Directional Comparison Blocking Fundamentals

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Introduction

- Review the fundamentals of directional comparison blocking schemes (DCB), which is one of several directional comparison communication assisted schemes
- Discuss the operational concept of the DCB scheme using “on/off” power line carrier
- Address issues pertaining to reliability and performance
  - pros and cons of using “non-directional” or “directional” start of the blocking signal
  - blocking coordination timer
  - carrier hole issues and mitigation
- Develop an understanding that an apparently simple DCB scheme requires a deeper understanding to insure optimum implementation.

Terms

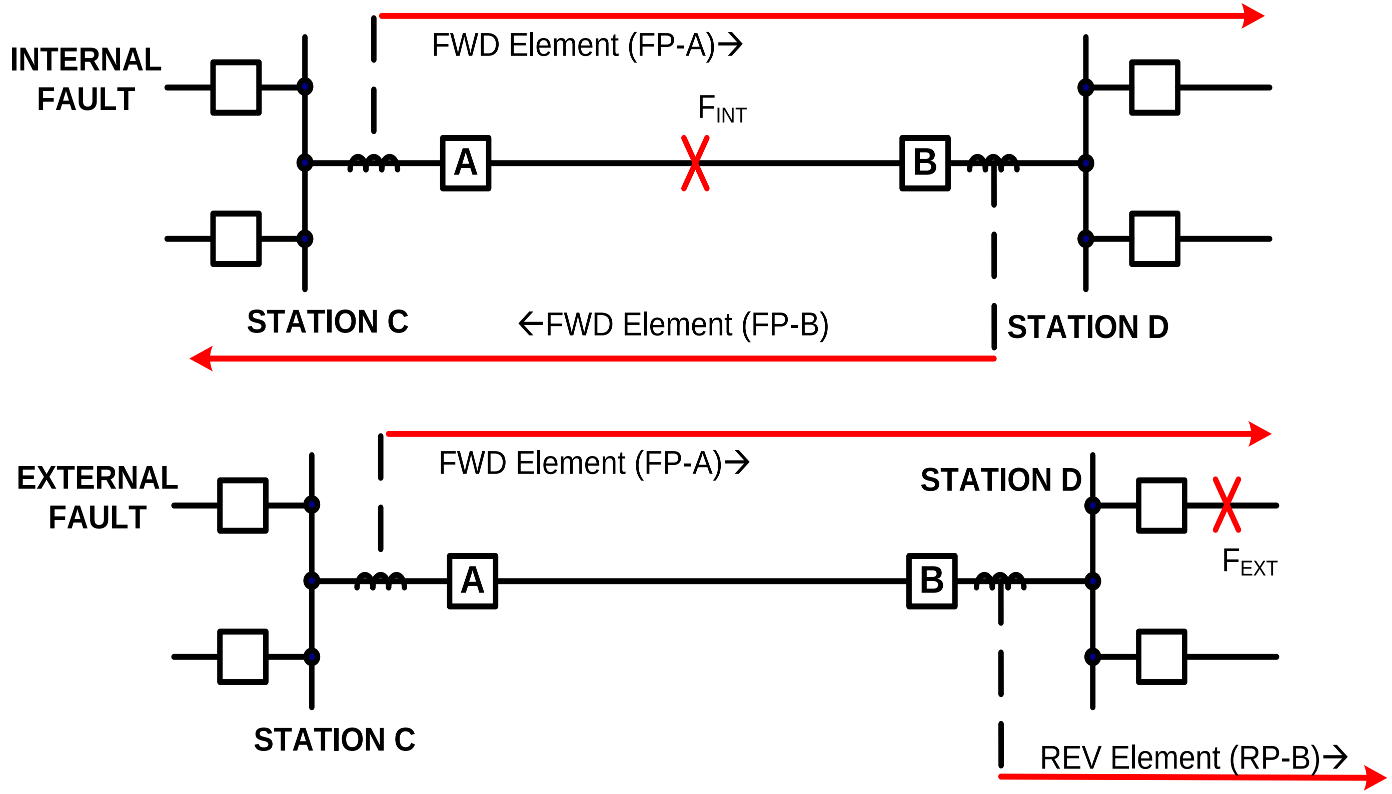
- **Pilot** – A scheme utilizing communication of information between source terminals of the transmission line. It is also known as a communications assisted scheme.
- **PLC** – Power Line Carrier - a pilot scheme using the power line as the signal medium.
- **FP** – A forward directional protection element (e.g. overcurrent or impedance function) used in a DCB scheme to detect a forward fault.
- **F** – The suffix on an IEEE relay number defined in C37.2 to indicate a protection element that detects a forward fault (e.g. 21F, 67NF).

Terms

- **RP** – A reverse directional protection element (e.g. overcurrent or impedance function) used in a DCB scheme to detect a reverse fault.
- **R** – The suffix on an IEEE relay number defined in C37.2 to indicate a protection element that detects a reverse fault (e.g. 21R, 67NR).
- **BLOCK** – A carrier signal received from the remote terminal(s) that is used to block tripping of the forward pilot supervised protection elements.
- **I0** – Normally a low set 50N unit, but used here as a generic non-directional start.

Directional Comparison

Directional Comparison relaying interprets the direction to the fault as internal or external



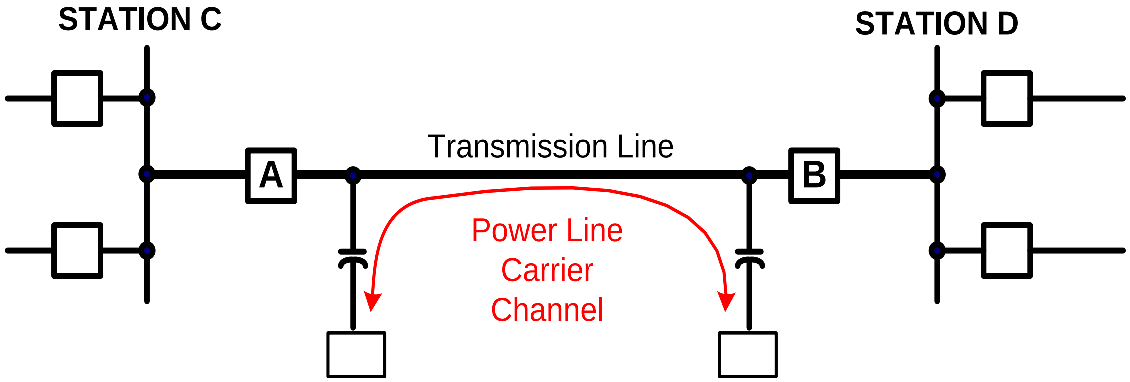
Directional Comparison Schemes

- Commonly used types of directional comparison systems
  - POTT – permissive overreaching transfer trip
  - PUTT – permissive underreaching transfer trip
  - DCB – directional comparison blocking
  - DCUB – directional comparison unblocking

