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Next Generation 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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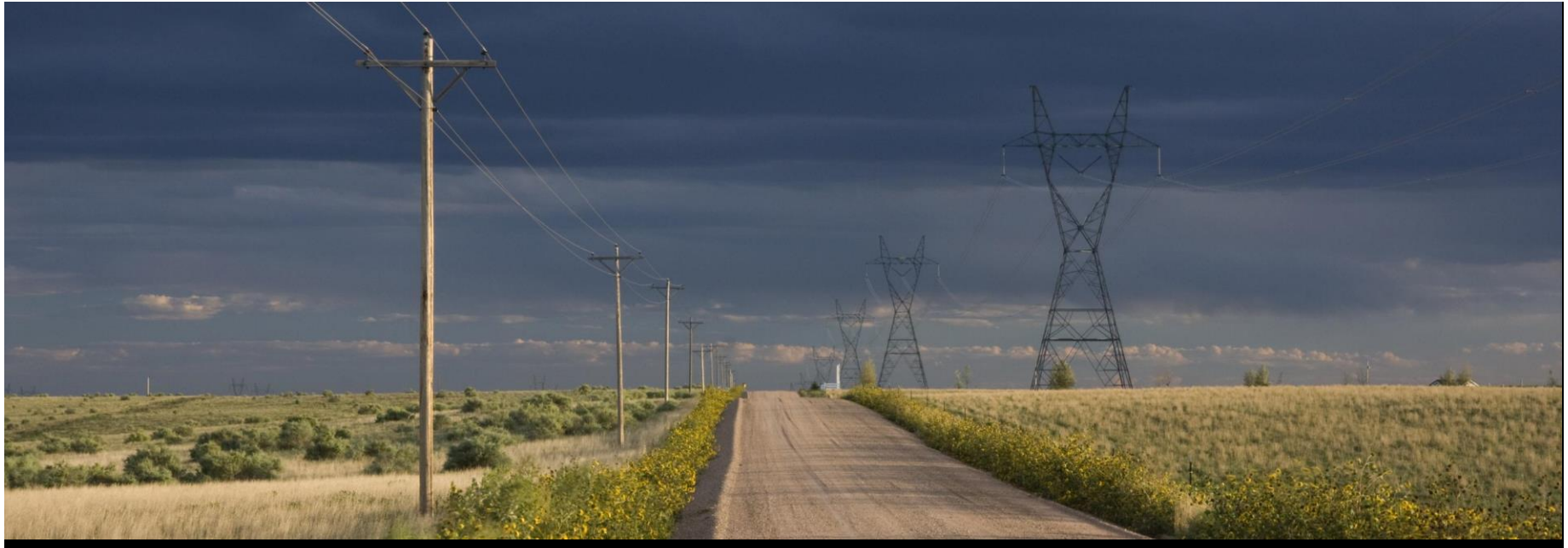


ABB Protective Relay School Webinar Series

Line Current Differential Protection

Roger Hedding

July 23, 2015

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.

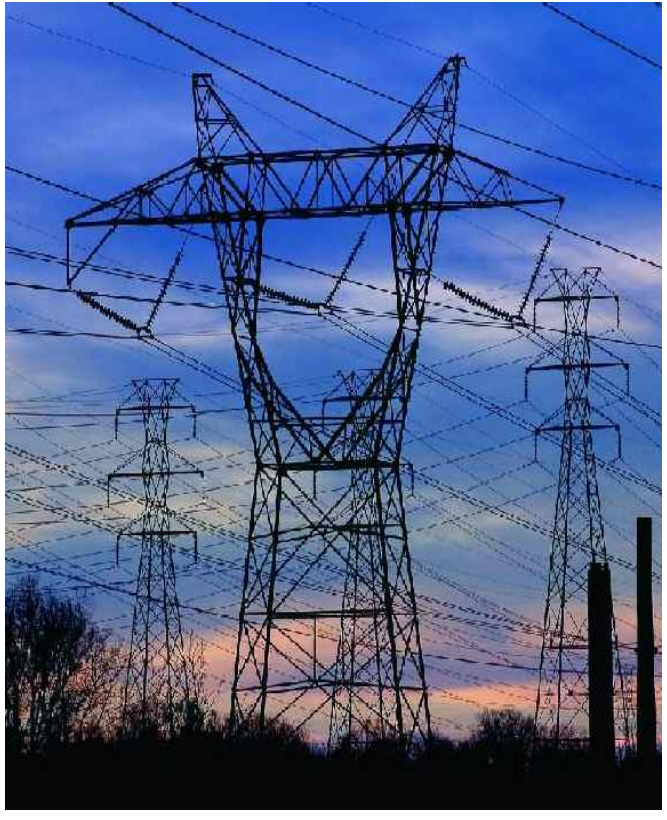
As a Senior Consultant he guides the applications and development of relay products for the North American market. Roger is a IEEE senior member, and Past Chair of the IEEE Power Systems Relay Committee. Roger has authored or co-authored many papers in power systems protection.

Learning objectives

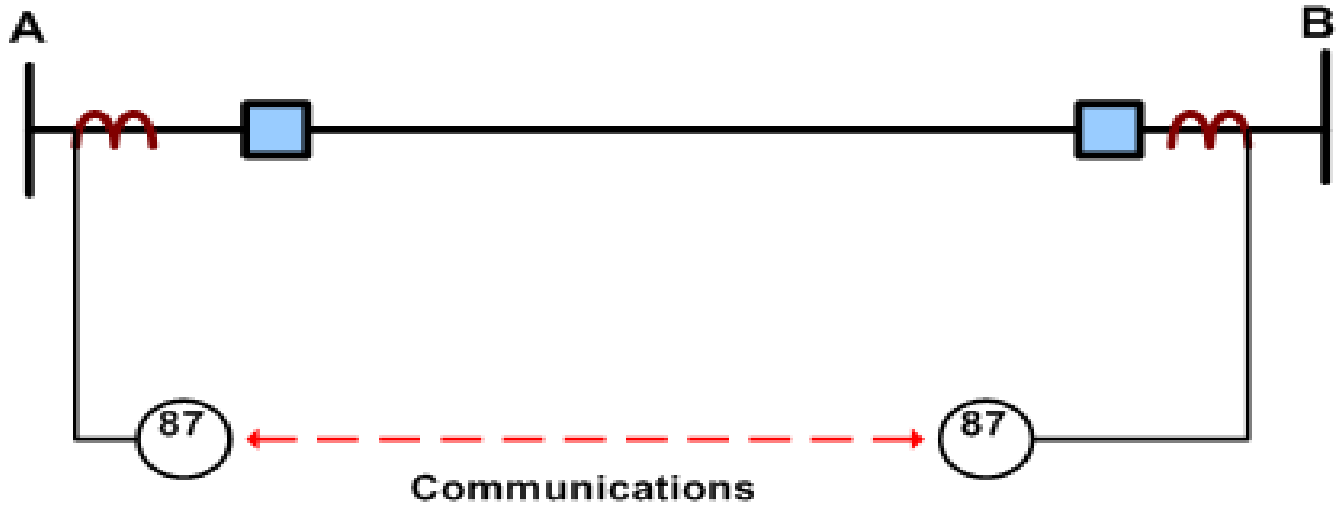
- What is a current differential relay ?
- What is a line current differential relay ?
- What are the application issues of line current differential relays vs line distance relays ?

Line differential protection
Agenda

- Introduction
- Differential Relay
- Line Current Differential Relay
- Application Issues
- Communications
- Summary



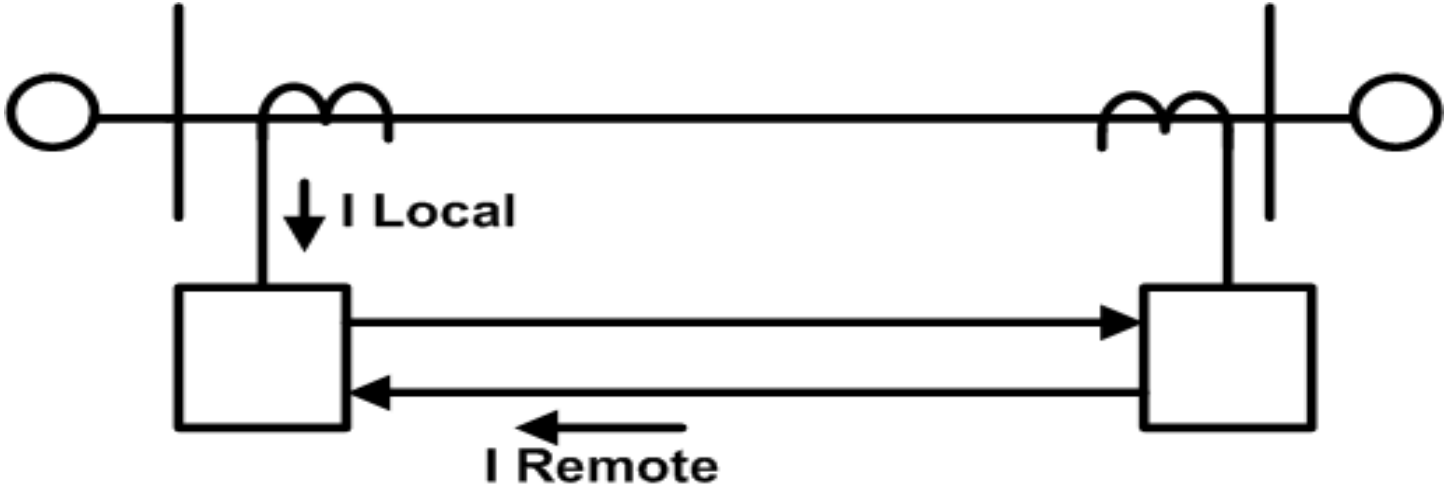
Simple line differential protection
Application



Multi-terminal differential protection

- Unit Protection
- Task – To Determine if fault is within protected zone or outside the protected zone
- Protected Zone
  - Transmission Line Terminals
  - Power Transformer Terminals
- Measures Currents at the terminals of the protected circuit
- Transmits information about the currents to the remote end(s)
- Compares the currents using classical current differential principles
- Supplemented by additional criteria
- High Dependability – Operates for all faults which it is designed to operate
- Highly Security – Doesn’t operate for faults for which it should not operate
- Good performance during evolving faults, and cross country faults
- Immune to power swings, mutual coupling, and series impedance unbalances
- With sample data its easy to calculate
  - Sequence components
  - Harmonic Currents

Line current differential
Basics



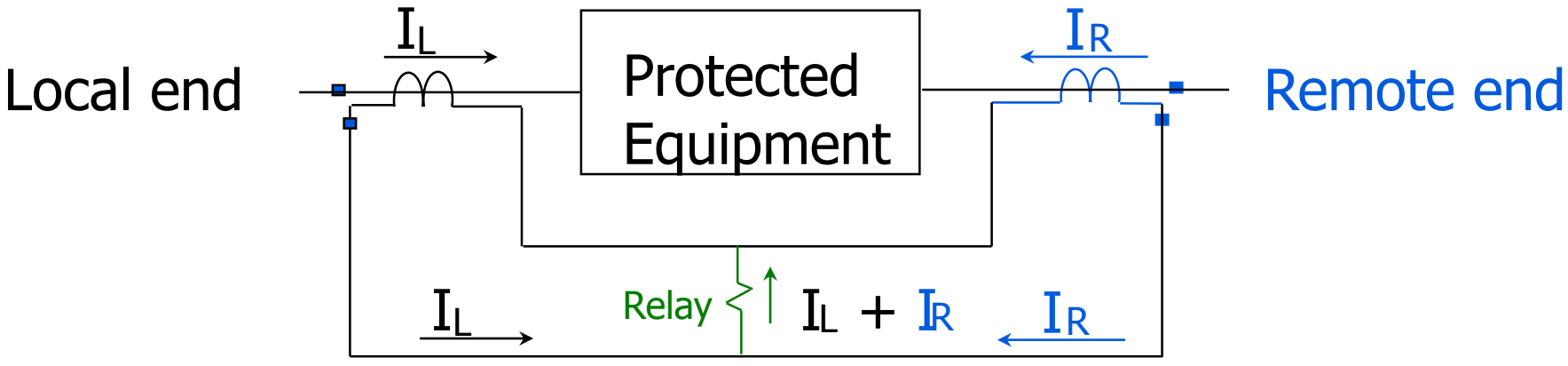
Current only scheme

- ✓ No dependence on VTs
  - Relief from Fuse fail, CCVT, Power swings
- ✓ Can be very sensitive in detecting ground faults- Not matched by distance relays
- ✓ Segregated phase
  - Ideal for evolving faults
  - and cross country faults
  - Single pole tripping
  - Series compensated lines
- ✗ Communication dependent

Types of current only schemes

- Current Differential
  - Analog
  - Digital
- Phase Comparison
  - Segregated
  - Combined Sequence
  - Not used much anymore

Current differential relay

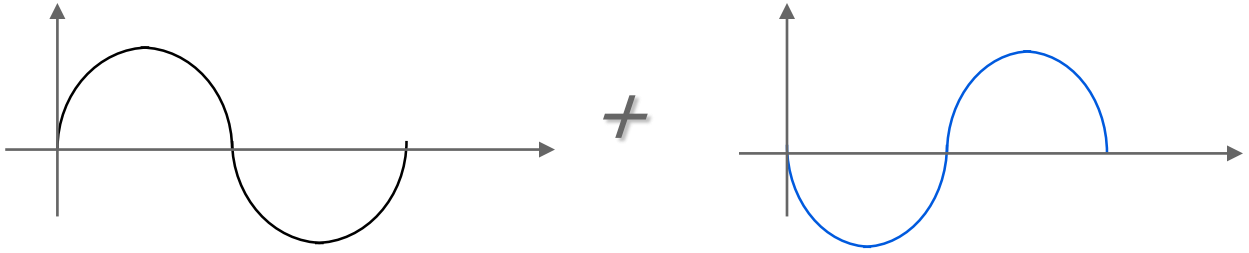


Normal operations or external faults

$I_L = -I_R$

$I_L + I_R = 0$

$\Rightarrow$ Should NOT TRIP!



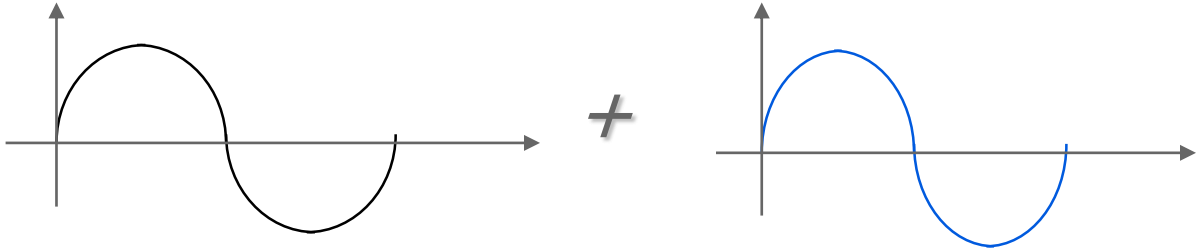
Local end

Remote end

Internal faults

$$I_L + I_R \neq 0$$

$\Rightarrow$ Should TRIP!

