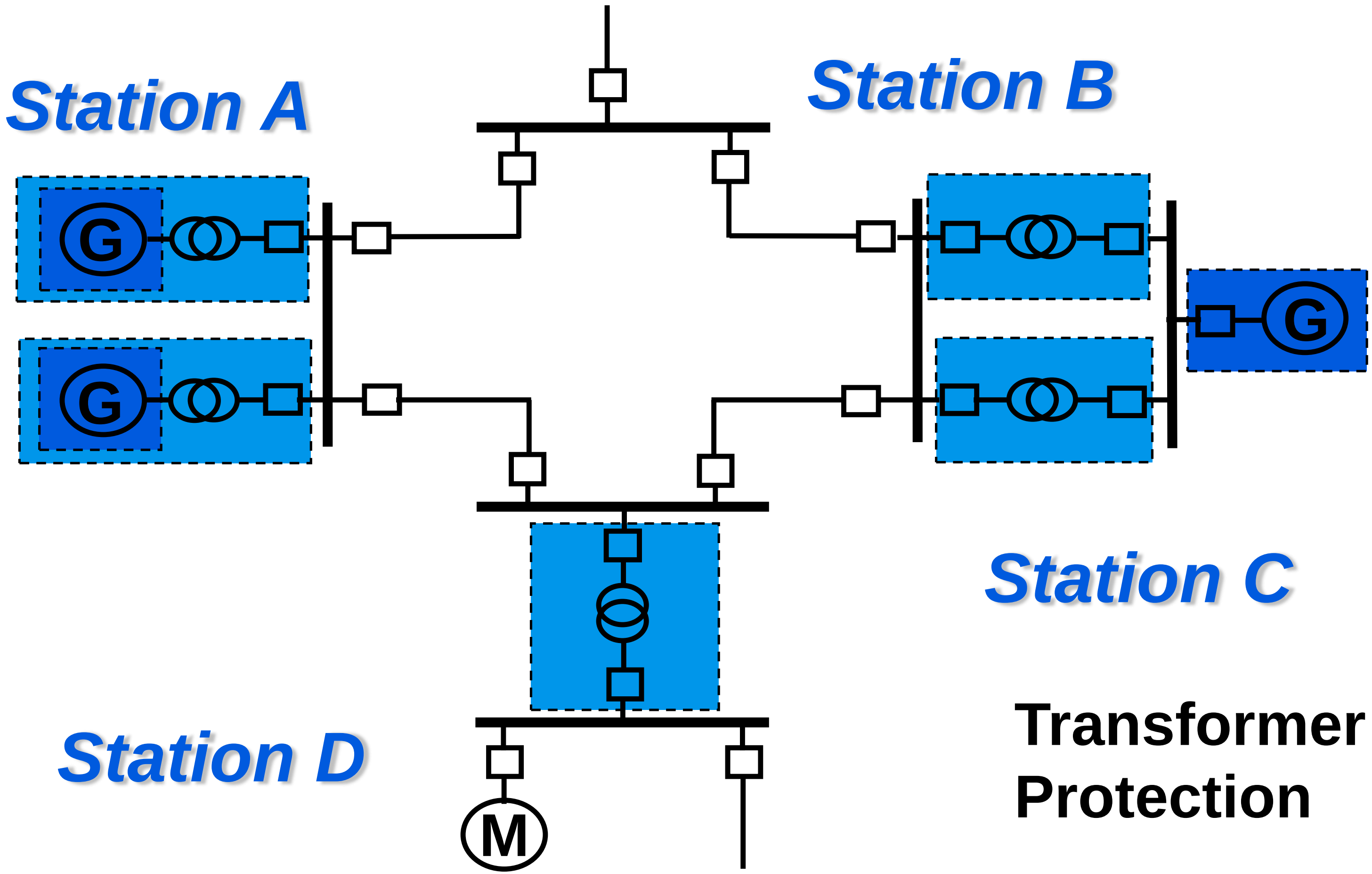
Zones of protection



Generator Protection

Zones of protection



Transformer Protection

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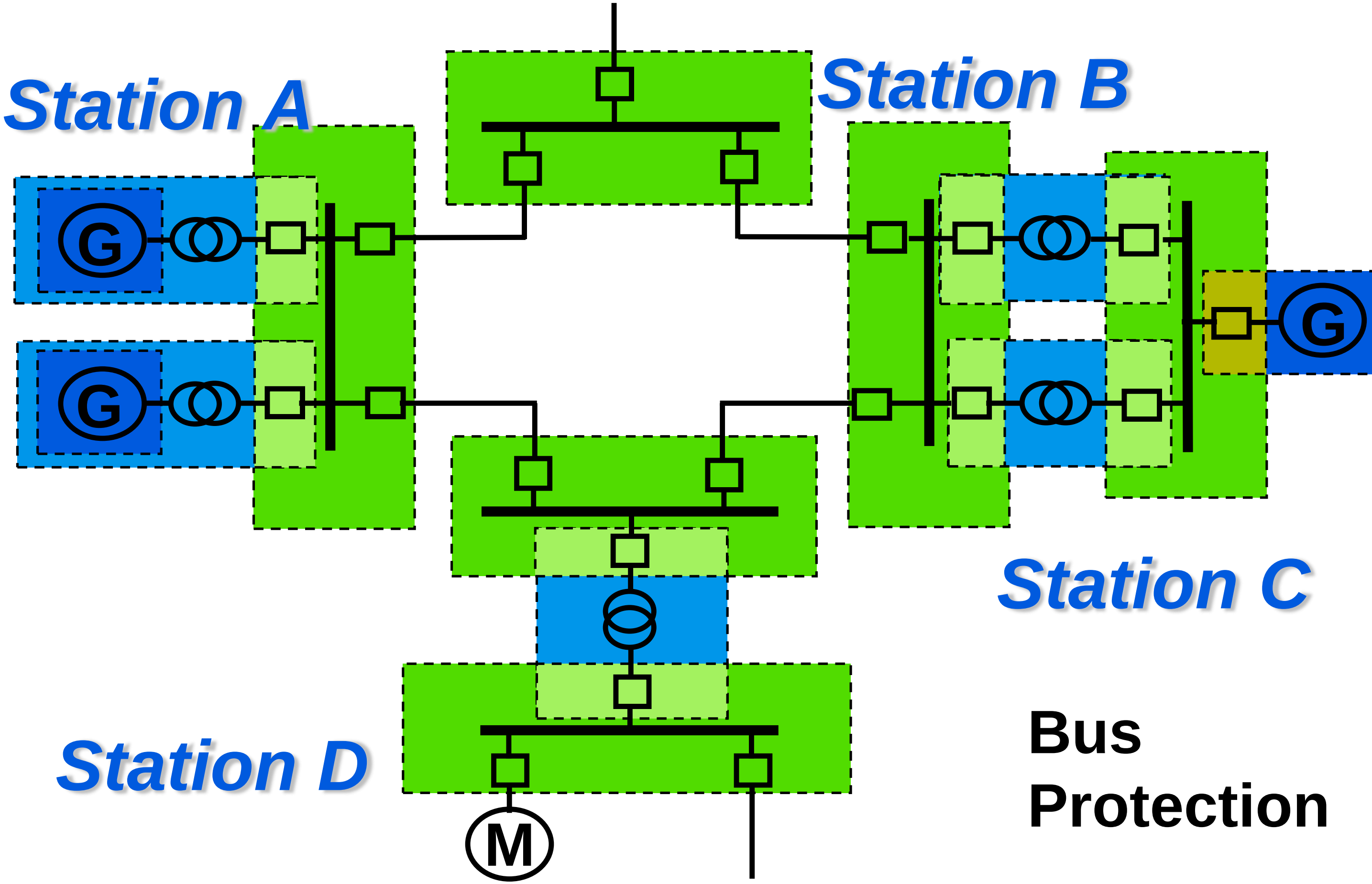
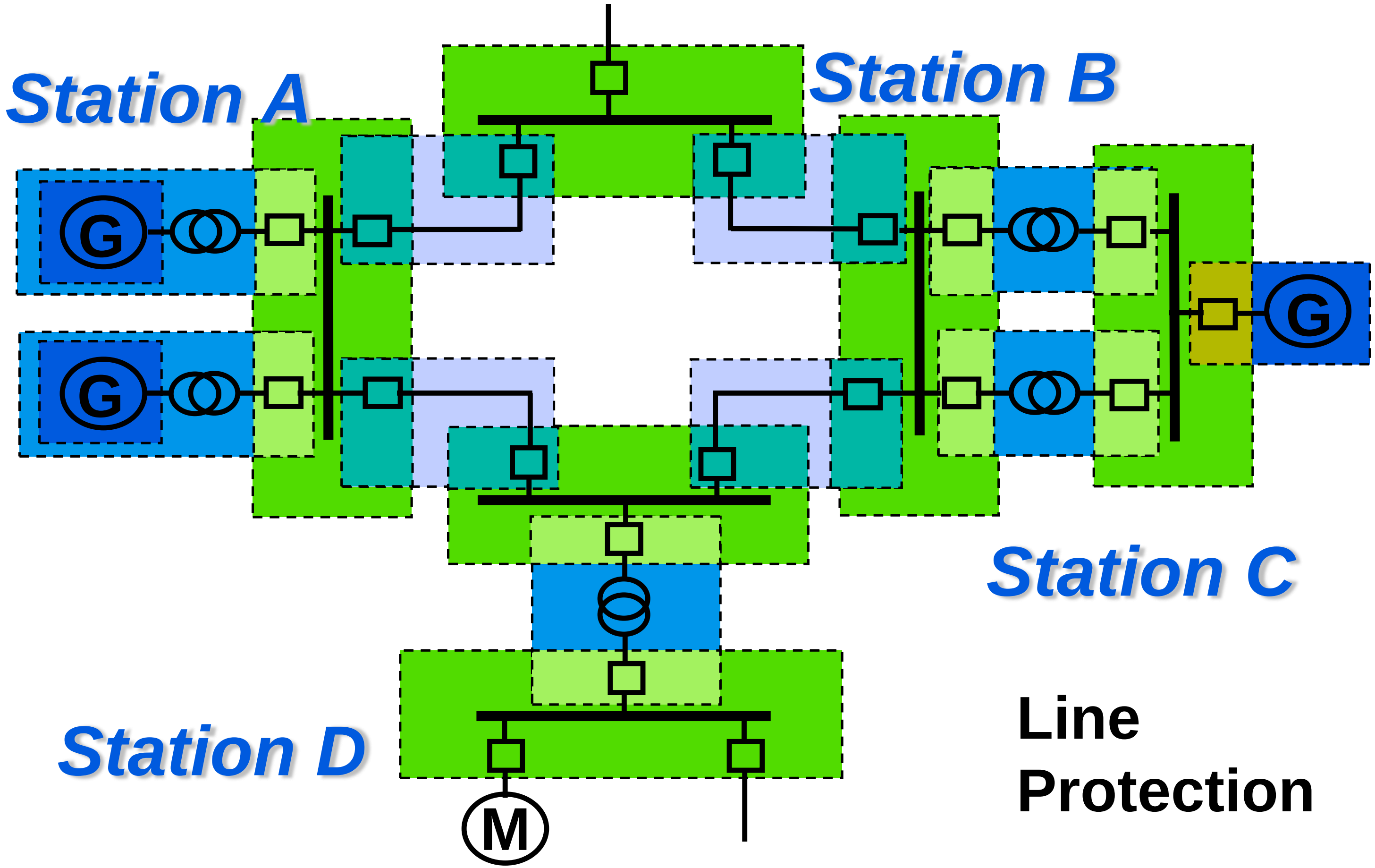
Zones of protection



