Apply a Wireless Line Sensor System to Enhance Distribution Protection Schemes

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Distribution System

- Protection objectives
  - Minimize fault duration
  - Reduce number of affected customers

- Protection methods
  - Use inverse-time overcurrent elements
  - Coordinate devices to provide selectivity
• Sacrifice speed for selectivity
• Can increase fault-clearing times for faults closer to source
• Do not know where fault is
• Cannot differentiate fused sections from unfused sections
• Must wait for fuse coordination time margin before tripping
Speed Matters

• Public safety – fire ignition and property damage
• Equipment life – damaged components, cable connections, and jumpers
• Power quality
  ▪ Different requirements and expectations
  ▪ CBEMA curve – acceptable voltage
Fuse-Saving Schemes

- Recloser arms fast-curve for first trip and slow-curve after reclosing
- Recloser trips on fast-curve for any fault
- Fuses clear permanent downstream faults after reclosing
- Recloser clears temporary or permanent faults
Fuse-Saving Scheme Advantages

• Minimizes customer outages

• Reduces maintenance costs by minimizing fuse replacements

• Improves System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI)

• Restores services after temporary fault
 Fuse-Saving Scheme Disadvantages

- Is difficult to coordinate
- Leads to frequent temporary interruptions
- Increases Momentary Average Interruption Frequency Index (MAIFI)
Fuse-Blowing Schemes
“Trip-Saving” Scheme

- Fuse clears downstream faults
- Recloser trips for main line section or unfused section faults
Fuse-Blowing Scheme Advantages

- Improved power quality on unfaulted line sections
- Easy coordination
- Reduced MAIFI
Fuse-Blowing Scheme Disadvantages

• All faults become permanent outages
• Personnel must replace fuses after every event
• Fault duration on main feeder or unfused sections is increased
Wireless Protection Sensor (WPS) System

Recloser Control

Collector

High-Speed Serial Communications Protocol

WPS = FT (fault transmitter)
Collector = FR (fault receiver)
WPS Latencies

WPS Information Available in <1 Cycle

- Fault Detected
- Collector Receives Sensor Data
- Protection Device Receives Sensor Data
- Protection Device Makes Decision

Ts, Tc, Tpr, Tst, Tl (Total Latency)
WPS Latencies
WPS System Test Results

Current Loop → WPS
Collector → Protection Device
Oscilloscope

Graph showing fault current and other measurements with specific values and time delays.
Latency Requirements
Fuse-Saving Scheme

<table>
<thead>
<tr>
<th>Fuse Size</th>
<th>Maximum Coordination Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>15T</td>
<td>570 A</td>
</tr>
<tr>
<td>40T</td>
<td>1,500 A</td>
</tr>
<tr>
<td>65T</td>
<td>2,500 A</td>
</tr>
<tr>
<td>100T</td>
<td>3,800 A</td>
</tr>
<tr>
<td>140T</td>
<td>5,850 A</td>
</tr>
</tbody>
</table>

- Fault Detected
- Sensor Data Available 16.67 ms
- Recloser Interrupting Time
- Recloser Contacts Open, Clear Fault 50 ms
1. Protection devices should not make protection decisions based solely on fault data from WPSs.

2. Protection devices should fall back to backup scheme in absence of sensor data.

3. Protection devices should use sensor fault information to enhance / augment / optimize existing schemes.
Application #1
Switchover on the Fly From Fuse-Blowing to Fuse-Saving Scheme (Permissive)

- Specific (candidate) line section(s)
  - Fuse-blowing always active
  - Fuse-saving only enabled under certain conditions
- Other line sections – fuse-blowing works as usual
Switchover on the Fly From Fuse-Blowing to Fuse-Saving Scheme (Permissive)
Application #2
Switchover on the Fly From Fuse-Saving to Fuse-Blowing Scheme (Blocking)

• Specific (candidate) line section(s)
  ▪ Fuse-blowing always active
  ▪ Fuse-saving blocked under certain conditions

• Other line sections – fuse-saving works as usual
Switchover on the Fly From Fuse-Saving to Fuse-Blowing Scheme (Blocking)
Application #3
Switchover on the Fly Between Feeder Cable and First-Span Overhead Protection (Permissive)

- Blocks reclose for faults by default
- Dynamically enables reclosing for overhead faults
Switchover on the Fly Between Feeder Cable and First-Span Overhead Protection (Permissive)

<table>
<thead>
<tr>
<th>High-Set Element</th>
<th>Overhead Sensor</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>No operation</td>
<td>No operation</td>
<td>Enable reclosing</td>
</tr>
<tr>
<td>No operation</td>
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<td>Enable reclosing</td>
</tr>
<tr>
<td>Operation</td>
<td>No operation</td>
<td>Block reclosing</td>
</tr>
</tbody>
</table>

Assumption: Other Logic Blocks

High-Set Element on Reclosing

WPS Fault Indication

50PTO 50GTO

51PPU 51GPU
Application #4
Speed Up Tripping for Faults on Unfused Sections

- Eliminates delay for fuse to blow
- Speeds up trip response on unfused sections
Application #5
Speed Up Tripping for Faults by Discriminating Between Laterals for Fuse-Blowing Scheme

- Speeds up trip response
- Optimizes tripping time for multiple fuse sizes
Speed Up Tripping for Faults by Discriminating Between Laterals for Fuse-Blowing Scheme
Conclusion

• WPSs provide more visibility
• WPS information allows for speed without sacrificing selectivity
• Protection scheme operation is improved
  ▪ Smarter schemes
  ▪ Improved reclosing practices
  ▪ Shorter coordination margins and fault duration
Questions?