Improving Reliability and Safety of Electric Power Delivery Using DFA Technology

2018 CIGRE Grid of the Future conference
Reston, Virginia, October 2018

presented by

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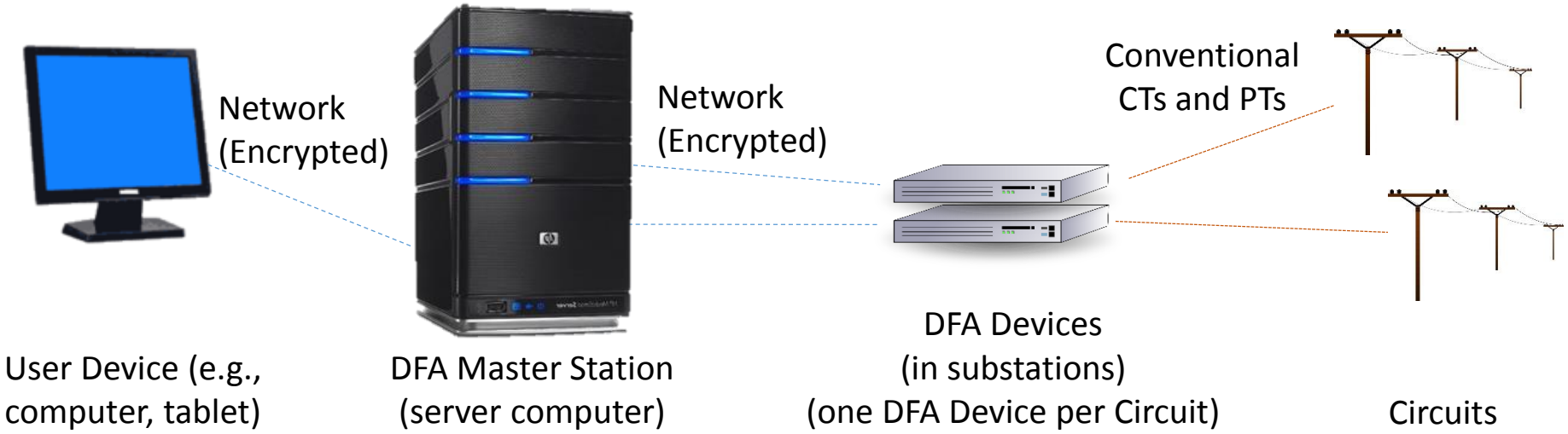
Takeaways

- Electrical signals contain much information about line health.
- But conventional technologies waste most of it.
- Proper use enables:
  - Improved Reliability – fewer interruptions, outages, …
  - Improved Safety – fewer hazards to personnel and public, reduced fire risk, …
- Three examples in this presentation:
  - Each affected reliability. Each affected safety.
  - None were actionable from conventional technologies, AMI, smart grid, etc.
  - All data comes from conventional CTs and PTs at the substation. Communications with line devices (e.g., reclosers) is not required.

Data System for Examples in This Presentation

- Texas A&M Engineering, working with EPRI and industry for two decades, has implemented a real-time monitoring system to detect line issues.
- The technology, known as Distribution Fault Anticipation (DFA), is installed on more than 100 distribution circuits.
- Substation-based DFA devices analyze waveform events and send reports to a central master station server in real-time. Circuit owners and Texas A&M access those reports via secure, browser-based login.
- Mid-South installed DFA on 10 circuits initially and added 10 more in 2018.
- <u>Important</u>: Sensing data comes from conventional, substation-installed CTs and PTs, without distributed sensing or communications with reclosers or other line devices.