Bus Protection

Zones of protection



Line Protection

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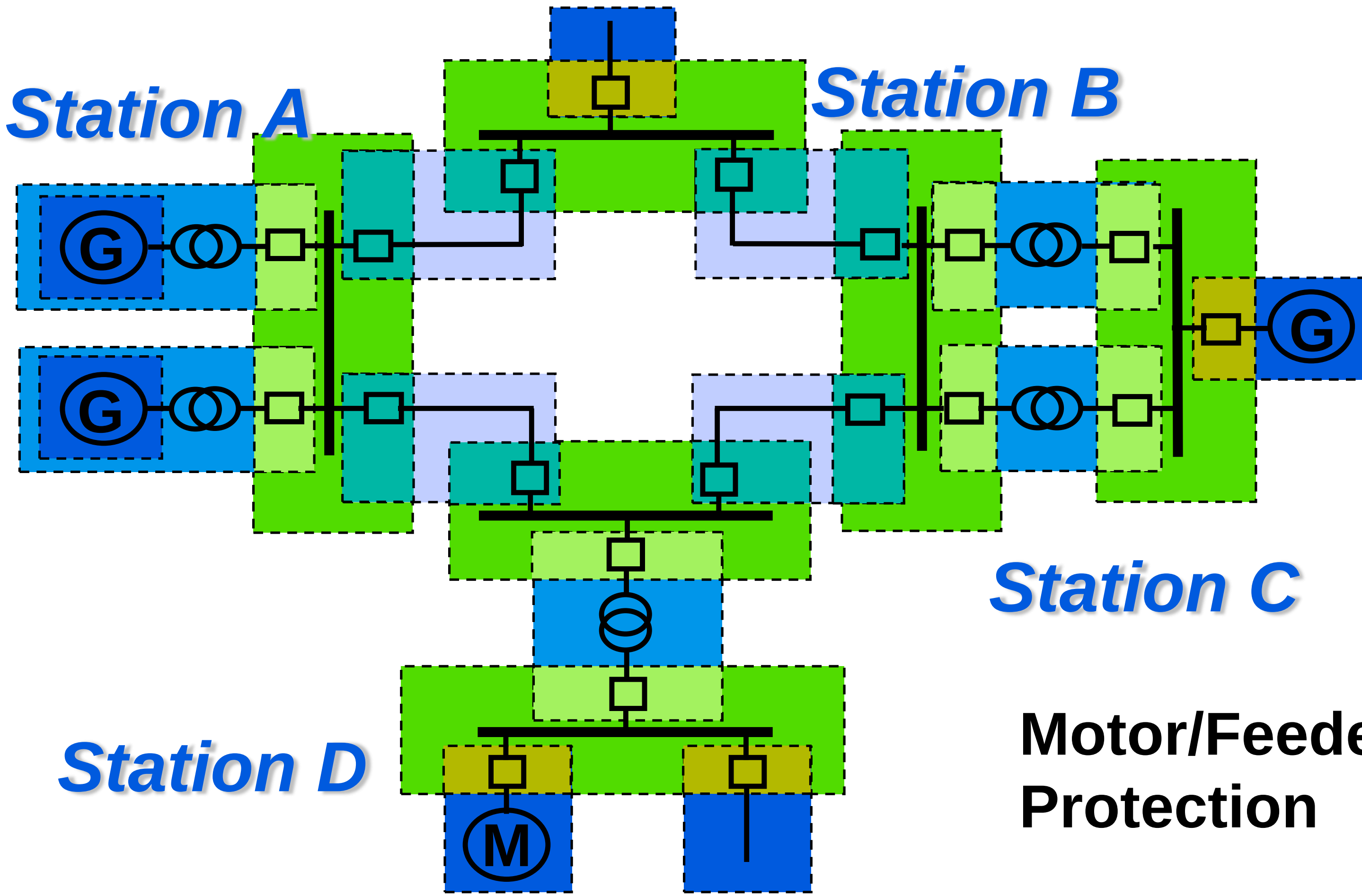
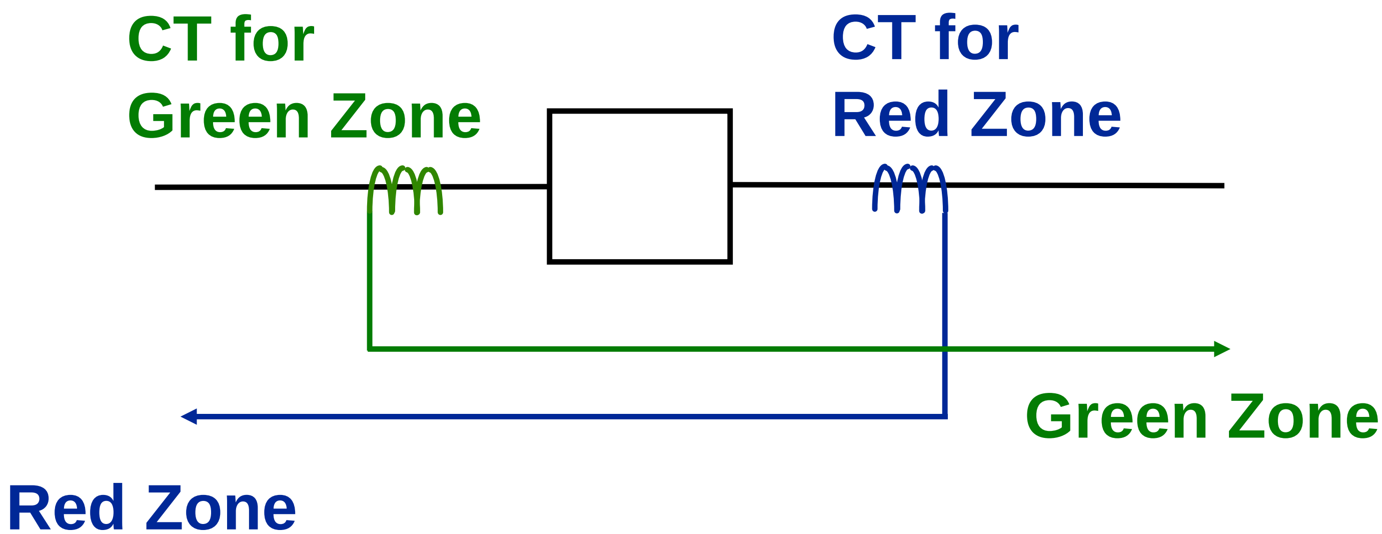
Zones of protection



Motor/Feeder Protection

Zones of protection



**Dead tank breaker,
Two CTs**

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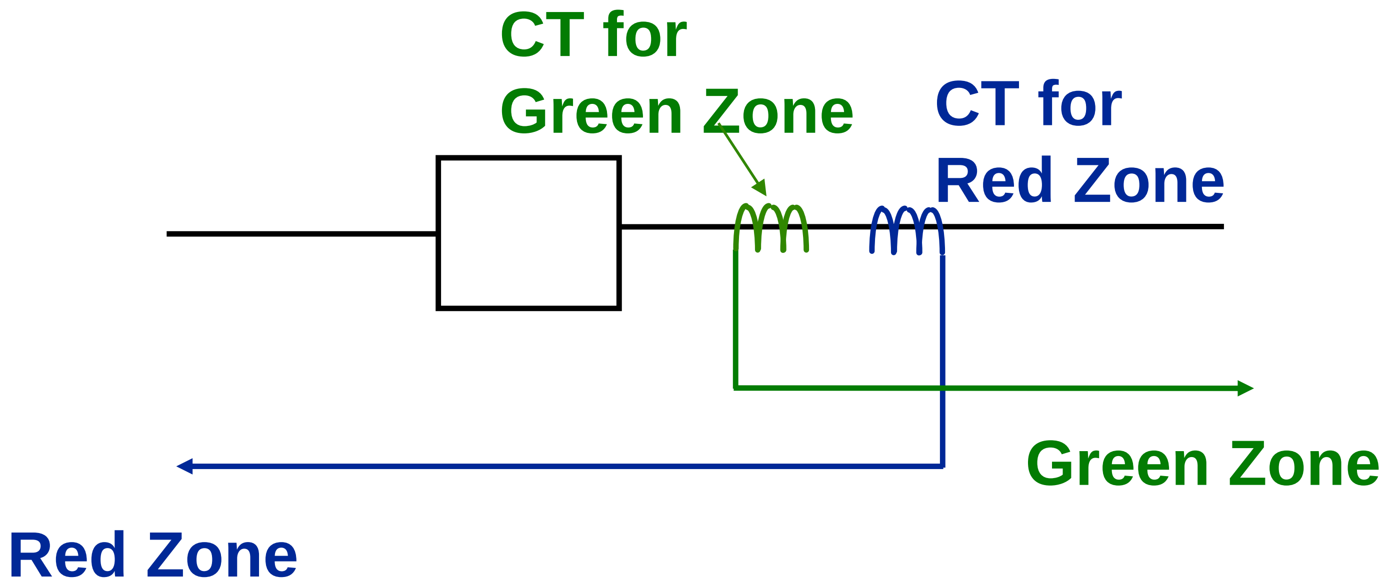
Zones of protection

