



Pilot Protection of Transmission Lines

Outline

- Transmission line introduction
- Typical protection schemes
- Need for pilot aided schemes
- Various pilot schemes
- Redundancy considerations
- Desirable attributes of pilot relay



Transmission Lines

- A Vital Part of the Power System:
- Provide path to transfer power between generation and load
- Operate at voltage levels from 69kV to 765kV
- Deregulated markets, economic, environmental requirements have pushed utilities to operate transmission lines close to their limits.



Transmission Lines

- Classification of line length dependson:
 - ❑ Source-to-line Impedance Ratio (SIR), and
 - ❑ Nominal voltage
- Length considerations:
 - ❑ Short Lines: $SIR > 4$
 - ❑ Medium Lines: $0.5 < SIR < 4$
 - ❑ Long Lines: $SIR < 0.5$

Typical Protection Schemes

Short Lines

- Current differential
- Phase comparison
- Permissive Overreach Transfer Trip (POTT)
- Directional Comparison Blocking (DCB)

Typical Protection Schemes

Medium Lines

- Phase comparison
- Directional Comparison Blocking (DCB)
- Permissive Underreach Transfer Trip (PUTT)
- Permissive Overreach Transfer Trip (POTT)
- Unblocking
- Step Distance
- Step or coordinated overcurrent
- Inverse time overcurrent
- Current Differential

Typical Protection Schemes

Long Lines

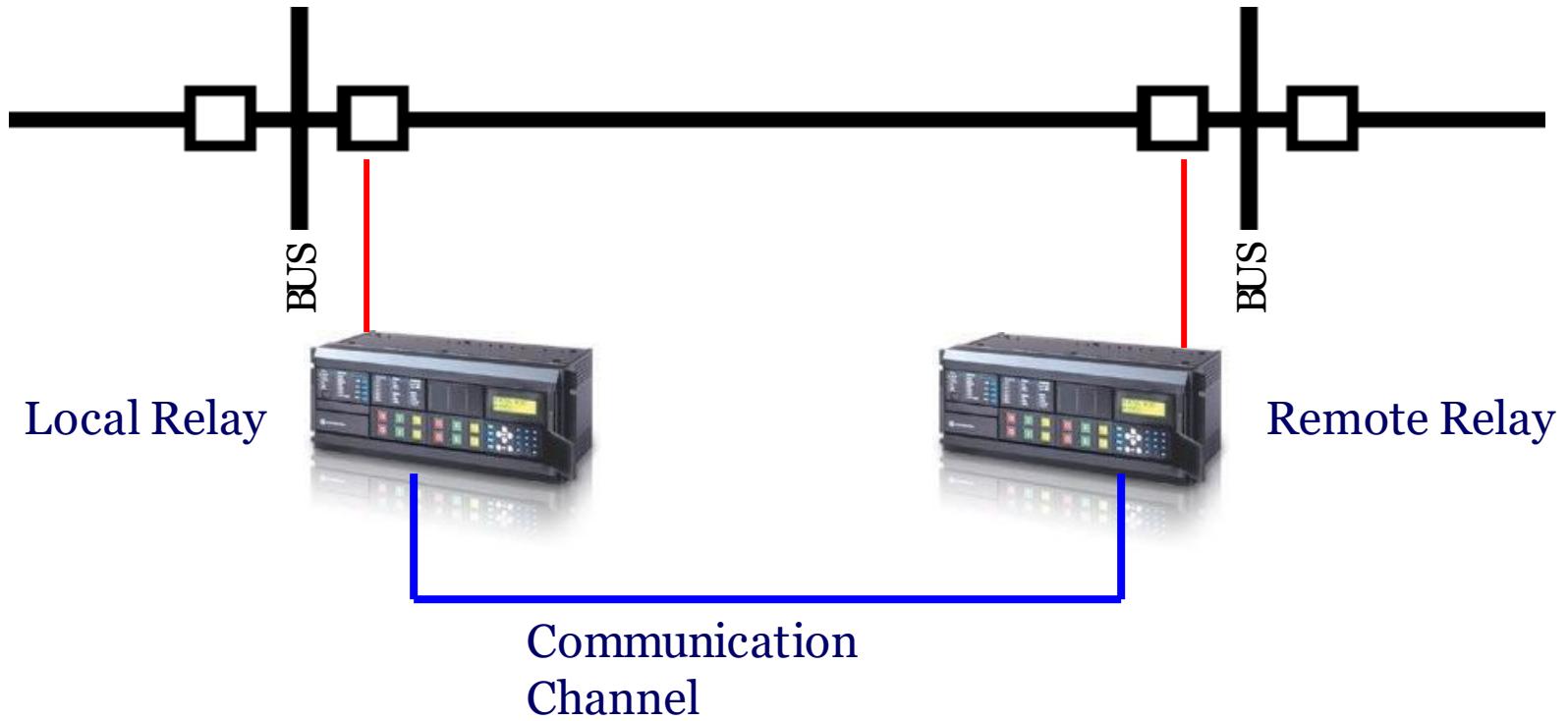
- Phase comparison
- Directional Comparison Blocking (DCB)
- Permissive Underreach Transfer Trip (PUTT)
- Permissive Overreach Transfer Trip (POTT)
- Unblocking
- Step Distance
- Step or coordinated overcurrent
- Current Differential

Introduction

- Nonpilot protection using overcurrent and distance relays, contain a fundamental difficulty :

It is not possible to instantaneously clear a fault from both ends of a transmission line if the fault is near one end of the line.
- Pilot protection is an adaptation of the principles of differential relaying that avoids the use of control cable between terminals.
- The term ‘pilot’ refers to a communication channel between two or more ends of a transmission line to provide instantaneous clearing over 100% of the line.
- This form of protection is also known as ‘teleprotection’.

Need For Pilot Aided Schemes

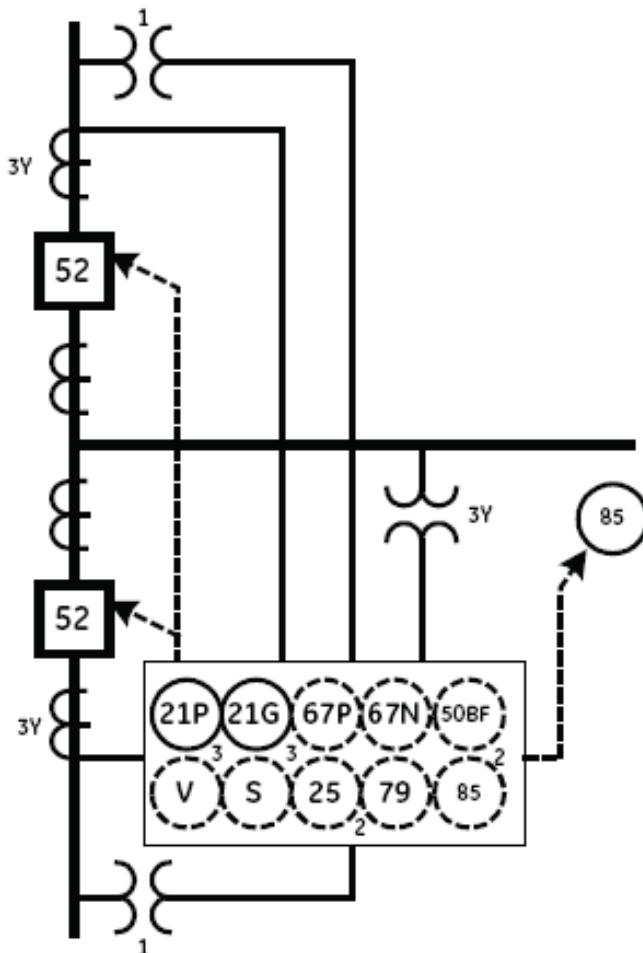


Pilot Communications Channels

- Distance-based pilot schemes traditionally utilize simple on/off communications between relays, but can also utilize peer-to-peer communications and GOOSE messaging over digital channels
- Typical communications media include:
 - Pilot-wire (50Hz, 60Hz, AT)
 - Power line carrier
 - Microwave
 - Radio
 - Optic fiber (directly connected or multiplexed channels)

Distance-based Pilot Protection

Pilot Protection Schemes – Dual Breaker



Typical Functions

- 21P Phase distance
- 21G Ground distance
- 85 Power line carrier / micro-wave transmitter & receiver

Additional Functions

- 67P Phase directional overcurrent
- 67N Neutral directional overcurrent
- 50BF Breaker Failure
- 25 Synchrocheck
- 79 Reclosing
- V, S Voltage and Power metering