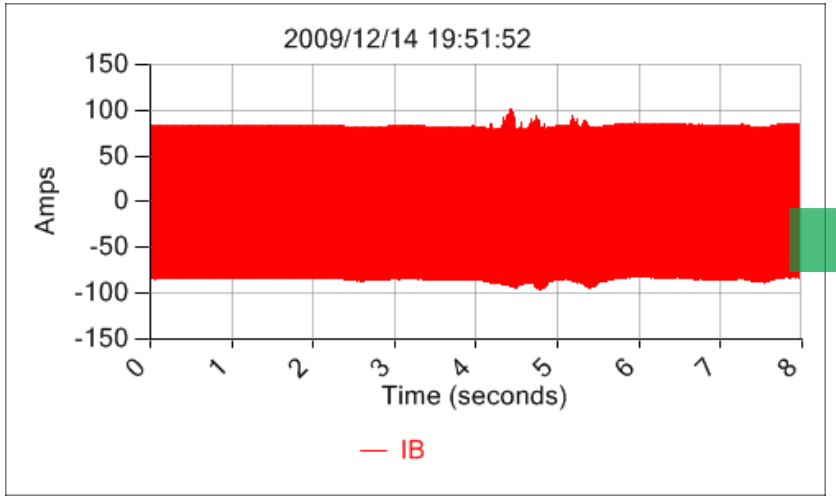
Data System for Examples



Waveform analysis software runs automatically in each substation-installed DFA device, which then sends reports to the DFA Master Station for access by personnel. The Master Station deploys improved waveform analysis software as it becomes available.

Basic Concept – Waveforms Reveal Problems

- Graph shows line current during “normal” operations.
- Conventional technologies waste (ignore) this information entirely.
- Software embedded in the DFA system reports this event as a failing clamp (which can persist for <u>weeks</u>, degrade service, even burn down a line).



Specialized, Automated Classification Software

Example 1

Failing Sub Switch (Series Arcing)

- Rural 25 kV distribution substation
- Three circuits, hundreds of customers
- Blade switch on substation metalwork
- Incipient failure
  - “Hot spot” visible in photograph
  - No customer calls
  - No indication from SCADA
  - No indication from smart meters, even when pinged after being alerted to the switch problem by the DFA monitoring system

A Momentary Aside

Brief Tutorial on Series Arcing

<u>Arcing – two distinct types</u>

- Shunt arcing: <u>unintended</u> current flow, usually phase-to-ground/neutral or phase-to-phase.
- Series arcing: “hot spot” resulting from failing contacts; interferes with <u>intended</u> current flow.

A Momentary Aside (cont'd)

Brief Tutorial on Series Arcing

Series Arcing – Some Characteristics

- Is poorly understood scientifically
- Affects load-carrying devices – clamps, switches, etc.
- Can exist for minutes to weeks prior to notice
- Tends to be highly intermittent - Can "flare up" for minutes and then go quiescent for days
- Causes vague symptoms, making it hard to diagnose
  - Flickering lights
  - Blown fuses (but replacement fuse may hold for a while)
  - Momentary operations, with successful auto-reclose
- Conventional location techniques (current magnitude or impedance) not applicable

A Momentary Aside (cont'd)

Miscellaneous Examples of Series Arcing

Eroded hotline clamp

Conductor burn-through at clamp

Sizzling substation blade switch

Example 1 (resumed)

Failing Sub Switch (Series Arcing)

<u>Chronology for This Example</u>

- Received DFA notification mid-day Saturday.
- Checked SCADA (nothing), pinged meters (nothing).
- DFA software, based on waveforms, estimated that the failing device was carrying most of the circuit's load, so line crews patrolled near the sub.
- Lineman heard buzzing upon arrival at substation.
- Location took 1.5 hours (in rural environment).
- Utility called in repair crews (Saturday night).

Example 1 (cont'd)

Failing Sub Switch (Series Arcing)

<u>Reliability impact</u>

- Avoided prolonged outage to at least one circuit, possibly three circuits (100's of customers).

<u>Safety impact</u>

- Avoided catastrophic switch failure and potentially a substation fire (crew safety, public safety).
- Crews made repairs without time pressure inherent to large outage (crew safety).

Example 2

Fault-Induced Conductor Slap

- Fault-induced conductor slap (FICS) tends to occur repeatedly in specific spans.
- Each episode causes a momentary interruption and possibly an outage, typically of a full circuit.
- Each episode emits particles that can start a fire.
- Each episode causes progressive conductor damage, which can break a line.
- Months can elapse between episodes.
- FICS seldom is recognized or diagnosed correctly.

