

Lessons Learned

- Relay work is hard and stressful, somedays you are the hero....other days you are the goat.
- Here are some true stories from the field that demonstrate some hero, but mostly goat.



Lessons Learned



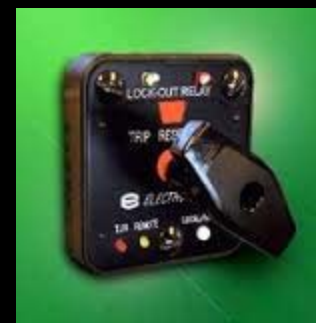
WELL CRAP

Christopher Substation

- 115Kv-13.09Kv distribution substation
- 25 MVA transformer with 5 feeder circuits
- Mostly commercial but some residential load
- All microprocessor relays
- 115Kv high side breaker
- Metalclad 13.09Kv switchgear
- Average load of around 20 MVA

Christopher Substation

- Car pole accident on feeder 22
- Transformer LOR rolled and tripped entire station offline
- 6000 customers
- Pretty sure it's not supposed to work like that!



Christopher Substation

- Arrived at substation to find two substation crews and four service linemen waiting on me to make a decision on what didn't work correctly
- LOR was rolled and I had a 150TG target on the transformer overcurrent relay
- This relay protects for 115Kv overcurrent and 13.09Kv neutral overcurrent

Christopher Substation

- Possible causes?
 - Slow feeder breaker caused bank protection to trip bus in a breaker failure condition?
 - Is there trouble with the transformer?
 - Is there trouble with the bus work? Possibly exposing a weak spot with the feeder fault?
 - What is with the 150TG target?

Christopher Substation

- Rule out possible causes
 - No slow feeder, SOE showed all feeder breakers were “externally” tripped
 - Back up trip comes from differential relay
 - No transformer trouble, tested good
 - No bus work issues, tested good
 - Relay in question tested fine and is working as programmed
 - A little stumped at the moment

Christopher Substation

- From station logbook I discover a “setting change” was made to the relay in question two weeks prior to this incident
- Phone the technician about the setting change
- Engineer calls about the same time
- Finally getting somewhere

Christopher Substation

- 3I0 and Ground bias for relay elements
 - 3I0 = calculated residual
 - Ground = actual current from a CT
 - 150TG overcurrent setting was set for 6.0 amp pick up and biased 3I0. This would mean the relay would issue a trip for 960 amps of 115Kv current. The purpose of this element is to trip the bank for trouble on the high side if the differential relay was disabled or out of service.

Christopher Substation

- Two weeks prior to incident:
 - Technician was doing an unrelated settings verification and noticed the 3I0 bias on the 150TG setting. He felt this should be changed to Ground bias as he inadvertently thought this element was protecting the 13.09Kv neutral, when in fact that was accomplished with an entirely different element. He contacted an engineer and the decision was made to change the bias.

Christopher Substation

- Once the change was made the 150TG element was now set for 6.0 amp pick up with Ground bias. This will cause the element to pick up and trip the transformer on 720 amps of 13.09Kv neutral current! Way to sensitive! The car pole accident created more than 720 amps of 13.09Kv neutral current and the 150TG element tripped the transformer.
- Setting was revised with the consultation of a different engineer.

Christopher Substation

- Conclusions
 - Pay very close attention to the relay elements and logic
 - Understand the intended operation of each relay element
 - Always fill out the log book for even the smallest actions

A photograph of an open log book with handwritten entries. The left page has a table with columns for time, date, and location. The right page has a table with columns for time, date, and location. The entries are handwritten in ink.

Lessons Learned



Obrien Substation

- 230Kv-115Kv substation
- 2-325 MVA transformers
- Multiple 115Kv lines
- Multiple 230Kv lines
- Newly commissioned relay packages for both transformers
- Transformer #1 energized for about a week

Obrien Substation

- Beautiful summer day, easy Friday
- LOR for transformer #1 rolls
- Transformer #1 trips offline
- Overcurrent target on Primary relay
 - Possible settings issue?
 - Overloaded transformer?
 - 200MW was recorded just before transformer tripped

Obrien Substation

- Review settings in Primary relay
 - 51P element was responsible for the trip
 - Set for 2.5 amp pick up with 6.0 time dial
 - CT ratio 200:1 PT ratio 2000:1
 - The math for pick up calculation:
 - $2.5 \text{ P.U.} \times 200 = 500 \text{ amps} \times 132794 \text{ L-N} = 66397000\text{w}$
 - $66397000/1,000,000 = 66.397 \text{ MW} \times 3 = 199.191 \text{ MW}$
 - $199.191 \text{ MW} = \text{TRIP}$ (we recorded just over 200MW)

Obrien Substation

- We hit 200MW and tripped
 - Bank is rated for 325 MW with an 8 hour 10% overload
 - We discovered that the settings were transposed
 - Relay was set 2.5 P.U. with 6.0 time dial
 - Should have been set 6.0 P.U. with 2.5 time dial
 - The math: $6.0 \times 200 = 1200 \text{ amps} \times 132794 = 159352800 \text{ watts}$
 - $159352800 / 1,000,000 = 159.353 \text{ MW} \times 3 = 478.058 \text{ MW}$

Obrien Substation

- Transformer was restored to service about 10 minutes after tripping with new settings installed
- Technician was asked if he checked the settings in the secondary relay and he replied “yes”
- 10 minutes later the transformer tripped again!