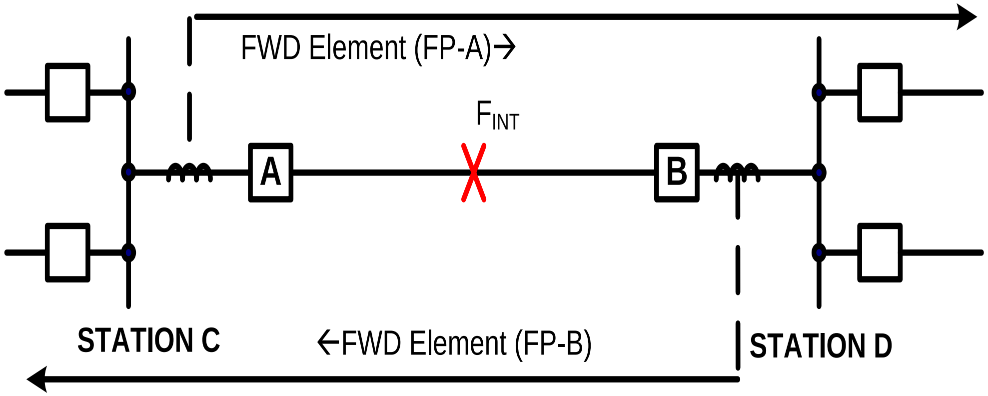
Directional Comparison Blocking

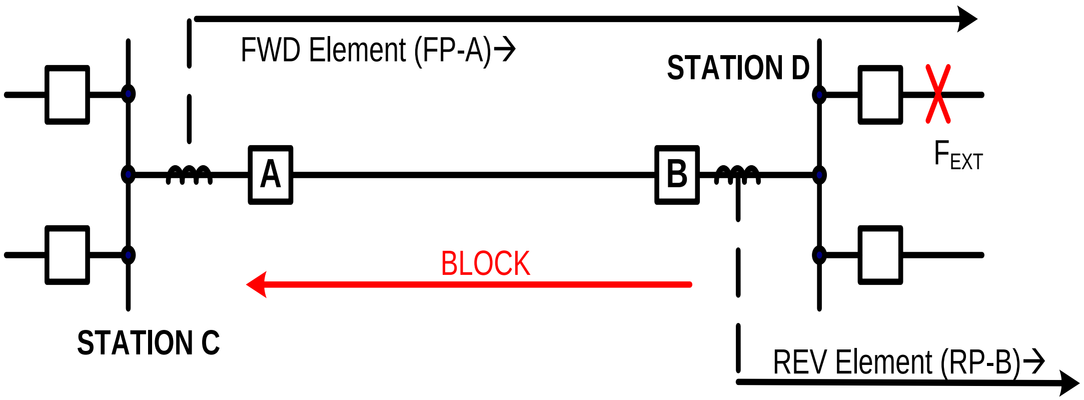
- DCB is specifically intended to be used with systems where communications is less secure (likely to be lost) during line fault conditions

- On/Off power-line carrier – *signal communications is on same conductor that you are protecting*



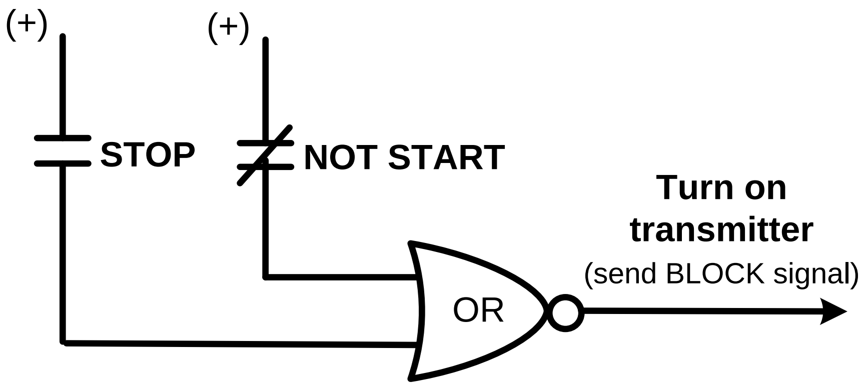
Directional Comparison Blocking



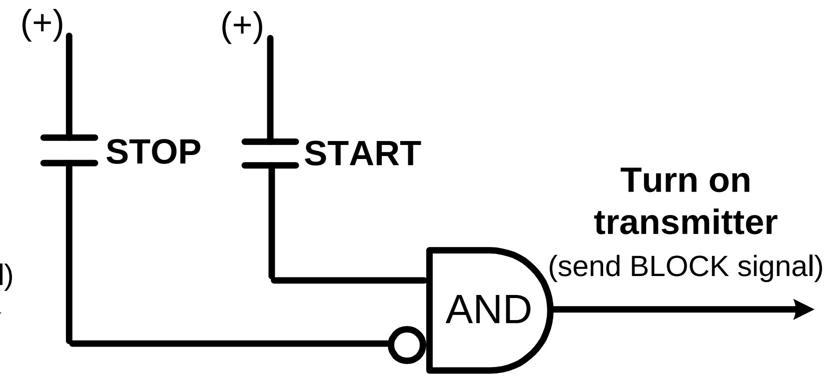


- Dependable during <u>internal faults</u> – *trips without depending on carrier signal*
- Secure for <u>external faults</u> – *blocks tripping for external faults*
- RP-B must be set more sensitive than FP-A

Basic Channel Start and Stop Logic



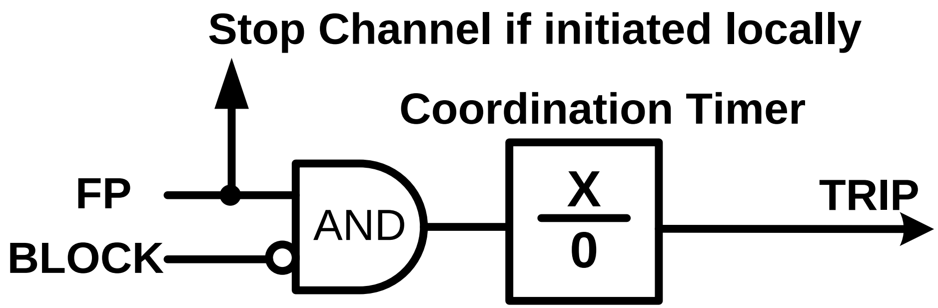
(a) Key transmitter with opening of normally closed contact



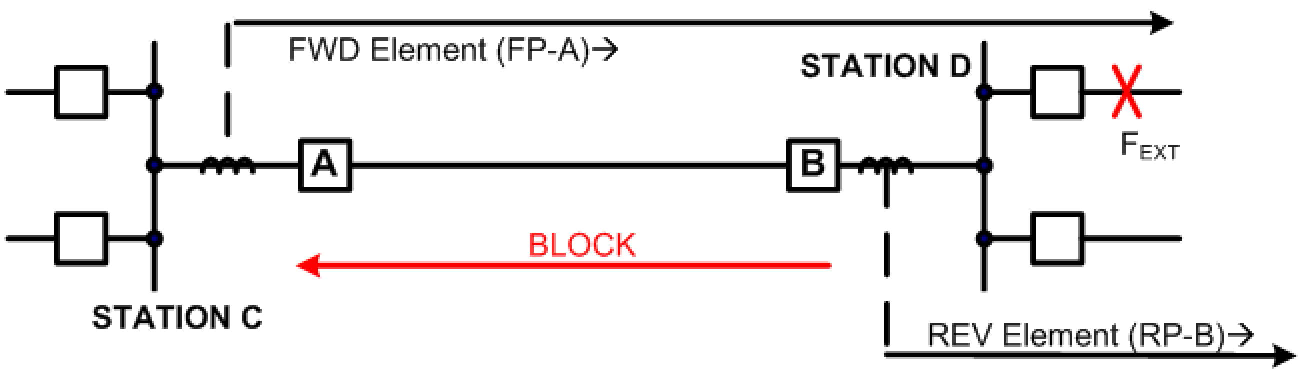
(b) Key transmitter with closing of normally open contact

