Distance Protection for Distribution Feeders

Presented By:
Why use distance protection for distribution feeders?

- Distance protection is mainly used for protecting transmission lines.
- Distance is occasionally used to solve coordination issues in distribution feeders historically.
- Not used often for distribution protection because of the (historically) high price.
- EPCOR identified problems in protecting feeder circuits that could be solved using distance protection.
- With the new generation of microprocessor relays, the cost of including distance functions is less prohibitive.
About EPCOR Distribution Grid

• 19 Distribution feeders @ 25kV
  – 60% Aerial, 40% Underground
• 240 Distribution feeders @ 15kV
  – 50% Aerial, 50% Underground
• 27 Distribution feeders @ 5kV
  – 100% Aerial
Typical 15kV Feeder
Simplified Single Line Diagram for Typical 15kV Feeder

<table>
<thead>
<tr>
<th>LENGTH (M)</th>
<th>1323M</th>
<th>890M</th>
<th>1865M</th>
<th>2917M</th>
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<tbody>
<tr>
<td>COND. SIZE</td>
<td>500 MCM CU PILC H</td>
<td>336.4 MCM ACSR</td>
<td>336.4 MCM ACSR (1016)</td>
<td>336.4 MCM ACSR (1174)</td>
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<tr>
<td></td>
<td>500 MCM CU XLPE CN (849)</td>
<td>500 MCM CU XLPE CN (556)</td>
<td>350 MCM AL XLPE CN (1207)</td>
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<tr>
<td>IMP. (Ω/KM)</td>
<td>R1</td>
<td>X1</td>
<td>R0</td>
<td>X0</td>
</tr>
<tr>
<td>N/A</td>
<td>0.188</td>
<td>0.385</td>
<td>0.426</td>
<td>1.307</td>
</tr>
<tr>
<td>N/A</td>
<td>0.186</td>
<td>0.385</td>
<td>0.426</td>
<td>1.307</td>
</tr>
<tr>
<td>N/A</td>
<td>0.186</td>
<td>0.385</td>
<td>0.426</td>
<td>1.307</td>
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<tr>
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<td>0.266</td>
<td>0.241</td>
<td>0.727</td>
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<tr>
<td>TOTAL IMP. (Ω)</td>
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<td>0.1606</td>
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<td>SOURCE</td>
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<td>SYSTEM MODEL DWG.WI</td>
<td>SYSTEM MODEL DWG.WI</td>
<td>SYSTEM MODEL DWG.WI</td>
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</table>

WOODCROFT SUB

1323M EXPRESS CABLE

EXPULSION FUSE

CURRENT LIMITER FUSE

1/4 CYCLE OPERATION

ZONE 1 90% OF EXPRESS CABLE

ZONE 2 90% OF EXPRESS CABLE PLUS FIRST LINE

ZONE 3 90% OF EXPRESS CABLE PLUS FIRST LINE AND SECOND LINE

ZONE 4 90% OF EXPRESS CABLE PLUS FIRST LINE AND SECOND LINE AND THIRD LINE

6995M

W1 LAT

FDS 697 50K

FDS 619 25K

8738
Existing EPCOR Distribution
Feeder Protection Philosophy

- Fuse Burning Philosophy
- Time Delayed Overcurrent
  - Phase
  - Ground
- Instantaneous Overcurrent
  - Phase
  - Where applicable
- Backup Phase Overcurrent applied in Bus Differential relays where possible
- Broken Conductor Alarm
- Hot Line Tagging
- Single shot Auto-Recloser for aerial circuits
Typical Time Coordination Curve for 15kV Feeder
Identified Problems with Existing Feeder Protection Philosophy

• Operation time for close-in faults to the substation
• Auto-reclose not blocking for faults on the cable section of the circuit
• Sensitivity and safety on detecting fallen conductors
• Safety of personnel performing hot-line work
SYSTEM
MAX / MIN

Isc, KA

Isc max

INST. SETTING

Isc min

Protected section when in max condition

Cable Length, KM

UNDERGROUND CABLE LINE
Distance Characteristics

• Require both voltage and current inputs (not a disadvantage cost wise anymore)
• “Reach” settings based on positive sequence transmission line impedance.
  – Not influenced by different source impedance, fixed reach
  – Greater instantaneous trip zone coverage and security
• Phase and ground fault protection
• Greater selectivity and discretion
Protection Implementation
Distance Functions

- EPCOR’s first implementation of distance functions in feeder relays was Nov 2012 at Woodcroft Substation
- Distance protection is being applied at Two more substations in 2013
- Up to 4 distance measuring zones (ph + gnd) loops and one supervisory zone are applied
- Ground loops set more sensitive
- Zone picked up configured as SCADA alarms
- Not all zones enabled to trip at this moment. Behaviour is being monitored online to ensure security and increase confidence
- Used as a tool to learn dynamic load profile
Distance Protection Zones

- Multiple sections
- Tapped transformers protected by high-speed current limiting fuses from First Line Section
- Multiple line branches after First Line
- Maximum 4 – 5 feeder sections
- Ideal for modern 5-zone numerical distance IED applications
Protection Implementation
Zone 1 Distance

- Protect the express cable
- Instantaneous operation must block auto-reclosing
- 90% vs 110% reach (EPCOR operators demand reclosing for entire aerial sections to maintain service continuity)
- Accurate cable impedance (Z1, Z0) – measurement required
- Tripping enabled
**Protection Implementation**