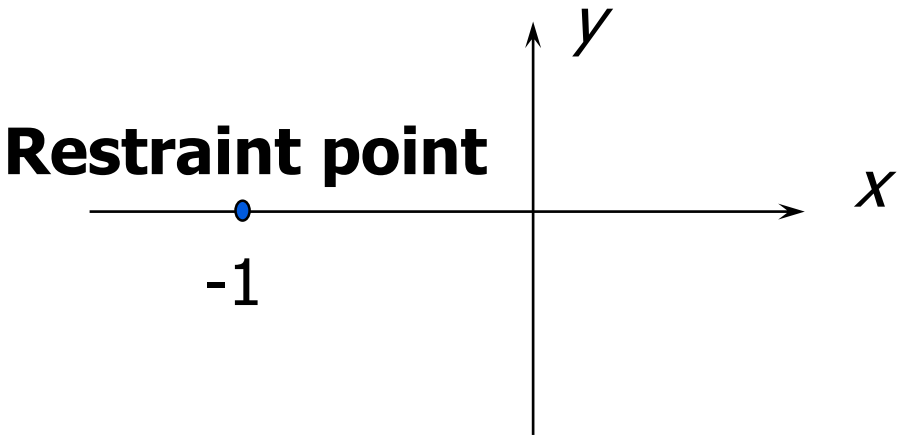


Local end

Remote end

Operating and restraint regions

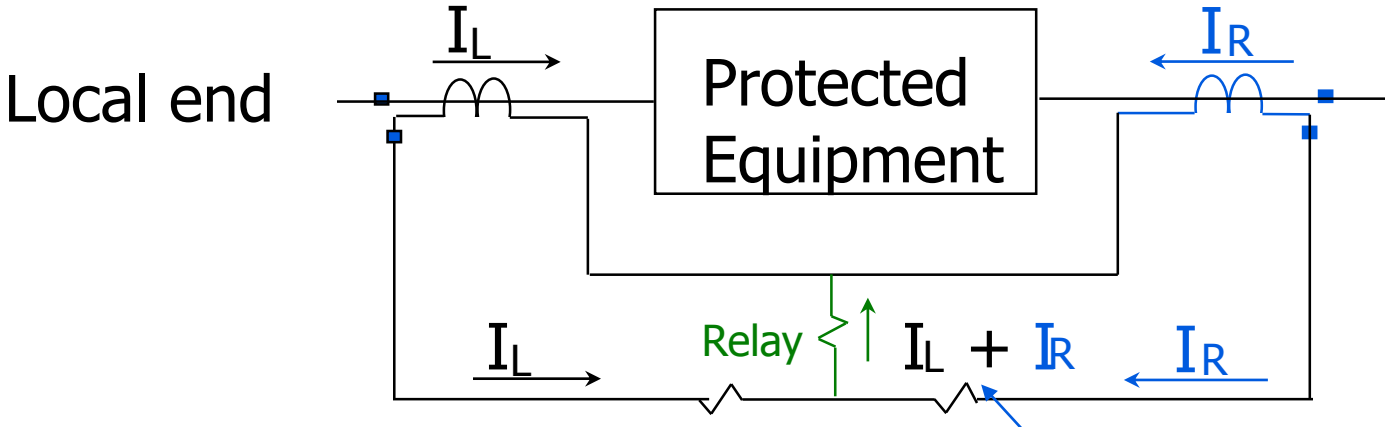
$$\frac{I_L}{I_R} = x + j\,y = -1$$



Operating and restraint regions

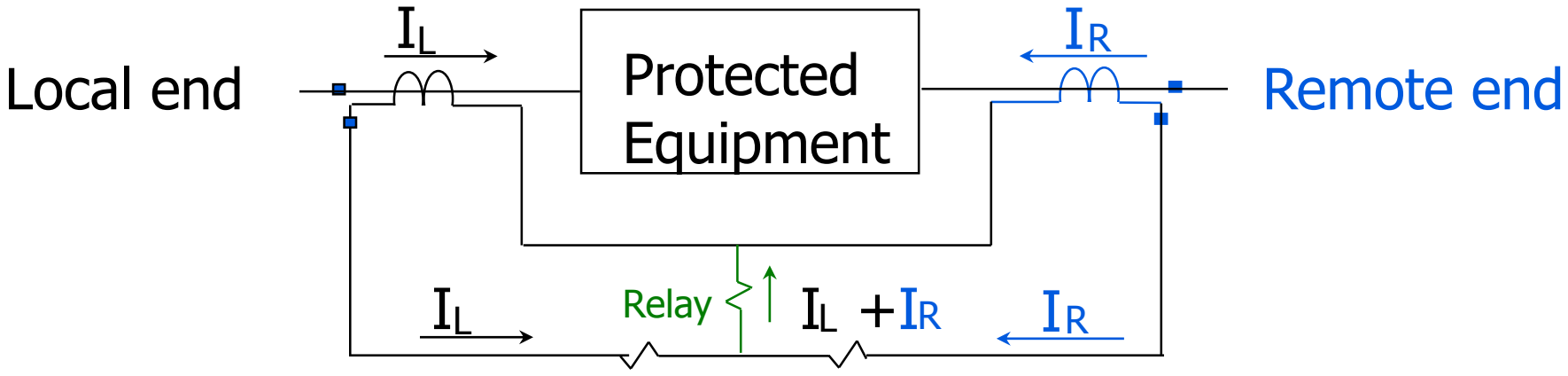
- High security for external faults
- High sensitivity for internal faults

Operating and restraint regions



Add restraint windings in addition to the original operating winding

Operating (trip) condition

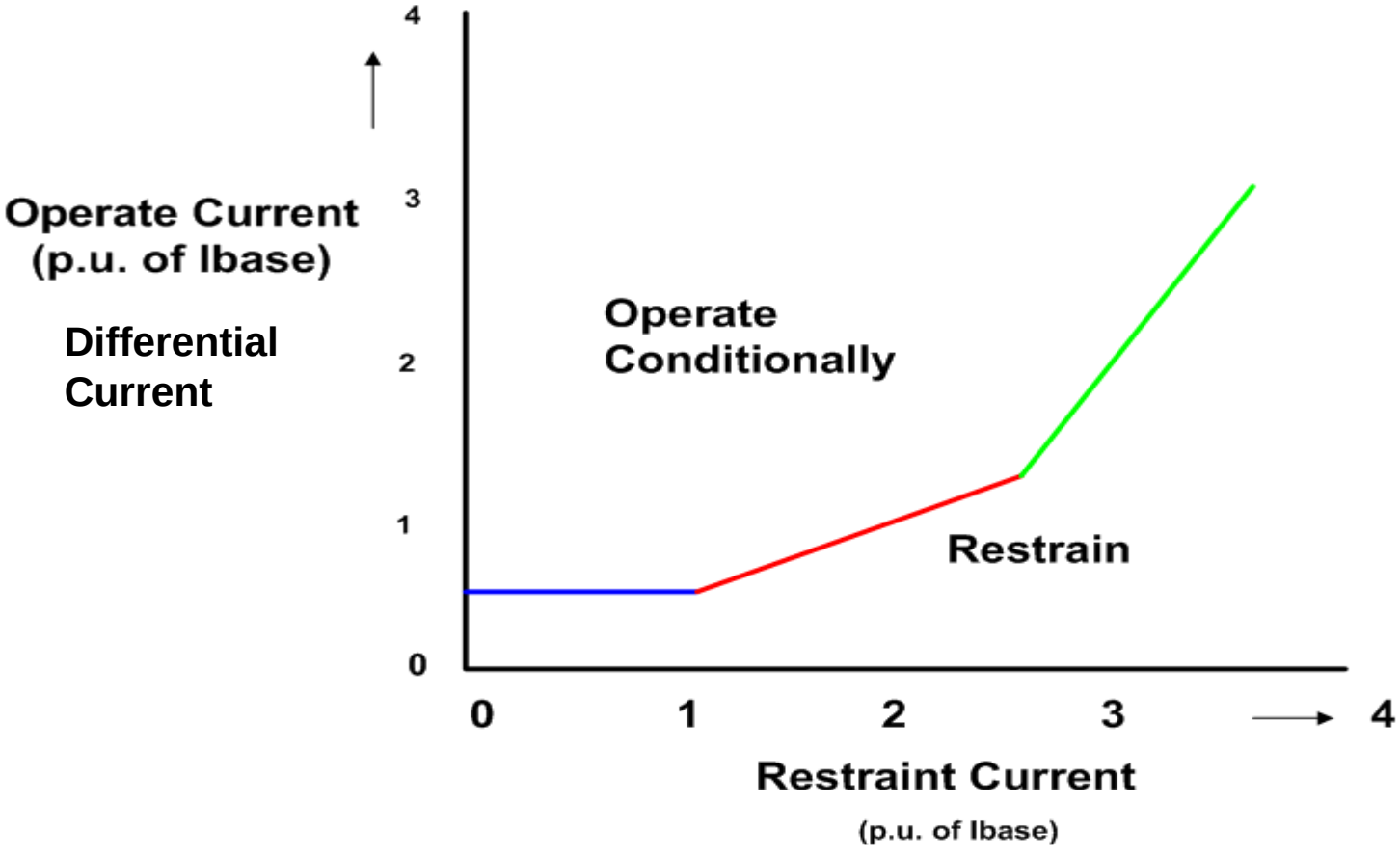


$$|I_L + I_R| \geq K(|I_L| + |I_R|)$$

or $$|I_L + I_R| \geq K(|I_L - I_R|)$$

or $$|I_L + I_R| \geq K|I_{max}|$$

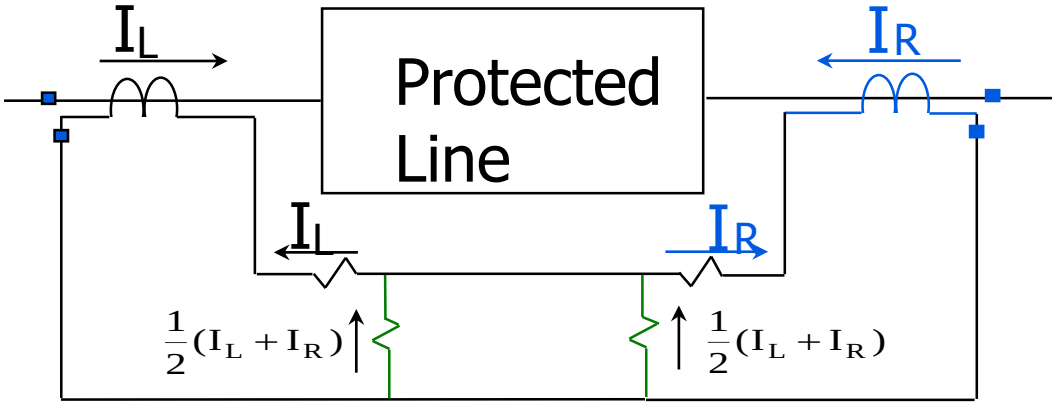
Operating and restraint regions



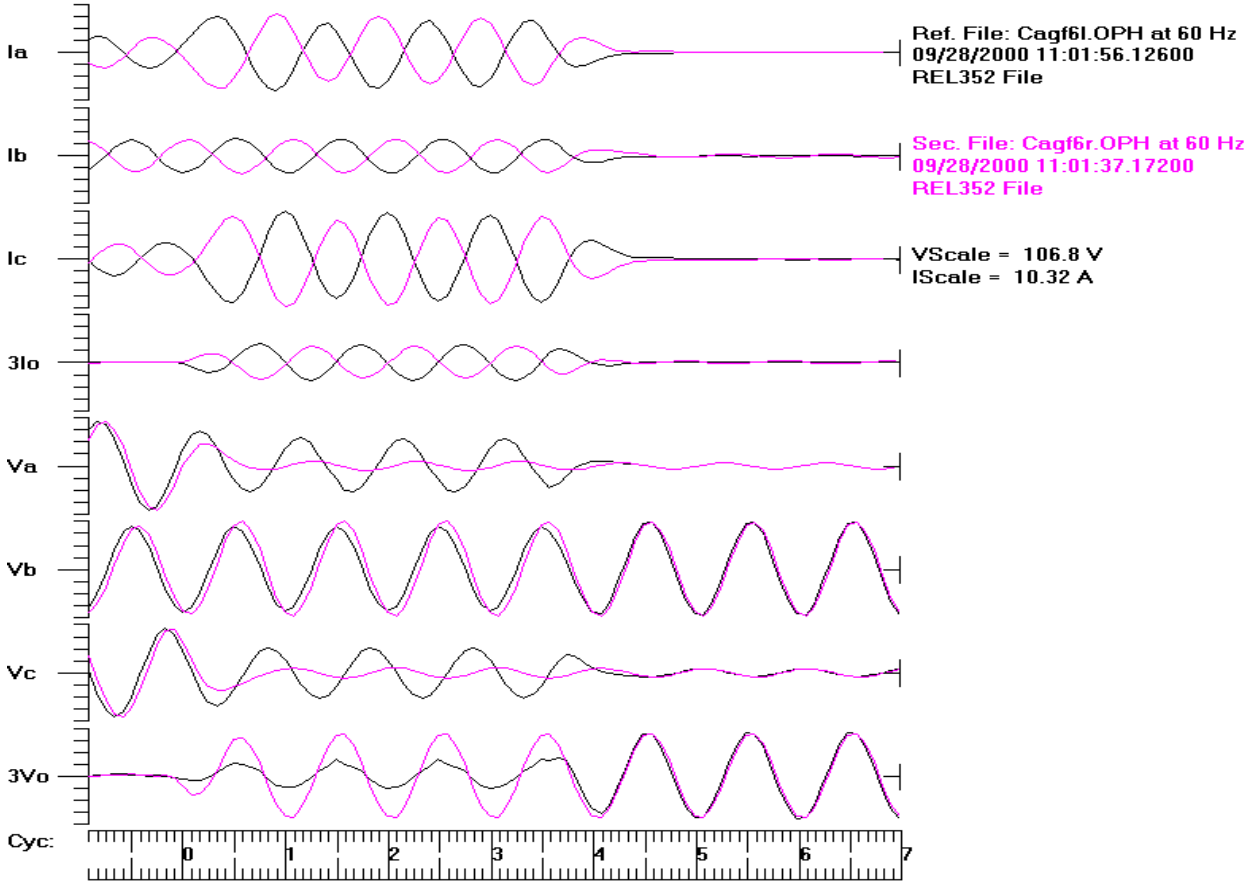
Line current differential relays

- Two terminals physically separated
- Two relays
- Communication between two terminals