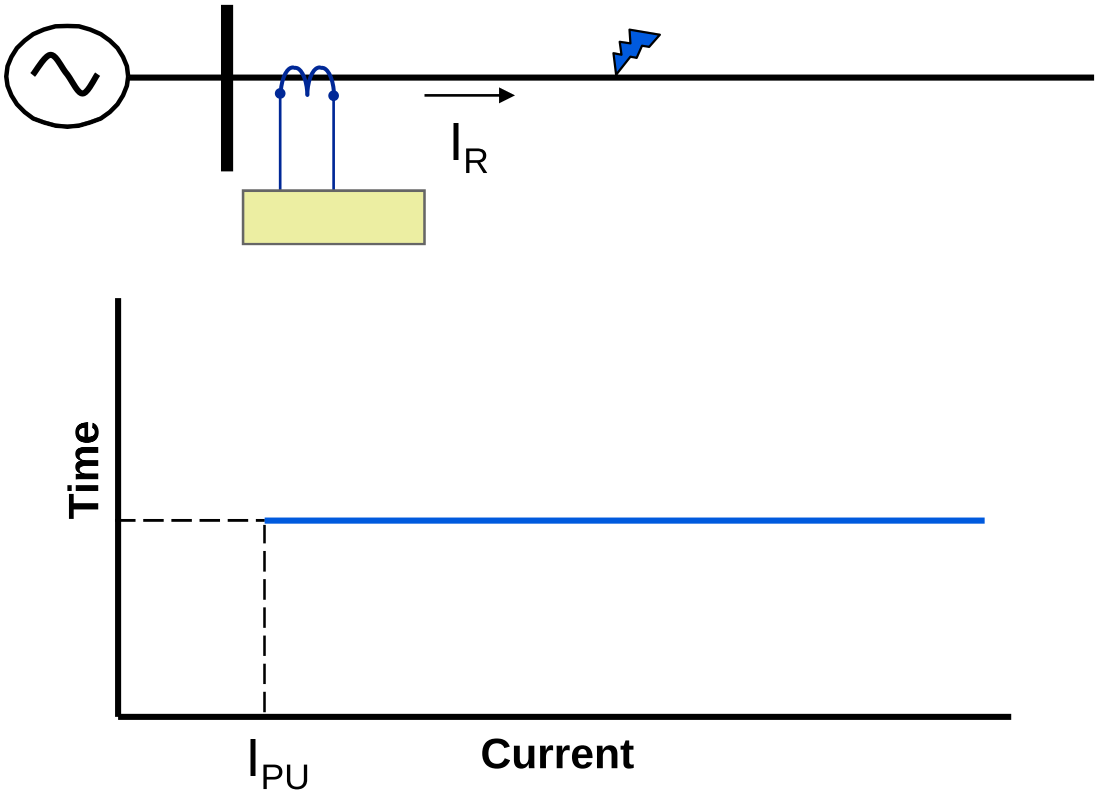


Live tank breaker,
Single CT

Basic protection principles

- Definite time-overcurrent
- Inverse time-overcurrent
- Directional
- Distance
- Differential
- Phase comparison
- Directional comparison

Definite time overcurrent (50)



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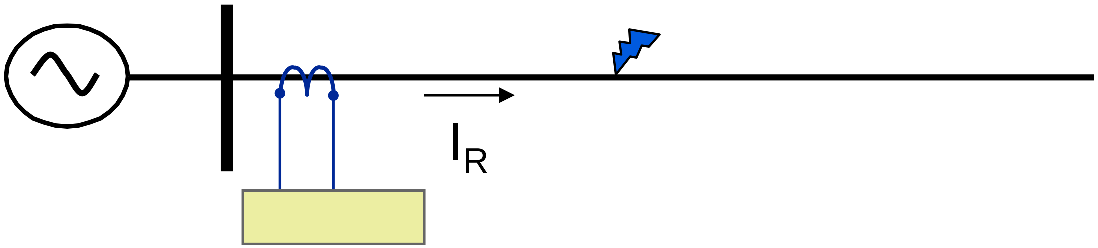
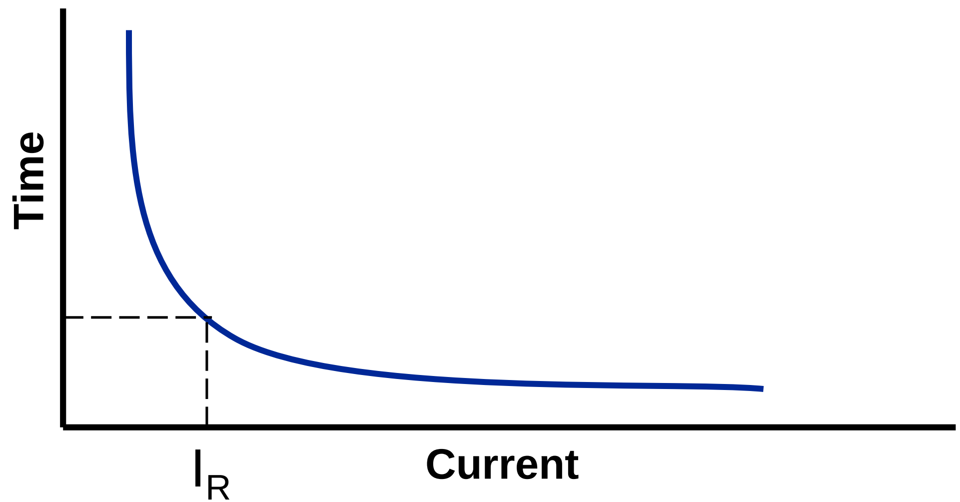
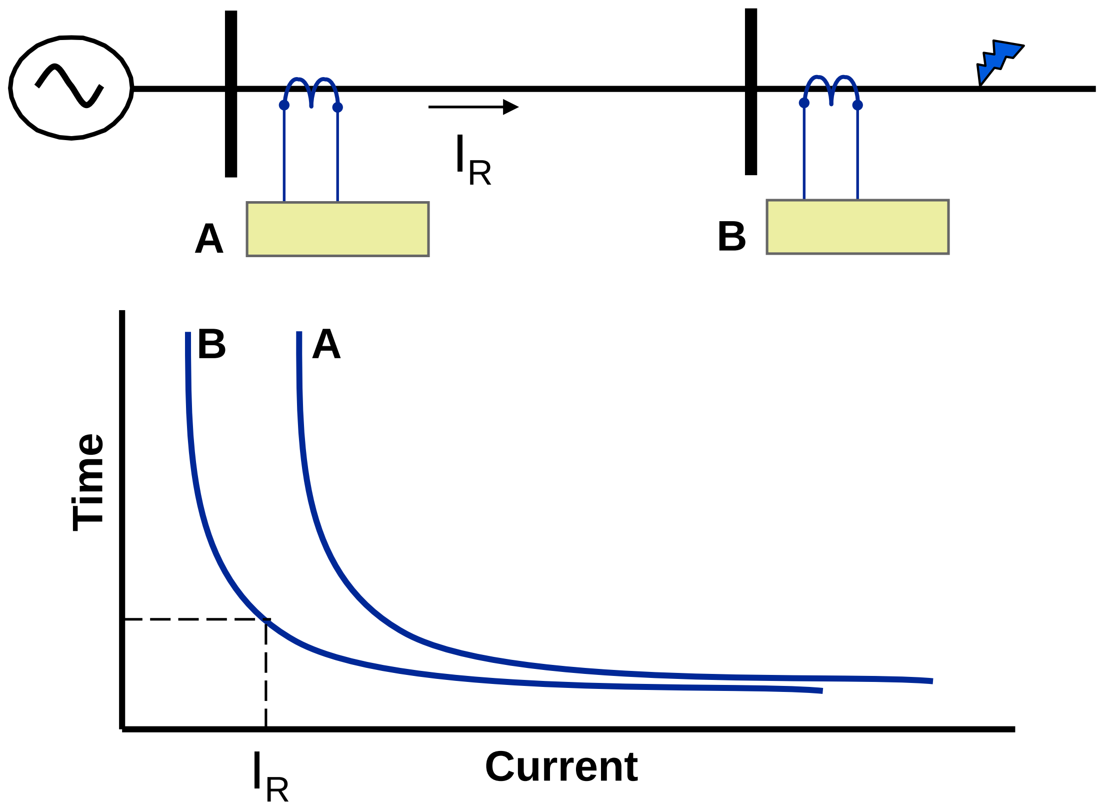
Inverse time overcurrent (51)





Inverse time overcurrent coordination



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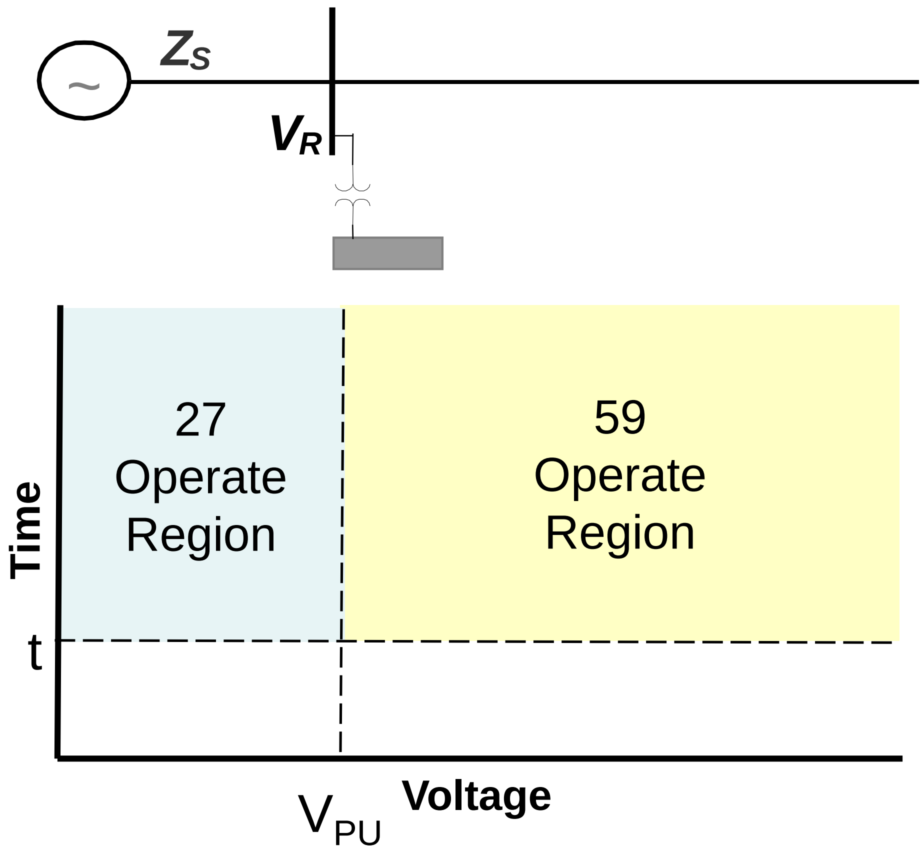
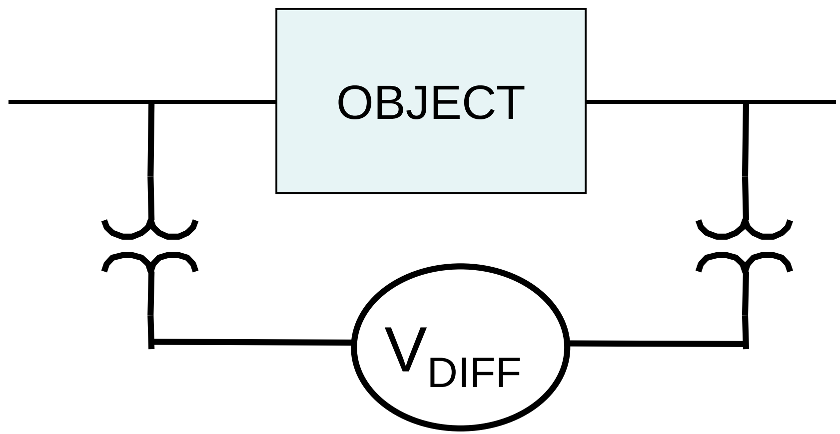
Basic protection principles
Over (59) and Under (27) voltage