Other Communications Options

- 85 Inter-Relay Communications
- 85 Sonet Multiplexer

Synchrophasors

- Phasor Measurement Unit

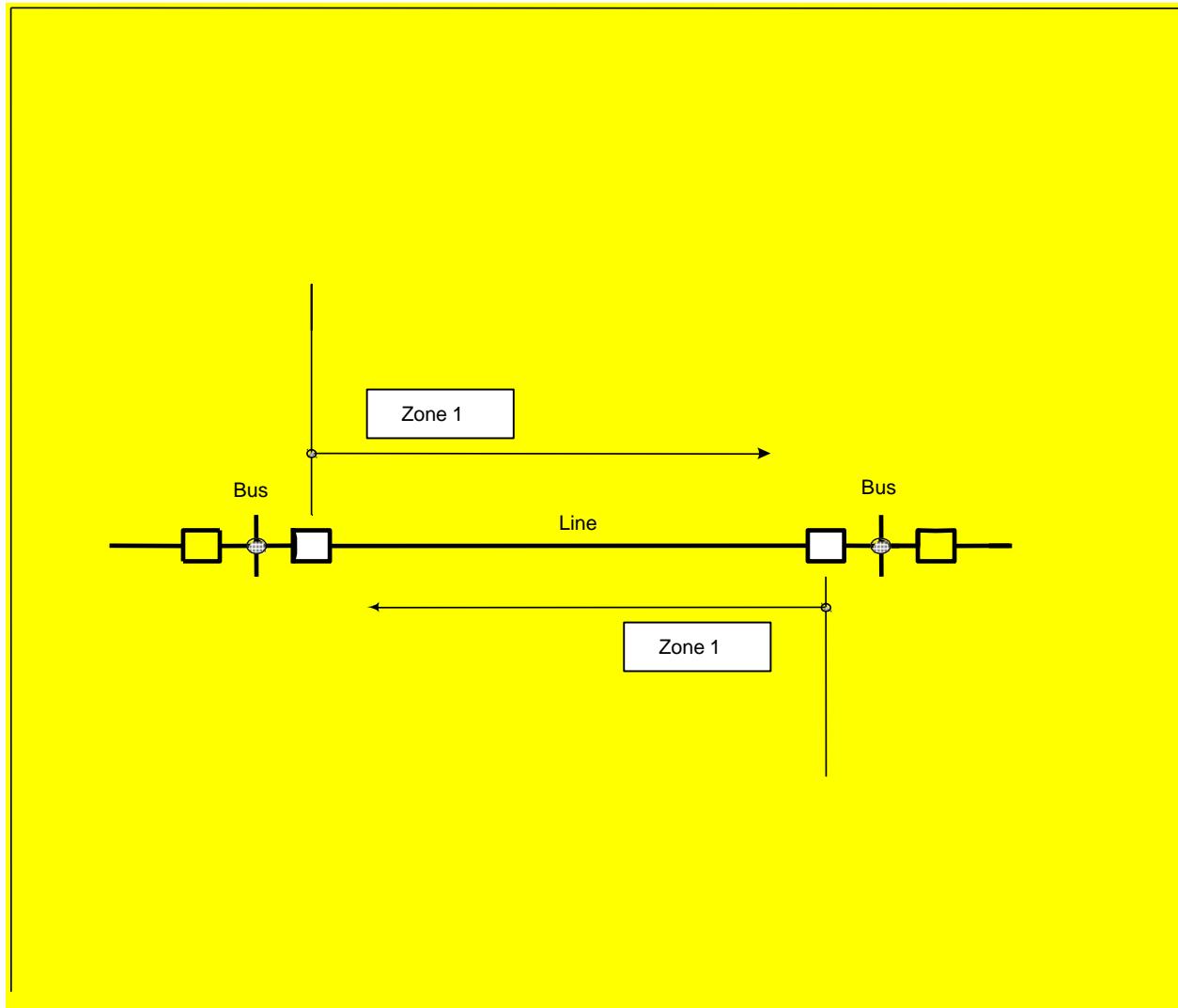
Pilot-Aided Distance-Based Schemes

- **DUTT** –Direct Under-reaching Transfer Trip
- **PUTT** –Permissive Under-reaching Transfer Trip
- **POTT** –Permissive Over-reaching Transfer Trip
- **Hybrid POTT** –Hybrid Permissive Over-reaching Transfer Trip
- **DCB** –Directional Comparison Blocking Scheme
- **DCUB** –Directional Comparison Unblocking Scheme

Direct Underreaching Transfer Trip (DUTT)

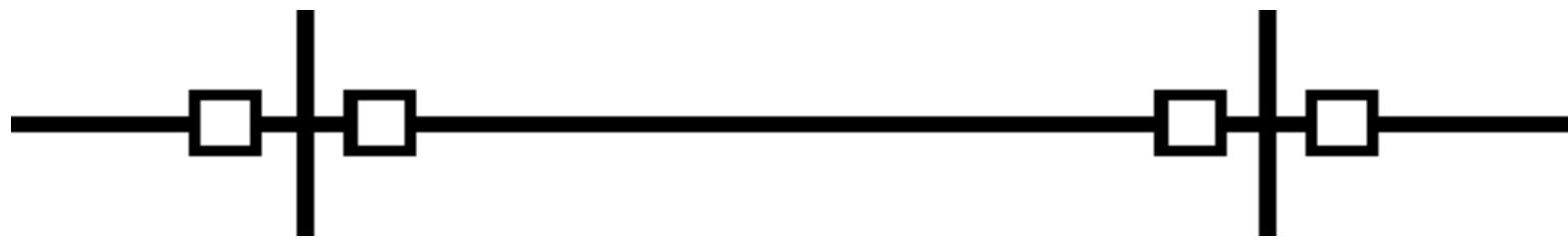
- Requires only underreaching (RU) functions which overlap in reach (Zone 1).
- Applied with FSK channel
 - GUARD frequency transmitted during normal conditions
 - TRIP frequency when one RU function operates
- Scheme does not provide tripping for faults beyond RU reach if remote breaker is open or channel is inoperative.
- Dual pilot channels improve security

DUTT Scheme



Permissive Underreaching Transfer Trip (PUTT)

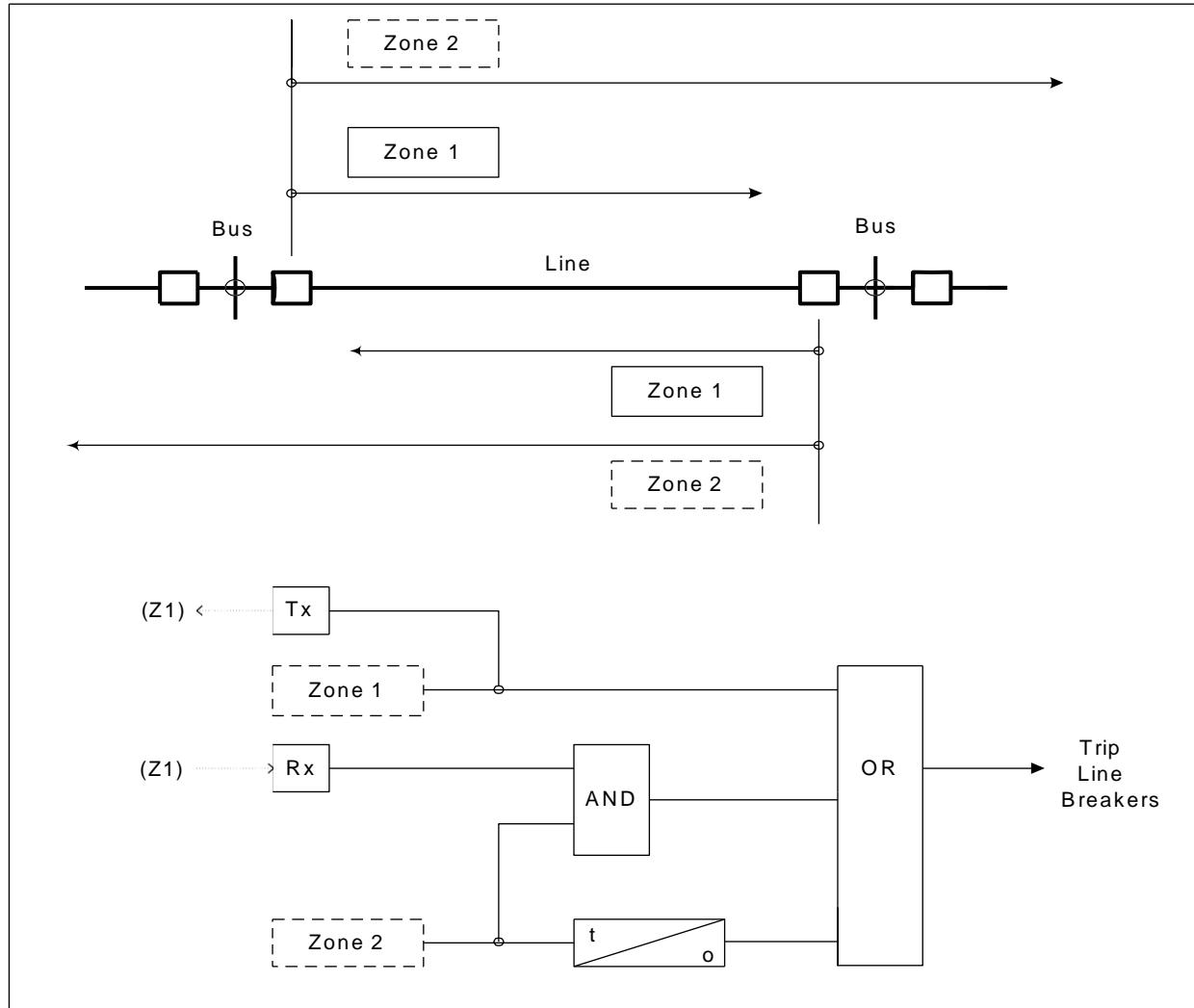
- Requires both under (RU) and overreaching (RO) functions
- Identical to DUTT, with pilot tripping signal supervised by RO(Zone 2)



Permissive Overreaching Transfer Trip (POTT)