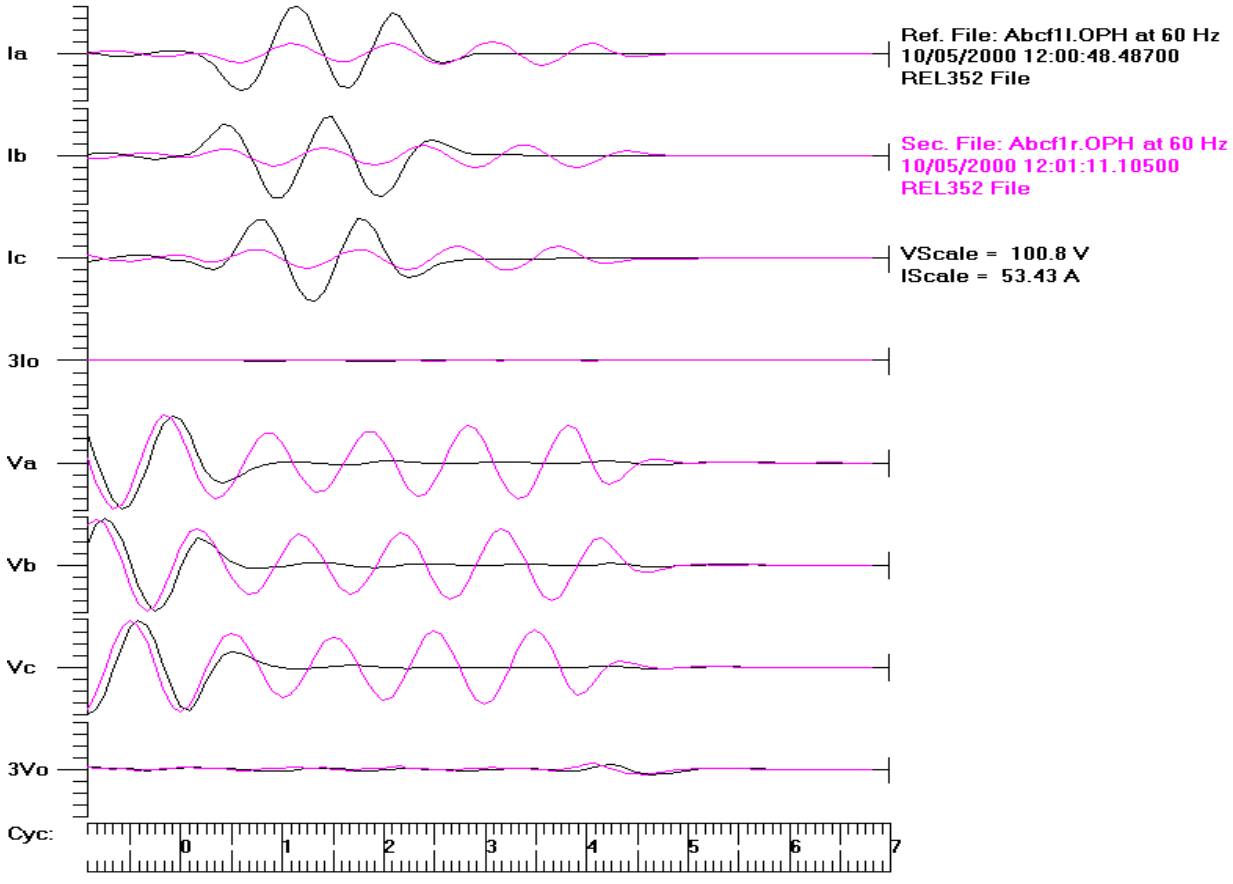
Line current differential relays



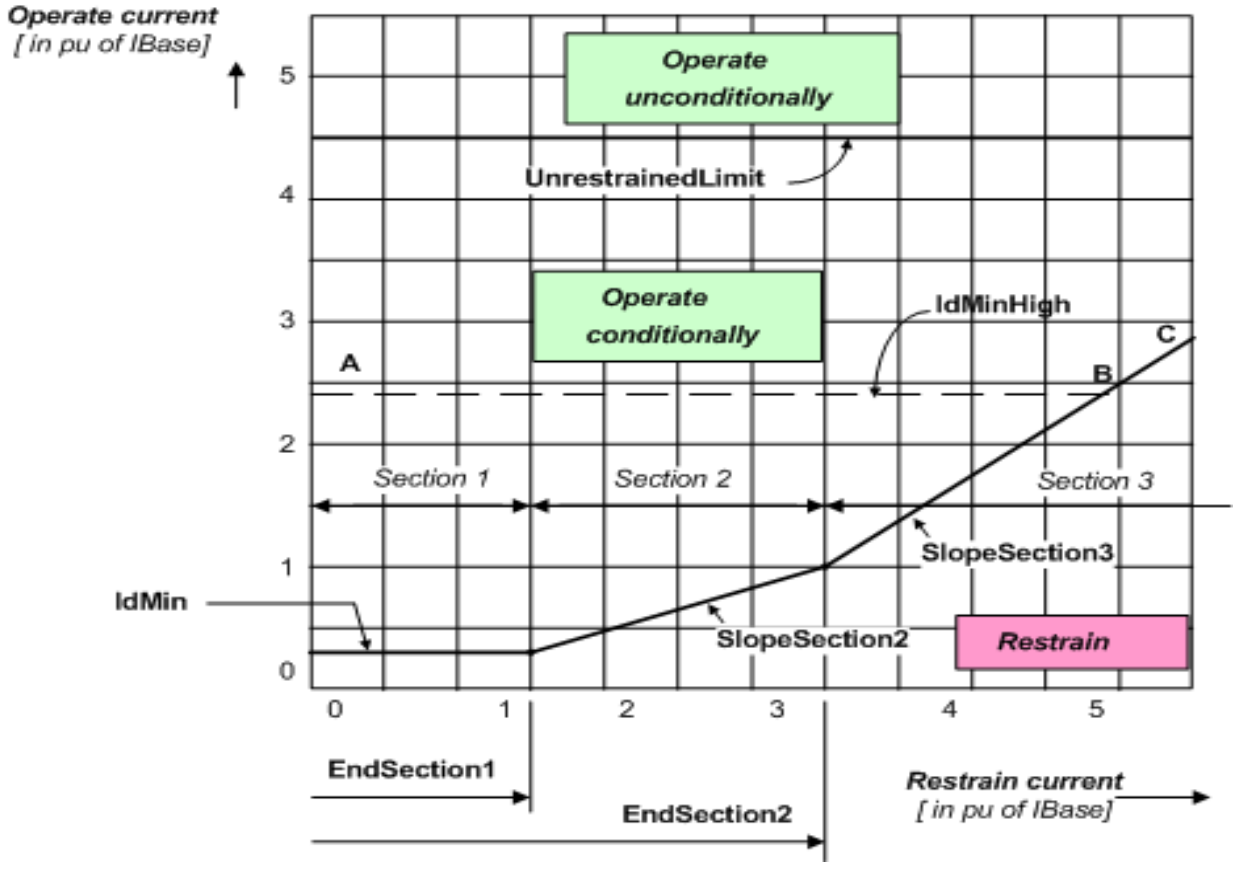
Normal conditions or external faults



Internal faults



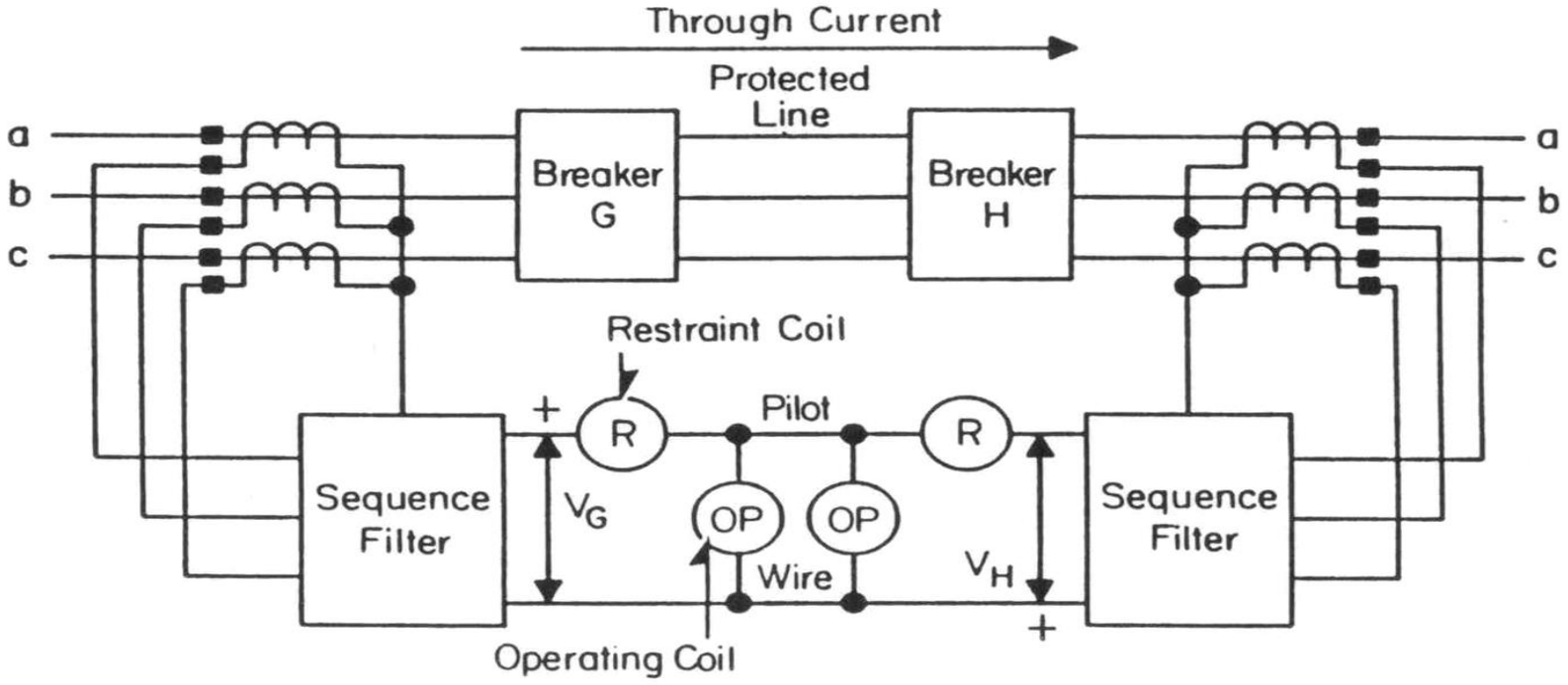
Line differential protection
Characteristic



Line current differential relays
First generation

- Reduce communication requirements
- Sequence filter

HCB pilot wire relay



Pilot wire relays
Problems

- Rise in station ground potential
- Induction from power line circuits

Pilot wire relays
Solutions

- Twisted wire pair
- Gaps/arrestors, etc.
- Drainage reactors
- Neutralizing reactors
- Insulating transformers

Non-metallic communications
Issues

- Propagation delay-time synchronization
- Signal corruption
- Communication network
  - Bits, bauds, bandwidth, switching, Mux
- Backup protection

Numerical relay

- First generation of numerical relays transmitted Fourier coefficients across channel
- Newest relays transmit sampled data across channel
  - Can do harmonic analysis
  - Calculate sequence components

Channel requirement

- Segregated phase differential protection typically calls for larger information exchange - digital communication
  - Ideal against cross country faults, series compensated lines, single pole tripping etc.

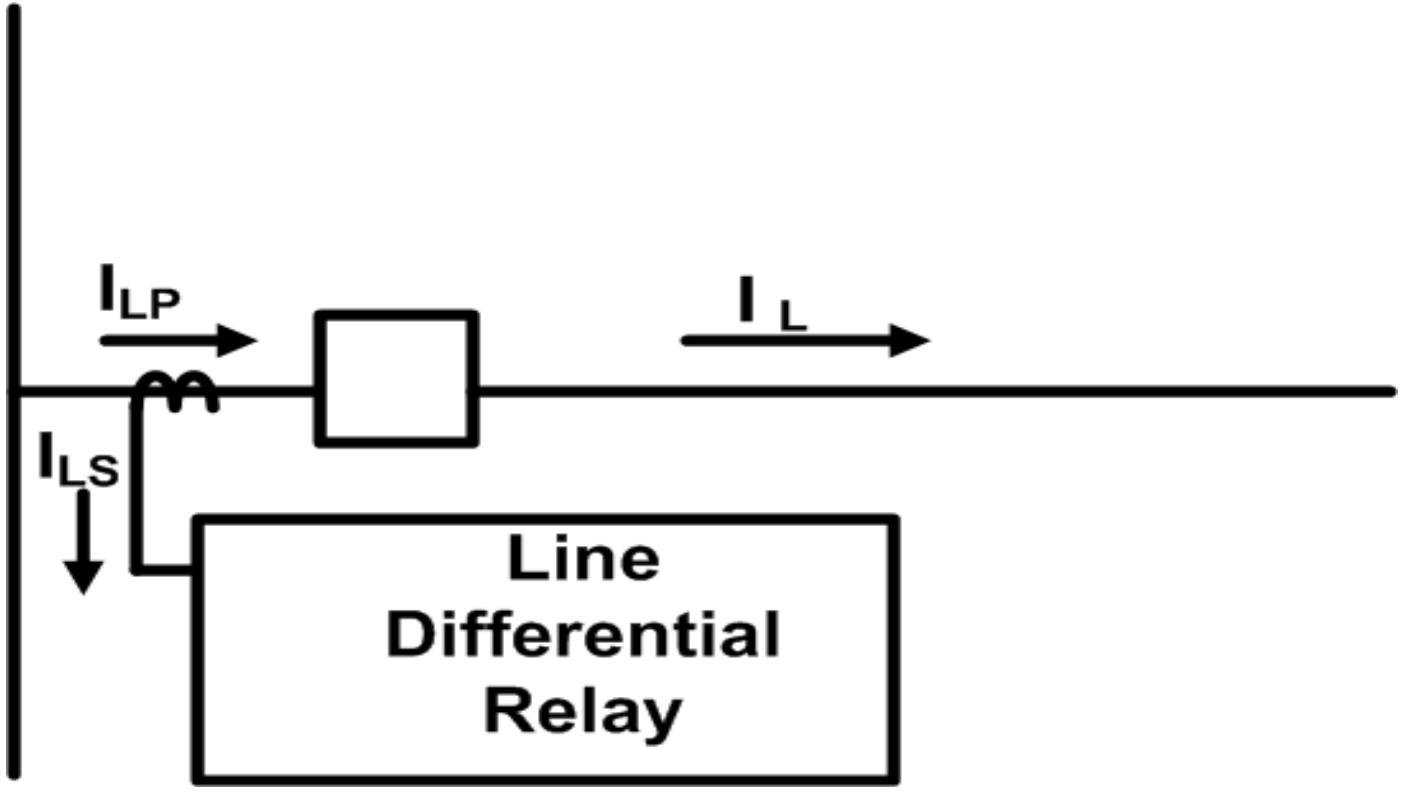
Channel options

- Direct Fiber
  - Short Range 1 – 3 Km
  - Medium Range 3 – 50 Km
  - Long Range 51 – 160 Km
- G.703
- Fiber to multiplexer
- Use C37.94 standard