- Reduces contact bounce issues
- Allows continuous monitoring of start circuit

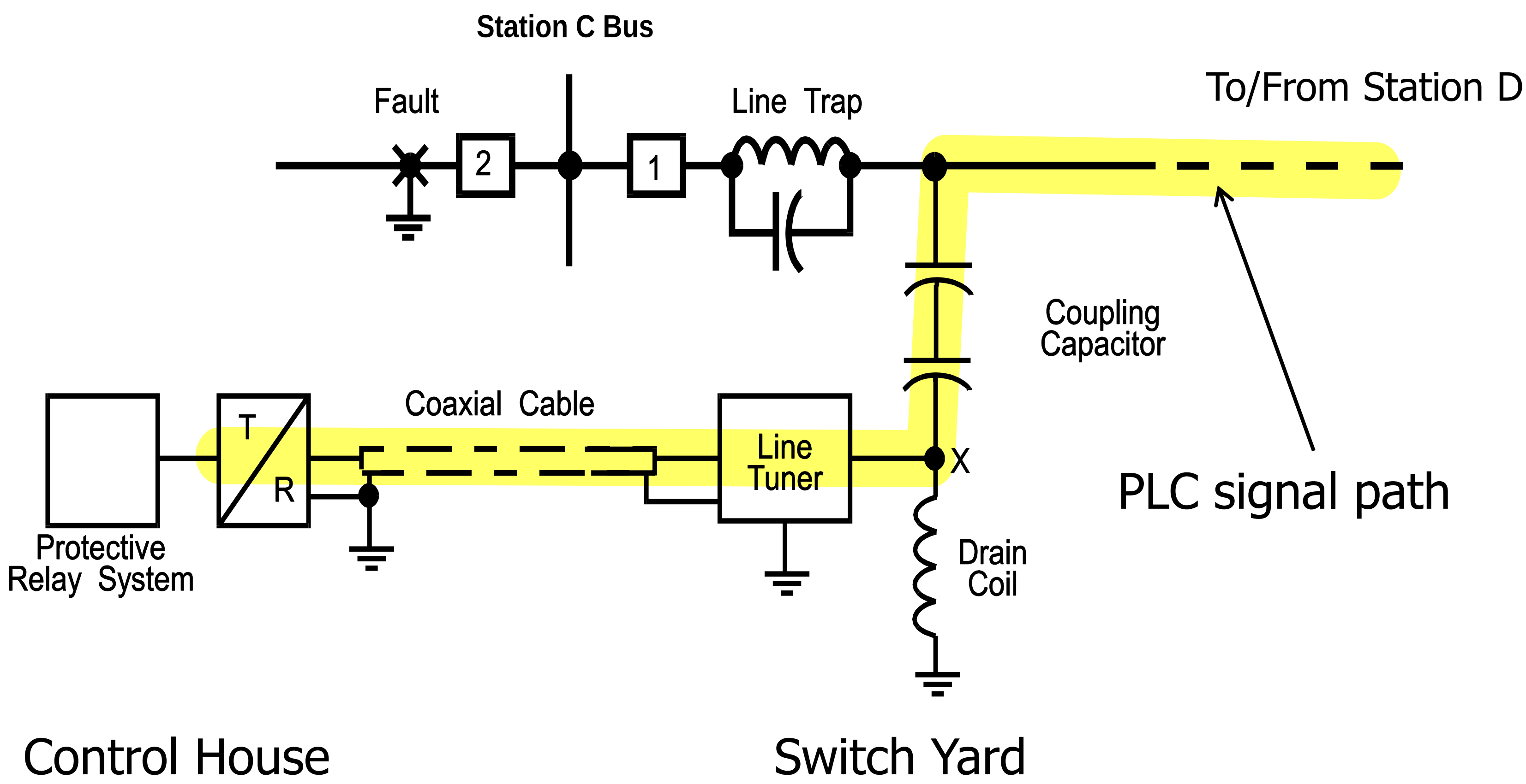
Basic TRIP Logic



At Station C with FP asserted allow **X** time to receive **BLOCK** signal from remote terminal before tripping.



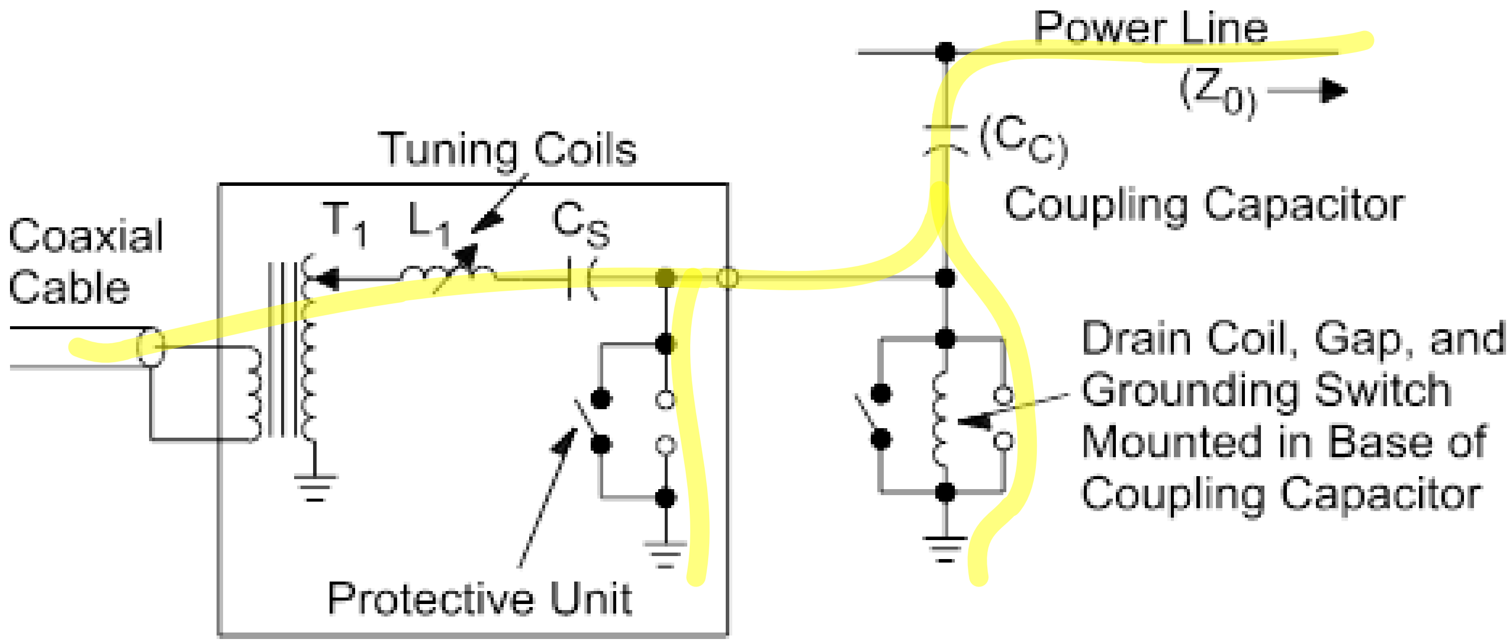
Channel Equipment



What are carrier holes?