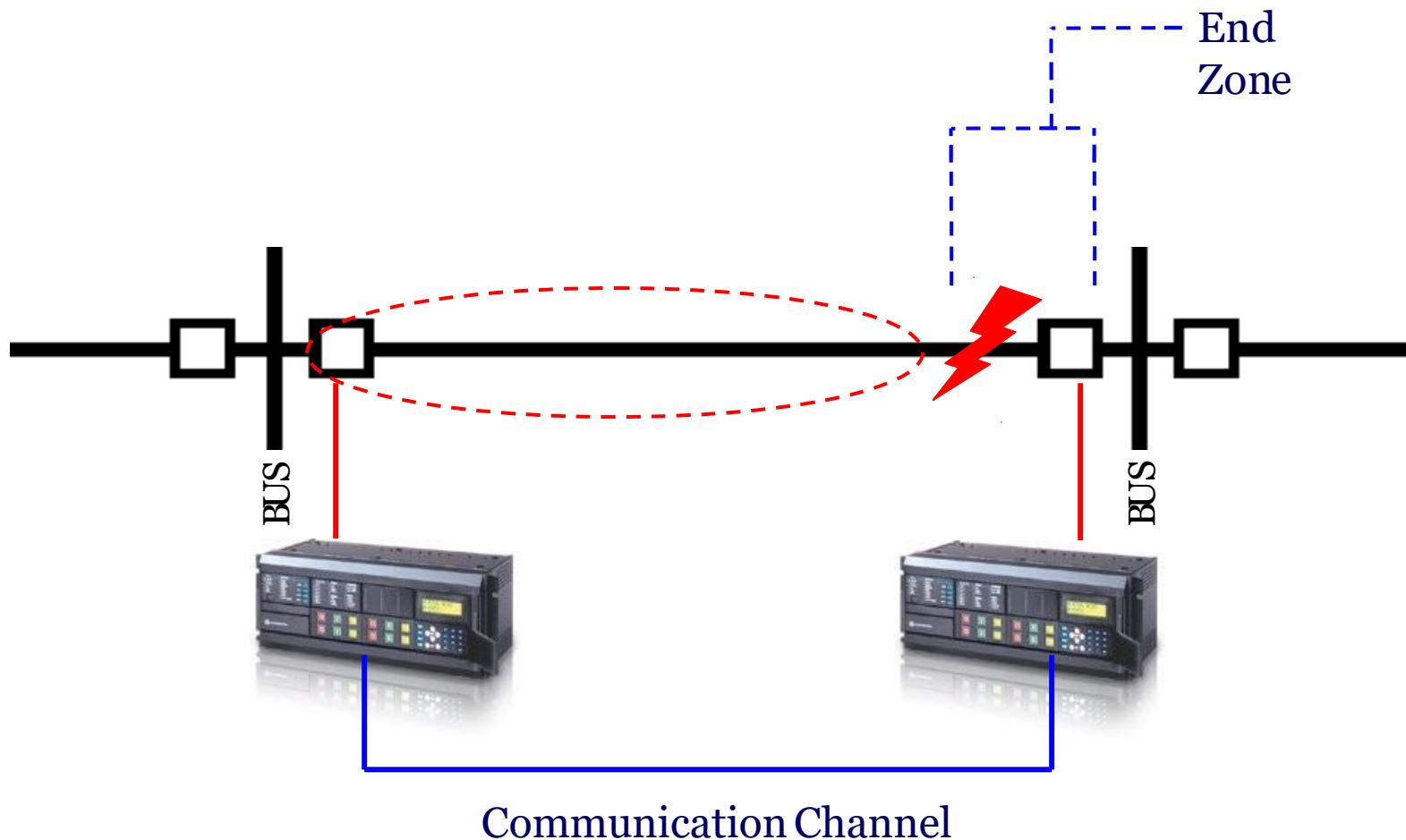
- Requires overreaching (RO) functions (Zone 2).
- Applied with FSKchannel:
 - GUARDfrequency sent in stand-by
 - TRIPfrequency when one ROfunction operates
- No trip for external faults if pilot channel is inoperative
- Time-delayed tripping can be provided

POTT Scheme

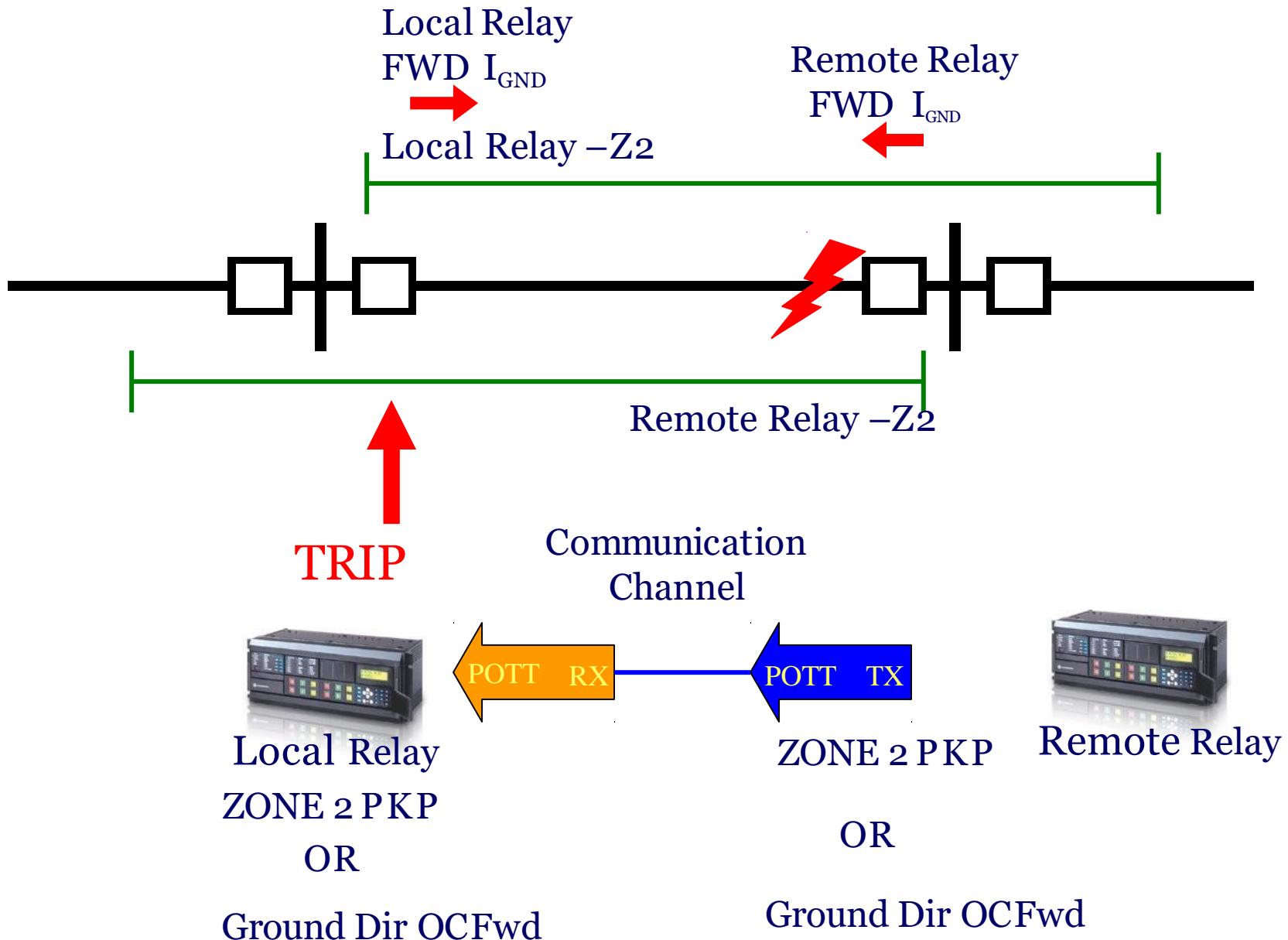


POTT Scheme

POTT –Permissive Over-reaching Transfer Trip



POTT Scheme



POTT Scheme



Local Relay

POTT RX 1
POTT RX 2
POTT RX 3
POTT RX 4

Communications
Channel(s)

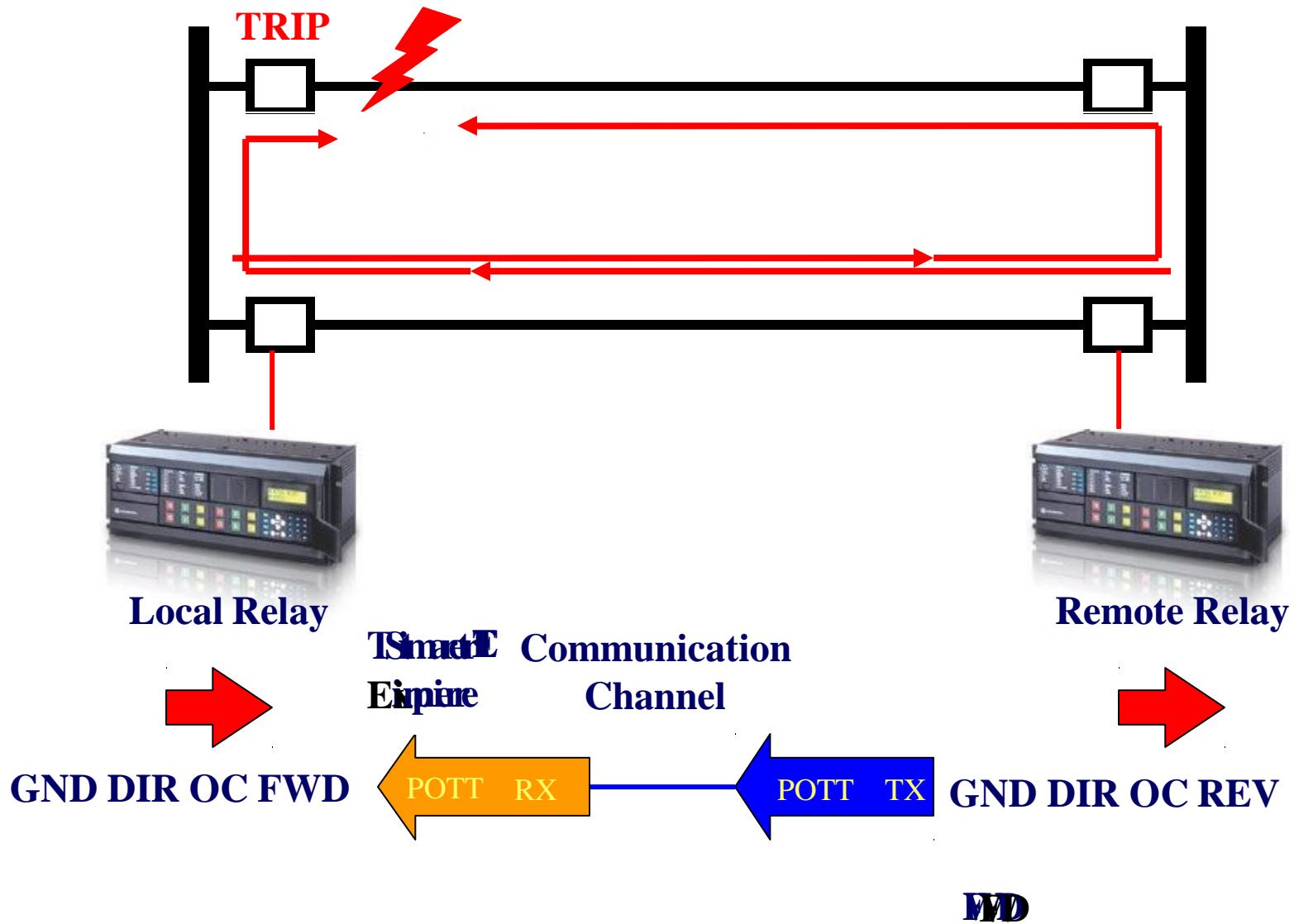
POTT TX 1 A to G
POTT TX 2 B to G
POTT TX 3 C to G
POTT TX 4 Multi Phase



