CASE STUDY

Jacksonville Electric Authority
Jacksonville, Florida

Facility Description

Jacksonville Electric Authority, located in Jacksonville, Florida, is the eighth largest community-owned electric utility company in the United States and the largest in Florida. JEA serves more than 417,000 electric customers, 305,000 water customers and 230,000 sewer customers. In addition to Duval County (Jacksonville), JEA has customers in Clay, Nassau and St. Johns counties.

Challenge

In 1993 PQI received a call from Jacksonville Electric Authority's chief electrical engineer, regarding an unusually high number of unexplained medium voltage feeder circuit 'outages' throughout their system. The majority of these 'outages' had occurred during normal business hours. Inclement weather did not seem to be a factor.

During our initial discussions, we learned that these unexplained 'outages' were all due to the operation of their feeder breakers' time-overcurrent neutral protection relays' (51N) responses.

This type of protection is included in their 'standard' three-phase, four-wire feeder protection schemes (i.e. 3 x 50/51 + 50/51N). In this scheme, their three feeder breaker current transformer secondary circuits (1/Ø) are 'wye' connected, with one 50/51 relay connected in each phase circuit and the 50/51N relay connected in the neutral circuit. In JEA's case, the 51N relays' pickup current was set at 10% of its 51 relays' phase current pickup.

50/51N feeder protection is used to detect phase-to-ground faults. In virtually all cases, evidence of a feeder circuit phase-to-ground fault could not be established.

To determine the cause of these unexplained outages, PQI visited all JEA transformer stations in Duval County (Jacksonville). Using a Fluke® 41 power quality analyzer and the appropriate relay test slide, we measured the current flowing through each 50/51 and 50/51N protective relay on each relay panel. Based on each relay's harmonic current profile, we quickly concluded that the troublesome 51N relay operations were due mainly to 180Hz harmonic currents on the medium voltage feeders. In the majority of cases, the 51N measured relay currents were approaching their pickup settings.

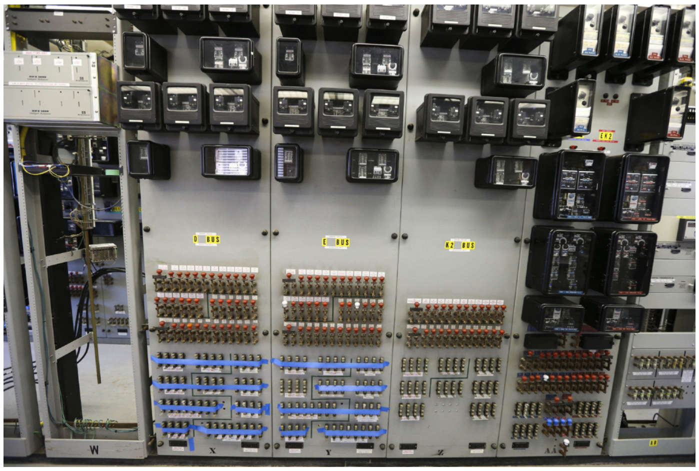
180Hz (I_3) is the lowest order, highest magnitude third-order zero-sequence harmonic current in a 60Hz power system. Zero-sequence harmonic currents also include 540Hz (I_9), 900Hz (I_{15}), 1260Hz (I_{21}), etc.

Transformer Station's Medium Voltage Yard

Typical Medium Voltage Feeder Circuit Panels with Westinghouse Type CO 50/51 & 50/51N Protective Relays

Since a 180Hz harmonic current can only be generated by a phase-to-neutral connected nonlinear load, we concluded that JEA's medium voltage customers must be supplied via wye-wye connected power transformers. This conclusion was confirmed. Wye-wye connect transformers allow zero-sequence harmonic currents to pass through in either direction. Because the power sources' zero-sequence impedance is higher at the loads with these winding configurations, zero-sequence voltages and voltage distortion are often substantially higher at the customers' loads. Voltage distortion at the loads has a significant negative impact on their energy efficiency.

With a 480/277-volt output, the usual source of zero-sequence current is 277-volt lighting, which includes nonlinear switch-mode power supplies. If the transformer's output is 208/120-volts, the problem is even greater, since most loads in a modern building include 120-volt nonlinear switch-mode power supplies.



Typical Medium Voltage Feeder Circuit Panels
with GE Type IAC 50/51 & 50/51N Protective Relays

Solution

To prevent future nuisance 51N 'pickups' and feeder outages, we advised the utility to calculate and recalibrate all 51 & 51N medium voltage feeder protective relay pickup settings to reflect the systems' zero-sequence current reality. This, we advised, could be done as follows:

51: Simultaneously measure the maximum RMS current, which includes all positive-, negative- and zero-sequence harmonic currents, and the fundamental (60Hz) current flowing in the current circuit of the most heavily loaded relay on each feeder circuit. Calculate a *'Correction Factor'* for the original pickup settings as follows:

'Correction Factor' = I_{RMS} / I_F

Example: If the RMS current was 9.3A and the fundamental (60Hz) current was 7.2A, the original 51 pickup setting's *'Correction Factor'* would be 1.29

51N: A calculated *'Correction Factor'* for the 51N would be identical to the method detailed above. However, the *'Correction Factor'* would be significantly higher, since the zero-sequence harmonic currents in the medium voltage circuits' three phases add arithmetically in its neutral. In addition, under balanced three-phase loading, the fundamental (60Hz) component is relatively small.

Example: If the RMS current was 6.3A and the fundamental (60Hz) current was 0.5A, the original 51N pickup setting's *'Correction Factor'* would be 12.6.

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Based on an appropriate sampling, we suggested the utility's protection specialists may wish to develop standard *'Correction Factors'* for their 51 and 51N protection schemes.

Although not part of PQI's scope-of-work in this case, the utility customers' voltage distortion and load efficiency problems, described above, could be solved by applying a Type Z I_0Filter™ at the wye-wye connected medium voltage power transformers' main secondary switchboards or panels, or, more appropriately, at the single-phase nonlinear loads' branch circuit panels.

The problems described in this Case Study are common on most utility medium voltage distribution systems and in their customers' low voltage systems.

Impact

Increasing the 51 and 51N protective relays' pickup settings resolved the medium voltage feeder circuit 'outage' problem.