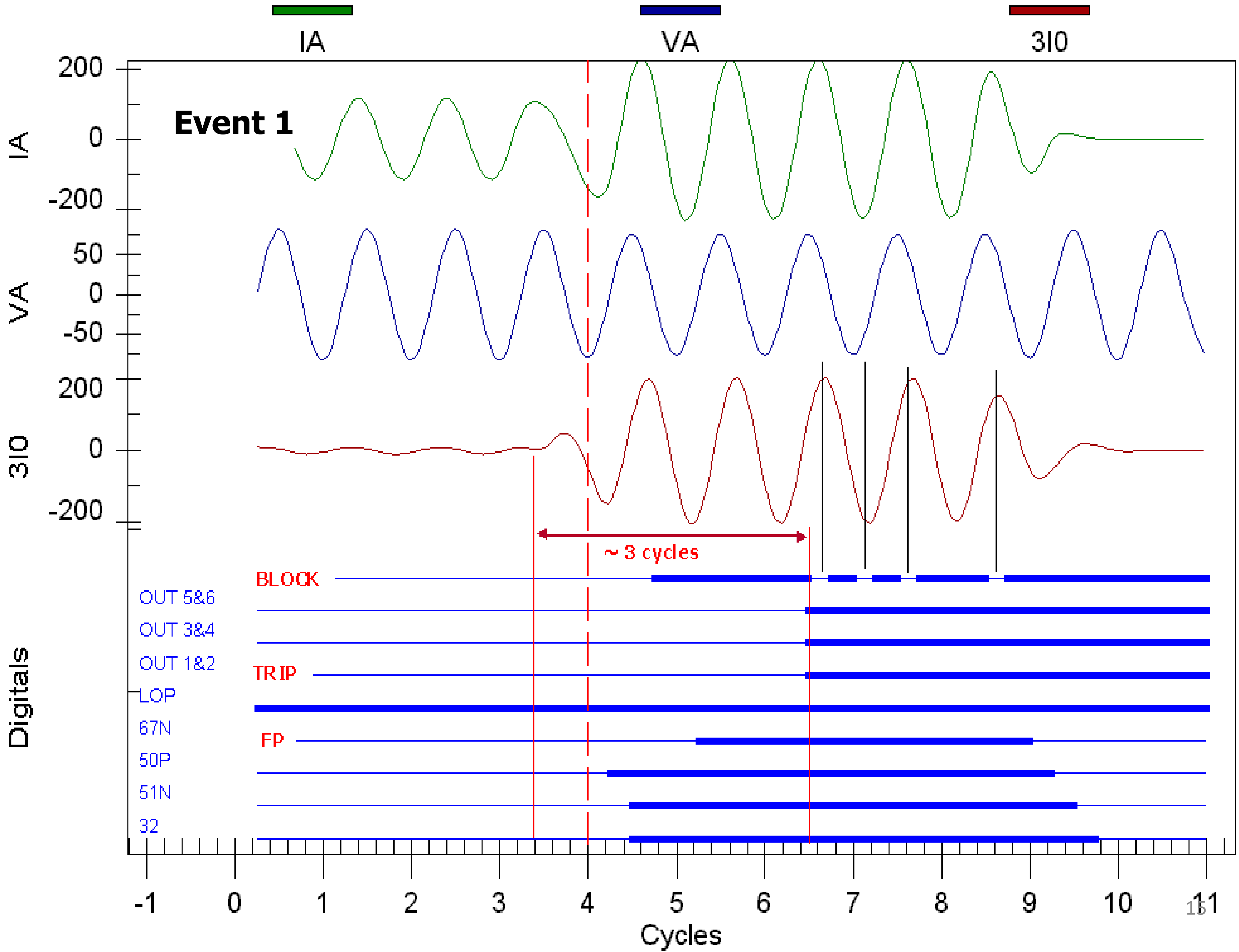
- Carrier holes are when the blocking signal disappears during an external fault due to something in the PLC signal path shorting to ground
- Culprits of carrier holes in the PLC signal path
  – Degraded insulation (age)
  – Poor ground connections
  – Incorrect protective gaps settings
  – Lack of maintenance

Protective Gaps

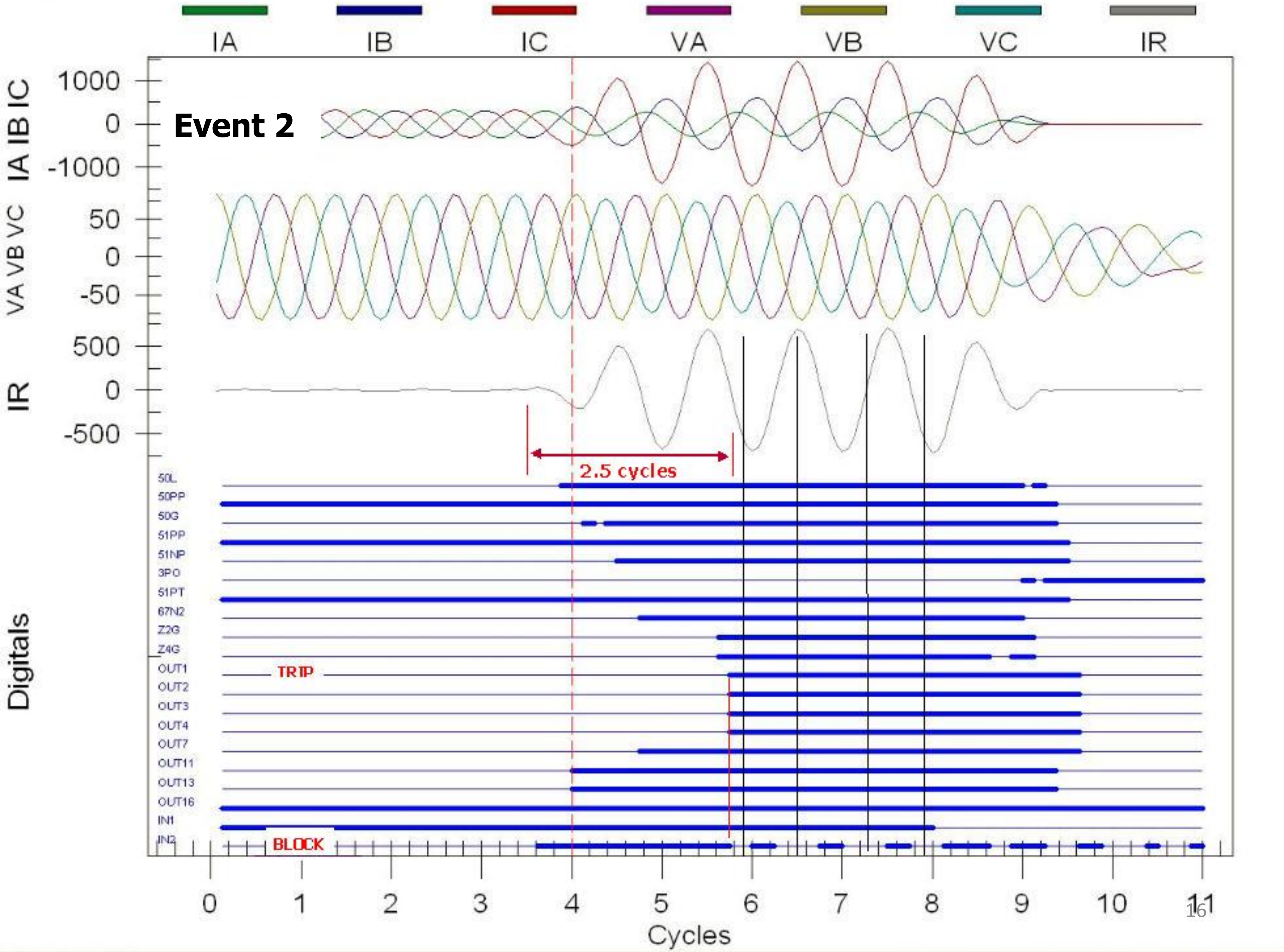


How long are carrier holes?