Definite time overvoltage (59/59N) at or above pickup value

Definite time undervoltage (27) below pickup value

Basic protection principles
Voltage balance (differential)



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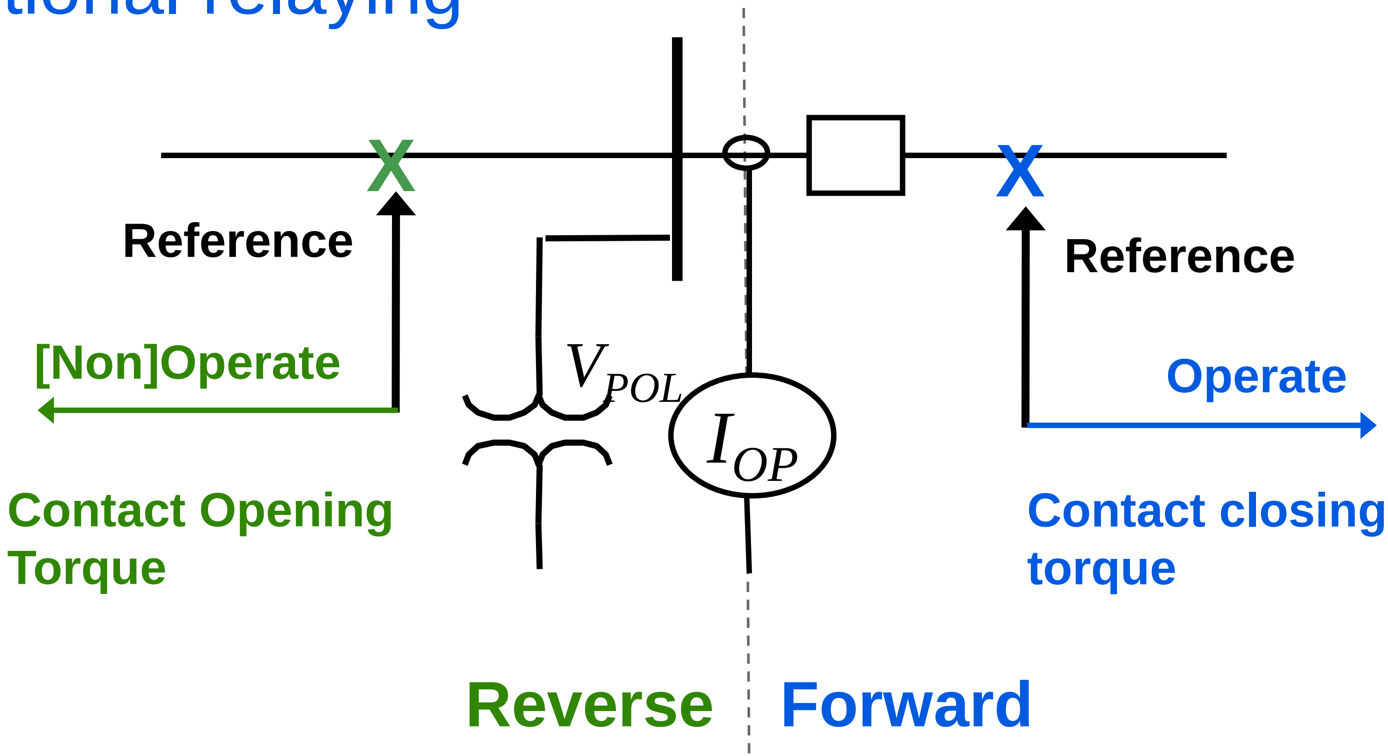
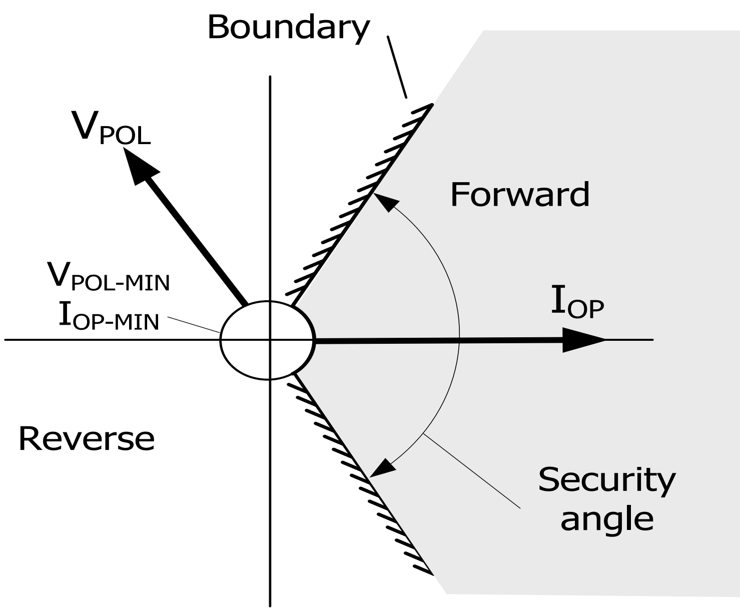
Basic protection principles
Directional relaying



Must reliably determine direction to the fault

Basic protection principles
Directional relaying



- Multi-phase faults
  - $I_{OP} = I_X$, X = A, B, C
  - $V_{POL} = V_{YZ}$, YZ = BC, CA, AB
- Ground faults
  - Zero sequence
    - $I_{OP} = 3I_0$
    - $V_{POL} = 3V_0$
  - Zero sequence current
    - $I_{OP} = 3I_0$
    - $I_{POL} = I_0$ (from Transformer)
  - Negative sequence
    - $I_{OP} = 3_{I2}$
    - $V_{POL} = 3_{V2}$

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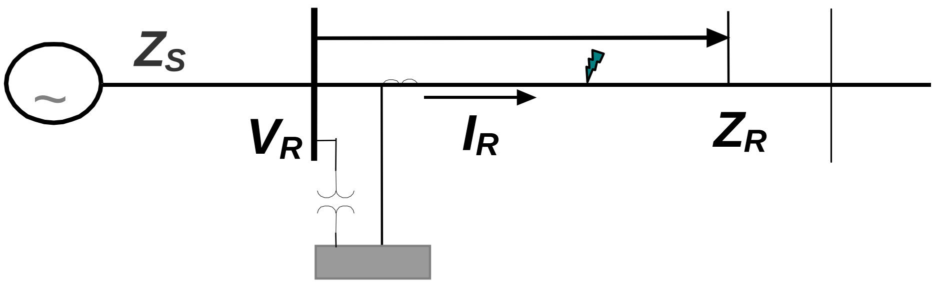
Basic protection principles
Distance relaying



- Distance relaying uses both voltage and current to determine if a fault is within the relay's set zone of protection
  - Based on Kirchoff's voltage law
  - Three phase system loops: AB, BC, CA, AG, BG, CG
  - Phase comparator principle
  - Phase and ground faults
  - Positive and zero sequence transmission line impedance

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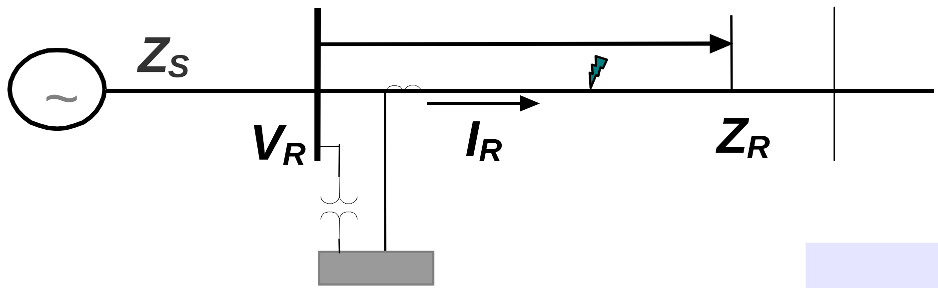
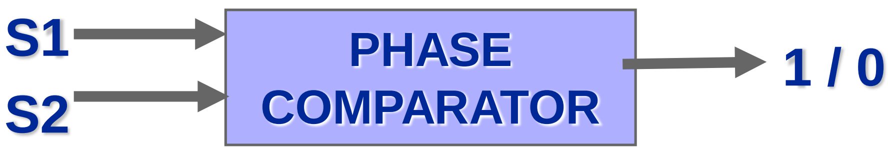
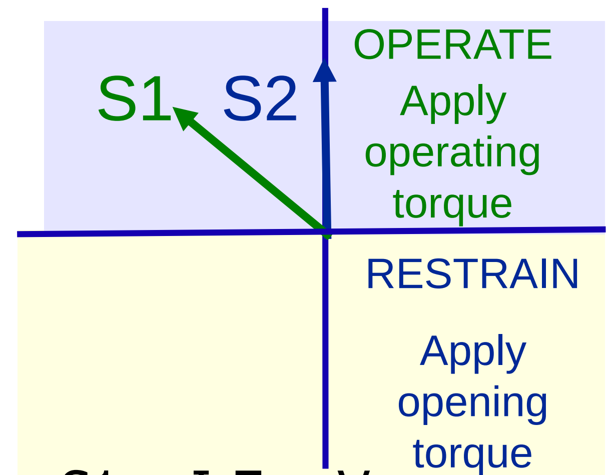
Basic protection principles
Distance – phase comparators







