NERC Lessons Learned

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Misoperation of 87N Transformer Ground Differential Relays Causing Loss of Load

Northeast Power Coordinating Council

April 14, 2020
Problem Statement

- 345 kV ring bus with 4 in-service XFMRs (1 standby)
- 13 kV feeder fault
- (3) 87N neutral/ground diff relays misoperated clearing the XFMRs
- Remaining XFMR overloaded before standby could be switched in
- (1) 345 kV path stayed in service
- Loss of load

Figure 1: One-line Diagram of Transmission and Area Substations [1]
• 87N relays misoperated from open or missing connection between the 13 kV transformer CTs and the neutral auxiliary CT that supplies each 87N relay
• Missing connection unbalances the differential configuration
• Missing neutral connection occurred during a 13 kV breaker retrofit program
• Original overall schematic not used
• Separate crew found issue later on 4th XFMR
Lessons Learned

• Missing wiring was corrected
• Process developed to redraw AC circuits with templates
• Standardization of commissioning testing for substation equipment and relay protection systems
• Provide feedback to supervision and engineering when problems are encountered

Figure 3: Added Neutral CT Connection to Complete 87N Circuit Post-Event [1]
Protracted Fault in a Transmission Substation

Northeast Power Coordinating Council

April 14, 2020
Problem Statement

- Single-phase-to-ground fault on CCVT
- Output temporarily isolated but coupling capacitors remained connected
- Communications equipment shut down because of an electrical transient associated with the fault
- Loss of communications prevented the line differential relaying from properly detecting the fault
- Remote back-up relays slow to detect fault for multiple reasons

Figure 4: One Line Diagram of Faulted Circuit and Line Differential Protection [2]
• Fault was not cleared by either the primary or the back-up relay protection
• Four multiplexers (with 8 power supplies) automatically shut down from transient
• Control scheme intended to protect the power supply from overloading
• Transient generated coupled into the 125V DC battery supply
• Continuity between two adjacent ground grids

Figure 5: Failed C Phase CCPD [2]
Lessons Learned

- All damaged equipment replaced
- DC supply for multiplexers shortened
- Ground grids reinforced
- Extent of condition review conducted system-wide to replace power supplies modified to disable shutdown scheme
- Diversify primary and backup equipment
- Equipment out of service should be completely isolated

Figure 6: Remnants of Bus Insulators [2]
Loss of Automatic Generation Control During Routine Update

Western Electricity Coordinating Council

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• Typical weekly AGC system build was being deployed
• AGC was controlled from Control Center #1 with a completely redundant hot-standby system at Control Center #2
• Installation done at CC #2 and control transferred
• Critical AGC task aborted and critical control functionality lost
• Switch back to CC #1 AGC since deployment completed
• Same critical task aborted on the Control Center #1 AGC
• Generation schedules could not be set and ACE could not be automatically calculated
• Change made to primary inadvertent interchange (PII) alarm text
  • PII alarm text were modified from i4 to i5 to allow excess of +/- 999
  • New alarm exceeded limit of 80
  • Run-time abort after first alarm
  • Immediately deployed code to ignore the PII alarm
  • Permanent remedy to shorten text to 72 characters with 5 digits for MW

**PRIOR TO BUILD:** LARGE CHANGE IN PII FROM XXXX TO XXXX MW.
SELECT ACCEPT TO ALLOW PII TO UPDATE. (79 characters)

**AFTER BUILD:** LARGE CHANGE IN PII FROM XXXXX TO XXXXXX MW.
SELECT ACCEPT TO ALLOW PII TO UPDATE. (81 characters)

**CURRENT:** LARGE CHANGE IN PII FROM XXXXXX TO XXXXXX MW.
SELECT ACCEPT TO UPDATE PII. (72 characters)

*Figure 7: PII Alarm Text [3]*
Lessons Learned

• Validate changes in a test environment first regardless of size
• Software testing process should include:
  – Test Scope
  – Test Design
  – Test Execution
  – Test Closure
• Operate in parallel enough time to determine that no adverse condition has been introduced prior putting that center in control
• Avoid standard library functions that are not bounds checked
1. Misoperation of 87N Transformer Ground Differential Relays Causing Loss of Load

2. Protracted Fault in a Transmission Substation

3. Loss of Automatic Generation Control During Routine Update