- 2 to 30 ms or more, but generally less than 8 ms (1/2 cycle)
- Function of:
  - Condition of PLC channel equipment
  - Voltage transients produced during fault inception and clearing



IA
VA
3I0
Event 1
200
0
-200
50
0
-50
200
0
-200
~ 3 cycles
BLOCK
OUT 5&6
OUT 3&4
OUT 1&2
TRIP
LOP
67N
FP
50P
51N
32
Digitals
-1 0 1 2 3 4 5 6 7 8 9 10 11
Cycles


IA IB IC VA VB VC IR
Event 2
IA IB IC
1000
0
-1000
VA VB VC
50
0
-50
IR
500
0
-500
2.5 cycles
Digitals
50L
50PP
50G
51PP
51NP
3PO
51PT
67N2
Z2G
Z4G
OUT1
TRIP
OUT2
OUT3
OUT4
OUT7
OUT11
OUT13
OUT16
IN1
IN2
BLOCK
0 1 2 3 4 5 6 7 8 9 10 11
Cycles

Event 1 and 2 Summaries

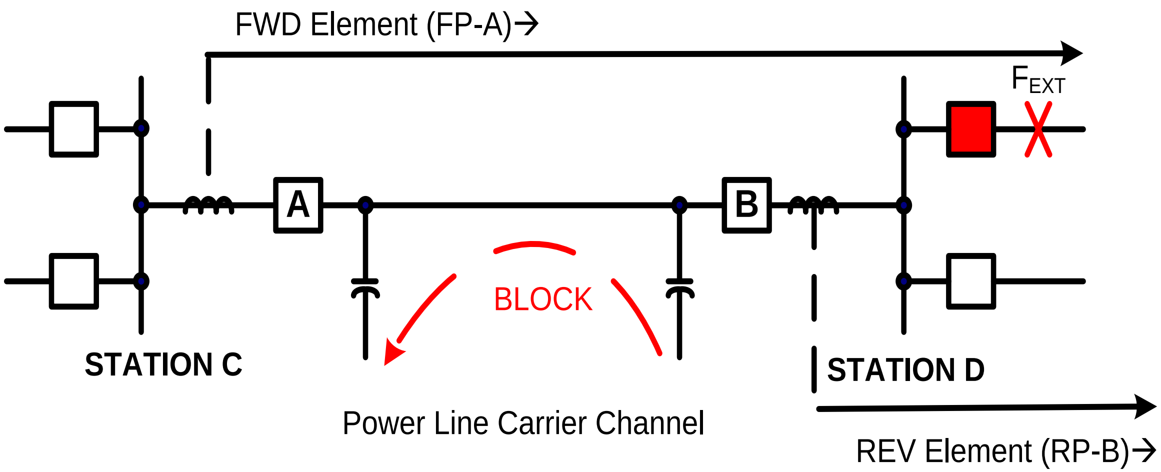
Event 1

- External fault
- 3.0 cycles to first hole from fault inception
- ¼ cycle holes
- Close alignment of hole centers to 3I0 max and min peaks
- Holes end with fault clearing
- Local end PLC protection gap issues

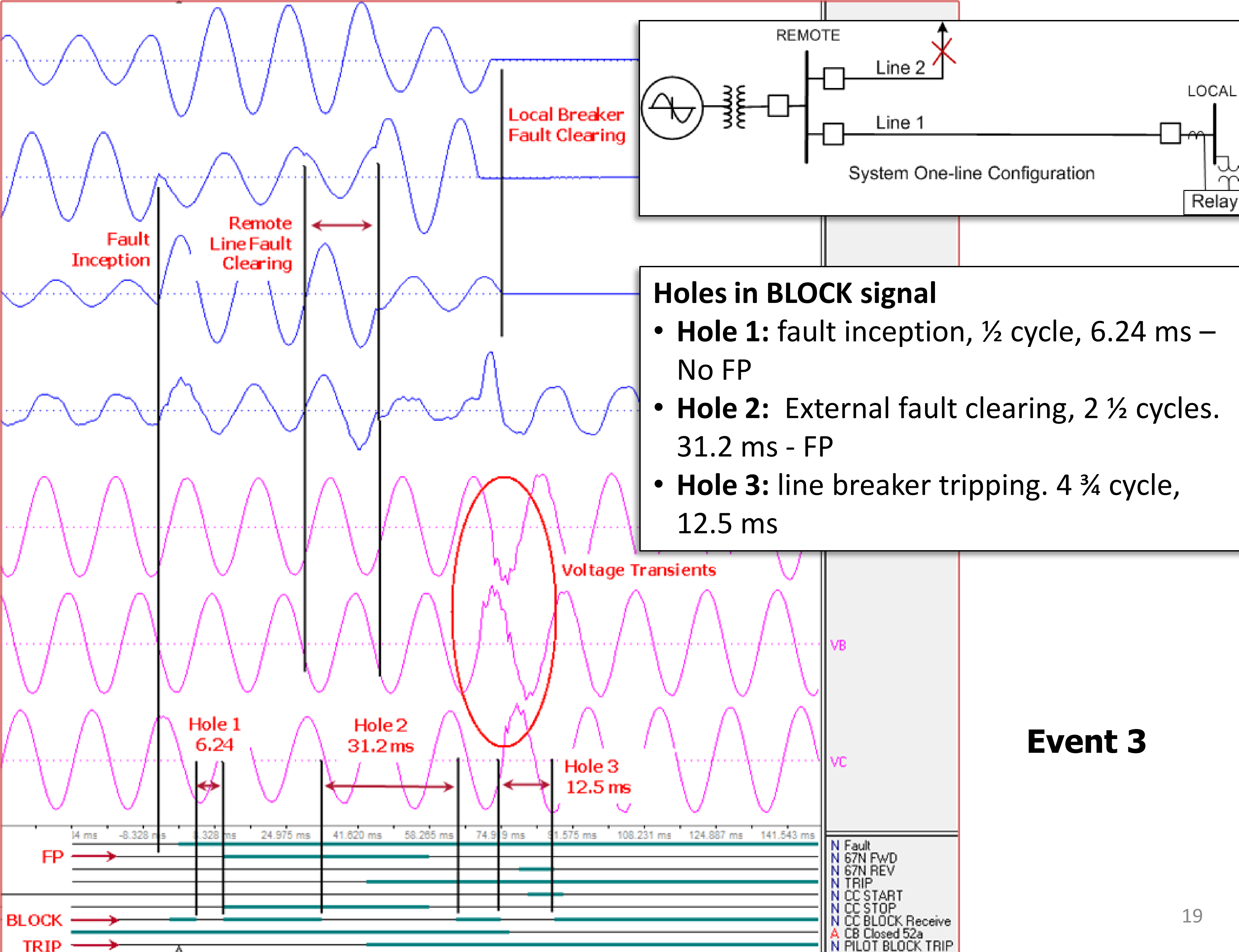
Event 2

- External Fault
- 2 ½ cycles to first hole from fault inception
- ¼ - ½ cycle holes
- Hole centers are not consistently aligned with 3I0 max and min peaks
- Holes continue after fault clearing
- Remote end PLC protection gap and line tuner grounding issues