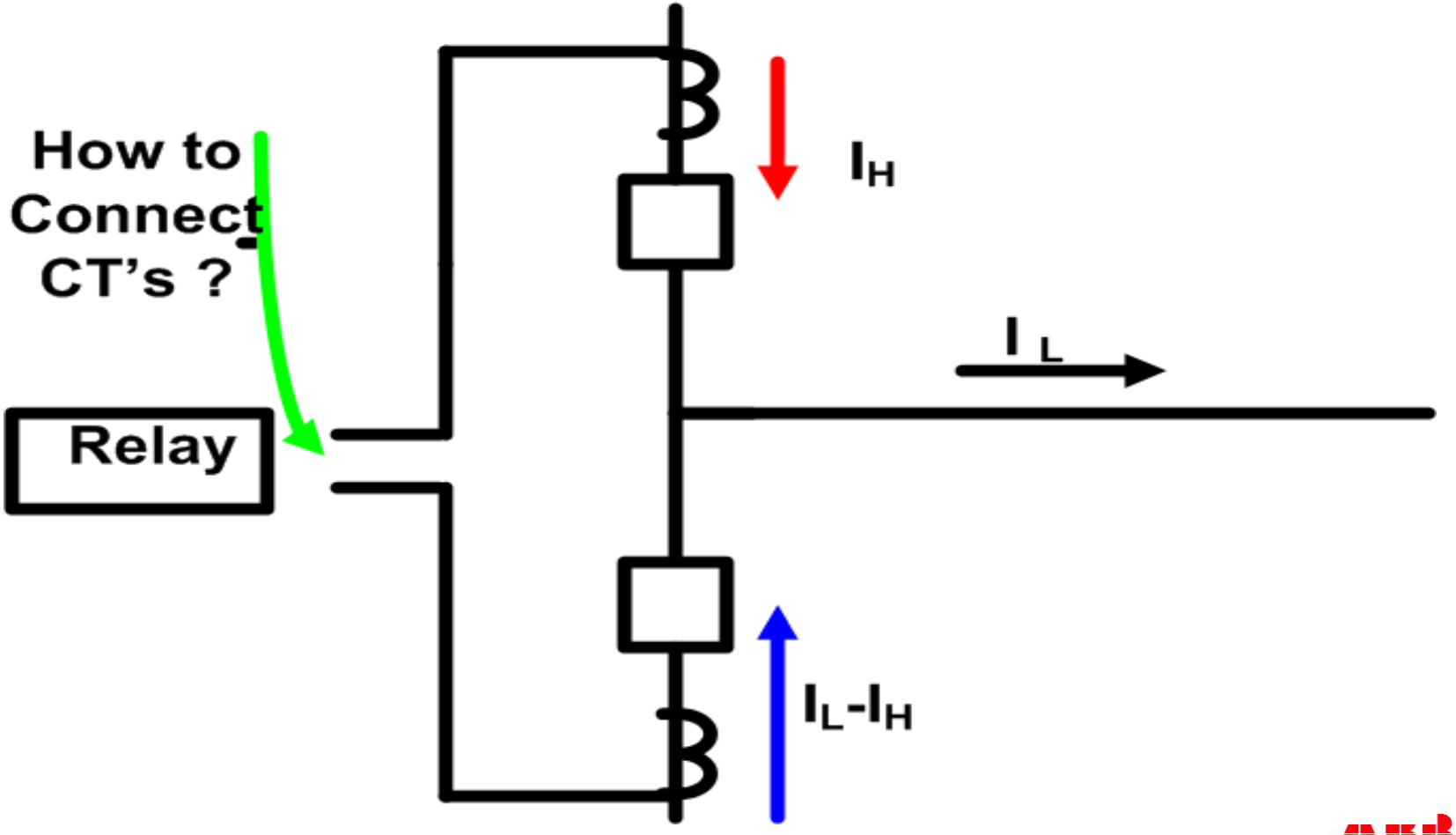
Line termination

- Single breaker
- Ring bus
- Breaker and one half
- Transformer

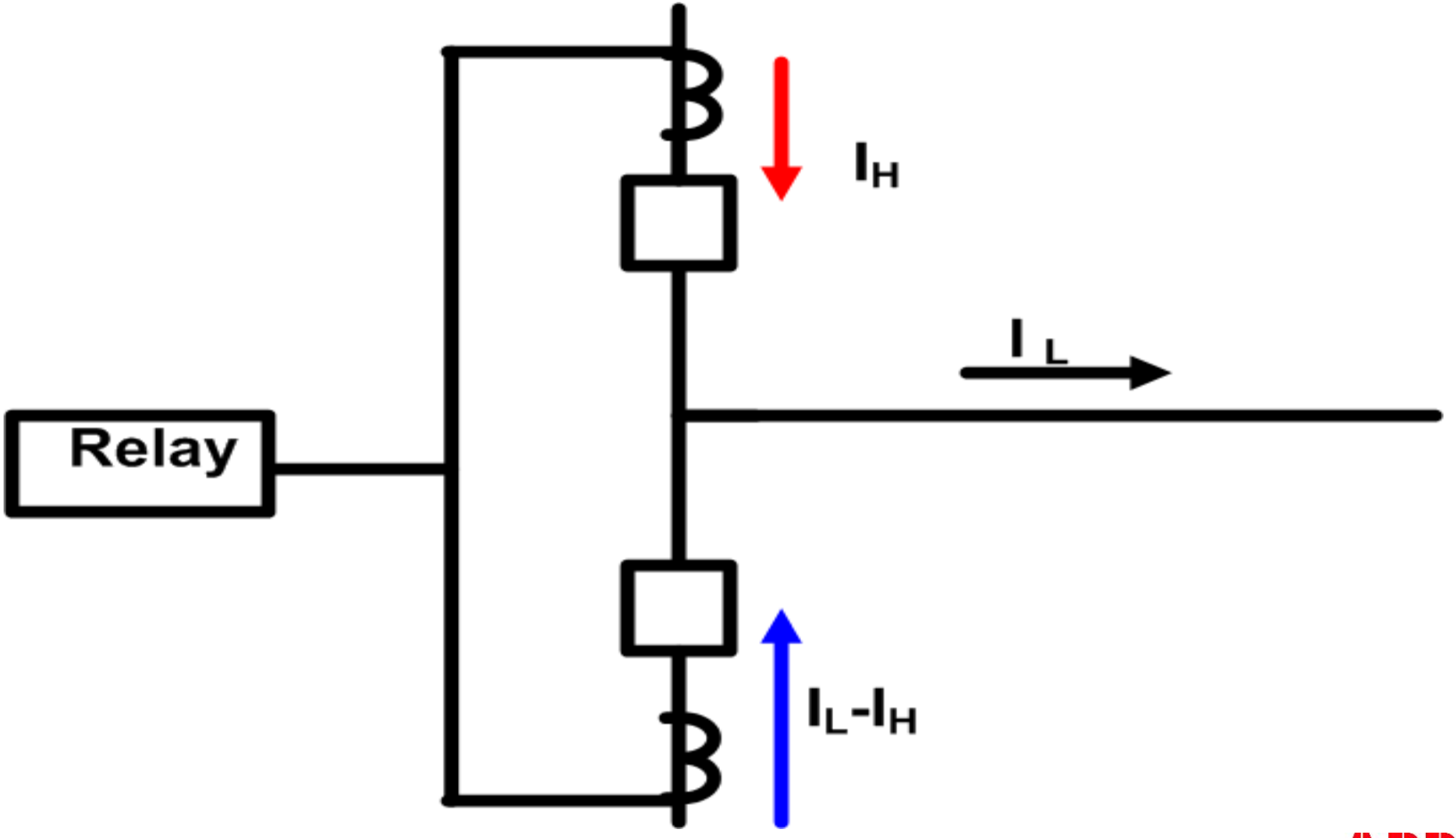
Single breaker



Ring bus or breaker and 1/2



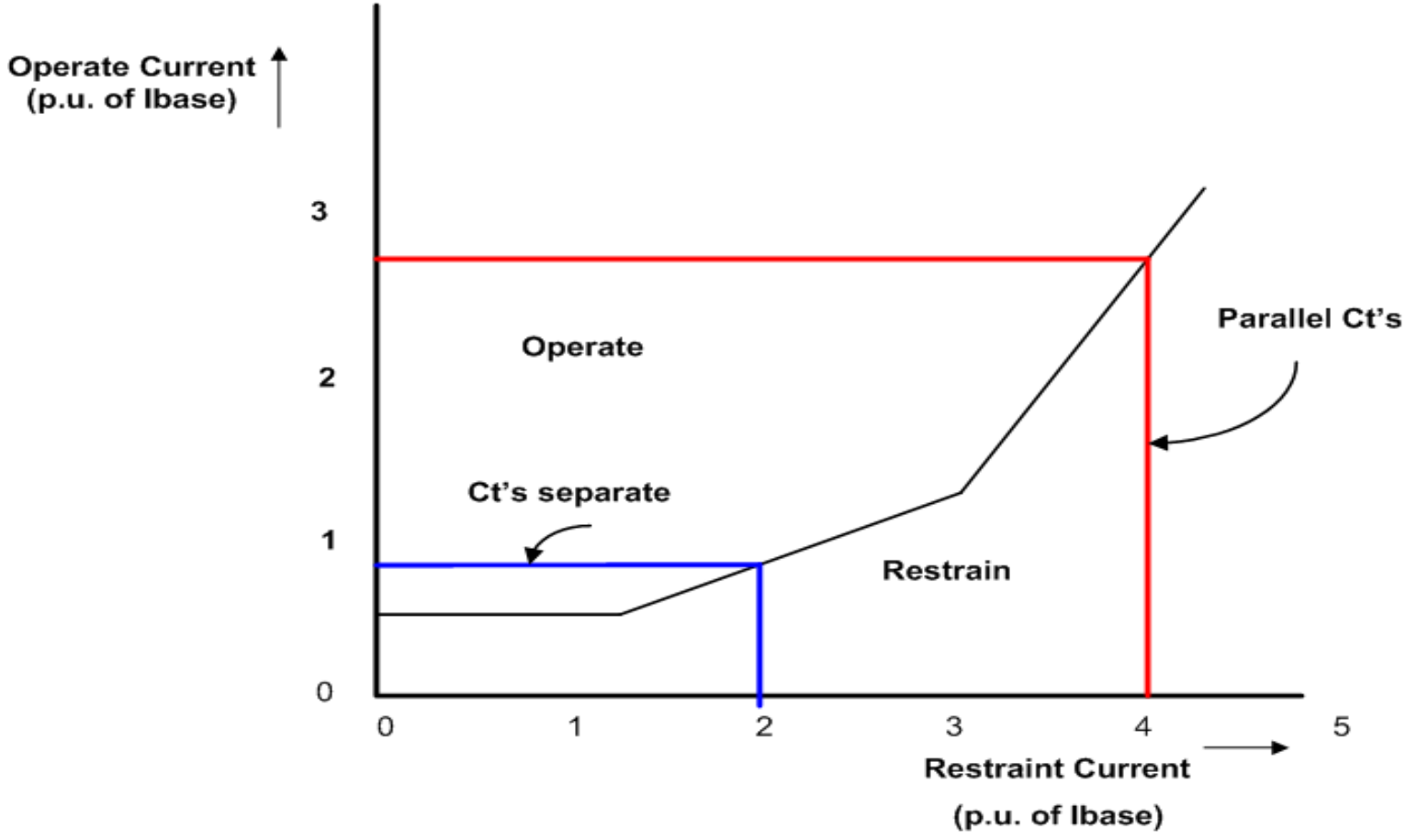
Classical current transformer connection



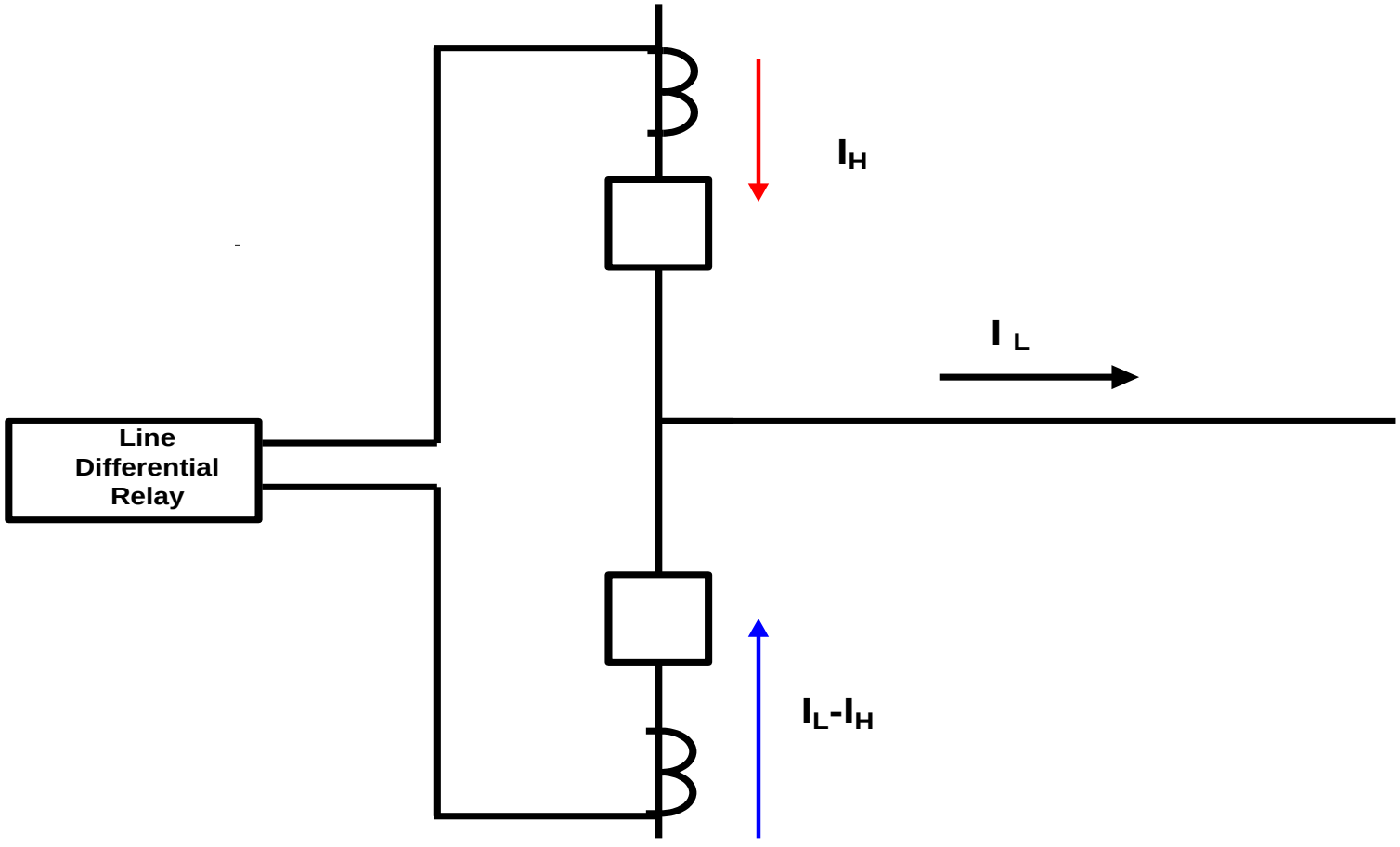
Classical connection
Problems

- Individual current transformer information
  - Current transformer health
    - Open circuit
    - Shorted
    - Saturated
  - Metering information
- Larger restraint current requires operate current
  - Reduced sensitivity