Compares the phase angles of two voltages derived from system voltages and currents during a fault and relay impedance reach setting to determine operation.

$$S1 = I_R Z_R - V_R$$

$$S2 = V_R$$

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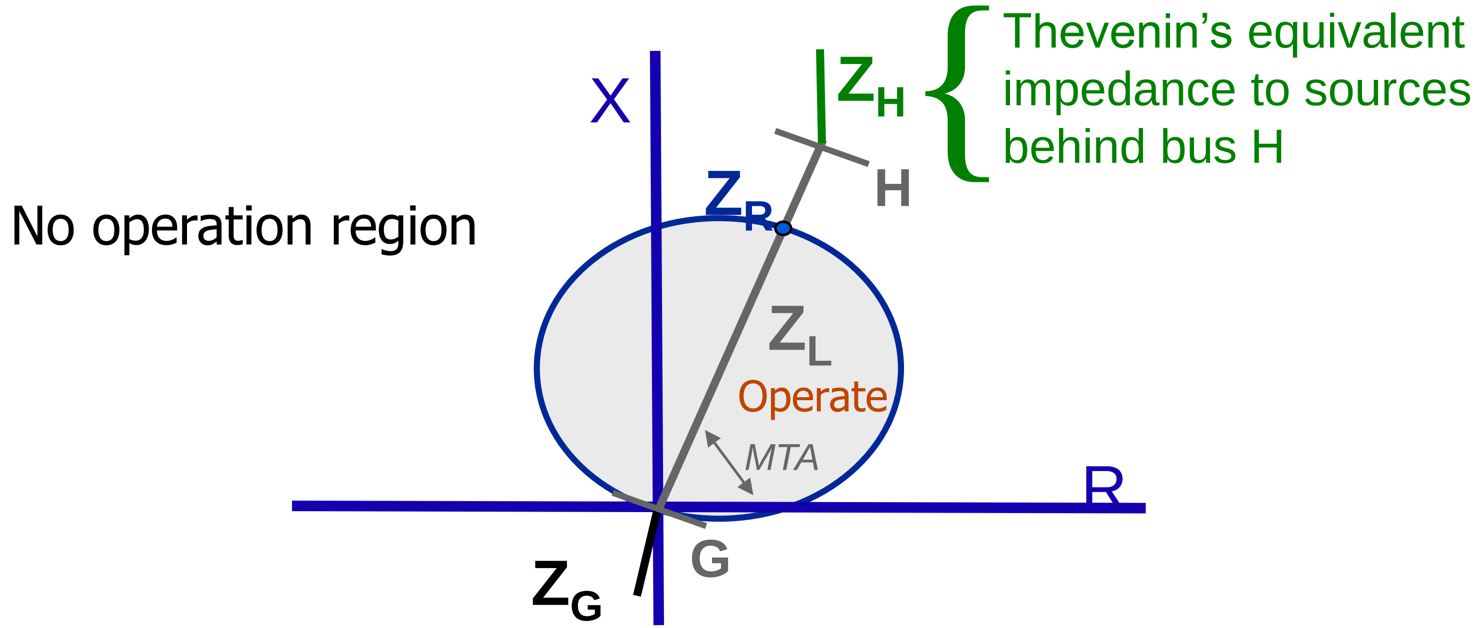
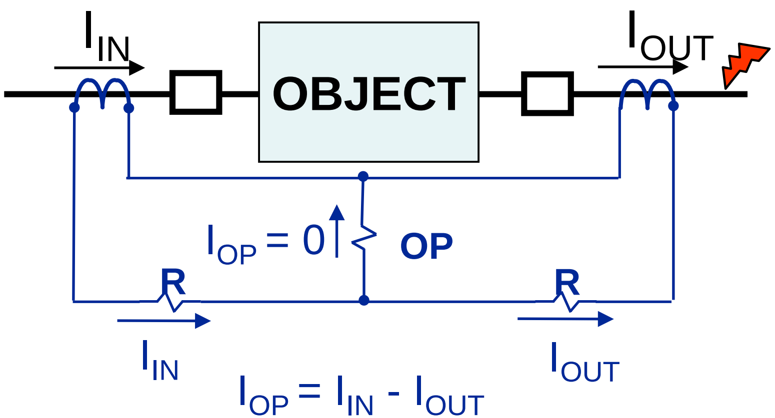
Basic protection principles
Typical distance characteristic

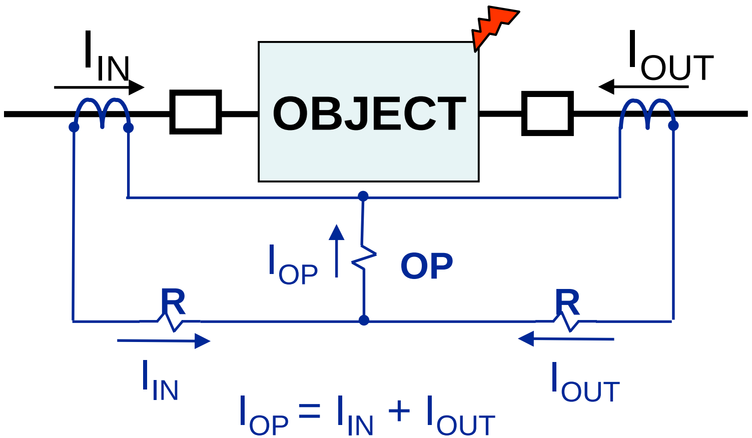


Mho unit characteristic - self polarized

Basic protection principles
Differential protection



External Fault



Internal Fault

Differential protection is based on Kirchoff's current law.

- Generators
- Motors
- Transformers
- Transmission Lines
- Busses
- Shunt Reactors

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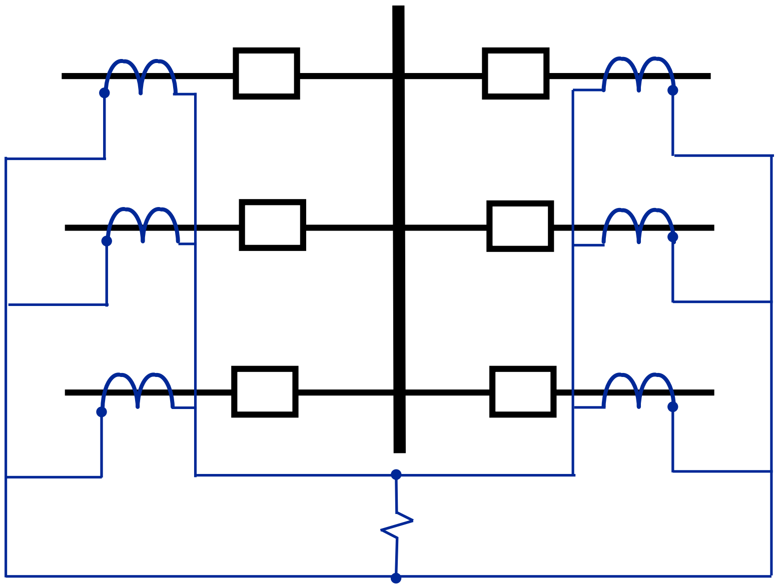
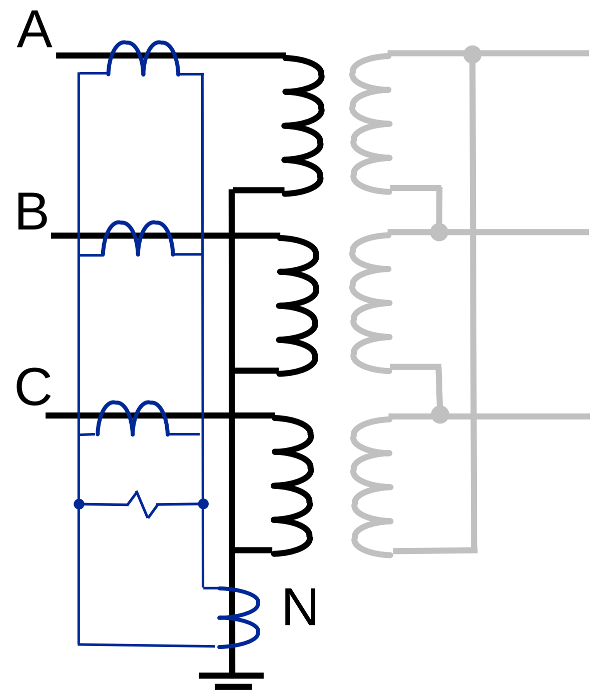
Basic protection principles
Types of differential measurement