External Line Fault Clearing



- External line fault clearing with breaker C
- 2- 5 (or more) cycles
- Voltage surges that cause protective gaps to short



Holes in BLOCK signal

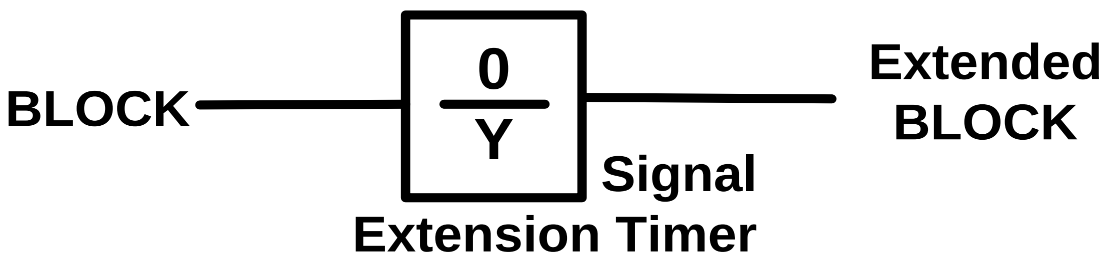
- **Hole 1:** fault inception, ½ cycle, 6.24 ms – No FP
- **Hole 2:** External fault clearing, 2 ½ cycles. 31.2 ms - FP
- **Hole 3:** line breaker tripping. 4 ¾ cycle, 12.5 ms

Event 3

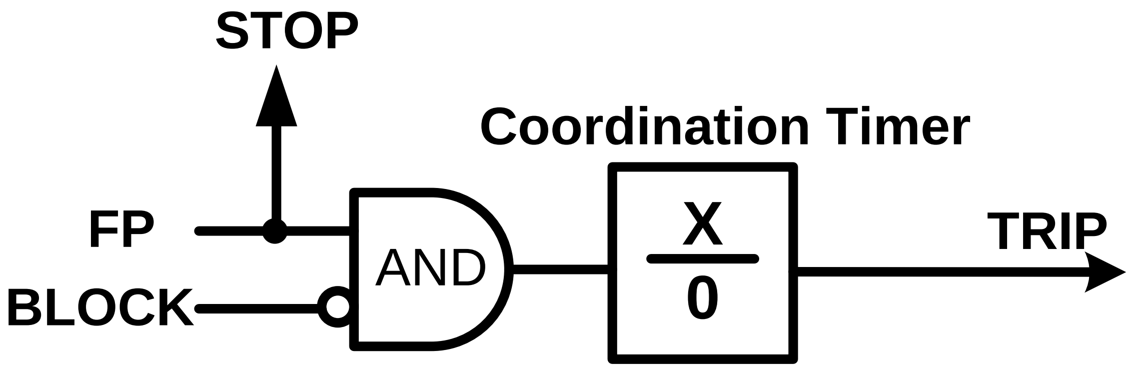
How To Deal With Carrier Holes?

- Do preventative maintenance
- Allow mis-operations and then do corrective maintenance
- Mask the holes with a ‘BLOCK signal extension timer’ to prevent a mis-operation, and if so, how big of a hole do we mask?
- Mask and alarm

BLOCK Signal Extension Timer

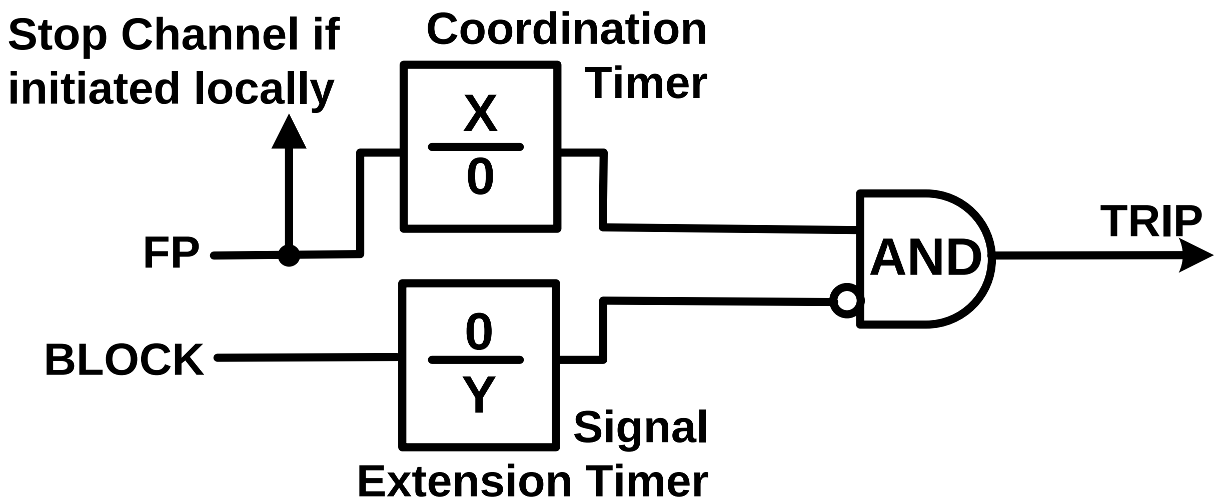


Coordination and BLOCK Signal Extension Timer



- Effectively masks the carrier hole <u>up to the set coordination time</u>
- Should review fault records of “good” no-trips to see if holes exist

Coordination and BLOCK Signal Extension Timer

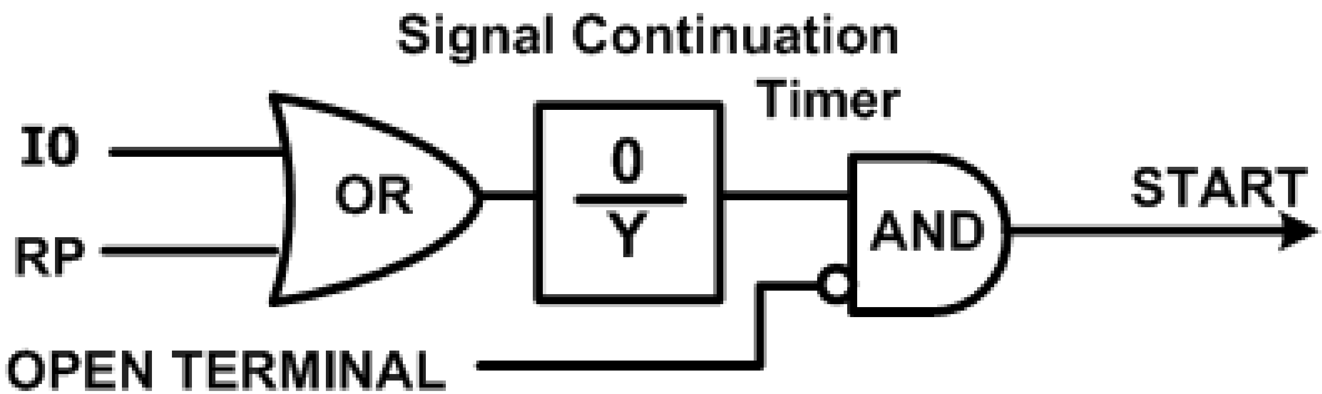


- Set Coordination and BLOCK Extension timers separately
- Should review fault records of “good” no-trips to see if holes exist