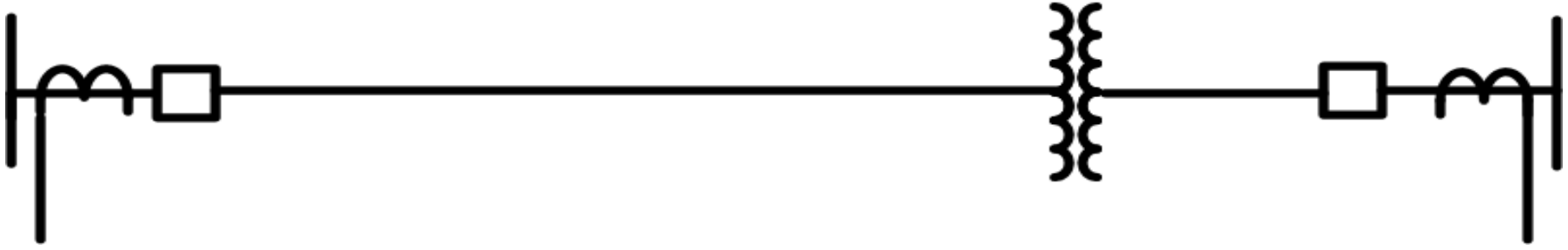
Differential characteristic



Preferred dual breaker connection

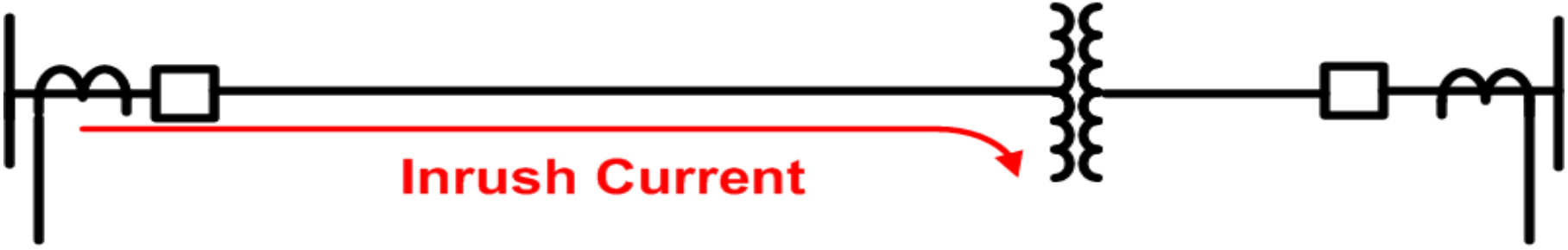


Transformer terminated line



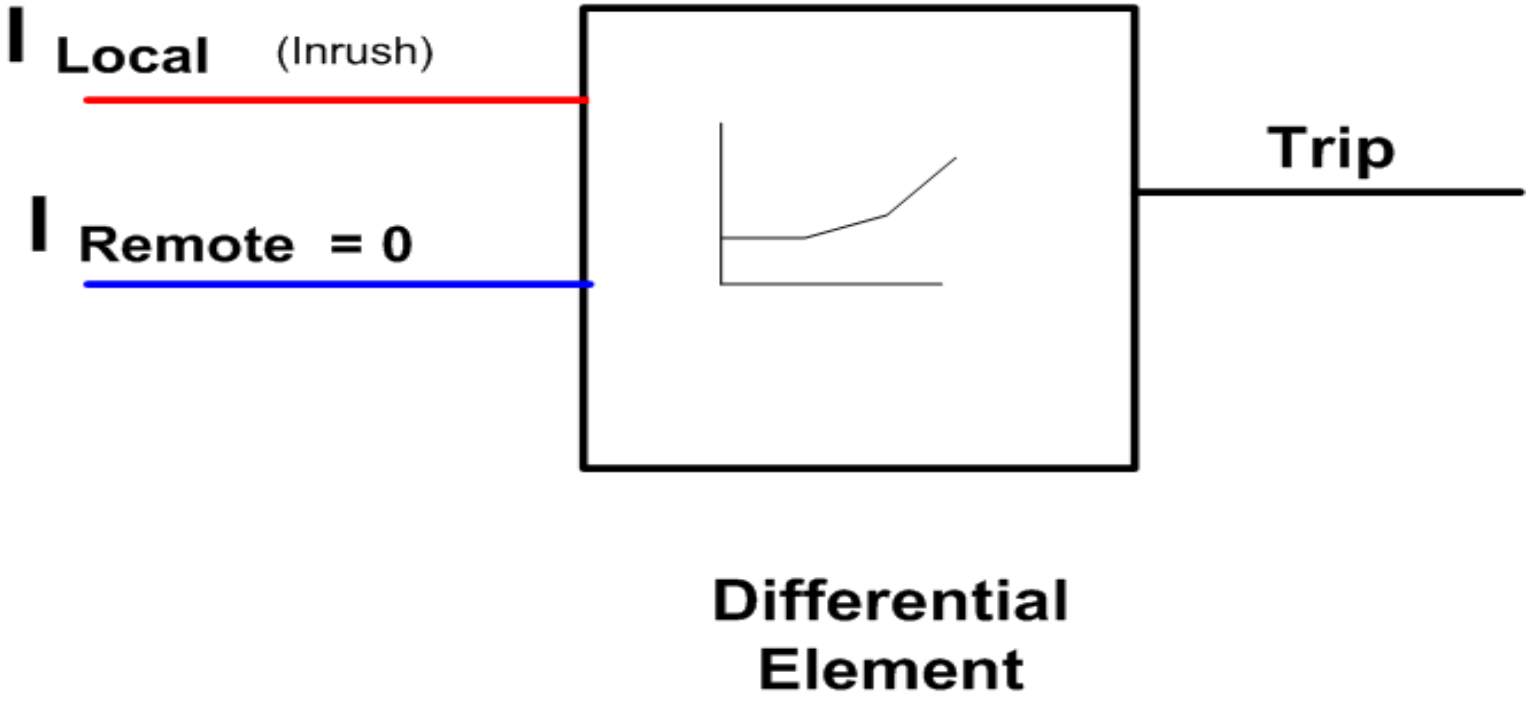
Transformer inrush

Current Phase shift across transformer
Transformer inrush current
Low side faults on delta wye grounded transformer



Take care of in settings by giving vector group of winding configuration

Classical differential operation



Inrush characteristic

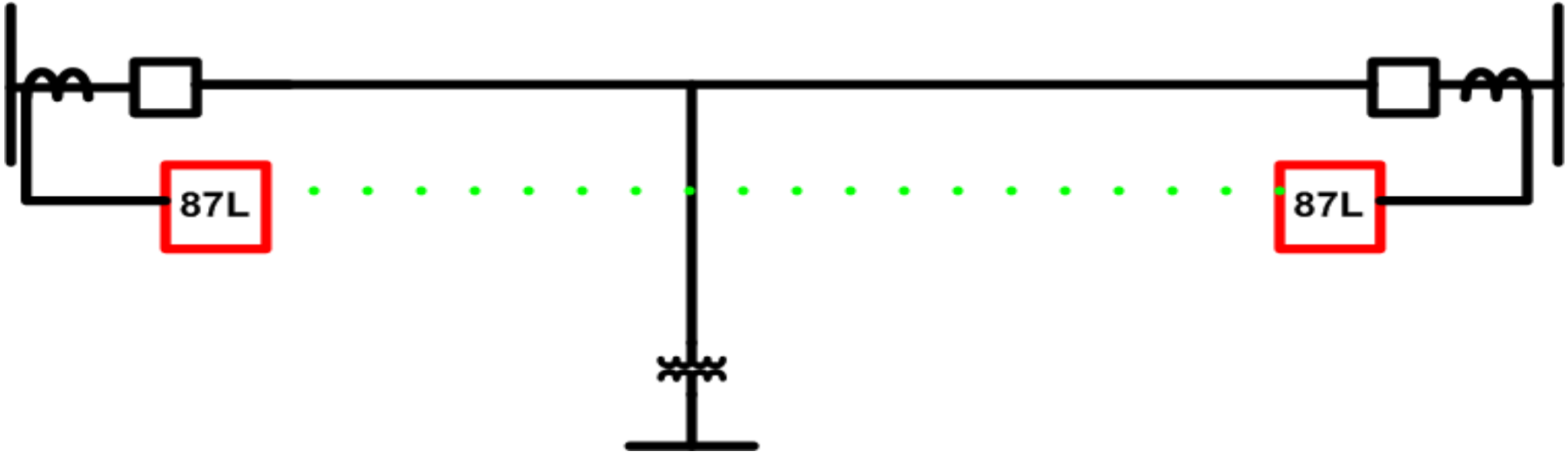
- 2nd Harmonic
- Over 7% of Fundamental (60 HZ) Current

Delta wye transformer
External ground fault

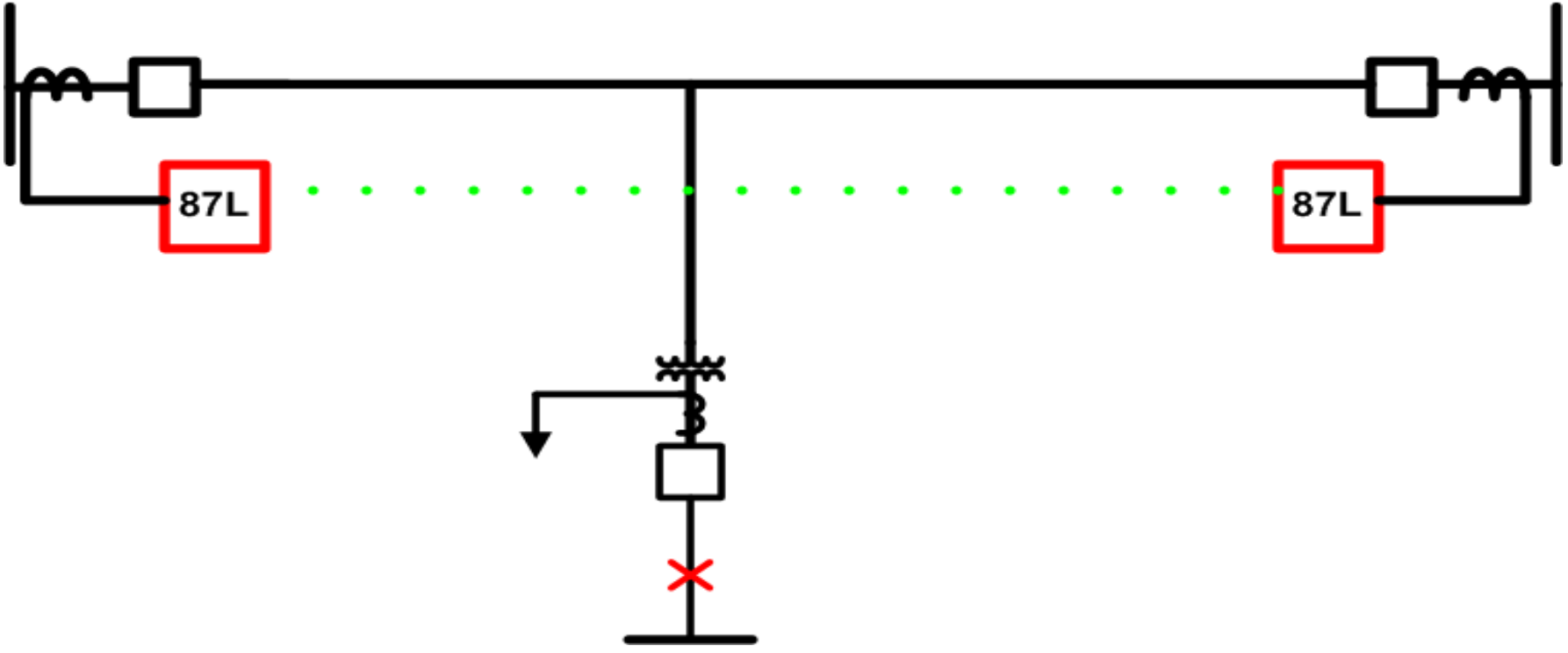
Transformer terminated line
Concerns

- External ground faults causing zero sequence current to flow only on one side of transformer (delta – wye)
  - Eliminate zero sequence current
  - Previously done by using auxiliary CT in zero sequence trap
  - Do numerically in relay