Remote Relay

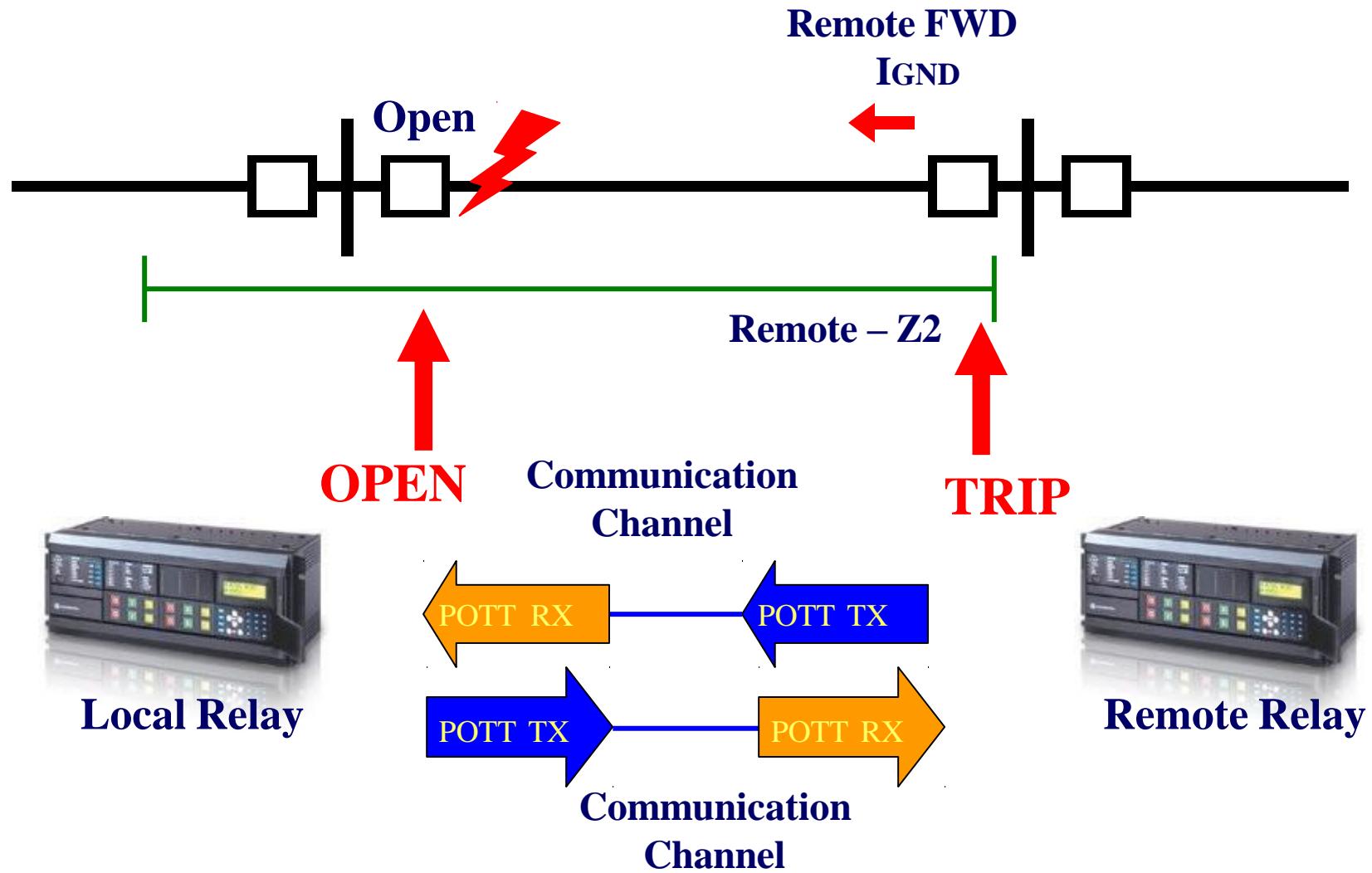
POTT Scheme

Current reversal example



POTT Scheme

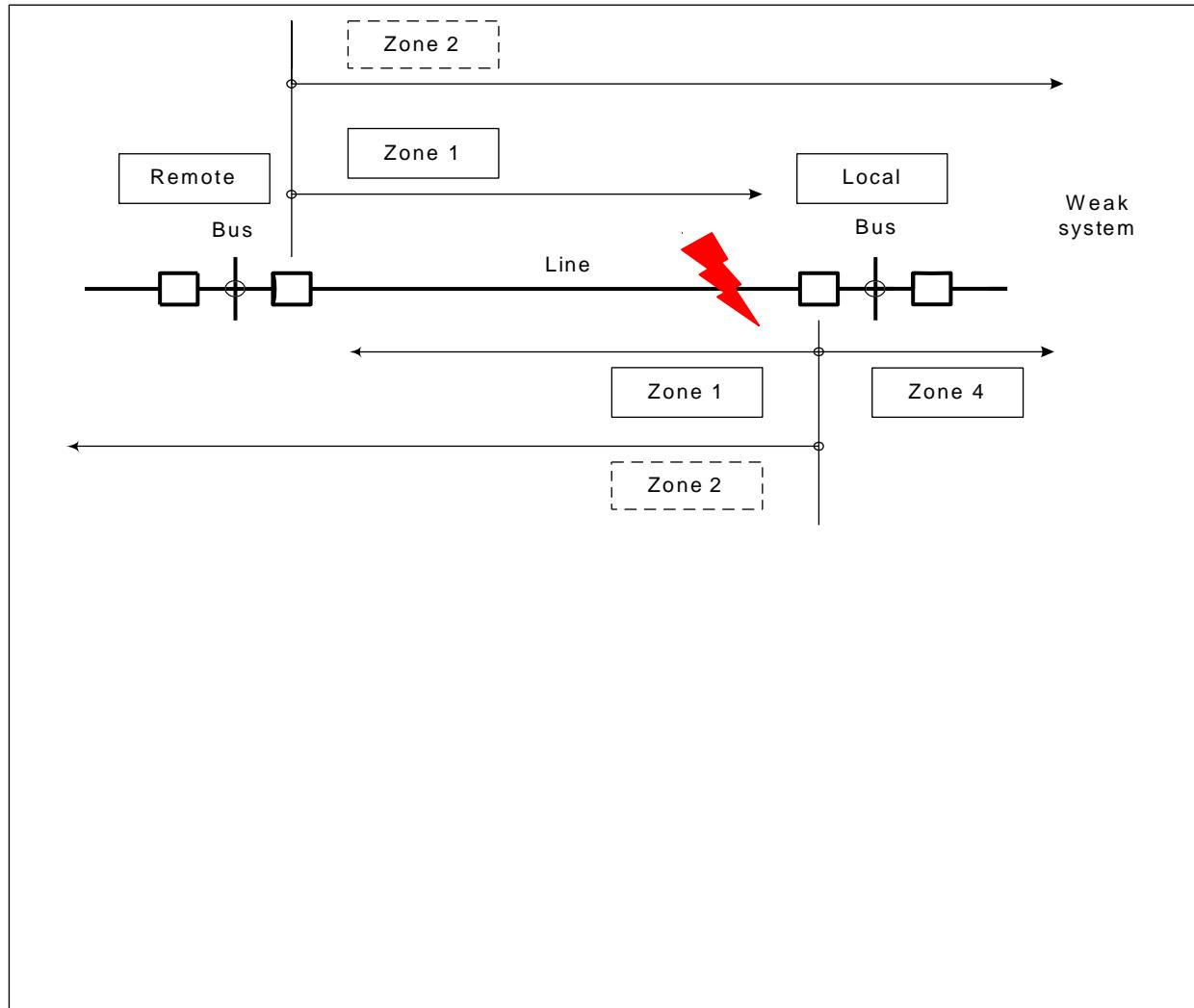
Echo example



Hybrid POTT

- Intended for three-terminal lines and weak infeed conditions
- Echo feature adds security during weak infeed conditions
- Reverse-looking distance and oc elements used to identify external faults