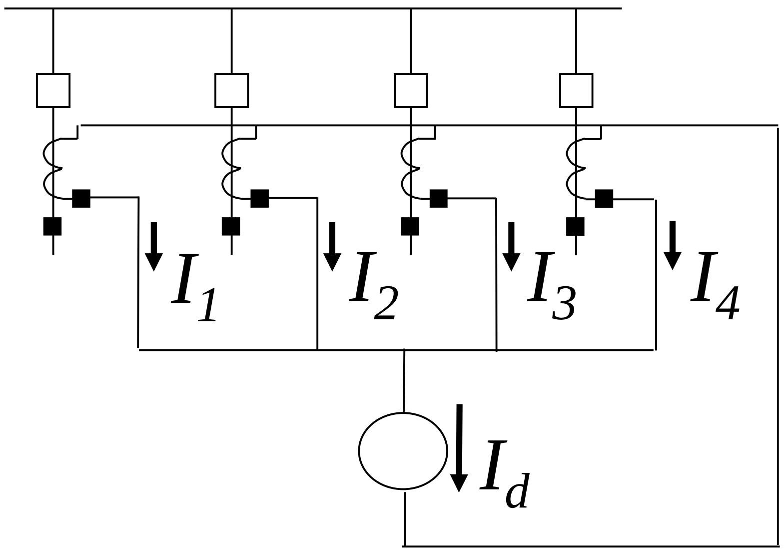


Bus



Ground fault on transformer windings

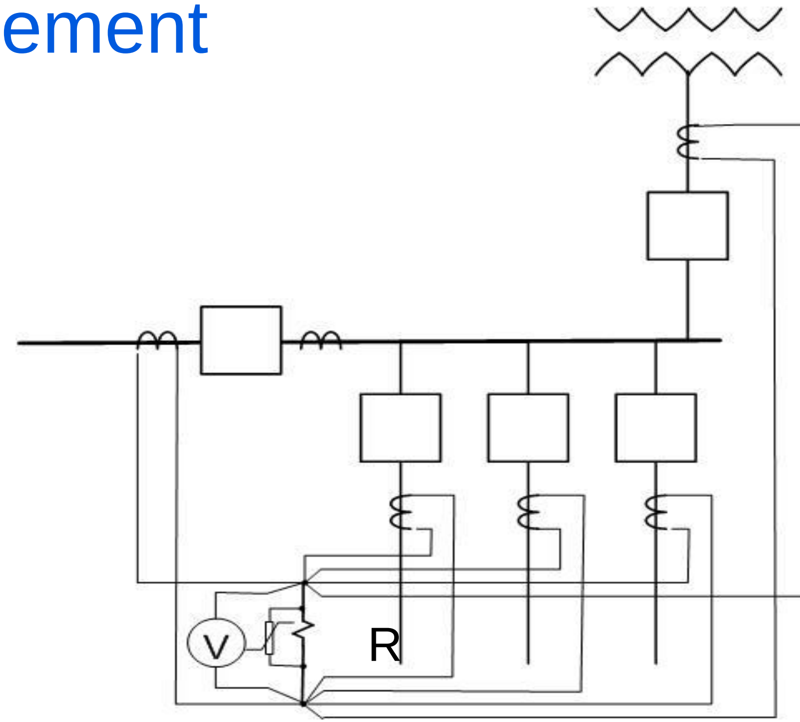
Basic protection principles
Types of differential measurement



$$I_d = I_1 + I_2 + I_3 + I_4$$

Simple overcurrent

- Sum all feeder currents



High impedance

- R = 1500 Ω
- Measure V

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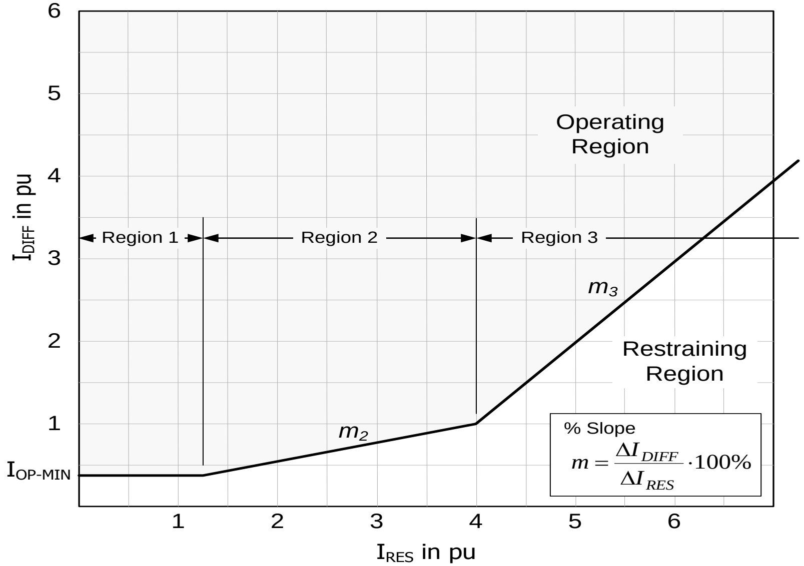
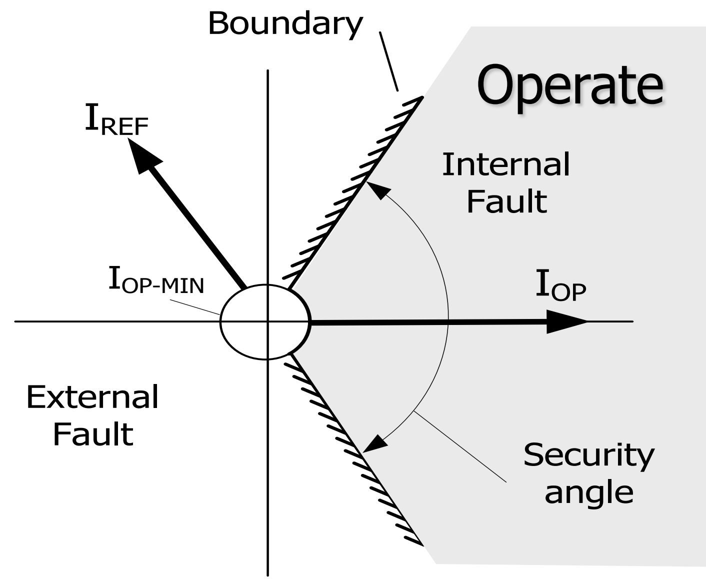
Basic protection principles
Types of differential measurement



Percentage differential

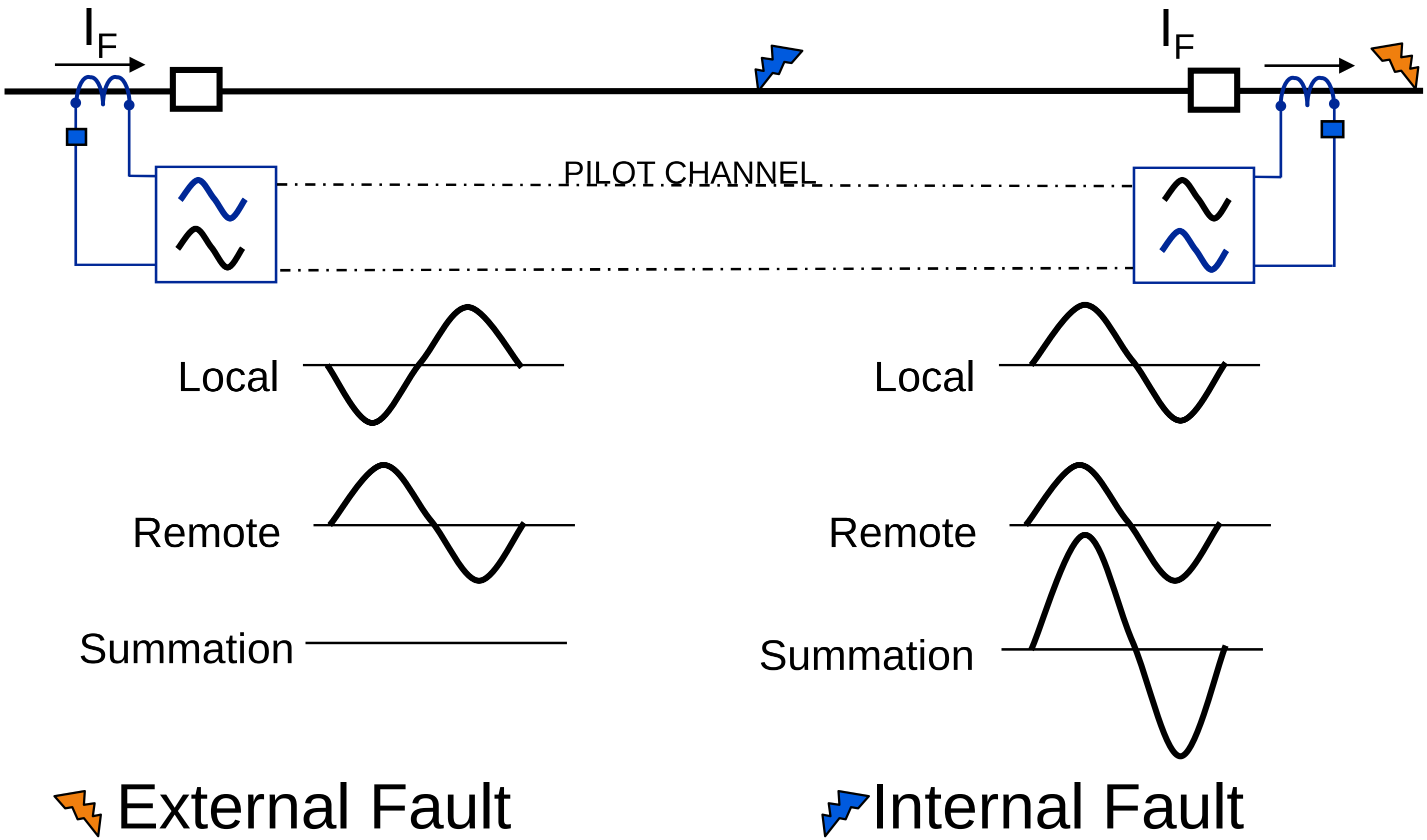
- Restraining: I_{RES}
- Operate quantity: I_{DIFF}
- I_{DIFF} in % (or pu) of I_{RES}



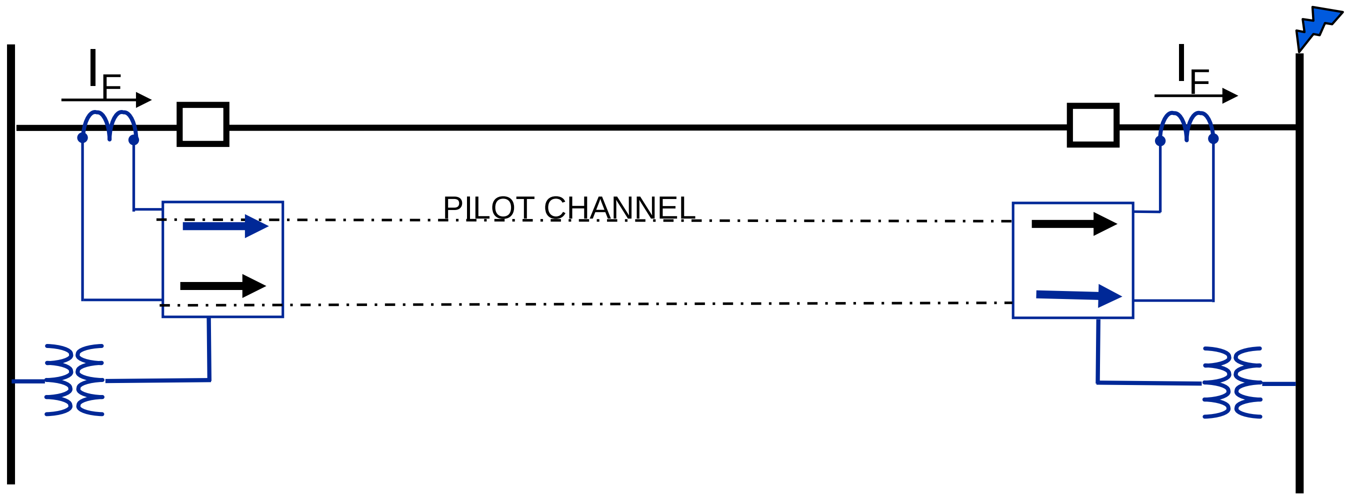
Directional criteria

- Reference quantity: I_{REF}
- Operate quantity: I_{OP}
- Security angle
- Generally I_0 or I_2 differential

