Automated Power System Waveform Analytics for Improved Visibility, Situational Awareness, and Operational Efficiency

B. Don Russell (Presenter)
Carl L. Benner
Jeffrey Wischkaemper
Karthick Muthu Manivannan
Texas A&M University

College Station, Texas 77843-3128
bdrussell@tamu.edu, 979-845-7912

Grid of the Future Symposium
CIGRE US National Committee
21 October 2013
Boston, Massachusetts USA
Situational Awareness or “Visibility” (Conventional vs. Smart Grid vs. DFA)

Undetected Incipient Events (hours, days, weeks)

Detected incipient events. Find and fix sooner. Avoid major event.

Major Event - Outage, Line Down, Fire

Smart Grid Response Potentially faster but still reactive.

DFA Situational Awareness

Detect incipient events. Find and fix sooner. Avoid major event.
Monitoring Topology

High-fidelity DFA devices, connected to conventional CTs and PTs, one per feeder.

Substation
Transformer

Failing Apparatus
Inputs: Substation CT and PT Waveforms

Waveform Analytics

On-Line Signal Processing and Pattern Recognition Analytics
(Performed by Device in Substation)

Outputs

- Line recloser* tripped 8% of phase-A load twice, but reclosed and did not cause outage
- Failing hot-line clamp on phase B*
- Failed 1200 kVAR line capacitor* (phase B inoperable)
- Breaker lockout caused by fault-induced conductor slap

*Analytics applied to high-fidelity substation waveforms report on hydraulic line reclosers, switched line capacitors, apparatus failures, etc, without requiring communications to line devices.
Subject Feeder (125 miles of O/H line)

Unmonitored Line Reclosers (about 20 on this feeder)

- Distribution feeder; conventional overhead construction; 125 miles; numerous reclosers
- Normal operating conditions; no active customer complaints; fair weather.
- 9/28/2011: On-line DFA waveform analytics detected that the “same” fault had occurred twice in the past 18 days. The system responded by generating the line-item report shown above.
- Drilling down into the report provided details of the two fault events.

DFA waveform analytics often provide the only notice of these recurrent “blinks.” The analytics also provide location information – even for faults that have not caused outages yet.
Subject Feeder
(125 miles of O/H line)

Unmonitored Line Reclosers
(about 20 on this feeder)

To Locate Fault: First identify which recloser is operating, by comparing analytics outputs to model.

- Faults were on phase C.
  - Eliminate segments w/o phase-C.
- Operations were single-phase.
  - Eliminate three-phase reclosers.
- First-shot open intervals: 2.0s and 2.1s
  - Eliminate reclosers with first-shot open intervals other than 2 seconds.
- Momentary load loss: 21% and 19%
  - Eliminate reclosers carrying much different load.
- This process identifies which recloser is operating, replacing the time-consuming practice of checking counters. In this particular case, this reduced the search area by 76%.
After identifying which recloser is operating, compare analytics-generated fault currents (510A) to the feeder model. (Measured fault currents commonly match within ~1% from episode to episode.)

Looking only downstream of the previously identified recloser, fault-magnitude analysis targeted a small search area (purple rectangle).

Crew found failing arrester within 4 spans. Future 53-customer outage was averted.

This is not an isolated case. On-line analytics have been used multiple times to 1) detect and 2) locate incipient failures. Remember that these are failures that have not caused outages.
Feeder Lockout (4,000 Customers)

- Fault-induced conductor slap (FICS) locked out 4,000-customer feeder.
- FICS is a complex phenomenon. Investigations are manpower-intensive and often conclude with “no cause found.”
- Within minutes of the subject lockout, the DFA system reported the cause and the location parameters.
- FICS recurs in susceptible spans. Knowing that FICS occurred and finding the offending span enables remediation, so as to avoid future feeder outages.

**Benefits:** Reduced manpower and improved reliability.
Failed Line Apparatus

- Blown arrester caused outage in hard-to-patrol area.
- DFA data provided fault current and suggested blown arrester.
- Feeder has many miles past the tripped device. Knowing the fault current reduces search time substantially.
- Crew typically must look for broken apparatus, tree contacts, downed lines, …. Knowing cause, from waveform analytics, speeds search.

**Benefits**: Reduced manpower; fewer close-to-test attempts; and quicker restoration.
• Momentary breaker operations occurred during two storms, three weeks apart.
• DFA provided notice that both incidents were the same fault.
• DFA also provided information to locate branches pushing phases.
• Trimming prevented future consequences, including momentary operations, feeder lockouts, line damage, and potential burn-down.

Benefits: Improved reliability; reduced damage; scheduled, fair-weather repairs; and improved personnel and public safety.
Intelligent, communicating reclosers are available, but a large population of unmonitored reclosers remains in service for the foreseeable future.

DFA reports recloser operations, in detail, based on substation waveforms.

DFA has revealed multiple cases of reclosers operating incorrectly:
- Excess operations before lockout.
- Failure to complete sequence.

DFA provides visibility of recloser operations, particularly for utilities that test reclosers irregularly.

**Benefits:** Notice of latent problems; improved protection; improved operations; and improved safety.
Summary

- DFA technology applies sophisticated waveform analytics to high-fidelity CT and PT waveforms, to provide heightened visibility, or awareness, of feeder conditions. This enables improved reliability, operational efficiency, and safety.

- The DFA system automates the analytics process, so as to deliver actionable intelligence, not just data.

- DFA is a data-driven technology that embodies multiple functions.

- DFA provides benefits not available from “smart grid” technologies, and can function with a substation-only presence, without requiring distributed sensing, intelligence, or communications.

- Utility partners have used DFA to demonstrate the avoidance of outages and improvements in operational efficiency.