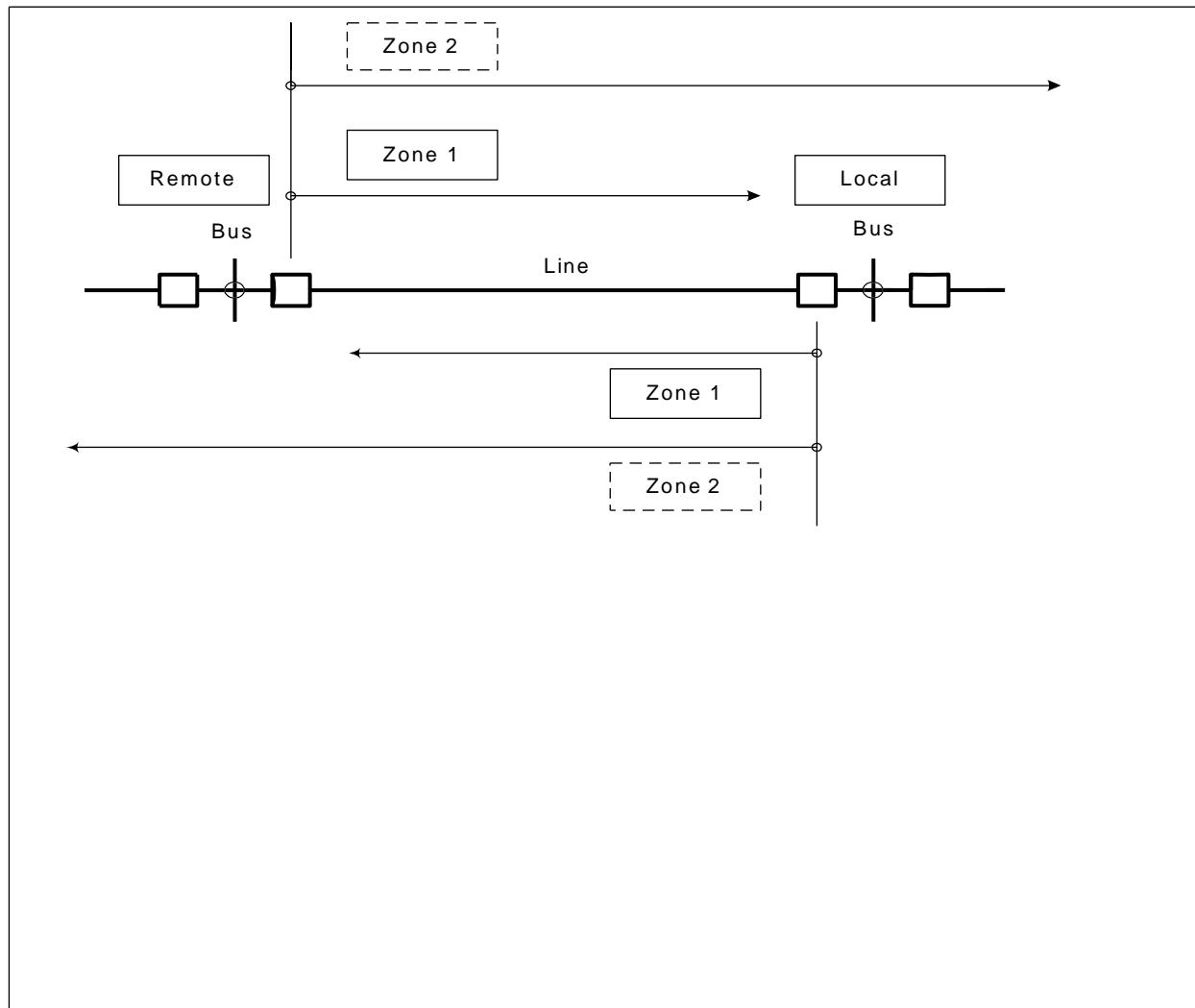
Hybrid POTT



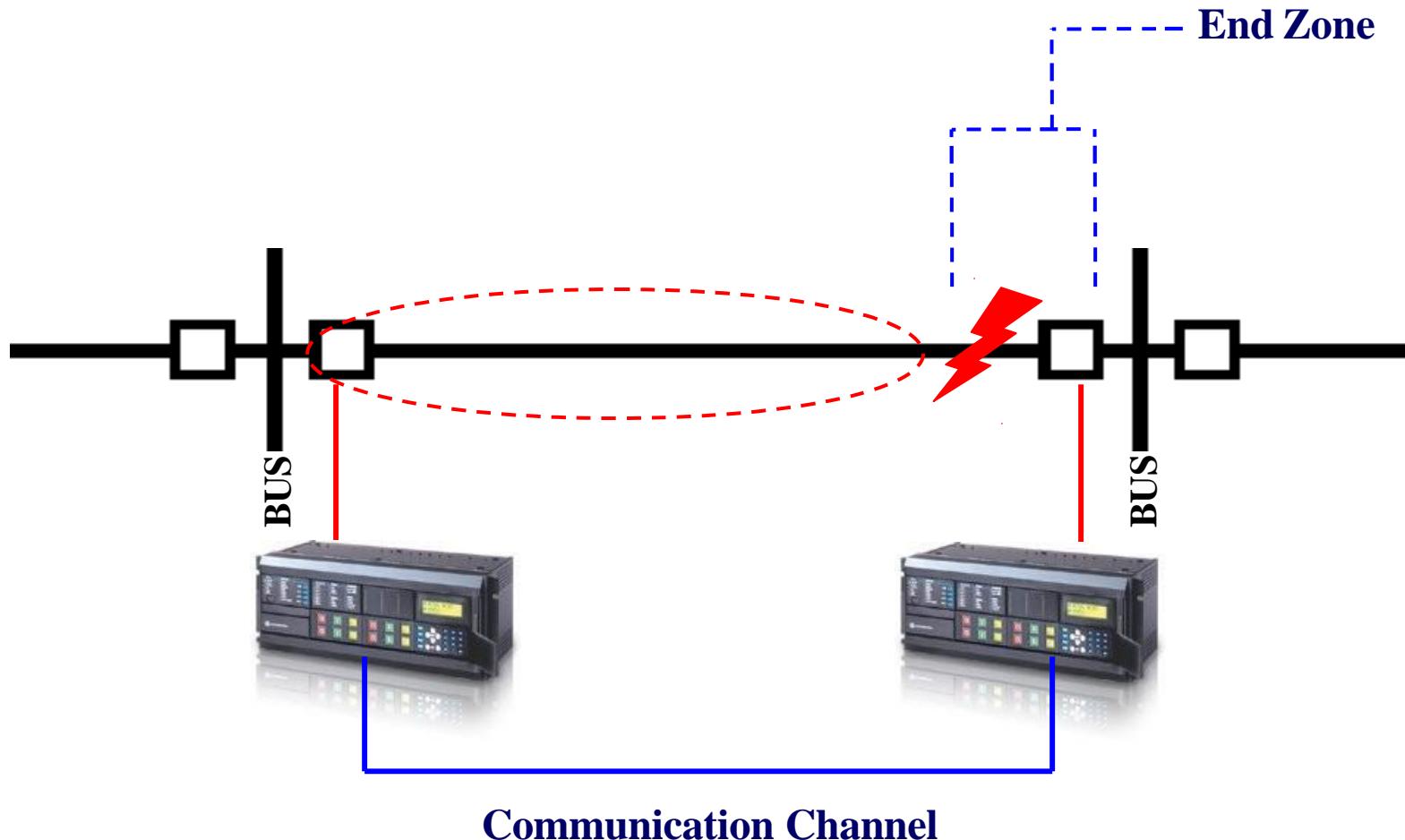
Directional Comparison Blocking (DCB)

- Requires overreaching (RO) tripping and blocking (B) functions
- ON/OFF pilot channel typically used (i.e., PLC)
 - Transmitter is keyed to ON state when blocking function(s) operate
 - Receipt of signal from remote end blocks tripping relays
- Tripping function set with Zone 2 reach or greater
- Blocking functions include Zone 3 reverse and low-set ground overcurrent elements

DCB Scheme

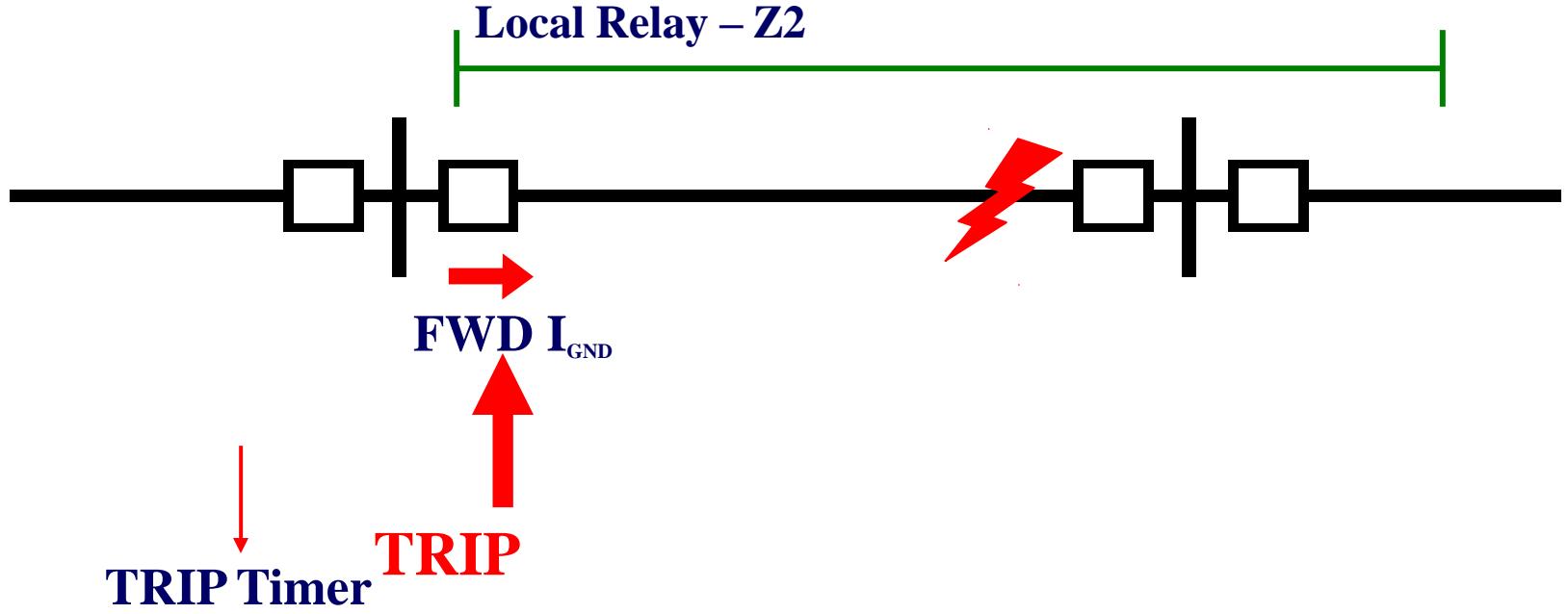


Directional Comparison Blocking (DCB)



Directional Comparison Blocking (DCB)

