Predictive Data Analytics for Fault Prevention and Improved Reliability

Troy Knutson, P.E.
Who are we?

- 1 of 11 owners of Minnkota Power Cooperative
- Service to 52,000+ members
- 5,000 mi² service area
- 4,700 miles of line
- 40% UG & 60% OH
- 272 MW Peak
Early adopter of technology
• Automated switching scheme in the early ‘70s
• AMR in 1996
• SCADA in 1996

Strategic reliability goals
• SAIDI below 45 minutes
• ASAI of 99.99 or better
• How can we do better?
• Where haven’t we looked?

<table>
<thead>
<tr>
<th>ITEM (a)</th>
<th>Power Supplier (b)</th>
<th>Major Event (c)</th>
<th>Planned (d)</th>
<th>All Other (e)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>4.59</td>
<td>27.01</td>
<td>9.95</td>
<td>23.95</td>
<td>65.50</td>
</tr>
<tr>
<td>2015</td>
<td>12.72</td>
<td>8.26</td>
<td>5.88</td>
<td>19.70</td>
<td>46.56</td>
</tr>
<tr>
<td>2016</td>
<td>5.48</td>
<td>59.81</td>
<td>4.98</td>
<td>25.70</td>
<td>95.97</td>
</tr>
<tr>
<td>2017</td>
<td>7.18</td>
<td>12.77</td>
<td>4.94</td>
<td>18.30</td>
<td>43.19</td>
</tr>
<tr>
<td>2018</td>
<td>4.70</td>
<td>11.55</td>
<td>5.78</td>
<td>23.27</td>
<td>45.30</td>
</tr>
<tr>
<td>5 Yr Avg</td>
<td>6.93</td>
<td>23.88</td>
<td>6.31</td>
<td>22.18</td>
<td>59.30</td>
</tr>
</tbody>
</table>
How it all Started

Breaker operation
- 3:15 a.m. 12/29/17
- Coincidentally looked at the outage viewer
- Used the EA model
- Ran out the line
- Found neutral down
- Was within .5 mile of model!

Neutral wire down
Notifications

Finding out about alarms
• After outages
• In passing conversations

An email group was created
• Technical Services, Operations, and Engineering notified
• Sent by control center

Information consisted of
• Breaker operation or AMT
• Sub, Feeder, Phase target
• Time/date
• Fault current
• Current weather conditions

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Above Minimum Trips

<table>
<thead>
<tr>
<th>Sub</th>
<th>Fdr</th>
<th>Phs</th>
<th>Time</th>
<th>Date</th>
<th>Fault Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>HL 2</td>
<td>B</td>
<td>8</td>
<td>18:25</td>
<td>12-12-18</td>
<td>281A</td>
</tr>
</tbody>
</table>

ALL METERS PINGED ON

Breaker Operation

Weather

CLEAR / 35 DEGREES
Breaker Operations

Control center “pings” AMI system on that feeder

If outage is determined
• Cause is assumed
• No further investigation

If no outage
• Notifications sent out
• An investigation begins
Above Minimum Trips

“AMT” alarms are overcurrent alarms
• Too fast to open breaker

Control Center “pings” AMI system on that feeder

If there is a resultant outage
• Cause is assumed
• Downline overcurrent devices operating

If no outage
• Notifications are sent out
• An investigation begins

AMT alarms seemed to trend higher before outages
Analysis

Engineering evaluates data

- Use engineering analysis model
- Fault analysis/locator tool
- Event and oscillography files from relay
  - Phase target
  - Element that tripped
  - Waveform event capture
Analysis

Use distribution system knowledge
- Splice locations
- Cable age/performance history
- Other devices with known history
- Meter blink history
- Vegetation management
Specific areas identified

Line patrolled out

If nothing apparent found
  • Fault indicators left behind
  • Manual-reset FCIs
  • Rated response time 12 ms
  • Perfect for transient events
Case Study 1
Reed Substation – Feeder 4
Heavy industrial loaded sub
Mostly UG cable
Mix of newer jacketed cable
Some older unjacketed cable (1980s vintage)
Cooper Form 5 controls on reclosers
AMT 3/29/18 5:00 A.M.

B phase target
2,254 Amps
Nothing found
FCIs left behind on B phase
3/31/18 8:46 A.M. and 9:17 A.M.

B phase target
Nothing found
Additional FCI added upstream
B phase target
One tripped
FCIs re-arranged
B phase target
Multiple tripped
Indicated one stretch of cable
History of failures
Switched over to alternate breaker in sub
Cooper Form 6 control
Load transferred to another feeder
Left energized to test theory
B phase target
Multiple tripped
Indicated same stretch of cable
Form 6 control event file downloaded
AMT 4/14/18 Several

8 ms event captured
• It was decided to hi-pot test the cable
  • Internal discussion
• Found failing splice
  • Located well
• Splice fixed
• Cable re-energized
• No load added initially
• AMT alarms disappeared!
Case Study 1 – Lessons Learned

• Possible to find a failing splice before a final failure
• Saved nearly 700 industrial members from an outage
• Fault locator tool didn’t lead to great results
• Manual reset fault indicators worked great
• Many opportunities were given to find this
  • Won’t always be the case
• Mix of commercial and residential
• Almost exclusively UG cable
• Mostly new cable since 1990s
• Cooper Form 6 controls on reclosers
• SCADA devices at sub and downline
AMT 10/9/18 – 7:39 p.m.

- A and B phase target
- 3kA and 2.1kA fault currents
- Fault locator tool
- SCADA fault indicators

SCADA FCIs all tripped

Fault locator tool location
AMT 10/9/18 – 7:39 p.m.

• Indicated SCADA padmount switchgear
• Critical location where three feeders come together
• Switch was given visual inspection

SCADA FCIs tripped
SCADA FCIs did not trip
• Visual open window black
• Some oil leaking out of bushings
• Isolated and taken out of service
• History with this manufacturer
  • On this roadway
• DGA taken recently
  • High moisture (37.5 ppm)
  • Higher levels of acetylene & Ethylene (94 & 58 ppm)
• Meets caution levels in industry guidelines
Other Findings

These techniques have been applied since and found other issues including:

- Neutral wires broken
- Poles hit by farm equipment
- Blown arresters
- Animals
- Failing transformers
- Vegetation
- Voltage regulator issues
- Recloser issues
Other Findings

Cracked lightning arrester
Other Findings

Trees burning in line
Other Findings

Damaged animal protection
Conclusions

A root cause will not be found each time
  • May increase frustration by crews in the short term
  • Investigations are not a waste of time
    • Better response time
    • Prior knowledge

Identifying UG cable locations
  • Fault currents don’t match up
  • Incipient nature of faults
  • Apply wide swath of manual reset FCIs
Conclusions

Breaker controls make a difference
- Each manufacturer provides varying event info
- Some are more helpful than others
- Most helpful include phase target and fault current
- Oscillography capabilities can be useful

Breaker operations are more accurate than AMT alarms
- More success from these events
- True fault current durations
- More accurate fault locations

It is worth the effort!
- No need for SCADA
- Good check against model
Next Steps

- Build a database of events
  - Waveform & oscillography
  - Identify common events
- Build a targeted maintenance program off of the data
QUESTIONS ANSWERED HERE
EVEN THE SILLY ONES

Troy Knutson, P.E.
tknutson@kwh.com
Thank you!