Differential relay
(Line)



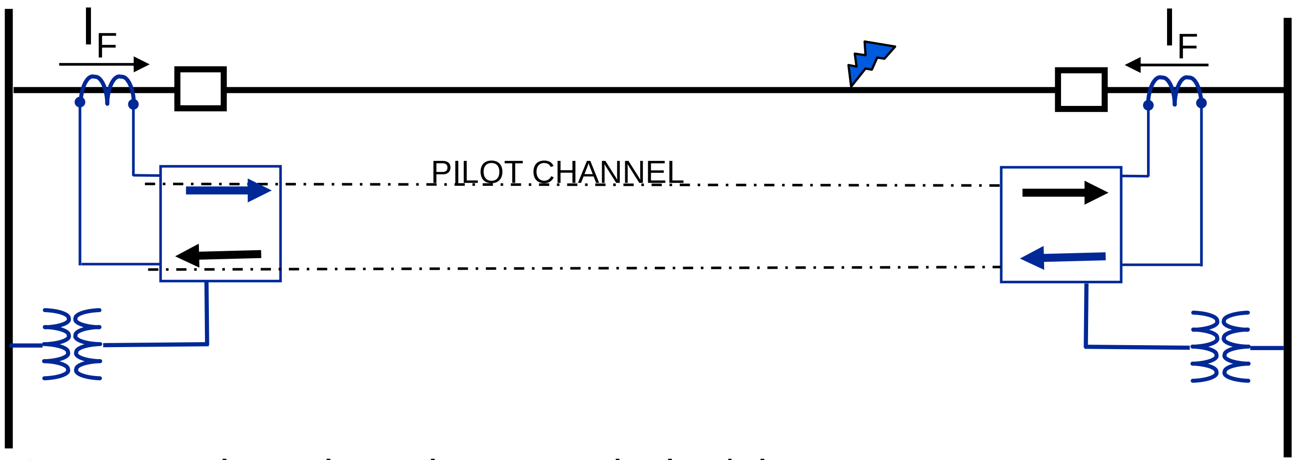
Directional comparison relay
External fault



POTT - sends permissive
PUTT - sends permissive
Unblock - sends unblock
Blocking - receives block

POTT - does nothing
PUTT - does nothing
Unblock - does nothing
Blocking - sends block

Directional comparison relay
Internal fault



POTT - sends and receives permissive/trips
PUTT - sends and receives permissive/trips
Unblock - sends and receives unblock/trips
Blocking - trips

POTT - sends and receives permissive/trips
PUTT - sends and receives permissive/trips
Unblock - sends and receives unblock/trips
Blocking - trips

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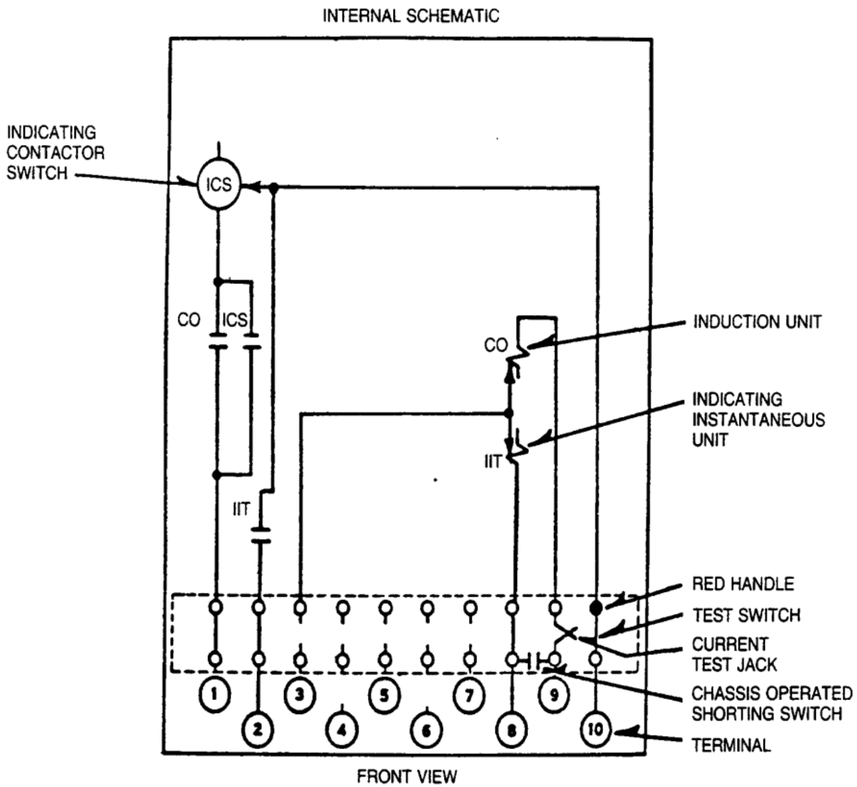
Internal schematic



Typical internal schematic for a switchboard mounted relay
(CO time overcurrent)

AC operating elements and contacts

- Dc operation indication (ICS) and seal-in
- Test switches
- Terminal numbers

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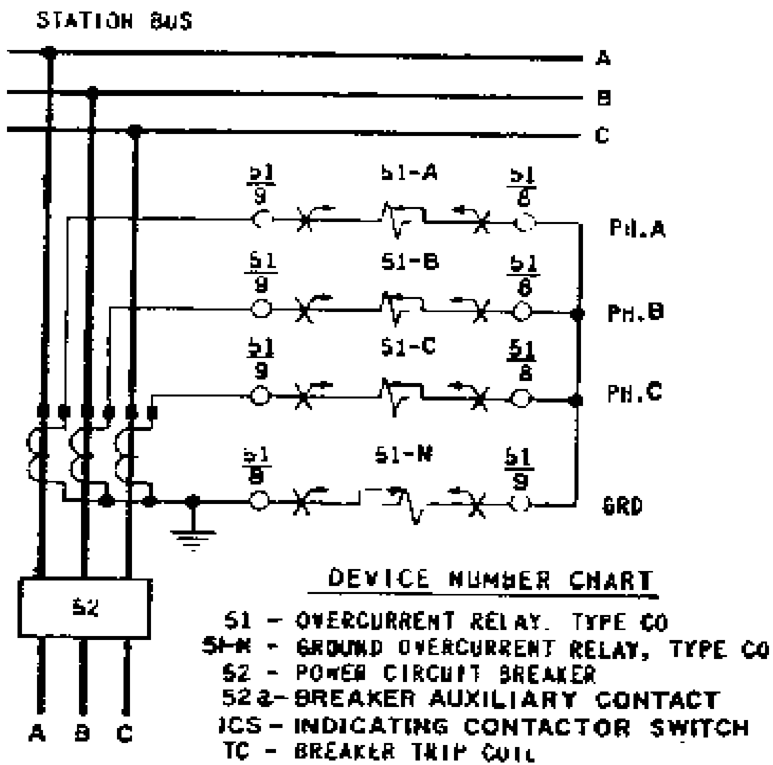
External AC schematic



Typical AC schematic for a switchboard mounted relay

(CO time overcurrent)

- AC operating elements
- CT [and VT] polarity, connections and inputs
- Phase rotation
- Test switch
- Terminal numbers
- Trip direction

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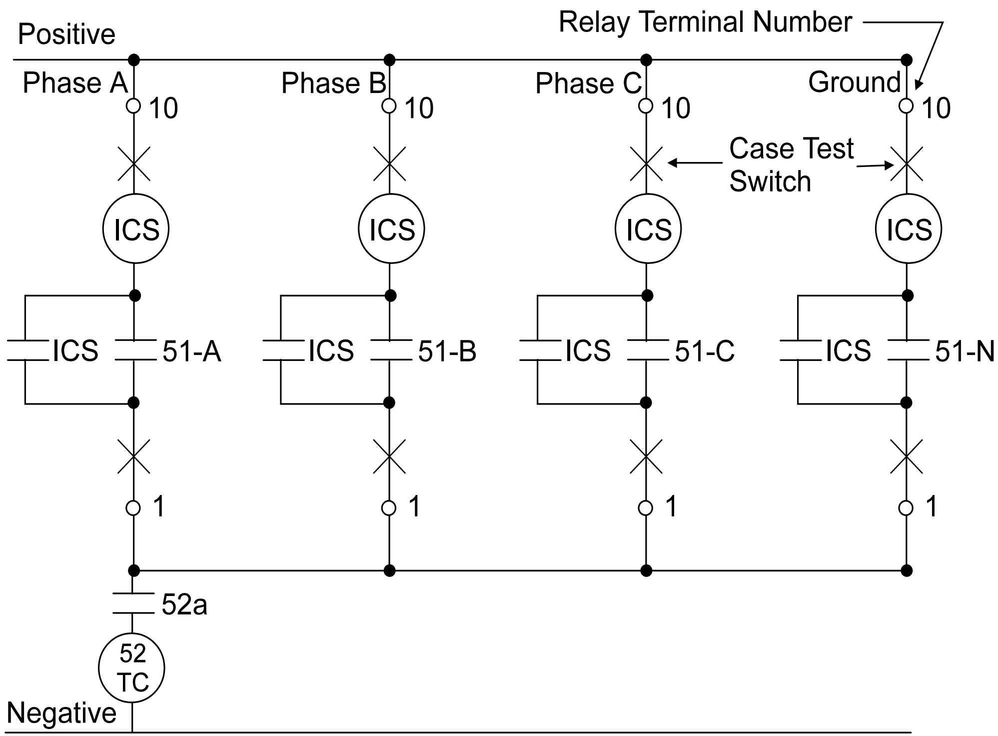
External DC schematic