Internal Faults



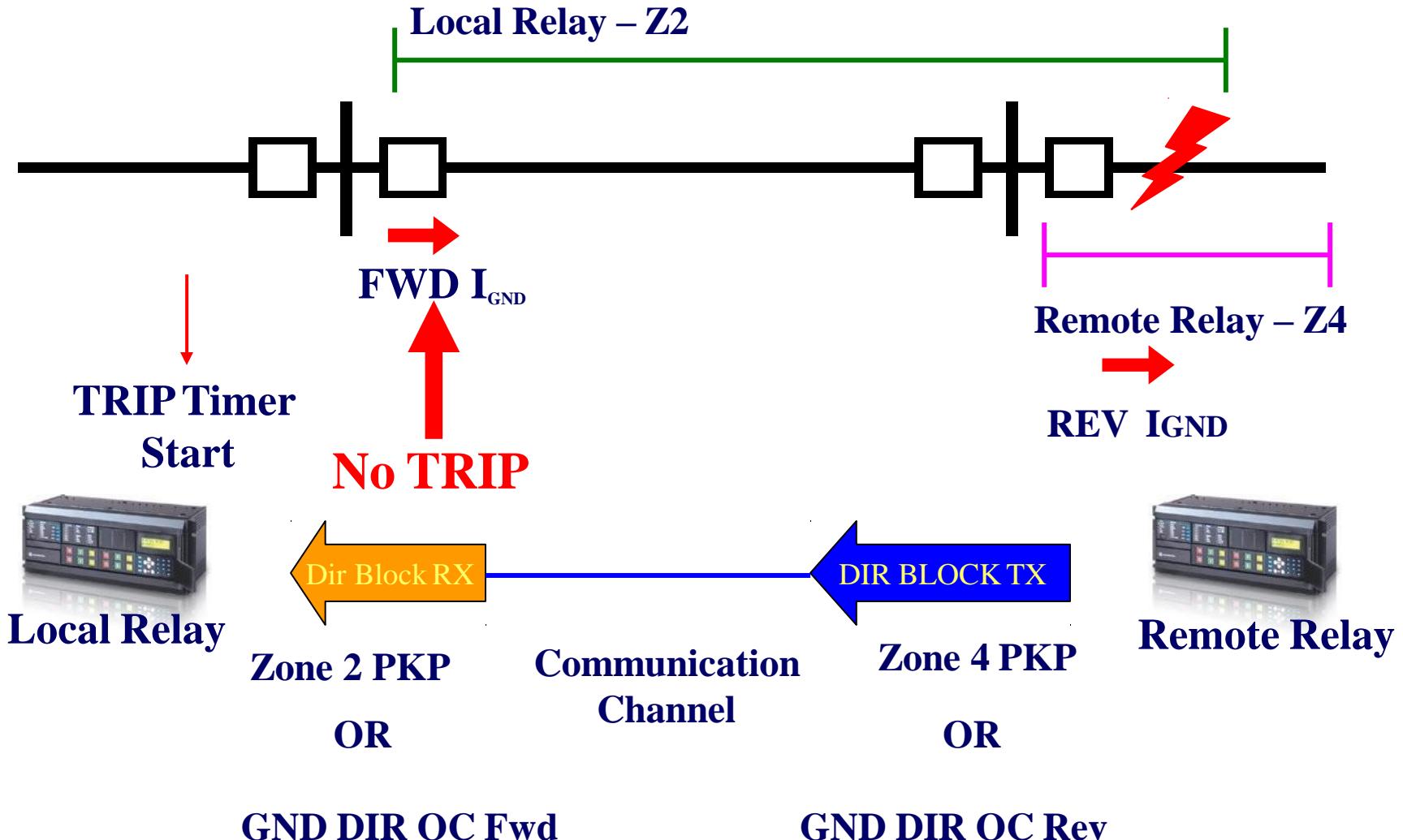
Zone 2 PKP
OR
Local Relay GND DIR OC Fwd



Remote Relay

Directional Comparison Blocking (DCB)

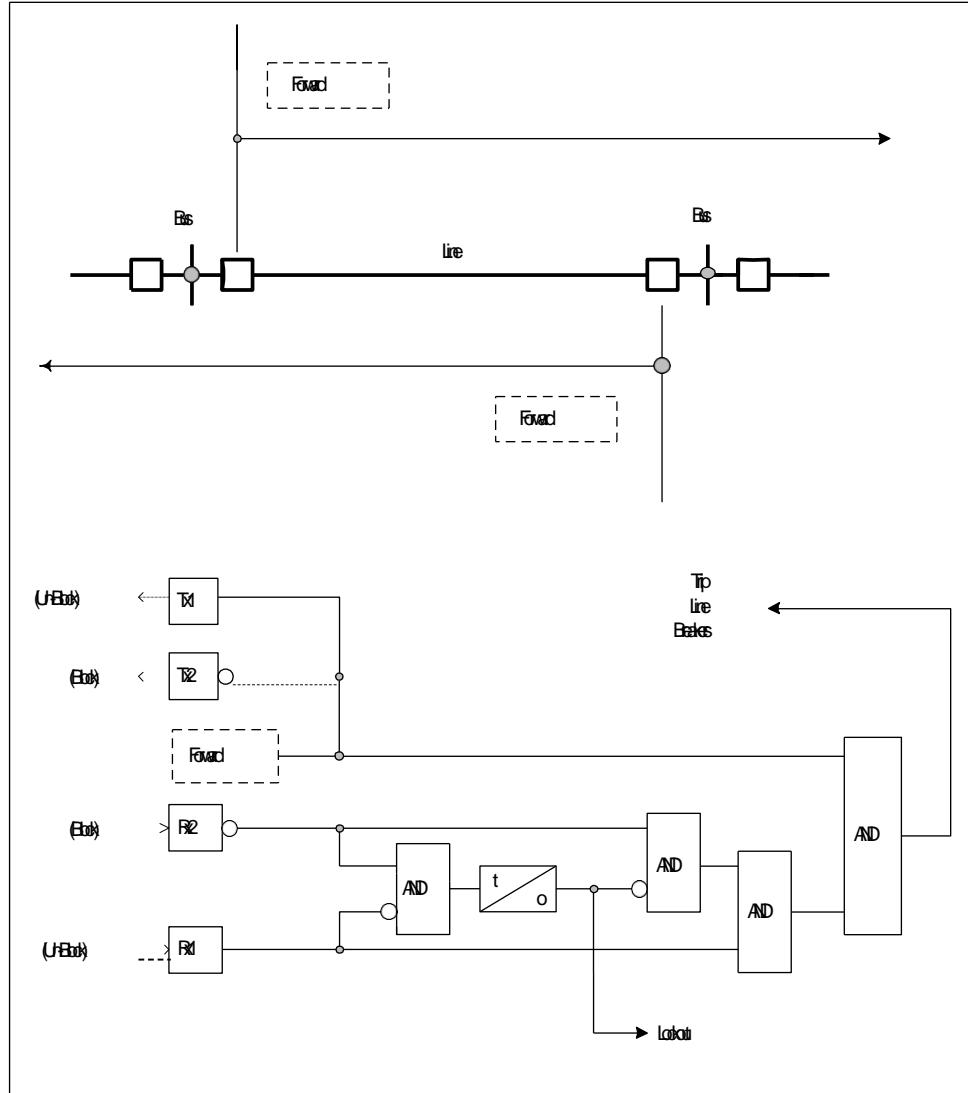
External Faults



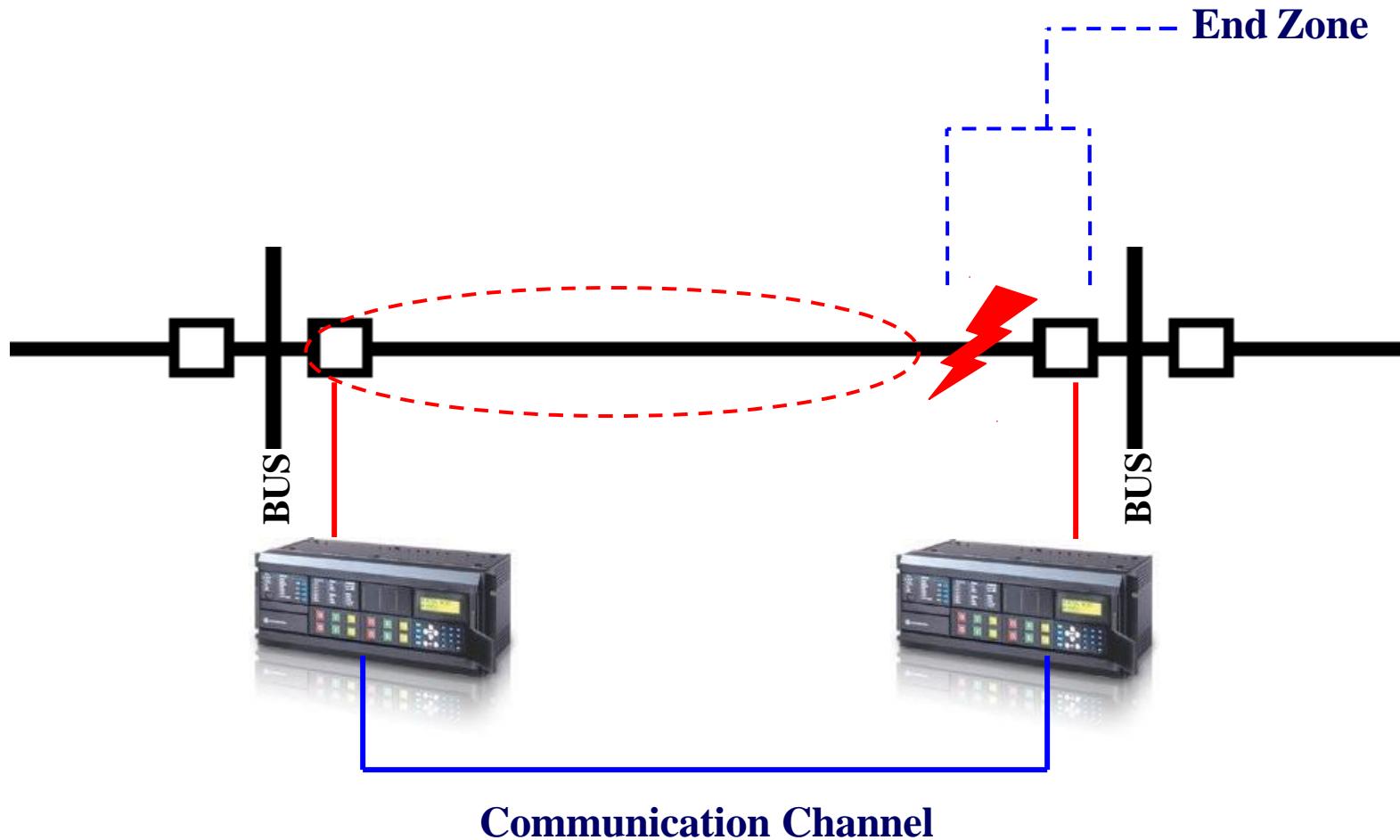
Directional Comparison Unblocking (DCUB)