Directional or Non-directional Starting

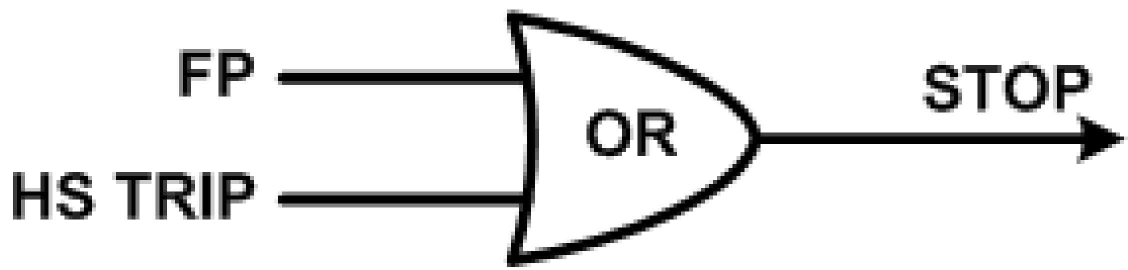
Directional	Non-directional
Must wait for reverse pilot units to operate	Fast start for all faults
Local coordination timer is set larger than remote’s max RP operating time + channel time + margin to prevent local FP from tripping	Requires minimum coordination time at to allow a higher-speed trip
Positive indication of reverse (external) fault – no START for internal faults	Must STOP the Blocking signal <u>fast</u> for internal faults Always sends a BLOCK blip (pulse of carrier) who’s effect needs to be considered
Typical Units: 21R, 50NR, 50QR	Typical Units: 50N, 50Q, dv/dt and di/dt

Channel START logic



- Directional (RP) or non-directional (I0) starting
- Closed Breaker
- Signal Continuation timer

Channel STOP logic



- STOP the transmission of BLOCK signal immediately, a delay in stopping is a delay in tripping
  - Forward Pilot units
  - High-speed trip (21-1, 50/50N direct trip)
- Caution: Do not stop for “any” multi-function relay trip.

Directional or Non-directional Starting

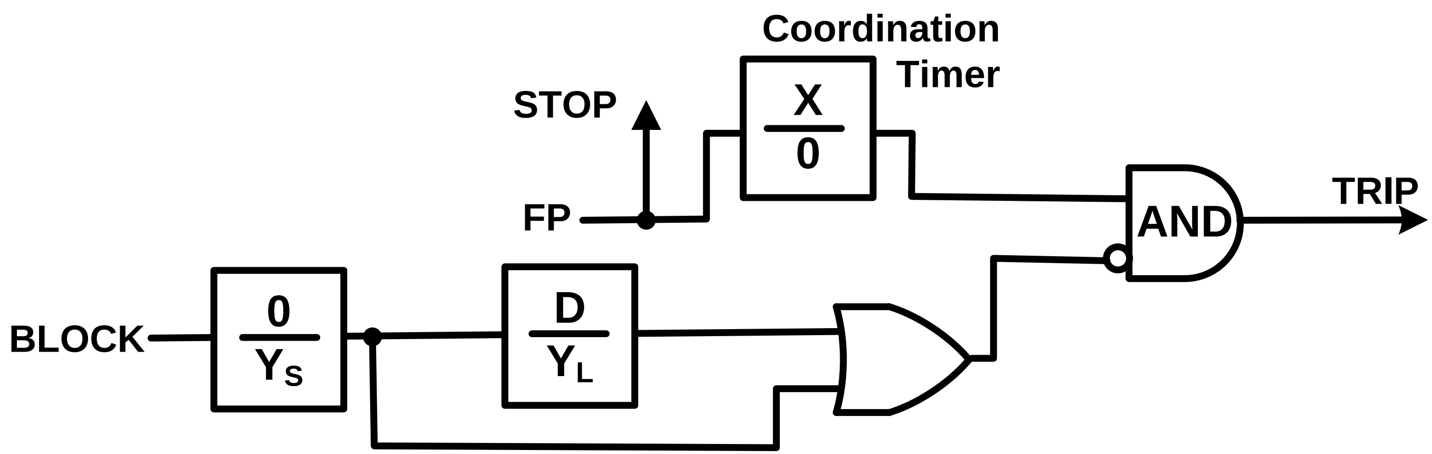
Basic selection considerations:

- Non-directional starting
  - How long is the initial carrier blocking signal pulse and what tripping delay it will cause
    - time it takes for forward pilot elements to operate and STOP the blocking channel
    - any logic timers that affect STOP and BLOCK dropout at either end
- Reverse direction starting
  - How long does it take the reverse starting elements to operate and START the carrier blocking signal
- How carrier holes are handled

Increase Security with Directional Start

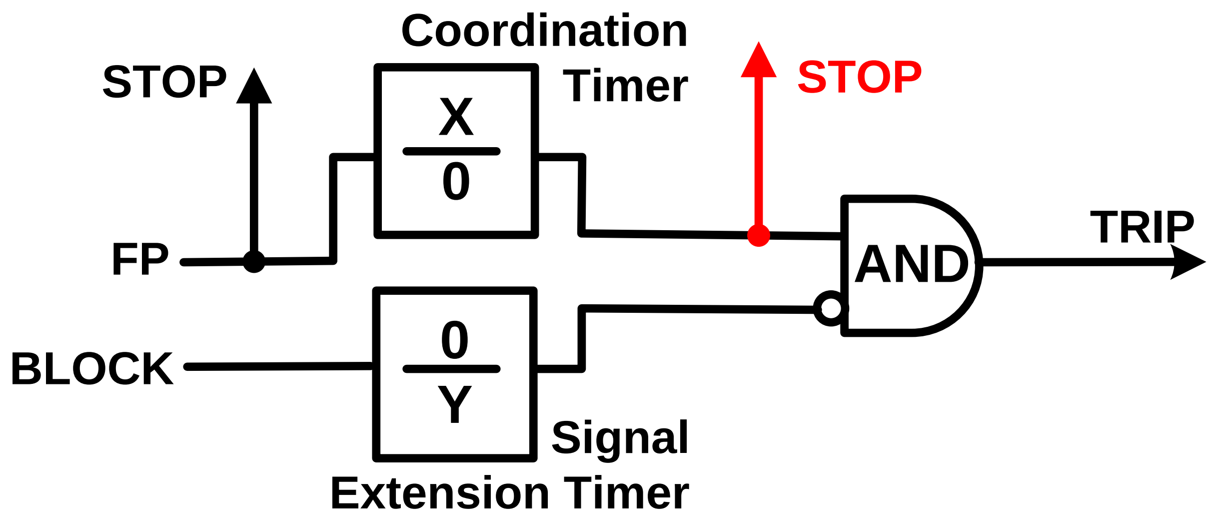
- Longer block extension timers can be used to increase security for larger carrier hole
- Only reverse directionally controlled elements are used to start blocking
- The relay will not start carrier unless it detects a reverse fault
- Using this approach the local relay never sends that initial blip of carrier
- When a block signal is received at the remote relay it is assumed with confidence that that the fault is external
- Much longer block extension delays (2-3 cycles) can be used without impacting fault clearing for internal faults for <u>most</u> probable cases
- With long block extension times dependable high speed tripping is compromised for evolving faults – external to internal