(See paper for full discussion of the FICS phenomenon.)

Example 2 (cont'd)

Fault-Induced Conductor Slap

(and by the way, a small fire)

<u>Specific Example</u>

- A tree far from the substation caused a fault.
- A mid-point recloser locked out to clear the fault.
- But FICS induced a second fault, miles closer to the substation, causing the substation breaker to lock out the circuit.
- DFA software reported this as FICS and provided fault current amplitude to guide location.
- Mid-South found arced conductor damage ("bright spots"), with burned grass beneath.

Example 2 (cont'd)

Fault-Induced Conductor Slap

(and by the way, a small fire)

- Without remediation, FICS occurs repeatedly in susceptible spans.
- Remediation is simple but occurs only if the FICS is recognized, which seldom happens.

<u>Reliability impact</u>

- Avoided future whole-circuit interruptions and outages.

<u>Safety impact</u>

- Consider the same span experiencing FICS again on a "red flag" (high fire risk) day!

Example 3

Charred Wooden Crossarm

The Circuit

- Long, rural 25 kV distribution line
- Next to pine forest with dry underbrush

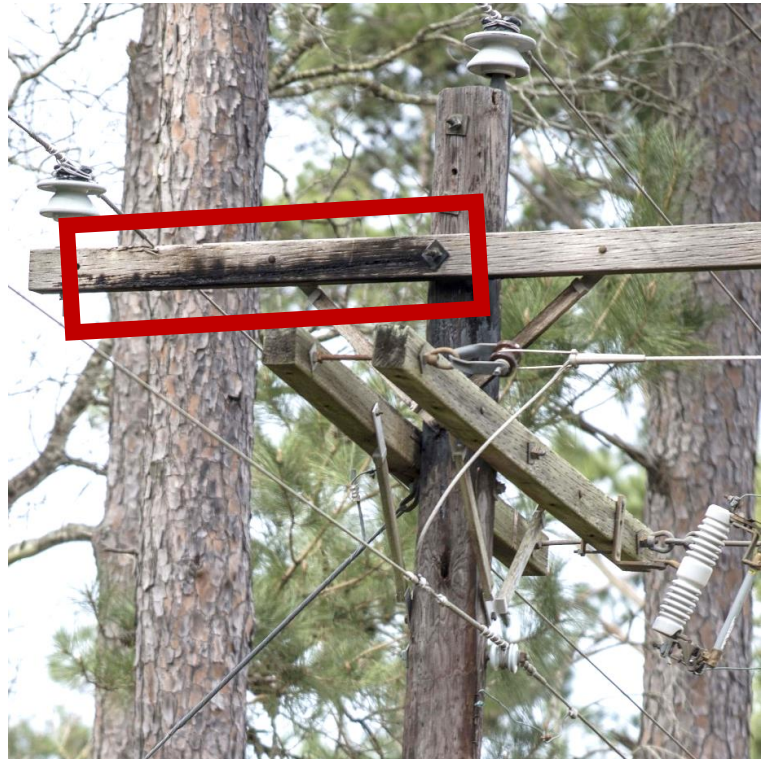
The Condition

- A phase conductor broke free from its insulator and lay on the wooden crossarm.
- This contact caused significant charring along bottom of crossarm (see photo).
  (Note: Problem had been corrected at the time the photo was taken.)

Example 3 (cont'd)

Charred Wooden Crossarm

- Condition caused two flashovers, about a day apart. Each trip/closed a mid-point recloser.
- DFA software reported each fault sequence of events (based on substation waveforms, without communications to recloser).
- Mid-South personnel noted the two similar events, a day apart, during fair weather, and investigated.
- Guided by their circuit model and DFA fault magnitude, a line crew readily located the problem (six spans from the prediction).



Example 3 (cont'd)

Charred Wooden Crossarm

<u>Reliability impact</u>

- Avoided additional interruptions to significant portion of circuit.
- Avoided long outage (broken line and/or crossarm).

<u>Safety impact</u>

- Avoided poletop fire or fallen, burning crossarm.
- Avoided possible downed conductor (fire hazard, crew safety, public safety).

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