- Applied to Permissive Overreaching (POR) schemes to overcome the possibility of carrier signal attenuation or loss as a result of the fault
- Unblocking provided in the receiver when signal is lost:
 - If signal is lost due to fault, at least one permissive ROfunctions will be picked up
 - Unblocking logic produces short-duration TRIP signal (150-300 ms). If ROfunction not picked up, channel lockout occurs until GUARD signal returns

DCUB Scheme

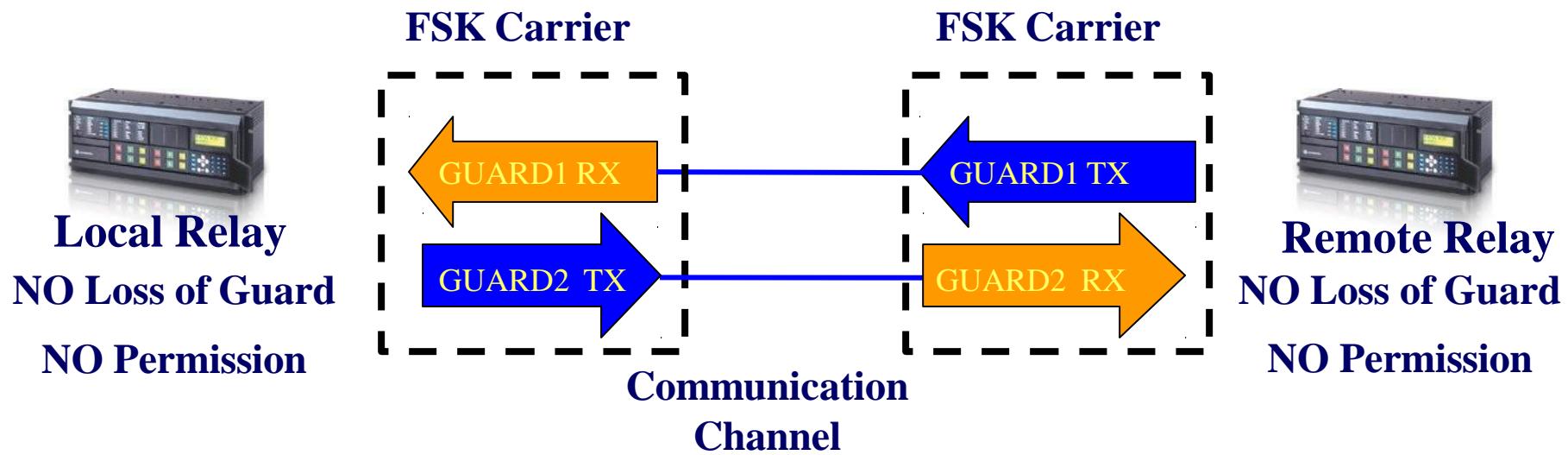


Directional Comparison Unblocking (DCUB)



Directional Comparison Unblockng (DCUB)

Normal conditions



Directional Comparison Unblock (DCUB)

Normal conditions, channel failure



Loss of Channel

FSK Carrier

FSK Carrier



Local Relay
Loss of Guard

Block Timer Expired

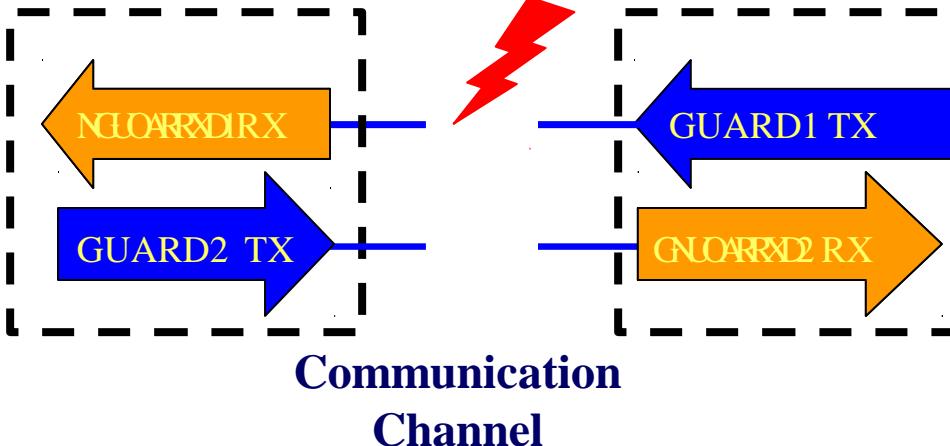
Block DCUB^{ed}
until Guard OK



Remote Relay
Loss of Guard

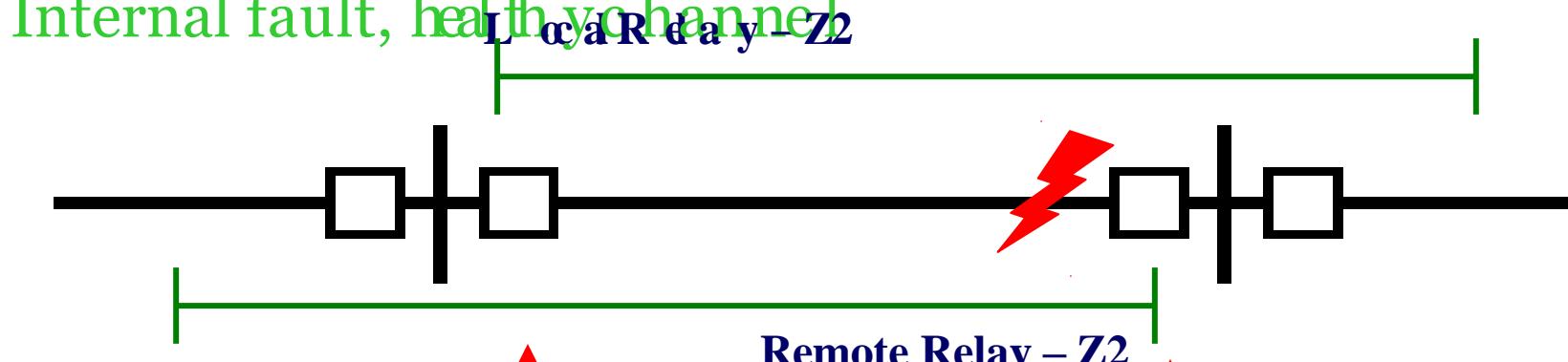
Block Timer Expired

Block DCUB^{ed}
until Guard OK



Directional Comparison Unblock (DCUB)