Typical DC schematic for a switchboard mounted relay

(CO time overcurrent)

- DC operating elements
- Interconnection to other devices
- Basic system logic
- Test switch
- Terminal numbers

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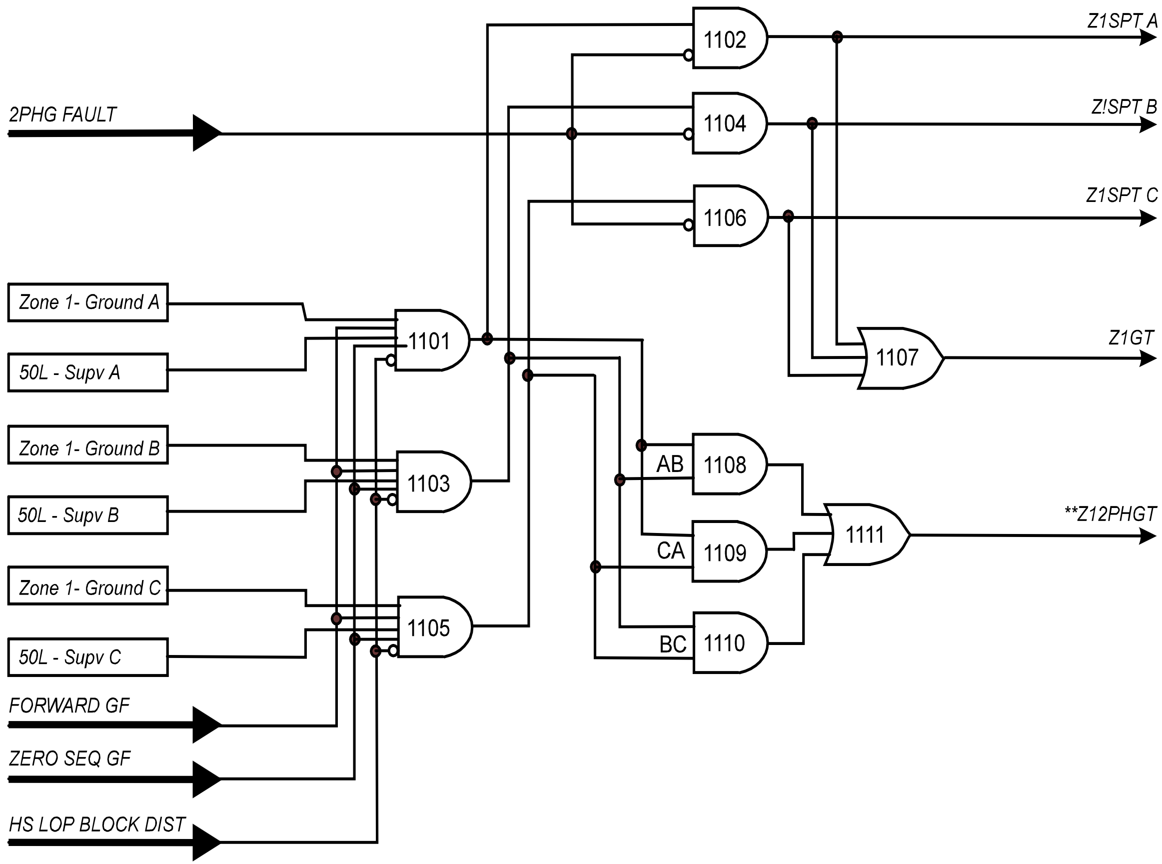
Logic diagram



Typical logic diagram for a for a system relay module

REL 512

zone-1 ground distance

- Operating elements
- Input signals from other logic modules
- Output signals for use by other logic modules

IEEE device function numbers

- A device function number, with an appropriate prefix and suffix where necessary, is used to identify the function of each device all types of switchgear
- IEEE Standard C37.2, 1991
  - This standard applies to the definition and application of function numbers for devices used in electrical substations and generating plants and in installations of power utilization and conversion apparatus

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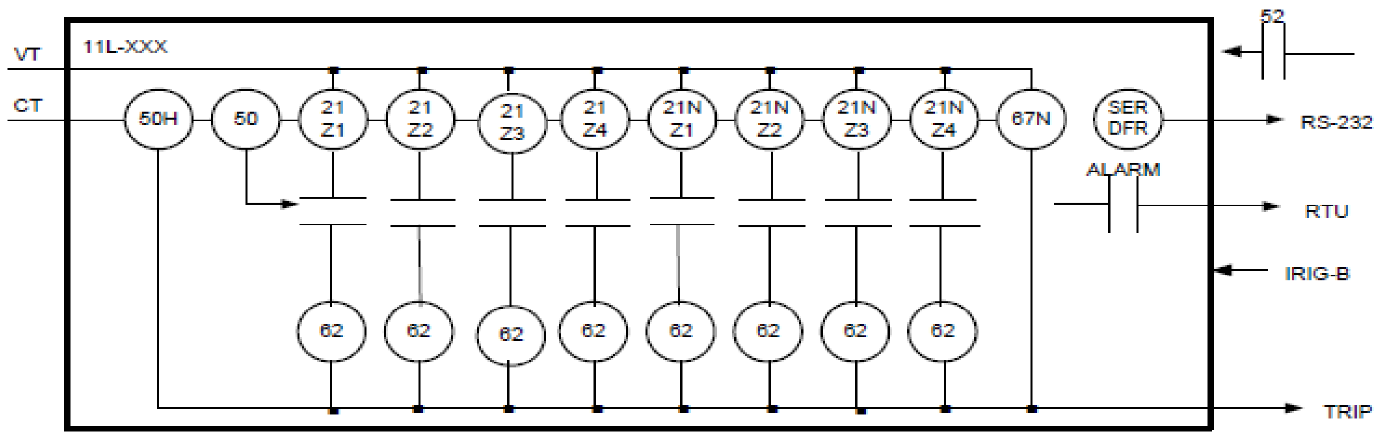
IEEE device function numbers and acronyms
Device 11

Fill Box Method for representing multiple functions in device 11



21-Z1 through Z4	are the phase distance relays for zones 1 through 4
21N-Z1 through Z4	are the ground distance relays for zones 1 through 4
50H	is the high set instantaneous overcurrent relay
50	is the instantaneous overcurrent relay
62	is the time delay for tripping
67N	is the directional relay in neutral
SER/DFR	are the sequence of events recorder/digital fault recorder

Fill Box Method for representing multiple functions in device 11

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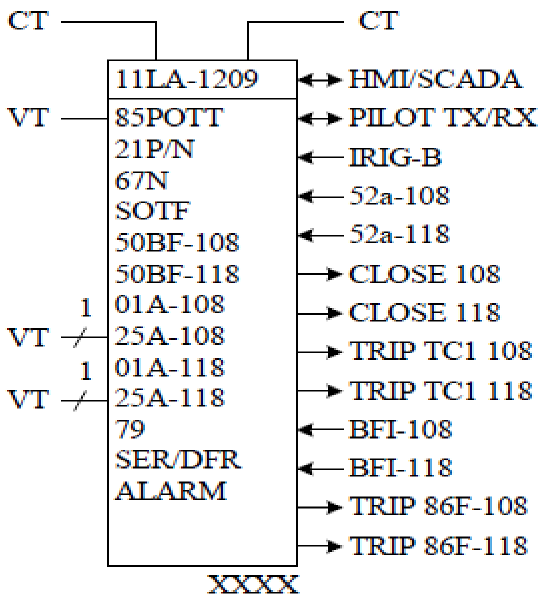
IEEE device function numbers and acronyms
Device 11

List Box Method for representing multiple functions in device 11



NOTES:

1. AC sensing connections are 3-Phase unless otherwise marked.
2. Functions apply to the multifunction device's designated zone of protection unless otherwise marked.
3. A/B designate System A and System B of the fully redundant system.
4. Device 01 is manual control of the designated power system element.

01A is local HMI and panel control.
01B is remote SCADA control.

List Box Method for representing multiple functions in device 11

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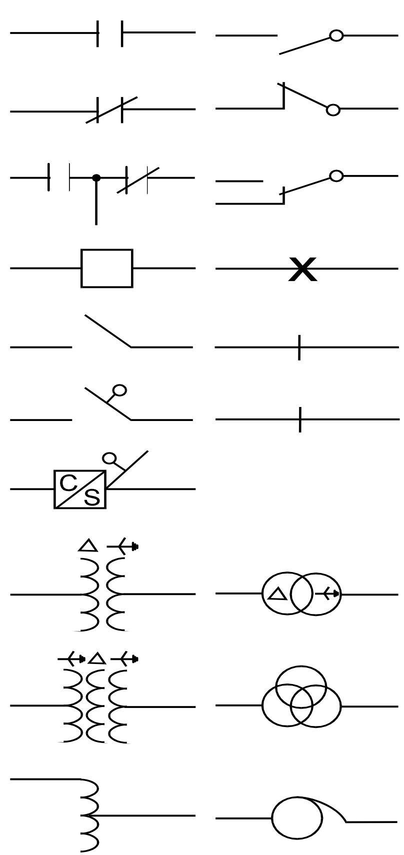
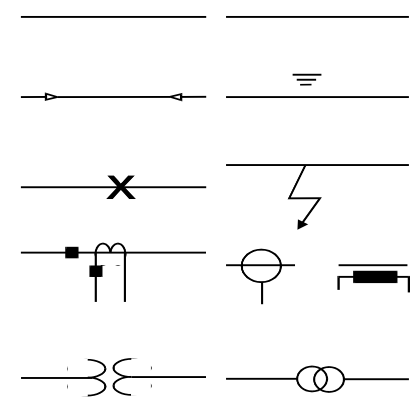
IEEE Standard 315 1975 (Reaffirmed 1993)
Graphic symbols for electrical and electronics diagrams

ELEMENT	IEEE	IEC
Normally Open Contact		
Normally Closed Contact		
Form C		
Breaker		
Disconnect Switch		
Motor Operated Disconnect Switch		
Circuit Switcher		
Transformer 2 Winding		
Transformer 3 Winding		
Autotransformer		



ELEMENT	IEEE	IEC
Overhead Line		
Underground Cable		
Fault		
Current Transformer		
Voltage Transformer		
Phase Designations (typical)	A B C (prefered) 1 2 3	R S T
Component Designations (positive, negative, zero)	1 2 0	1 2 0
Current	I	I
Voltage	V	U



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