Return to Service Failure, Cooperative Troubleshooting

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Presented by: Carlos Cordova, Jhobany Tortolero, Matthew Klein, Tony Limon
INTRODUCTION

• SCOPE: Relay protection upgrades for three (3) 4.16kV feeders with reclosers and recloser controls.
• WHAT: During restoration, the feeder in question tripped out of service and would not stay closed during subsequent close attempts.
• WHY: Tie switch and voltage regulators were not accounted for, created circulating current between two of the feeders.
• HOW: Cooperation between field engineering and office-based engineers was of utmost importance.
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AVAILABLE ONELINE
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INITIAL INVESTIGATION

- No equipment damage.
- No apparent signs of a fault.
- CT Ratio setting in the recloser control was found to be wrong and was corrected.
- Close was attempted again.
  - Recloser tripped out once more.
- Recloser failed contact resistance measurement threshold.
  - Client decided to replace the recloser.
- Event report gathered from relay.
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EVENT REPORT
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EVENT ANALYSIS

- A phase-time overcurrent element timed out and tripped recloser ~90ms after close.
- Balanced 3-phase fault.
- No voltage suppression noted.
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POSSIBILITIES

• Cold load pickup.
  • Feeder 1 was carrying both feeder loads and was fine.
• Internal fault in the recloser.
  • No conclusive physical evidence.
• Possible faults in the substation disconnect switches.
  • None found by field personnel.
• Incorrect nominal relay current
  • Corrected and close attempted but failed
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TELECONFERENCE WALKDOWN

- Starting at Feeder 3 Recloser
  - ~150ft underground cable to the exit point
  - Set of voltage regulators near the overhead riser
  - Followed by ~1000ft of overhead cable
  - Connected to feeder tie switch (new)
  - ~500ft of overhead cable toward substation to Feeder 1 regulators
  - ~500ft of cable to Feeder 1 recloser
- Ending at Feeder 1 Recloser

- Feeder 3 Regulators noted at +16 tap
- Feeder 1 Regulators noted at +1 tap
- Combined load current noted at ~250 Amps on Feeder 1 metering
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TELECONFERENCE WALKDOWN
ROOT CAUSE

• Given the connections and having knowledge of transformer paralleling, it was suggested that circulating current resulting from mismatched regulator banks could have enough magnitude to exceed the overcurrent pickup.

• Hand calculations
  • Assumed conductor impedance of 0.25 Ohms
  • 32-5/8% step regulators with +/- 10% regulation
  • Result was approximately 960 Amps circulating current
  • More detailed calculations warranted
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ROOT CAUSE
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Results

- Calculations

\[
\begin{align*}
L_{\text{Line Reactance}}^{\text{ABB Red Book}} &= j0.74 \text{ ohm/mile} \\
L_{\text{Line Resistance}}^{\text{SouthWire}} &= 0.4150 \text{ ohm/mile} \\
L_{\text{Line Impedance}}^{\text{4.0 Conductor}} &= L_{\text{Line Reactance}}^{\text{ABB Red Book}} + L_{\text{Line Resistance}}^{\text{SouthWire}} \\
L_{\text{Line Impedance}}^{\text{4.0 Conductor}} &= (0.415 + 0.74j) \text{ ohm/mile} \\
U_{\text{G49A}} &= 150 \text{ ft} \\
O_{\text{H49A}} &= 1000 \text{ ft} \\
O_{\text{H41A}} &= 500 \text{ ft} + 500 \text{ ft} \\
B_{\text{us Work}} &= 40 \text{ ft} \\
L_{\text{Line Length}} &= U_{\text{G49A}} + O_{\text{H49A}} + O_{\text{H41A}} + B_{\text{us Work}} = 2190 \text{ ft} \\
S_{\text{ystem voltage L_L}} &= 4160 \text{ V} \\
S_{\text{ystem voltage L_N}} &= \frac{S_{\text{ystem voltage L_L}}}{\sqrt{3}} = 2401.7771 \text{ V} \\
|\text{Calculated Current}| &= 751.6023 \text{ A} \\
\text{arg}(|\text{Calculated Current}|) &= -52.3752 \text{ deg}
\end{align*}
\]
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Results

• Calculations

\[ \text{Percent Diff} := \frac{\text{Event Analysis Fault Current} - \text{Calculated Current}}{\text{Event Analysis Fault Current}} \]

\[ \left| \text{Percent Diff} \right| = 20.4444\% \]
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CONCLUSION

• New temporary tie switch between the feeders placed outside the station
  • Physically feasible and easier to install where feeders cross
  • Existing fused bypass switches not used for this work
• Regulators were not mentioned in written switching orders
  • Regulators not depicted in the original station one-lines
  • A recommendation was made to set Feeder 1 and Feeder 2 regulators to matching taps
• Communication between field and office personnel is key
  • Breakdown contributed to missing the regulators in the switching plan
  • Coordination achieved quick and accurate solution to a complex problem
Thank You

Carlos Cordova, Jhobany Tortolero, Matthew Klein, Tony Limon
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