Line Switch Failure Causes Outage

DFA Technology Enables One-Month Advance Warning

Robert M. Cheney, Alabama Power Company
Carl L. Benner and Dr. B. Don Russell, Texas A&M University
Ashok Sundaram, Electric Power Research Institute

On the evening of December 15, 2007, a prolonged outage (43,846 customer-minutes) occurred because a main line switch failed – a failure that produced recognizable precursors a month earlier. The circuit was tied to another circuit until repairs could be made ten days later. This resulted in twice the normal number of customers receiving service from a single circuit, which also happens to be the backup circuit for a hospital. The outage occurred at night on a weekend, complicating repairs. It also occurred when manpower availability was low because many crew members had scheduled year-end time off and others were on loan to neighboring utilities recovering from ice storms.

Alabama Power Company (APCO), a Southern Company, participates in the EPRI-sponsored Distribution Fault Anticipation (DFA) project at Texas A&M University. A DFA prototype recorded early warning signs of this failure a full month before APCO or its customers were affected. As DFA technology becomes integrated into daily work practices, it may provide the means to mitigate failures and outages.

What Happened

The first indication of a problem traces back to September. While isolating a fault related to an automobile accident, a lineman had trouble opening a main line switch just downstream of a substation breaker. Visual inspection in the following days revealed no obvious problem, so remedial action was deferred.

Seven weeks later, on November 14, a fault out on the same circuit produced significant current (see ***The Details*** on the page following), causing the substation breaker to trip and reclose multiple times, but not lock out. The high-current faults stressed the already weak switch, and it began to produce failure precursors. These precursors were captured by the DFA prototype. Because the DFA was part of a research project, however, operations personnel were unaware of it. They also had not no outage report or indication of a problem from any other source.

Nothing further happened for a month. Then another fault occurred on the circuit on the evening of December 15. It drew significant current and caused the substation breaker to trip and reclose several times, but again not lock out. Switch failure precursors followed the faults, this time even more substantial than a month earlier. This time the precursors escalated and resulted in final failure of the switch, resulting in an outage for the entire circuit.

Failed switch with arc-damaged contacts

Making It Actionable

A line crew noted a problem with the switch in September, but it did not appear to be a significant problem and did not receive high priority. DFA records following faults on November 14 indicated a failing switch, likely to be very close to the substation. Integrated into work practices, this information would be sufficient to take action and avoid the outage.

Three switches were close enough to the substation to be suspect in this case, but closer inspection likely would have made obvious which one was failing. In the present case, determining which was failing would have been even more straightforward because the subject switch already was on a list of suspect apparatus. The November 14 indications could be used to elevate repair priority, a full month in advance of the outage. This would enable repairs under more favorable working conditions during normal working hours.

Conclusions and Next Steps

APCO is participating with EPRI and Texas A&M in a pilot DFA demonstration project sponsored by the US Department of Energy. APCO will perform first-ever installations of DFA-based equipment in pole-mount locations, as well as at the substation. This project also is investigating how to integrate DFA technology into daily work practices.

Says Chuck Wallis, Distribution Engineering Services Manager for Alabama Power Company, "Early warning signs weeks before a hard failure and outage can have significant impact on our reliability. We are excited about the benefits DFA technology has shown in prototype installations and look forward to integrating it into our distribution automation systems and our work practices as we move forward with a DOE-sponsored pilot project and beyond."

The Details

A substation-based DFA prototype recorded RMS and high-speed current and voltage waveforms related to the faults and incipient faults November 14 and again December 15. Figure 1 shows RMS currents during the initial fault on November 14. The fault began between phases A and C and produced current that varied between 4 500 and 5 800 amperes. It persisted four cycles before tripping the substation breaker. The breaker reclosed ten cycles later and the fault resumed about 2-1/2 seconds after that. The fault evolved into a three-phase fault after 51 cycles, and tripped the breaker again 11 cycles later. The breaker reclosed after 30 seconds and remained closed.

The DFA prototype recorded subtle anomalies following the high-current faults. Figure 2 shows the RMS current a few seconds after the second reclose. These substation-based measurements show relatively constant load currents of 105, 110, and 155 amps on the three phases. Phase A also exhibits an erratic current component, however, in addition to the load. The erratic behavior ceased after a short period.