**Zone 2 Distance**

- Protect faults up to the first branch fuse
- Pad-mounted transformer taps (protected by high speed current limiting fuse)
- Initiate auto-reclosing (single-shot only)
- Coordination is not a concern. Time delay 33ms to avoid racing with Zone 1 (which blocks 79)
- Reduce fault clearing time compared to OC
- Tripping not enabled at this moment (behaviour monitored)
Protection Implementation
Zone 3 Distance

- Protect all previous sections plus 90% of Second Line (up to 2nd branch fuse)
- Coordination with branch fuse is required
- Gain speed over OC (51) element (EPCOR owns relay and fuse)
- Initiates auto-reclosing
- Depending on length of Second Line, might not always be enabled (Requirement: length > 20% of previous sections)
- Tripping not enabled at this moment (behaviour monitored)
Protection Implementation
Zone 3 Distance
Protection Implementation
Zone 4 Distance

- Protect to the end of the feeder
- Very sensitive resistive reach
- Operation blocked when OC picks up. Ensure coordination with fuses. Operate only on low fault current
- >5.0 sec operation delay (coordination)
- Alarms to SCADA when picked up
- Serve as a circuit trouble annunciator (eg. fallen conductor).
- Tripping not enabled at this moment (Behaviour under load is being monitored)
Protection Implementation
OC Functions (50 P,N + 51 P,N)

- Backup protection to distance zones 1 – 3
- 50 P,N set up to only protect the express cable when applicable (e.g. Length of cable and source impedance). Block auto-reclosing
- 51 P,N picked up blocks Zone 4 operation. 51P,N operation initiates auto-reclosing
- Tripping at all times
Cable Impedance Measurement

- Output Isolation Transformer:
  - 500V – 10A
  - 250V – 20A
  - 100V – 50A
  - 50V – 100A

- Measuring Voltage Transformer:
  - 600:30V, 0.1%

- Surge Arrestors:
  - 1000Vrms Sparkover

- Measuring Current Transformer:
  - 100:2.5A, 0.1%

- Safe Potential Separation

- 4800VA Source
  - Variable Frequency
## Cable Impedance Measurement Results Comparison

<table>
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<tr>
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<th>W1</th>
<th></th>
<th>W2</th>
<th></th>
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<td></td>
<td>R1</td>
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<td>R0</td>
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<td>0.1167</td>
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<td>179.70%</td>
<td>-51.03%</td>
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<table>
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<tr>
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Pre-Commissioning and Online Monitoring
Online Monitoring
**Event Review – Cable Fault, W12, July-31-2013**

### Scheduled/ Unscheduled Interruptions

**Ytd for Substation: Woodcroft**

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<tr>
<th>Circuit Number</th>
<th>Date</th>
<th>Interrupt Length (min.)</th>
<th>Number of Customers</th>
<th>Customer Hours</th>
<th>Reason/ Cause(s)</th>
<th>Notes</th>
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Event Review – Cable Fault, W12, July-31-2013
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Event Review – Cable Fault, W12, July-31-2013
Event Review – Arc Arrestor Fault, W17, June-07-2013

<table>
<thead>
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<th>Circuit Nbr</th>
<th>Scheduled Interrupt</th>
<th>Unscheduled Interrupt</th>
<th>Interrupt Details</th>
<th>Report Nbr</th>
<th>Interrupt Type</th>
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<th>Power Down Time</th>
<th>Power Up Time</th>
<th>Act Duration (Minutes)</th>
<th>Nbr of Customers</th>
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<td>07-JUN-2013</td>
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<td>12.2</td>
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From Ave. To Ave. From St. To St. Notes
1098 111 135 142

Copy Default Region(s) From Circuit

Root Cause: 5.1.4.3 Lightning Arrestor
Consequential Impact 1
Consequential Impact 2

Action Taken
FOUND PHASE 1 OF FDS 802 BLOWN. INVESTIGATED FOUND ARRESTER @ 950947 HAD FLASHED OVER. CLEARED FAULTY ARRESTER & TX FROM LINE. REFUSED PHASE 1 @ FDS 802 & CLOSED. TX 950947 TESTED OK. RESTORED ALL CUSTOMERS SUPPLY.

Weather:
- Light: None
- Precipitation: None
- Temperature: 17°C

Device Location: Between @ & @

Relay 51/50: Target
Relay 51/50: Target
Relay 51/50N: Target
Event Review – Arc Arrestor Fault, W17, June-07-2013
Event Review – Arc Arrestor Fault, W17, June-07-2013
Event Review- Dead Bird @ BASE OF 50FS1196 August-15-2013

<table>
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<th>Circuits</th>
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<td>RAWINE DR</td>
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<td>140</td>
<td>142</td>
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Action Taken
CRDW's FOUND DEAD BIRD @ BASE OF 50FS1196
REFUSED 8 RESTORED CUSTOMERS

Wind* None
Precipitation* None
Temperature* 79

Device Location: Between 0 & 1, & 7

Relay - 51/50 Target
Relay - 51/50 Target
Relay 51/50, Target
Other Relays/Targets

Control Operator(s)*: HEGEN
Dispatch Clerk* M.M.
Field Case(s): 3022
Event Review- Dead Bird @ BASE OF 50FS1196 August-15-2013
Event Review - Dead Bird @ BASE OF 50FS1196 August-15-2013
Questions?