Obrien Substation

- It was discovered that the Technician actually didn't change the settings in the secondary relay
- Settings were changed and the transformer was returned to service
- The first trip was on System Protection Engineering...the second trip was on the Relay Technician

Obrien Substation

- Conclusions
 - Pay very close attention to the settings provided by engineering
 - Don't hesitate to "recalculate" the engineer's settings
 - Stay calm in situations...the technician was a bit stunned at the first trip and didn't fully understand the question asked of him
 - Stay focused...solve the problem...learn

Lessons Learned



Rolling Hills Substation

- 25 MVA transformer with LTC
- 4-13 Kv distribution circuits
- 6000 residential and commercial customers
- Electromechanical relays for feeder and bank protection
- 1970's vintage

Rolling Hills Substation

- Transformer trips offline
- LOR rolled opening high side protective device
- Substation operator is dispatched
 - Reports neutral overcurrent target on transformer relay
 - Reports all distribution breakers were found closed
 - Reports no other targets

Rolling Hills Substation

- Original assumptions:
 - Stuck or ratcheted neutral overcurrent relay causing miscoordination between transformer and feeder protection
 - Wrong settings applied to neutral overcurrent relay after last maintenance cycle
 - Possible feeder breaker failure

Rolling Hills Substation

- Background and Observation
 - Discovered multiple phase and ground targets on multiple feeder breakers
 - Upon questioning, the operator notes that one feeder breaker would not open electrically, he had to use the mechanical trip
 - That would have been nice to know!

Rolling Hills Substation

- Conclusions
 - Feeder breaker had bad trip solenoid causing it to not trip on feeder fault
 - Breaker failure
 - Transformer protection worked perfectly as back up for failed feeder breaker
 - Listen, but keep an open mind
 - Reset targets in a timely manner

Lessons Learned



Fredonia Generating Station

- 4-50 MW gas turbine generators
- 2-16Kv to 115KV GSU
- 2-16Kv to 230Kv GSU
- 115Kv switch yard
- 230Kv switch yard
- Located near Anacortes, Washington

Fredonia Generating Station

- Unit 4 down for maintenance
- Unit's 1, 2 ,3 all offline, but available
- Around 8 pm unit 4 GSU trips
- Substation and Generation personnel dispatched

Fredonia Generating Station

- One responder from Substation group
 - New wireman...been with PSE for 3 months
 - Two relay technicians working at substation 100 miles away are called to help, no response locally
 - Over the phone diagnosis provides no information
 - No targets on any relays was reported
 - Relay technicians will complete their work...get a few hours of sleep, and head towards FGS

Fredonia Generating Station

- Arrive at FGS
 - Meet with Substation and now Generation personnel
 - AHHH! It gets worse now...in the six hours it took the relay technicians to sleep for a bit and drive to FGS...the batteries have gone completely flat!
 - Unit 4 provides it's own station service
 - All relays and RTU are completely dead
 - Do see lock out relay rolled....

Fredonia Generating Station

- Troubleshooting
 - Ask Generator folks to please back feed some station service from anywhere to get the batteries back up....
 - Inexperienced Generation staff...not sure how to go about getting us station service
 - I will not be deterred...Use small generator to power my test set, and use test set to power relays...HA!

Fredonia Generation Station

- Troubleshooting
 - All microprocessor relays show no events
 - AH HA! 59N Bus Neutral overvoltage relay has a target
 - Now that it is daylight...dead crow on ground just below GSU low side switch
 - Two things don't belong in this substation....59N target and dead crow

Fredonia Generating Station

- Troubleshooting

- Diagnosis

- Crow flew onto GSU low side bus
 - When the bird attempted to fly away, it went A phase to ground
 - This caused A phase voltage to collapse, in turn causing both B and C phase voltages to rise
 - The open Delta connection of the low side PT's creates enough voltage to trigger relay
 - Relay trips properly

Fredonia Generating Station

- Problem solved...
 - Not quite
 - Generation personnel are unable to restore station service to unit 4
 - Decision was made to energize unit 4 GSU with dead relays! Are you kidding me!
 - We got lucky...bank energized with no issues and battery charger nearly jumped off the wall with all the current it was drawing

Fredonia Generating Station

- Conclusions
 - Inexperienced personnel will pose challenges
 - An alternate station service needs to be available
 - The battery bank was woefully undersized for the application...replace batteries
 - The dead crow was not visible until daylight hours
 - All targets from all relays should be noted
 - I will never accept energizing a transformer unprotected for as long as I work, never again

Talbot-O'Brien 230Kv Line



Talbot-Obrien 230Kv

- TOP-006 testing
 - New Breaker installation at Talbot Hill substation
 - TOP-006 Testing was not completed at time of installation
 - Decision was made to return after line was energized to perform TOP-006 testing
 - Primary relay was removed from service and test set was connected

Talbot-O'Brien 230Kv

- TOP-006 testing
 - Test set had minor issue...every now and then the three current channels would not all start at exactly the same time....
 - This was the case this time and caused the relay to issue a trip...but hey no worries, the trip is isolated
 - The phone rings.....

Talbot-Obrien 230Kv

- TOP-006 testing
 - Load Dispatcher asks if “I meant to do that”
 - “Do what?” I ask
 - “867 tripped” he says...
 - “867 is at Obrien...I’m at Talbot” I tell him
 - Oh wait....867 is the other end of the line that I am testing....
 - Darn it!

Talbot-Obrien 230kv

- TOP-006 testing
 - What could have happened?
 - TAL-OBR has transfer trip
 - I forgot to turn transfer trip off...
 - Relay issues a trip from misfiring test set
 - Relay sends a transfer trip to opposite end
 - All systems worked as designed

Talbot-O'Brien 230Kv

- TOP-006 testing
 - Conclusions
 - Understand the complete operation of the line/scheme under test
 - Turn transfer trip off while testing relays with line in service
 - Possibly test TOP-006 while line is out of service
 - Be humble....things happen....do your best to respond to the issue

Thank You

