Power System Protection

Dr. Lionel R. Orama Exclusa, PE
Week 10
Pilot Relaying for Transmission Lines

- Blocking schemes
- Tripping schemes
- Hybrid schemes
- Transmission Line Protection
  - Dependability
    - Ability to operate correctly when required (trip when required-internal fault)
  - Security
    - Ability to never operate incorrectly (do not trip when not required-external fault)
Blocking Schemes

• Directional comparison
• Phase comparison
• Characteristics
  – Two way communication between each pair of terminals
  – Typically power line carrier
  – Provides high speed protection of transmission lines
Blocking Schemes

• Advantages
  – Dependable
  – Does not require communication channel to trip

• Disadvantages
  – Less secure (channel required during external fault)
  – Loss of channel can cause false tripping

• Failure mode-comm. channel loss
Logic Circuits - short review

### AND Gate

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<tr>
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### OR Gate

<table>
<thead>
<tr>
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<tbody>
<tr>
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### NOT Gate

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### Mixed AND

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### Mixed OR

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### Time Delay Units

- **Upper Left Value**: ON Delay
- **Lower Right Value**: OFF Delay

### Fixed

- **X - Pickup Time**: Time that elapses between an input signal being received and an output signal appearing.

### Adjustable

- **Y - Dropout Time**: Time after the input signal is removed until the output signal goes to zero.
Directional comparison blocking scheme; Over-reaching relays

1. MT - Overreaching Trip
2. MB - Blocking
3. MB - Keys XMTR On
4. Receipt of Blocking Signal Blocks Tripping

5. C = Coordinating Time Delay
6. Trip When Local Trip Function Operates and No Blocking Signal Received
Directional comparison blocking scheme

Blocking relays over-reach a little, so a good continuous blocking signal exists for close in external faults.
Directional Comparison

- **Advantages**
  - Highly dependable
  - Does not require operation of communication channel to trip
  - Applicable on all types of line configurations

- **Disadvantages**
  - Loss of communication channel causes over-tripping
  - Less secure
Phase comparison blocking scheme; A current differential scheme

Internal Fault: OR must have O, O for 3 msec to Trip
External Fault: OR must not have O, O for > 3 msec
TERMINAL A

EXTERNAL FAULT

TERMINAL B

OUTPUT SQ. AMP
XMTOUT
RCVR OUT
OR
OUTPUT
NOT OUTPUT

INTERNAL FAULT

OUTPUT SQ. AMP
XMTOUT
RCVR IN
OR
OUTPUT
NOT OUTPUT

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Phase Comparison
(a form of current differential scheme)

• Advantages
  – Simple – one relay required
  – No PT required
  – Channel not require to trip for internal faults

• Disadvantages
  – Relatively insensitive
  – Slow
  – Loss of channel may cause tripping when not required (less secure)
Pilot Relaying Tripping Schemes

• Advantages
  – Secure, loss of channel does not cause over tripping
  – Simple schemes

• Disadvantages (limitations)
  – Less dependable, loss of channel delays tripping
Transfer Trip Schemes

• Direct Underreaching (DUTT)
• Permissive Underreaching (PUTT)
• Permissive Overreaching (POTT)
• Characteristics
  – Two way communication between each pair of terminals
  – Frequency shift signal generally used over a wire line or microwave
  – Provides high speed protection of transmission lines
Direct Underreaching Transfer Trip Operation

– External Fault (F1)
  • None of relays detect the fault- No trip

– Internal Fault (F2)
  • $M_{1A}$ detects fault, $M_{1B}$ does not
  • $M_{1A}$ directly trips CB A
  • $M_{1A}$ shift transmitter from guard to trip & transfer trip to B
• G (Guard)
  – Open when guard frequency is received (normal condition)
  – Closed when guard frequency is not received (fault)
• T (Trip)
  – Open when trip frequency is not received (normal condition)
  – Closed when trip frequency is received (fault)
Permissive Underreaching Transfer Trip Operation

- **External Fault (F1)**
  - M2_B detects fault, but M1_A or M2_A does not, **no trip**

- **Internal Fault (F2)**
  - M1_A detects & directly trips CB A
  - M2_A & M2_B detect, but not M1_B
  - M2_B permits transfer trip to A and B
  - M1_A shift transmitter to trip & completes transfer trip at A & B
Permissive Overreaching Transfer Trip Operation

- **External Fault (F1)**
  - $M_{2B}$ detects fault, but $M_{2A}$ does not
  - $M_{2B}$ keys transmitter from G to T & closes local contact (permits)
  - Transmitter at A remains on G

- **Internal Fault (F2)**
  - $M_{2A}$ & $M_{2B}$ detect fault
  - Each closes local contact (permits) & shift transmitter to transfer trip

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Hybrid Scheme

• Uses features of Tripping and Blocking Schemes
  – Has the dependability of the blocking
    • Only local relay must operate
  – Has the security of permissive trip scheme
    • Loss of channel does not make misoperation
• Advantage over POTT
  – Only local tripping relay must operate to trip local CB
  – For an internal fault $M_T^A$ operates, $M_T^B$ does not
    • $XMTR^A$ keyed - $RCVR^B$ ON
    • $MB^B$ does not operate - $XMTR^B$ keyed - $XMTR^B$ ON – TRIP A

• Advantage over Direct comparison Blocking
  – Loss of channel does not cause overtripping
Hybrid Scheme

• Advantages
  – Dependable – does not require relay OP at all terminals
  – Secure – loss of channel does not cause overtripping
  – Can provide weak infeed tripping

• Limitations
  – Requires blocking relays
  – Slightly more complex than other schemes
  – Tripping can be delayed if channel is lost
<table>
<thead>
<tr>
<th>Scheme</th>
<th>Most Common Channel</th>
<th>Relay Types</th>
<th>Carrier Types</th>
<th>Characteristics</th>
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</thead>
<tbody>
<tr>
<td>Phase Comparison</td>
<td>Power Line Carrier (PLC)</td>
<td>SLD</td>
<td>Blocking signal sent when Vnetwork positive.</td>
<td>Out of phase blocking signals produced for external fault. In phase blocking signals produced for internal fault.</td>
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<tr>
<td>Directional Comparison</td>
<td></td>
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<td>Keyed On-Off Blocking</td>
<td>Blocking &amp; tripping relay at each terminal.</td>
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<tr>
<td>Blocking</td>
<td>Power Line Carrier (PLC)</td>
<td>Distance Directional Overcurrent</td>
<td>Blocking signal sent when blocking relay operates.</td>
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<td>Tripping</td>
<td><strong>Wire Line (tones)</strong>*</td>
<td>Distance</td>
<td>Frequency Shift Tripping (CT/CR 51B, 61A, 71A)</td>
<td>Underreaching trip relay at each terminal.</td>
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<tr>
<td>DUTT</td>
<td>PLC-unblocking</td>
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<td>PUTT</td>
<td><strong>Wire Line (tones)</strong>*</td>
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<tr>
<td>POTT</td>
<td>PLC-unblocking</td>
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<tr>
<td>Hybrid</td>
<td></td>
<td>Distance</td>
<td>Frequency Shift Tripping</td>
<td>Blocking and tripping relay at each terminal like directional comparison. Do not need trip relay at remote end to operate to trip at local end. Local trip signal is &quot;echoed&quot; from remote end.</td>
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% of Entities Who use or Prefer

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<td>Step Distance/Dir. Overcurrent</td>
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Source IEEE survey
Transmission Line Categories

- A – Most Important
- B – Important
- C – Secondary (less important)
- D – Sub-transmission