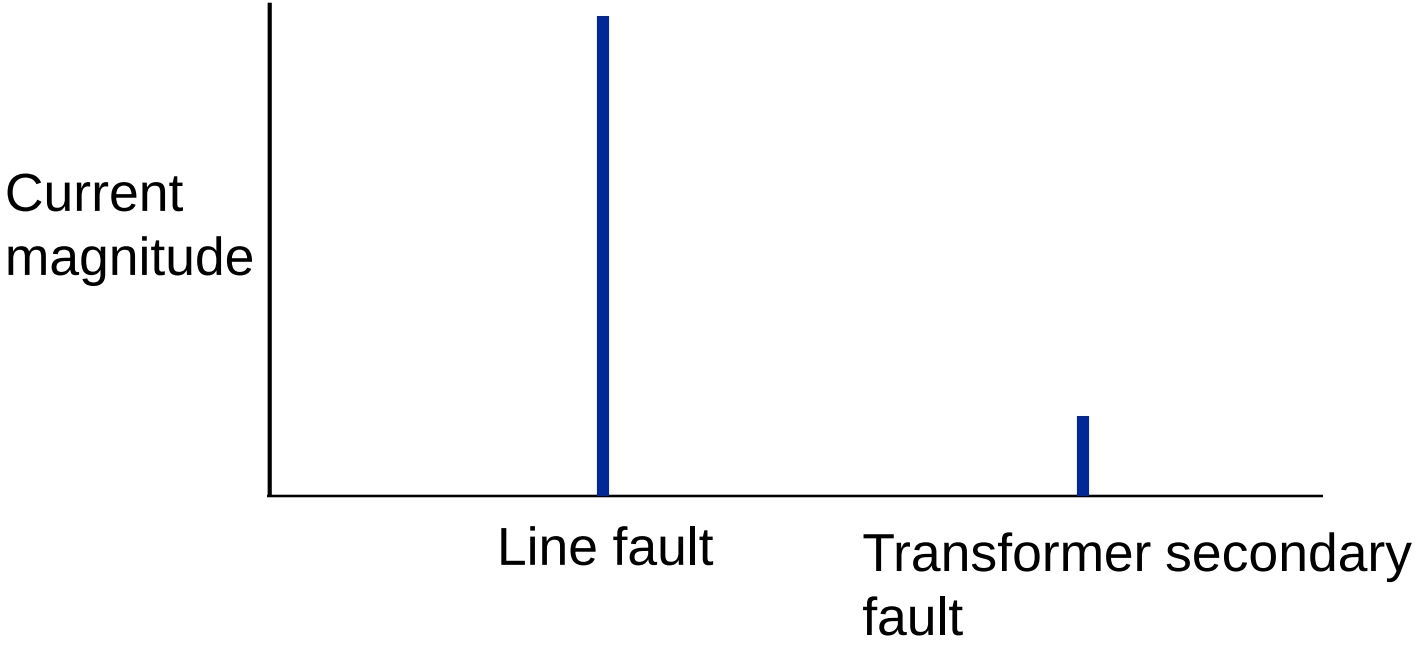
Tapped line



Secondary fault



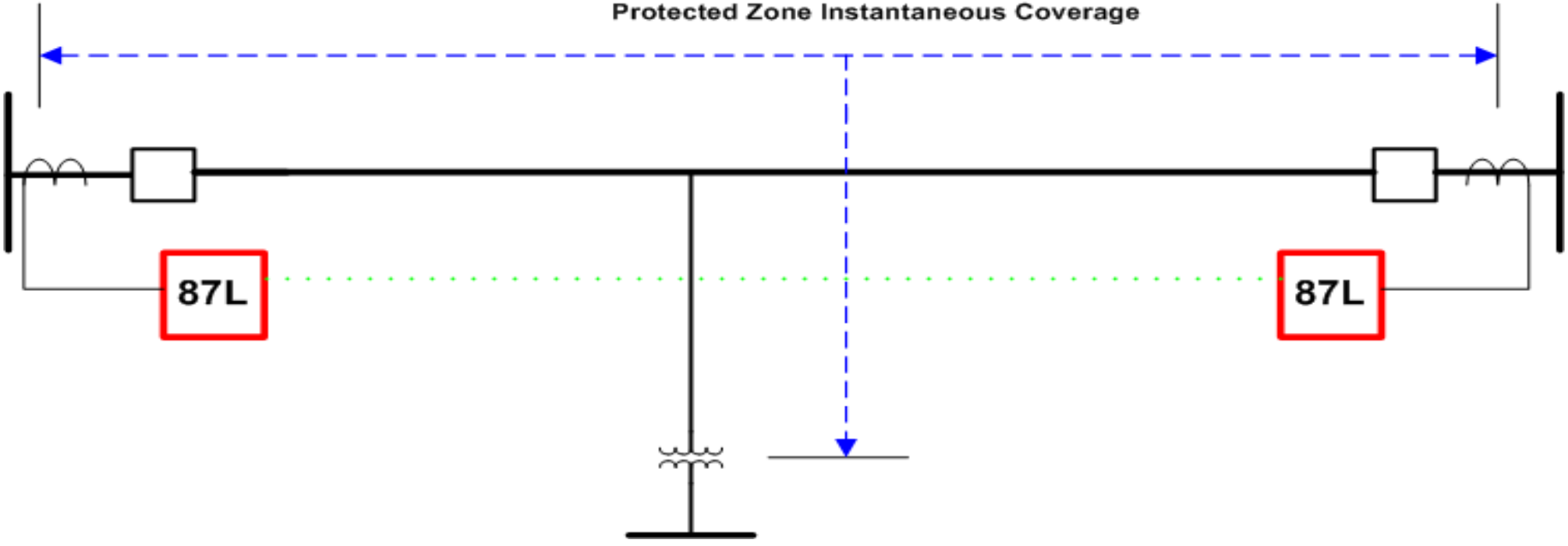
Relative fault currents



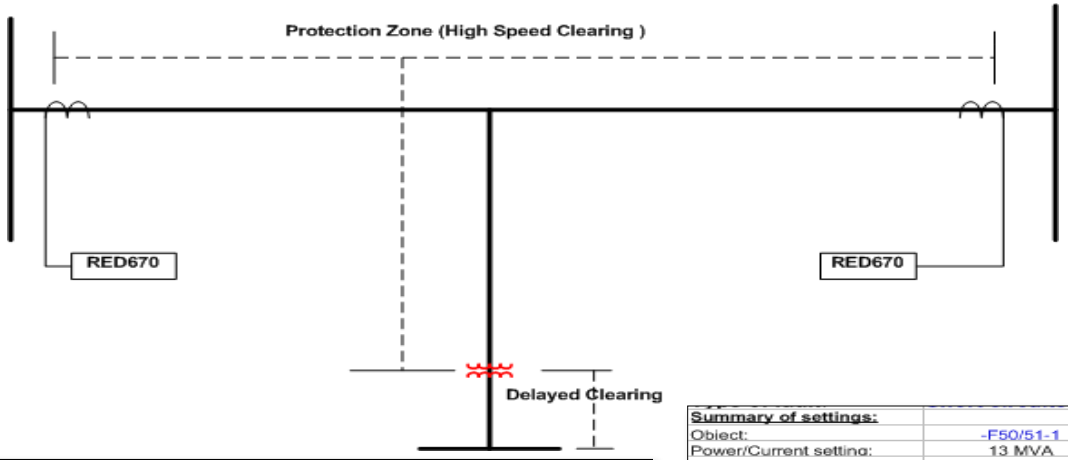
Small power transformer
Tapped line

- Time delay differential function for small differential current below a set limit
- Coordinate with downstream relays at tap
- Differential currents above limit with allow instantaneous operation

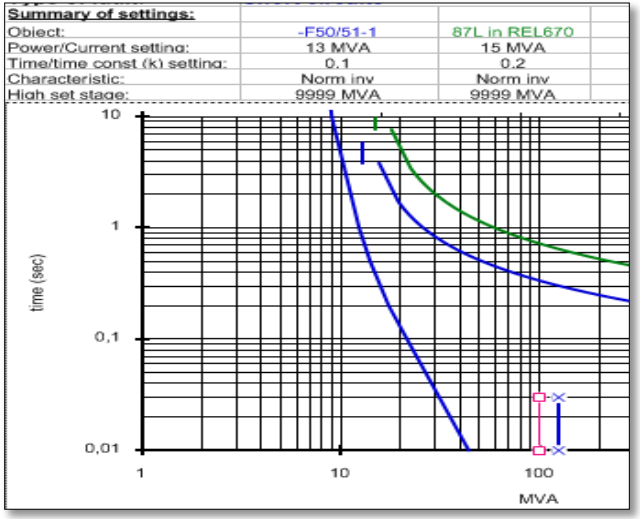
Tapped line



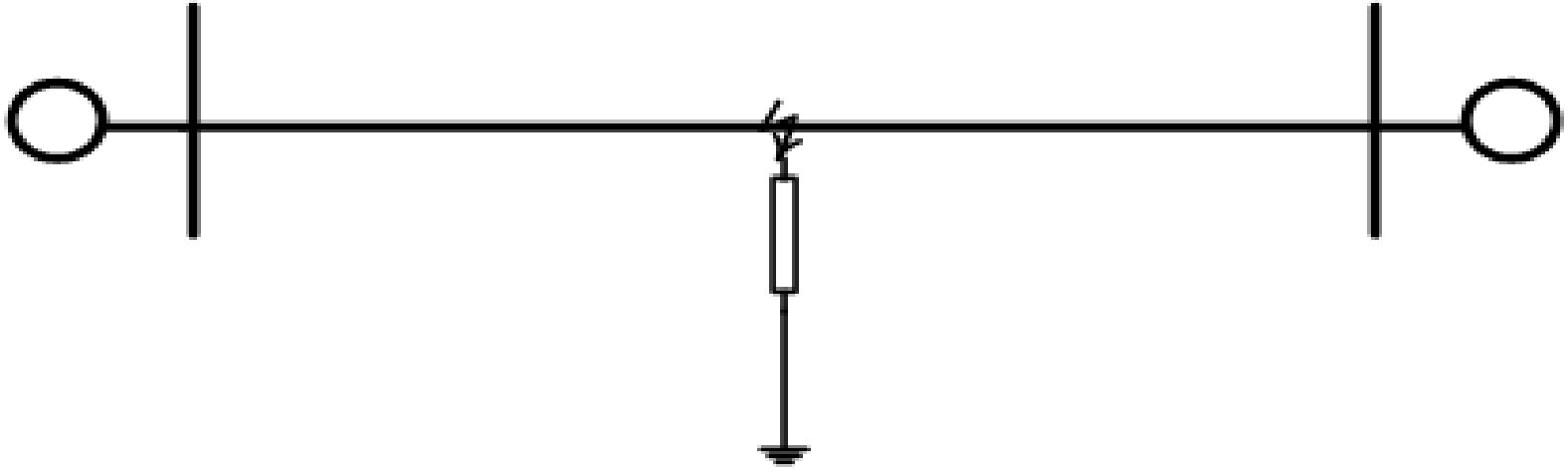
Differential protection
Tap to small transformer



Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
LineTrfDiff3Terminal(PDIF,87L)					
LT3D					
Operation		On			
IdMin		0.25	IB	0.20	2.00
AddDelay		On			
IMaxAddDelay		1.50	IB	0.20	5.00
tMinInv		0.300	s	0.001	6.000
CurveType		IEC Norm. inv.			
k		0.20		0.05	1.10