Internal fault, healthy channel



TRIP

TRIP Z1

FSK Carrier

FSK Carrier



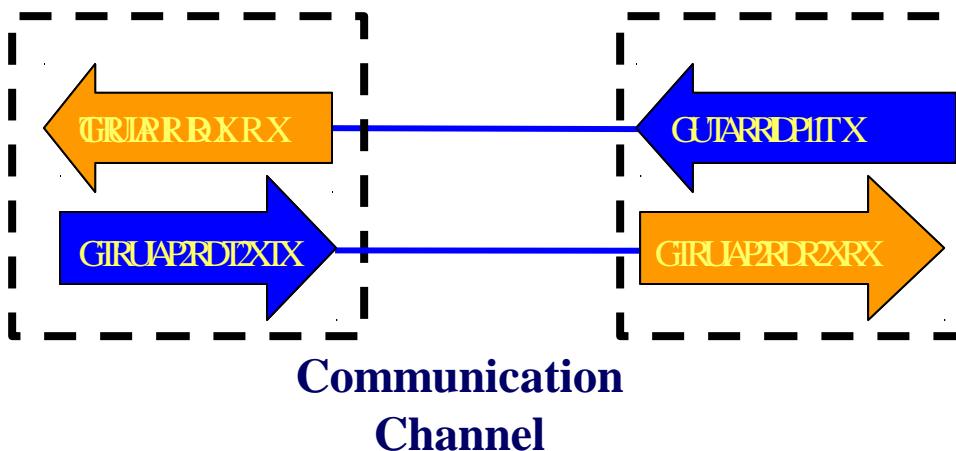
Local Relay

Zone 2 PKP

Loss of Guard
Permission

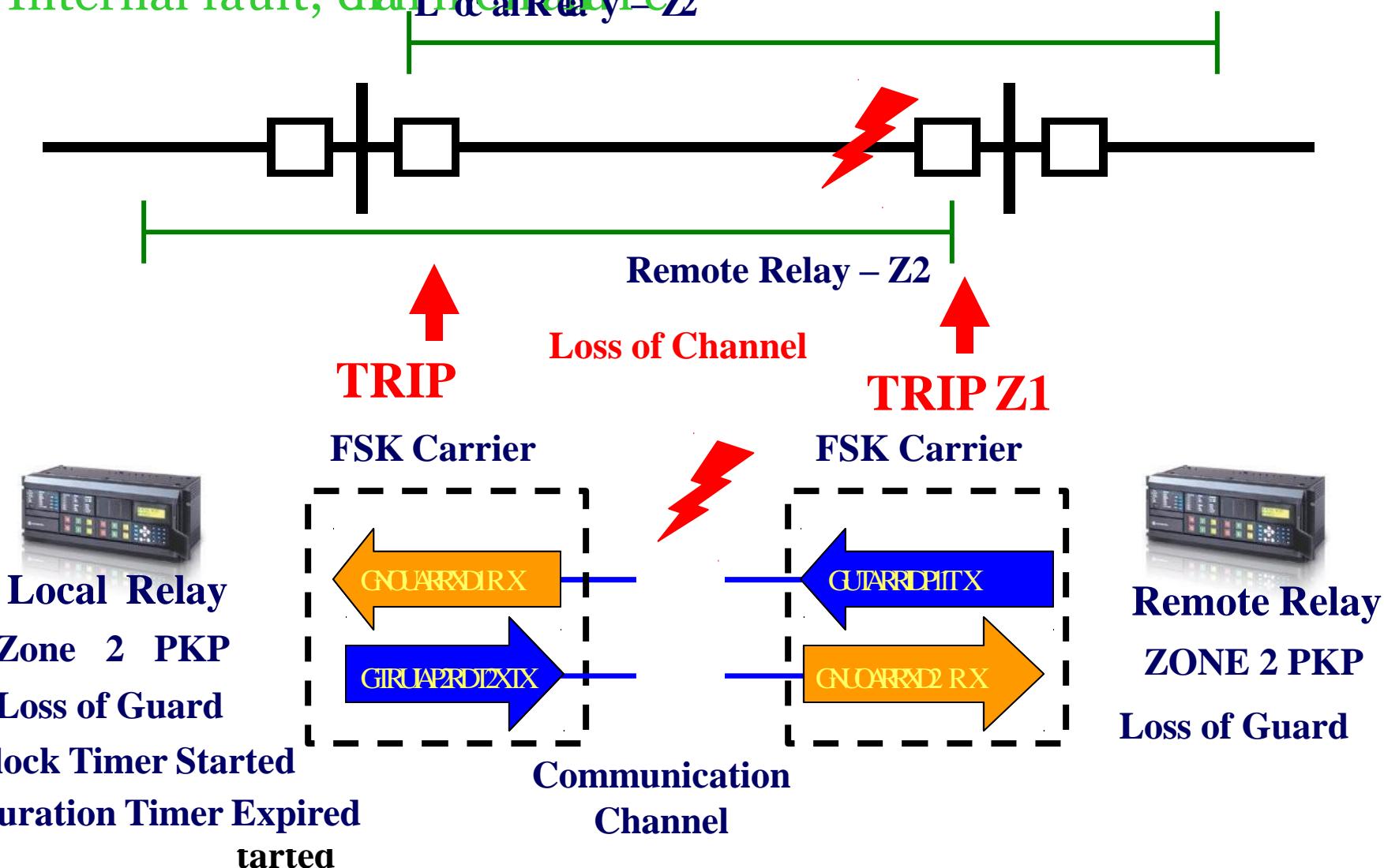


Remote Relay
ZONE 2 PKP



Directional Comparison Unblock (DCUB)

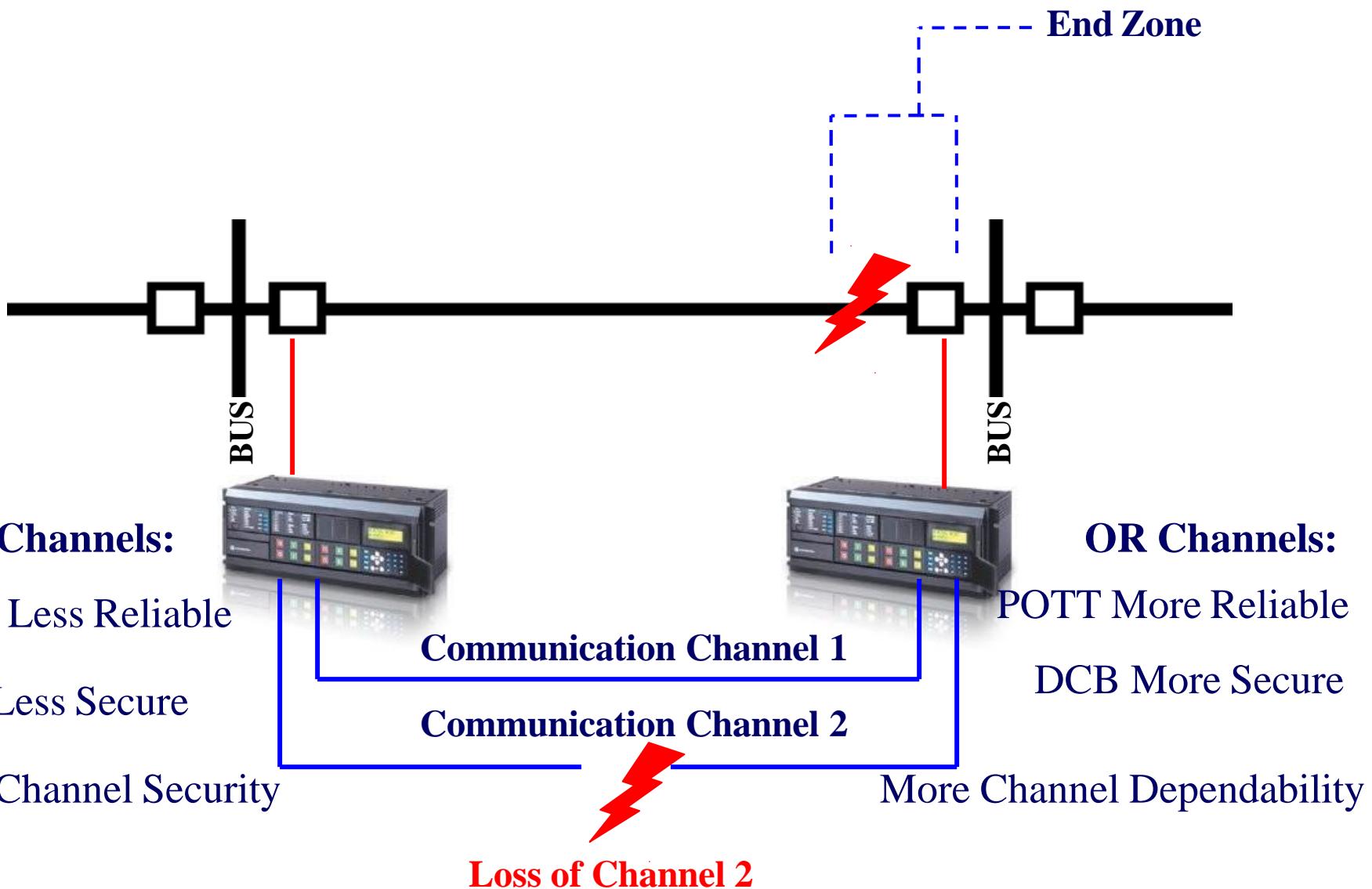
Internal fault, channel failure



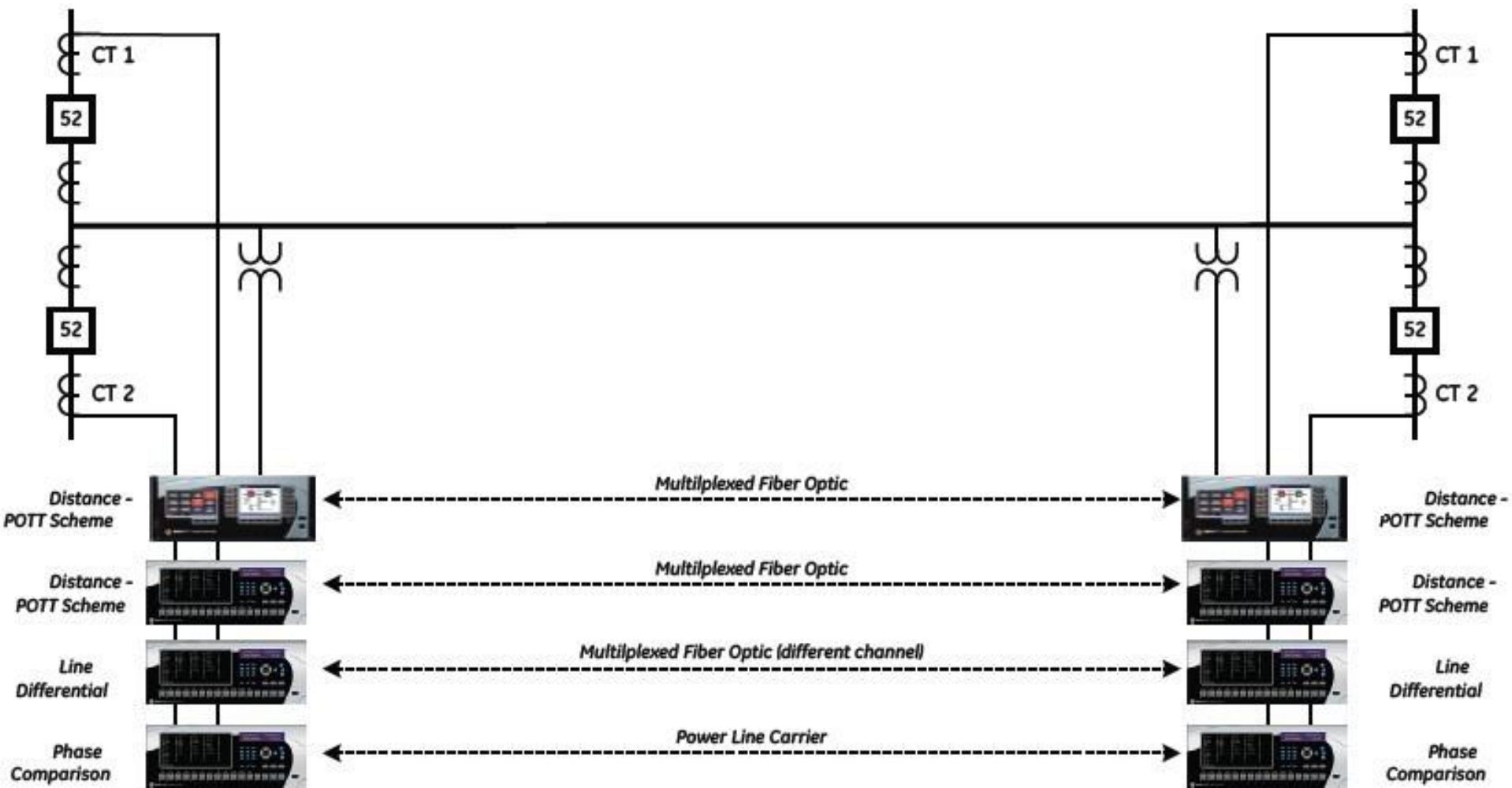
Redundancy Considerations

- Redundant protection systems increase dependability of the system:
 - Multiple sets of protection using *same protection principle* and multiple pilot channels overcome individual element failure, or
 - Multiple sets of protection using *different protection principles* and multiple channels protects against failure of one of the protection methods.
- Security can be improved using “voting” schemes (i.e., 2-out-of-3), potentially at expense of dependability.
- Redundancy of instrument transformers, battery systems, trip coil circuits, etc. also need to be considered.

Redundant Communications



Redundant Pilot Schemes



Pilot Relay Desirable Attributes

- Integrated functions:
 - weak infeed
 - echo
 - line pick-up (SOTF)
- Basic protection elements used to key the communication:
 - distance elements
 - fast and sensitive ground (zero and negative sequence) directional I/Os with current, voltage, and/or dual polarization



Questions?