Similar faults, trips, and recloses recurred 2-1/2 hours later (23:04, 23:06, and 23:09). Figure 3 shows a five-second period shortly after that evening's final fault, trip, and reclose. For about a minute, the phase-A current again exhibited erratic behavior indicative of a failing switch. That behavior declined and then ceased, with the circuit continuing to serve customers and APCO receiving no outage calls.

A full month later, on December 15, three more similar fault sequences occurred over a period of 13 minutes. High-current fault currents again were followed by erratic currents indicative of impending switch failure on phase A, even more pronounced than a month earlier. The sequence ended when the phase-A switch failed catastrophically and caused a 9 000-ampere fault that locked out the breaker and interrupted service to 294 customers for 2-1/2 hours.

It is believed that age and stresses over time put the switch in early stages of failure. The high-current fault events were precipitating events that produced thermal and mechanical stresses in the switch contacts. This caused the contacts to heat, which degraded their continuity and produced the early warning signals. For the November faults, the switch's mechanical and electrical integrity was sufficient to recover as the switch cooled in the minutes after the fault. However the contact arcing likely caused additional pitting and pushed the switch closer to failure. On December 15 the switch's condition was degraded to the point that it could not recover. At that point the contact arcing became severe enough to cause flashover and final destruction.

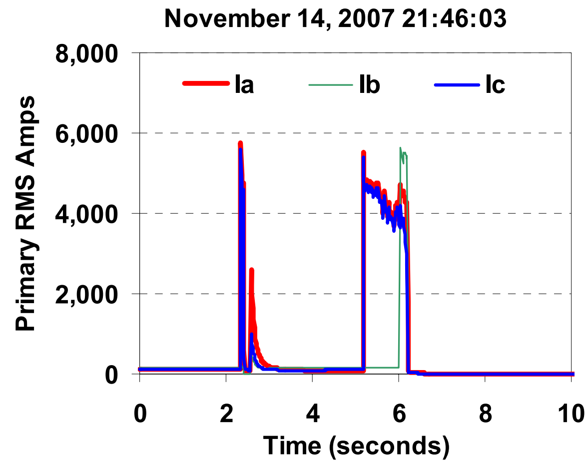

Figure 1. Initial fault and breaker operations

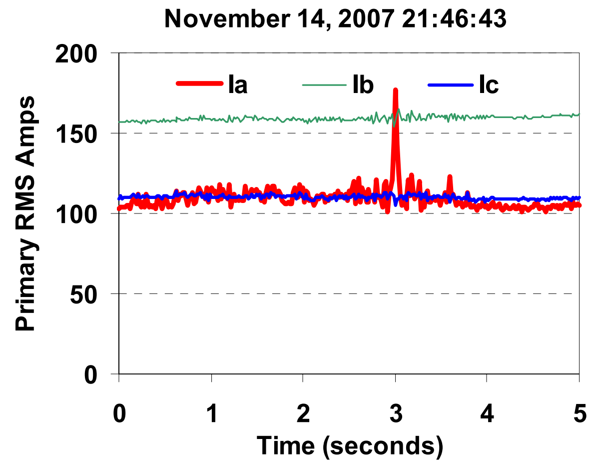

Figure 2. Early incipient switch failure signals

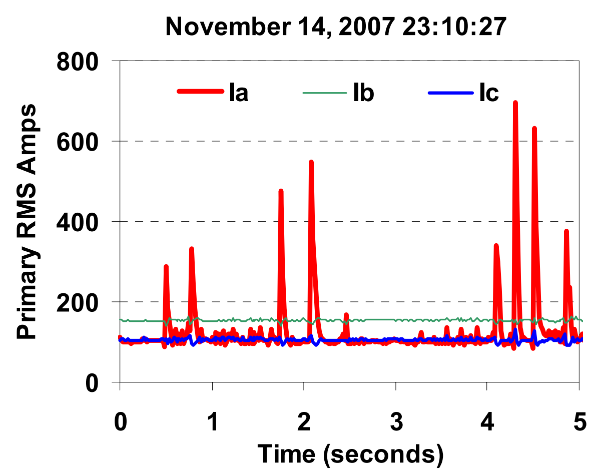

Figure 3. Incipient failure activity after final November fault