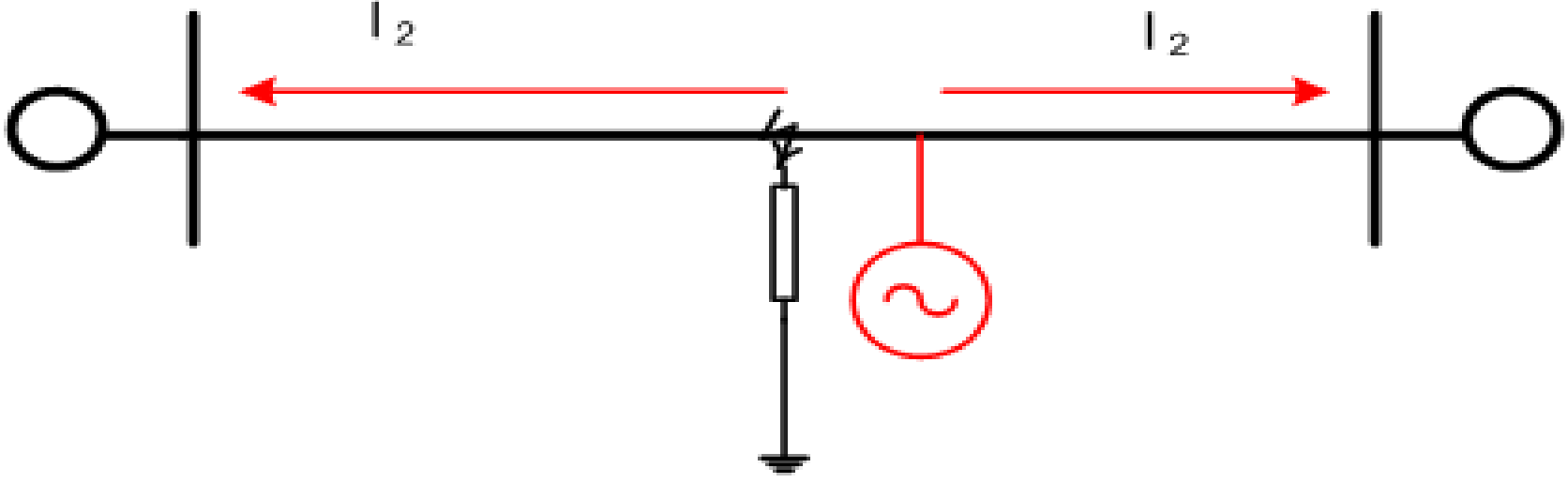


High impedance fault



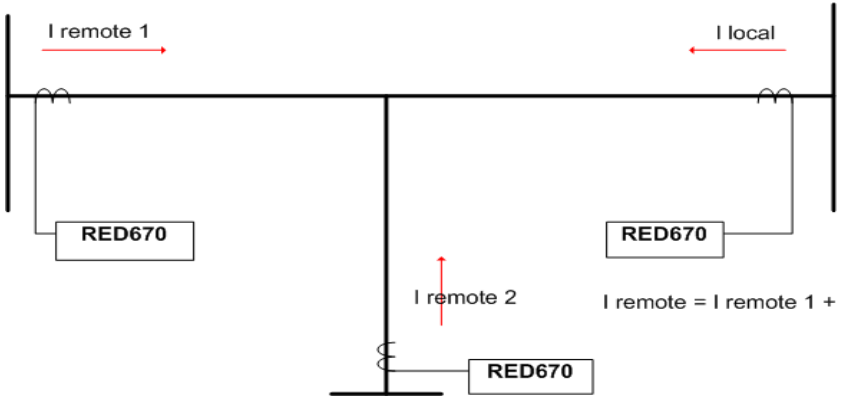
High Resistance Fault

Negative sequence
Fault discriminator



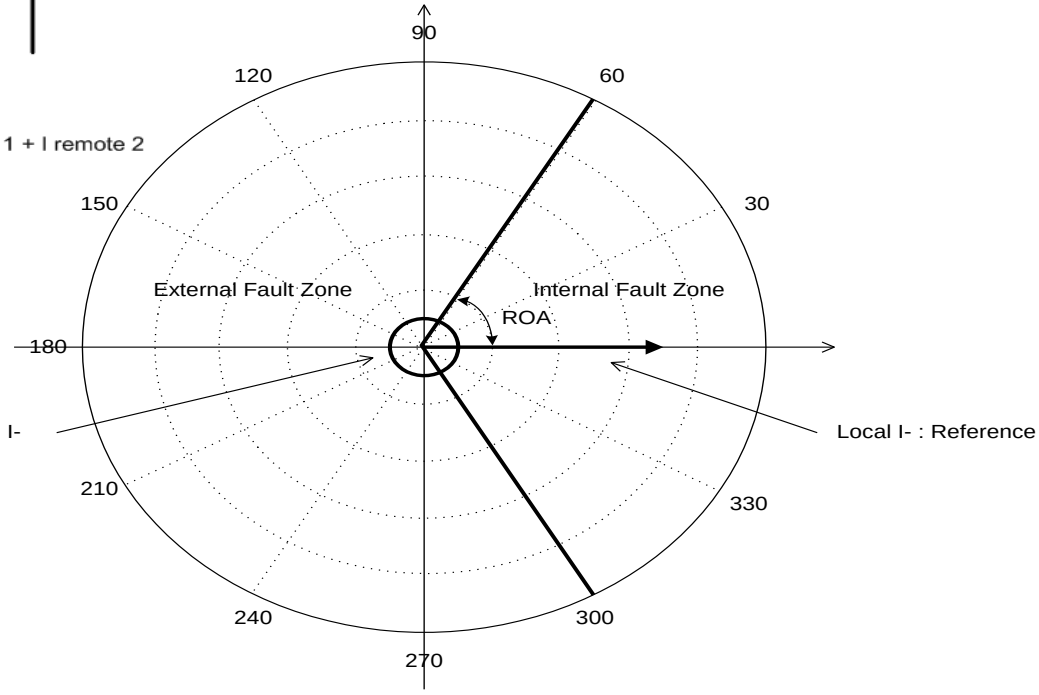
Negative Sequence From Fault

Negative sequence
Current fault discriminator



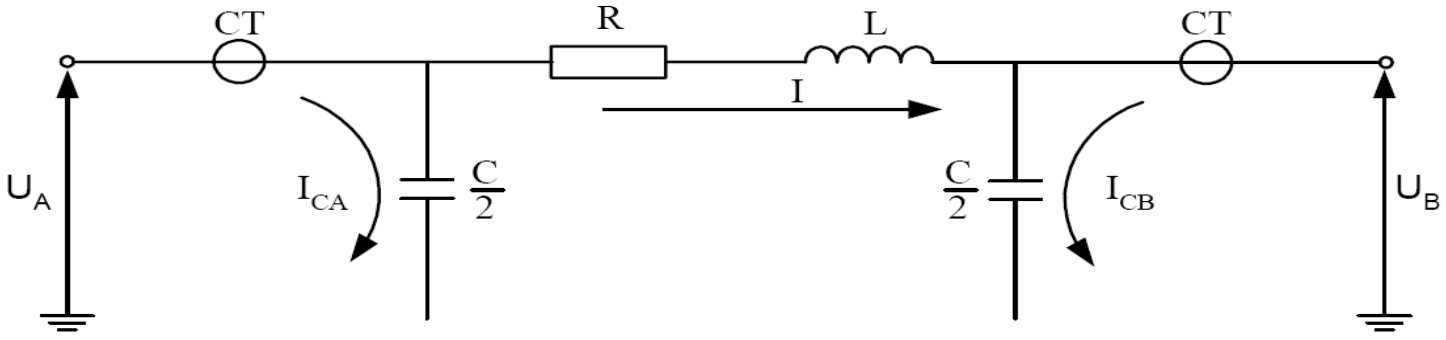
I remote = I remote 1 + I remote 2

- If the two currents flow in the same direction, the fault is internal.
- If the two currents flow in opposite directions, the fault is external.



Capacitive current Compensation

Equivalent "PI" Network of Line

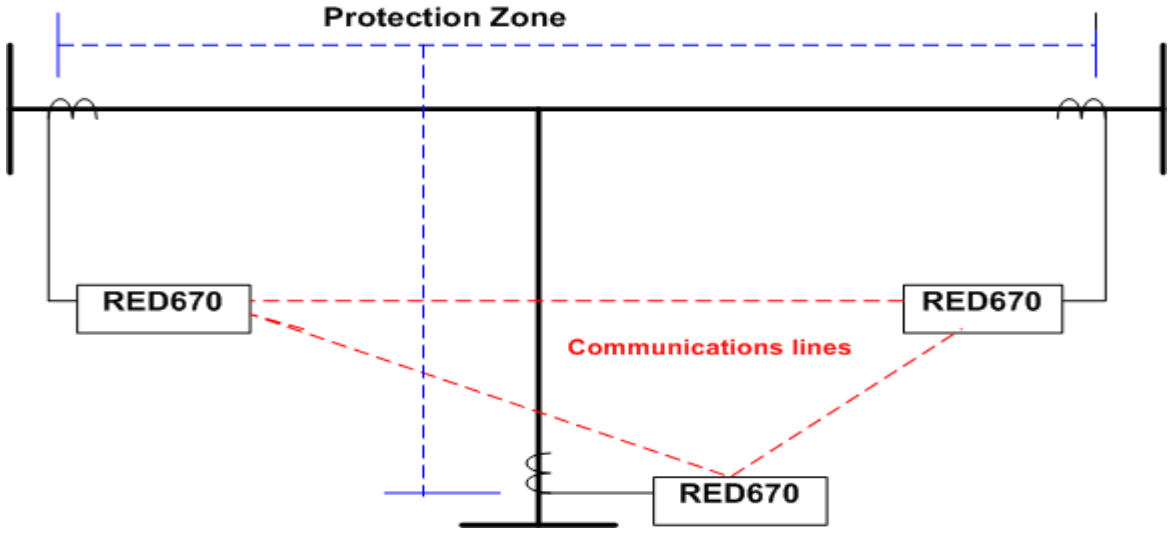


Make pick-up of differential above the capacitive current
Make a compensation in algorithm Ic = V/Xc

Charging current
Compensation

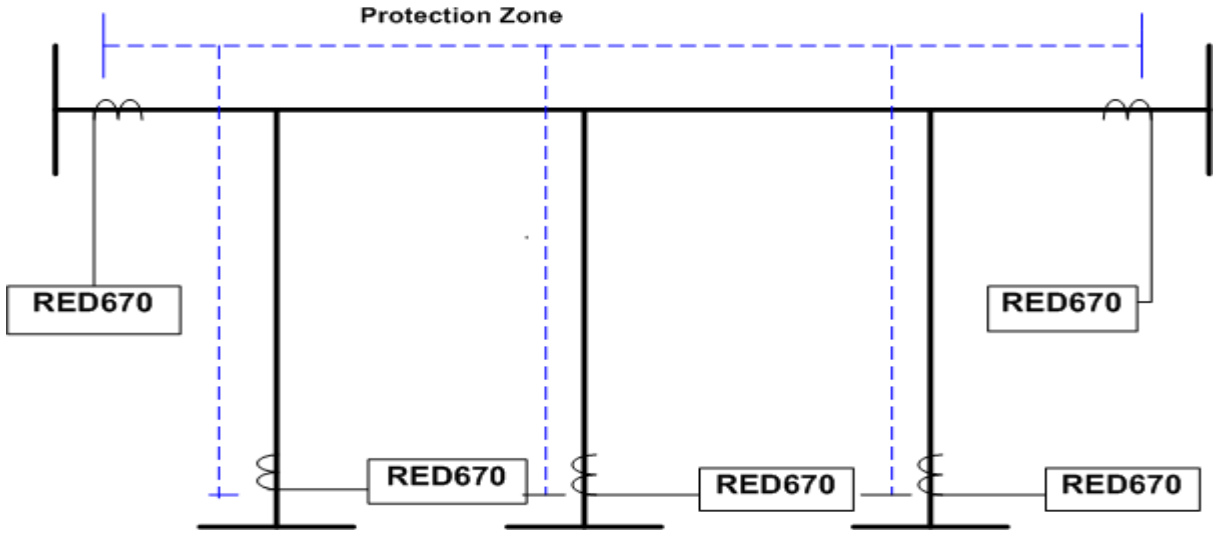
- Measure fundamental frequency differential current under normal steady state conditions
- Normal means no start signals, neither internal or external fault,
- Subtract it making resulting differential current zero
- No need to raise minimum operate current

Three terminal line
Application



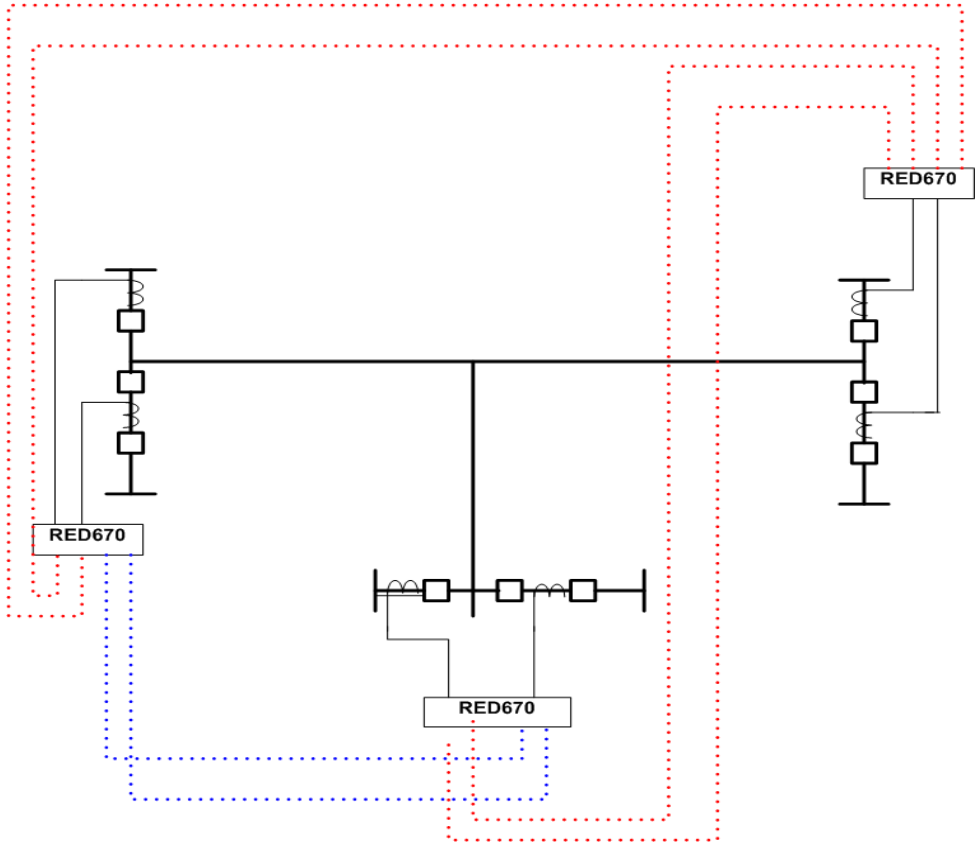
Current from all terminals

Five terminal line
Application



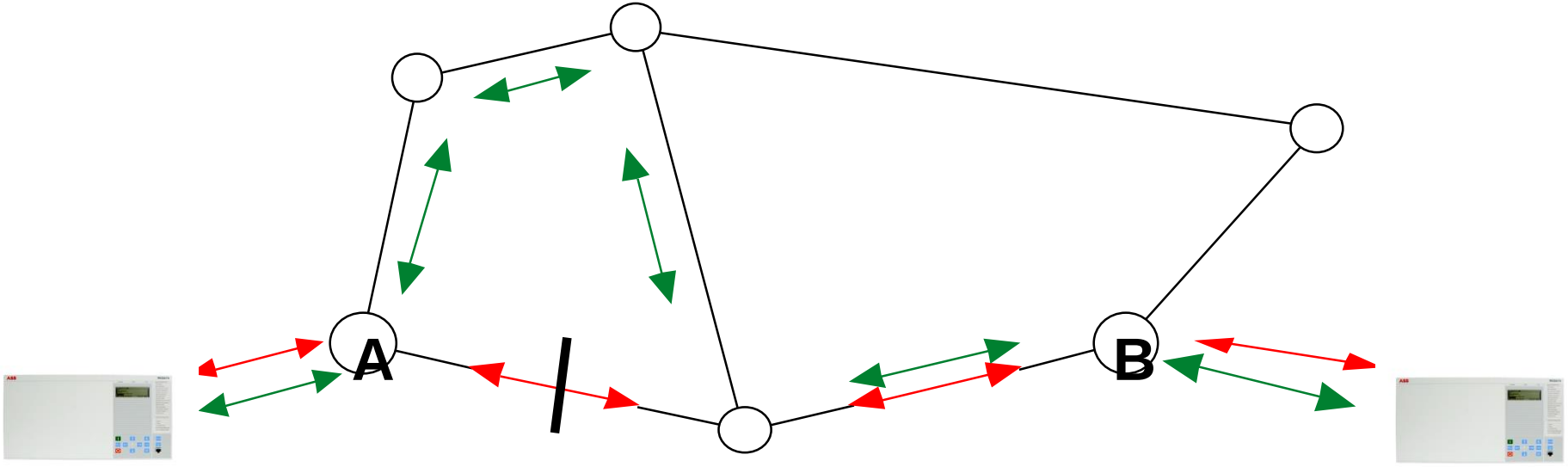
Fault current can be fed from all line ends

Four communications modules
Practical use



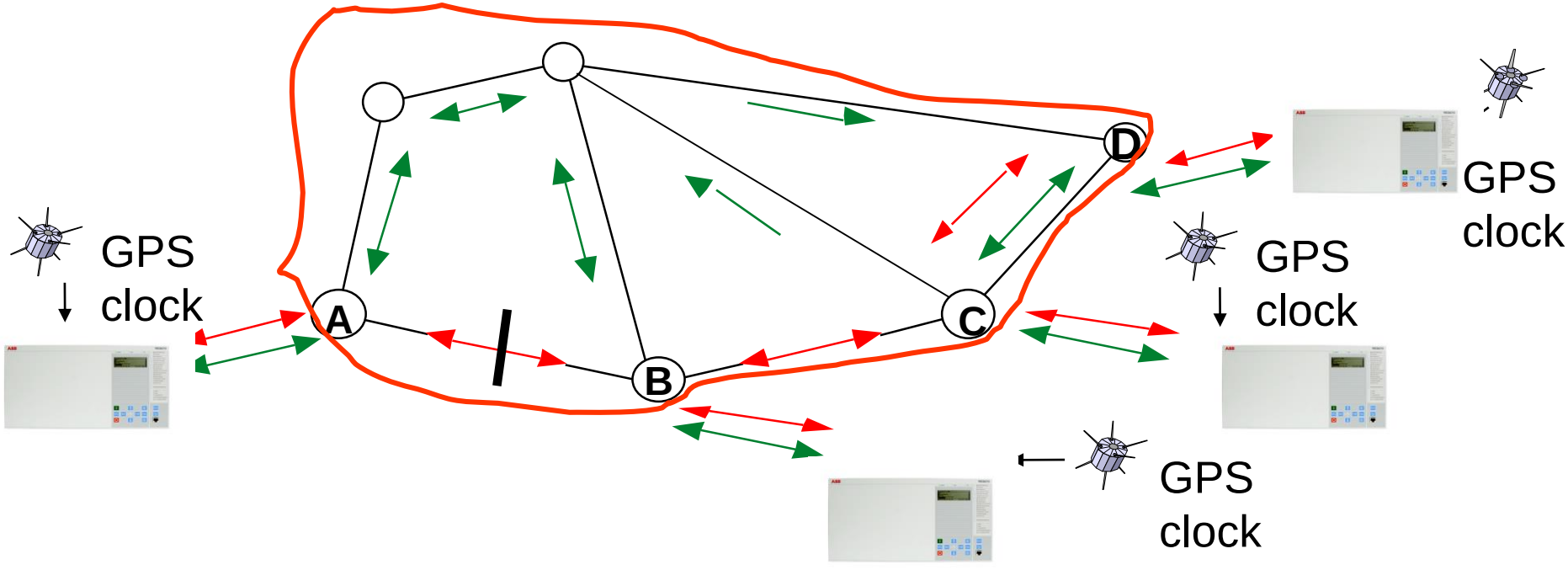
Route switched networks
With delay symmetry