Increase Security with BLOCK Signal Implementation Delay



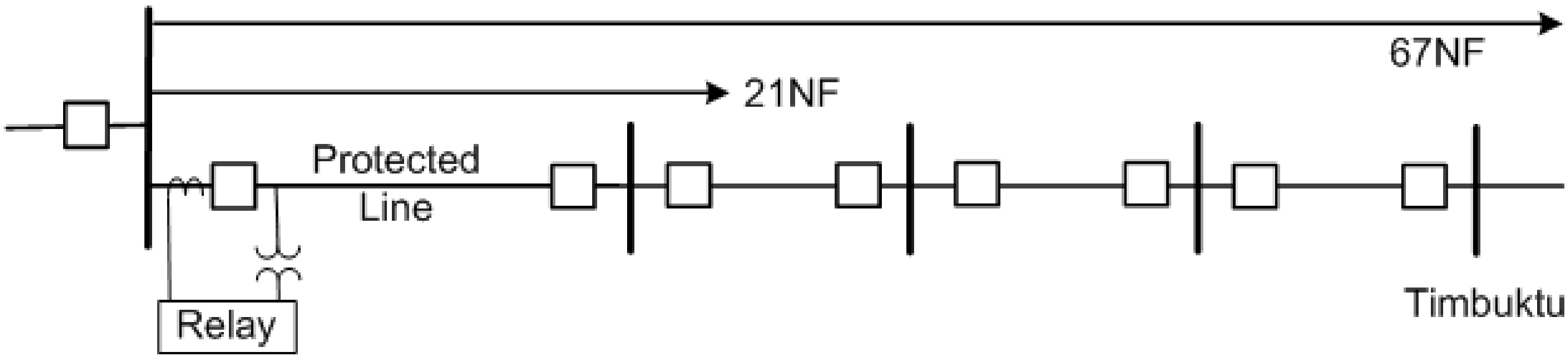
- Experience has shown that most DCB scheme misoperations due to carrier holes usually occur after two cycles into the fault
- Allow high speed tripping for a set time with small extension time Y_S for time D (two or more cycles)
- If tripping has not occurred and the blocking signal is still being received, an external fault is assumed and the long block extension timer, Y_L, is employed

Assertion of STOP Signal



- The assertion of the STOP signal after the coordination timer may unnecessarily delay tripping at remote terminal
- It may affect your decision to use directional or non-directional START

67NF Delay Timer



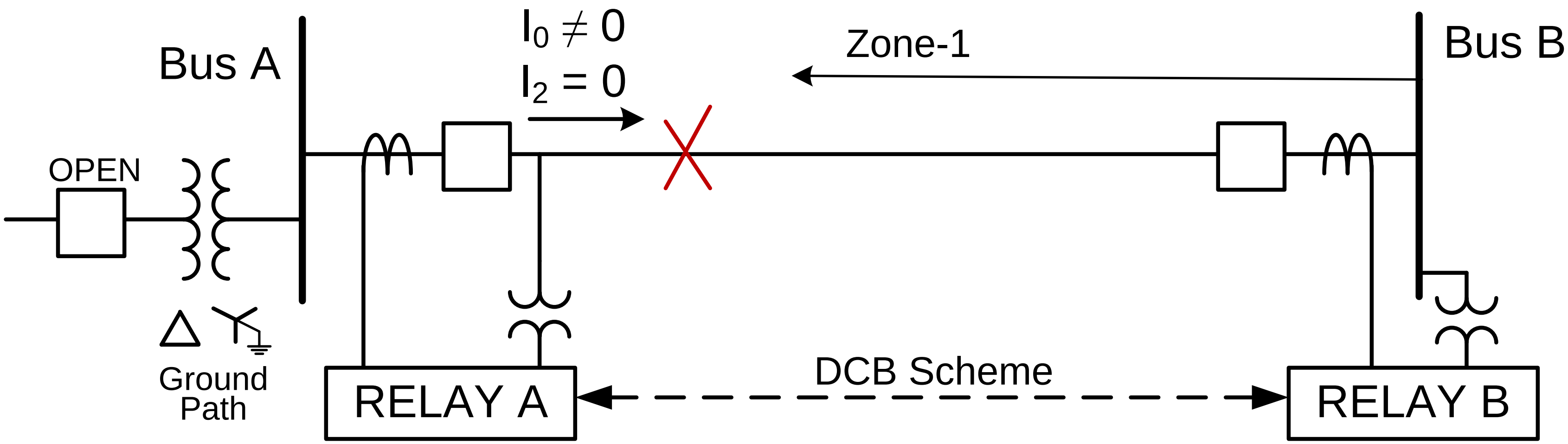
- Ground-distance element, 21NF
  - Covers the vast majority of system ground faults where fault resistance is not excessive
  - Does not detect faults beyond its reach setting, which usually reaches just beyond the remote bus.
- Forward directional ground overcurrent, 67NF
  - Set sensitively to cover fault resistance
  - May reach to Timbuktu – many busses away.

67NF Delay Timer

For secure tripping

- 21NF operates high speed
- 67NF operates with time delay to allow remote (external) line 21NF operations
  - Limit the exposure to overreach tripping if there is a channel blocking signal failure [or carrier unintentionally left off]
  - The 67NF time delay is generally set to a time that allows remote line clearing of external faults beyond the reach of 21NF (e.g. 8 cycles).
  - 67NF, properly applied, provides good coverage for high-resistive internal faults with increased security against tripping for remote faults

Coordination of I0 Start and RP/FP Units



- I0 (3I0) start at A may sustain a BLOCK at B if 67QF (3I0 negative sequence polarized) is used as FP at both terminals
- At Bus A 50QF will not operate and 21NF may not operate and BLOCK is sustained
- Use reverse start or 3I0 non-directional start and 67NF (zero sequence polarized) for FP units

Redundant Schemes

Consider the overall line protection

- If your DCB scheme is running in parallel with a highly reliable current differential scheme you can use longer coordination and block extension time delays to increase security of the overall scheme
- Minimum impact on overall speed and dependability

Conclusions / Recommendations

We have shown the complexities and necessary considerations for the implementation of a seemingly rather simple, and often taken for granted, DCB scheme.

- Understand and apply all logic and timers correctly
- Select carefully between directional and non-directional starting
- Address carrier holes.
  - Mask or not mask
  - How long of a hole is tollerated?
  - At a minimum alarm or study fault records to determine existence
  - Do maintenance

Preaching

- Our intent was not simply to inform the reader but also to motivate the reader to vigorously investigate and “what if” the schemes at use in their utility
- Just because “we’ve always done it this way” isn’t a sound basis for how we should proceed in the future with new technology and more flexible protection systems
- At the same time, changing just for the sake of change may open a can of worms that were not anticipated
- There is no substitute for careful study and real world experience garnered through event analysis and study.