The echo method allows for route switching with equal delay times for send and receive

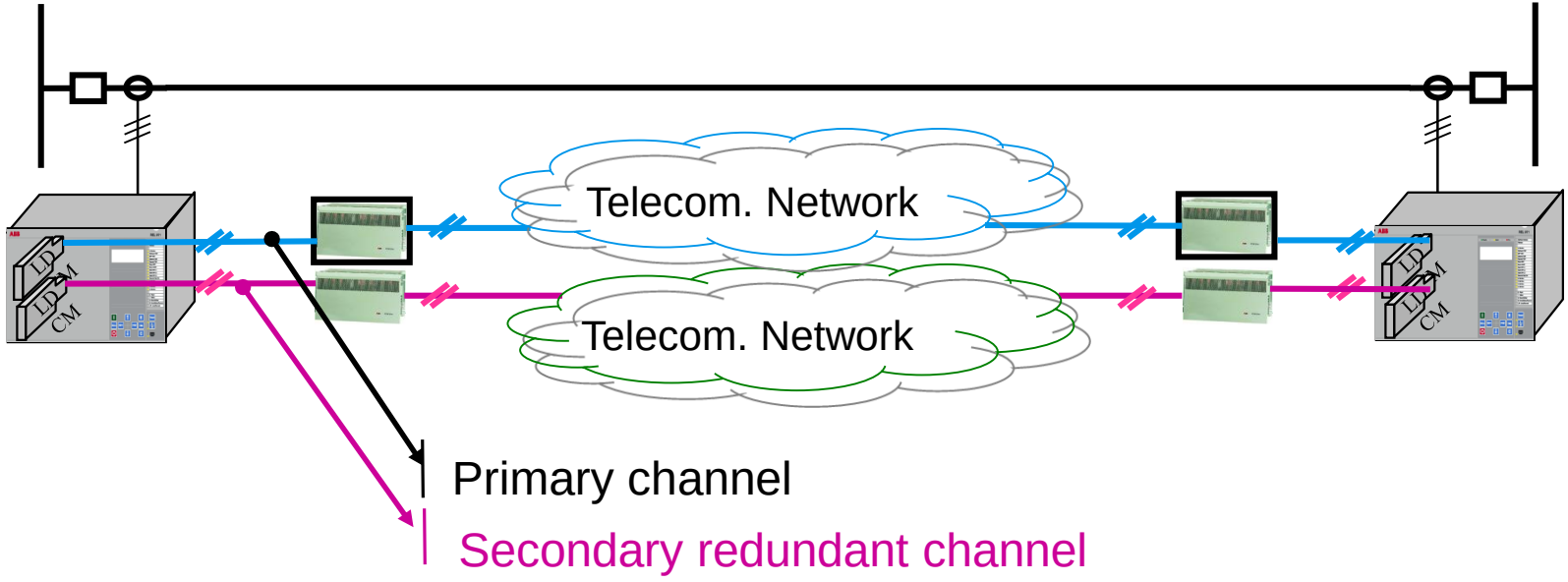


Route switched network
Without delay symmetry

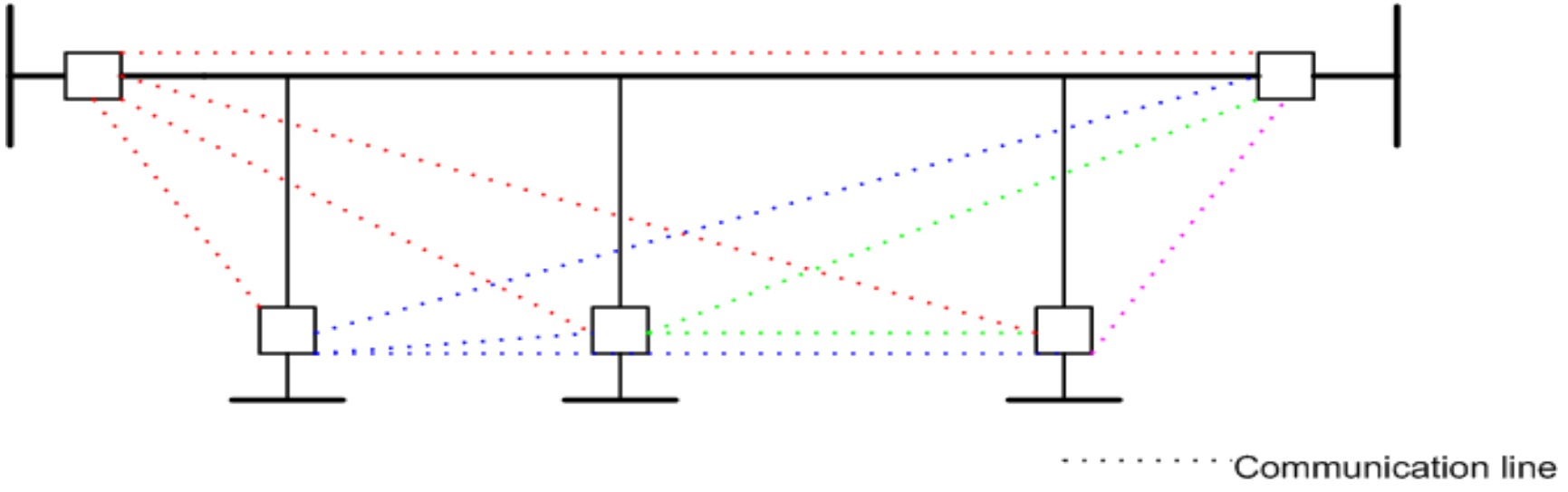
GPS time synchronization



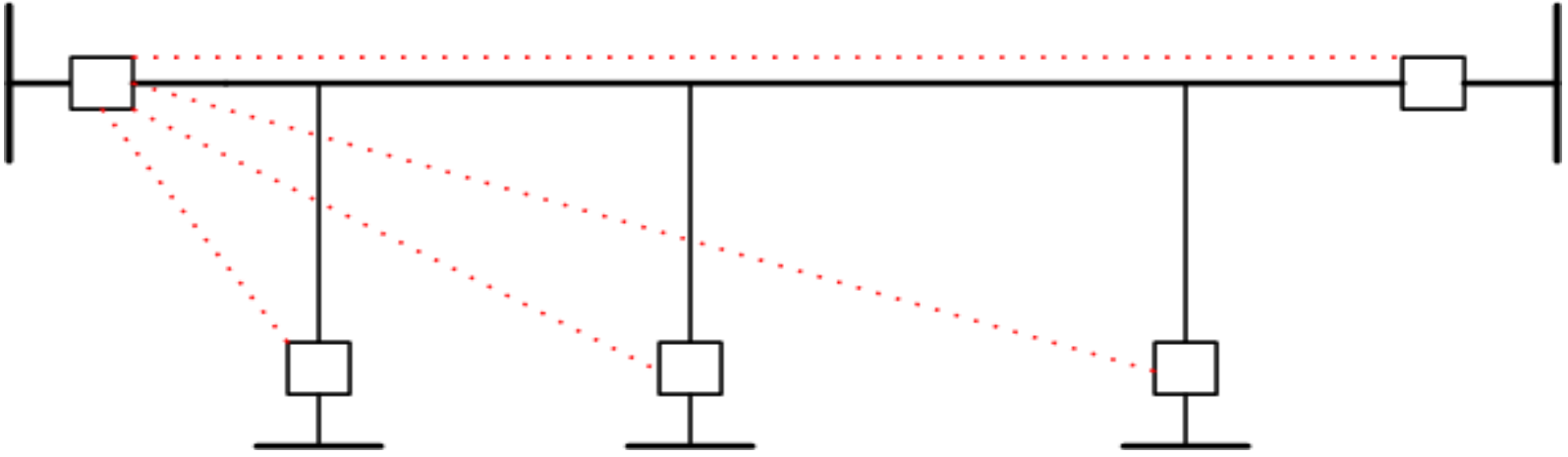
Redundant communication channels



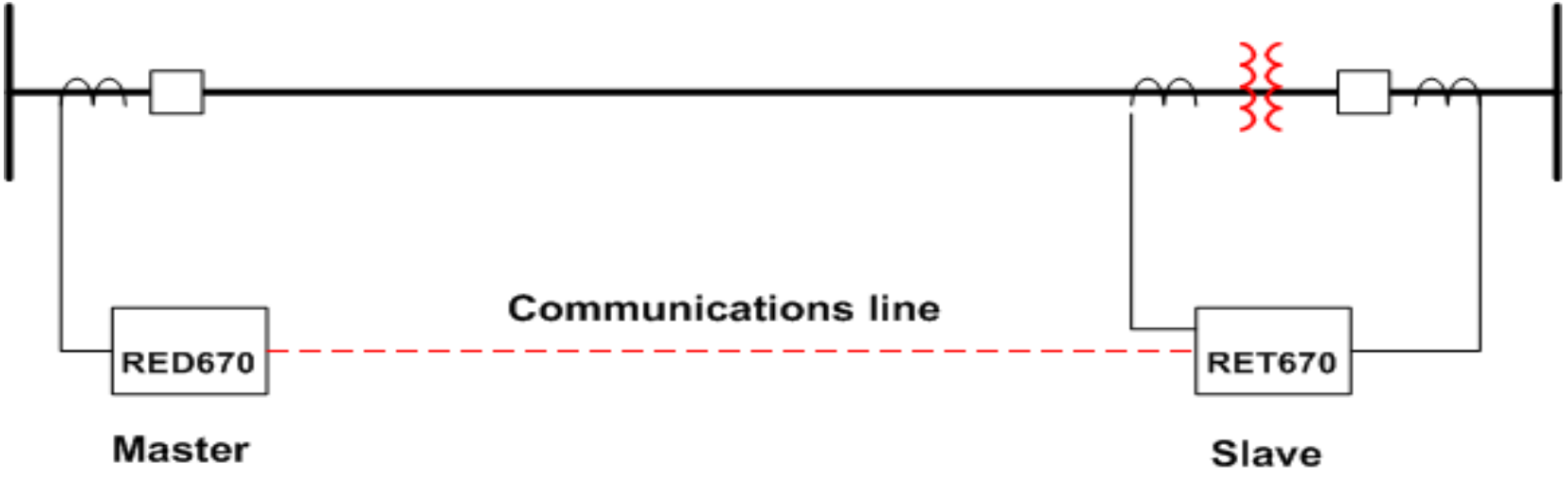
5-Terminal line
Master-master system



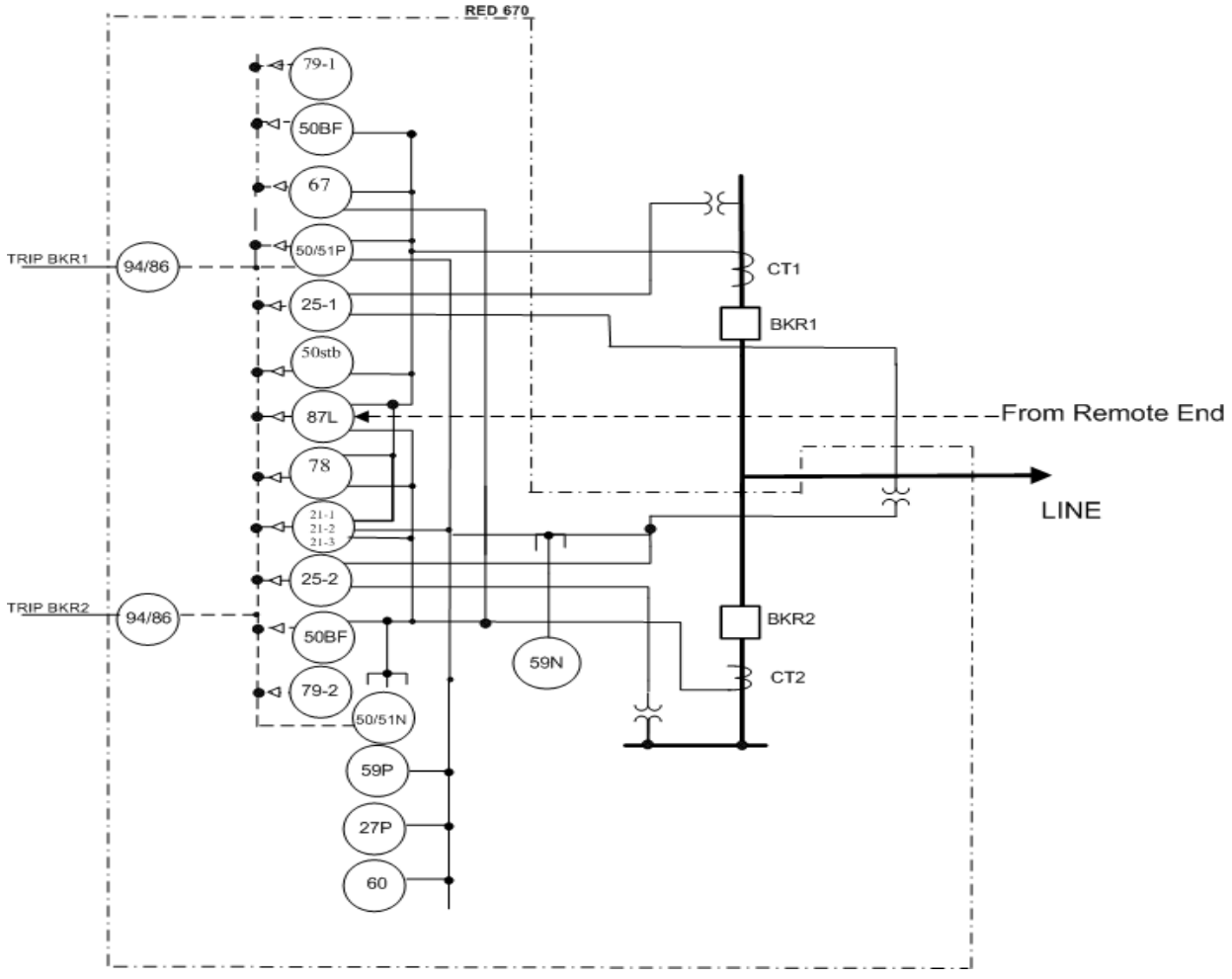
5-Terminal line
Master-slave system



Master-slave
Application example



Multifunction line current differential relay



Relion® RED670
Maximum power system reliability

Efficient substation automation for the protection, monitoring and control of high voltage overhead lines and cables

- Delivering significant savings in configuration, setting, erection, commissioning, maintenance, and space
- Improving availability with outstanding performance and efficient information management
- Enabling applications with multiple algorithms, multiple objects, integrated and distributed architectures
- Application flexibility makes them an excellent choice for both new and retrofit installations

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