Lessons Learned

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Relay Technician Puget Sound Energy

Outline

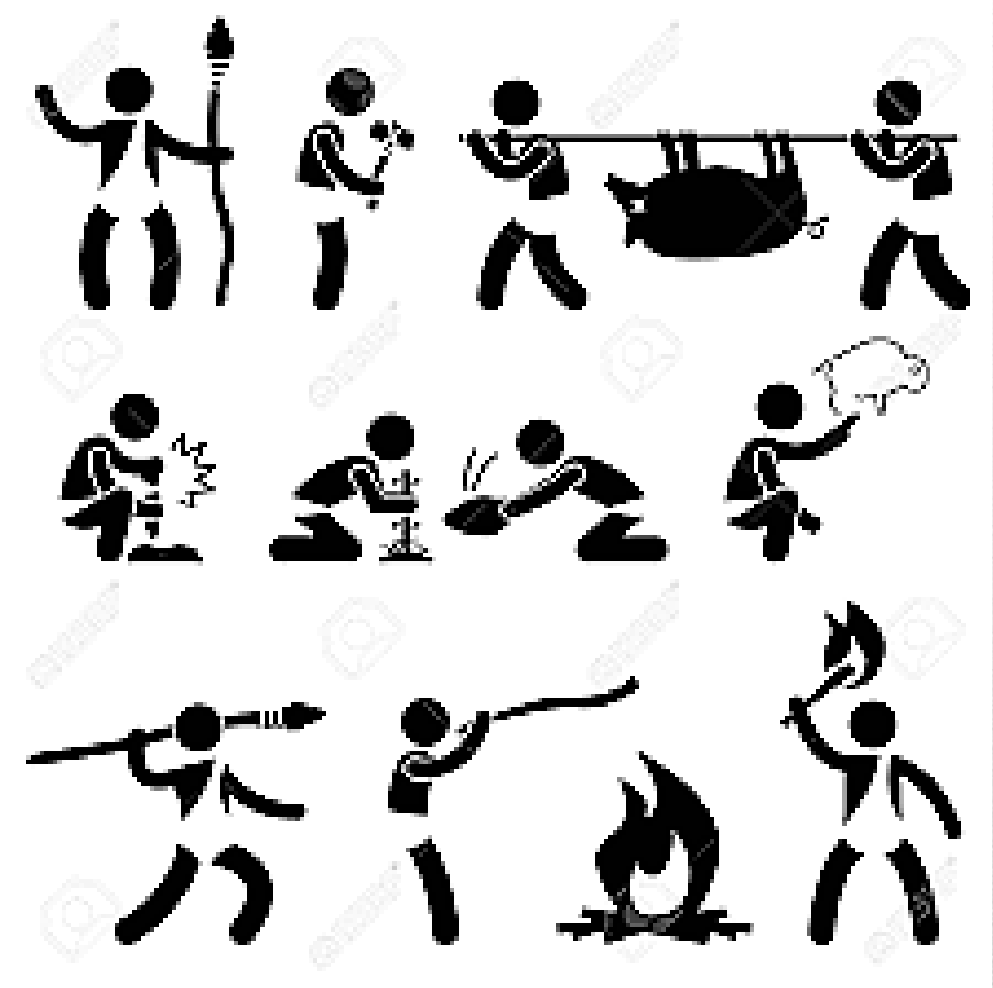
- Terms and Vocabulary
- Tools
- Electromechanical Relay Testing Concerns
- Microprocessor Relay Testing
- Results (Anticipated and Unanticipated)
- Root Cause Analysis
- Events and Observations

“Old Timer” Advice

- Relay work is **complicated** and **stressful**
- Math **is** involved
- You **will** make mistakes
- Electromechanical relays are **very** delicate
- Microprocessor relays do **exactly** as programmed
- 9.75 times out of 10, **you** connected/shorted/programmed something **wrong**, the relay is **not** broken or “messing” with you

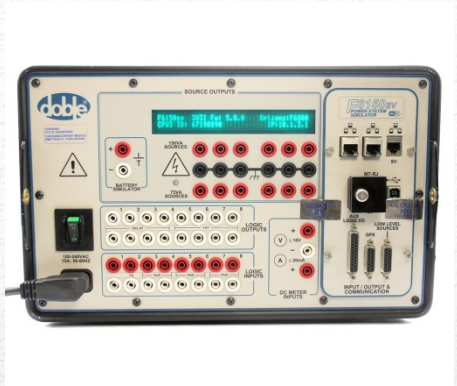
- Spurious Torque
- Directionally Controlled
- Polarizing Units
- Maximum Torque Angle
- Shunt Screws
- MHO Circles
- Polarity
- Manual Relay Testing

Terms and Vocabulary



Tools

- **System Simulator Test Set**
  - Proper use and care of test set
  - Calibration
  - Limitations
  - Repair



Tools

- **Multi-meter**
  - Proper use and care
  - Understand Operation of all functions
  - Understand Limitations and Ratings
  - Blown fuse replacement

Tools

- **Test Blocks**
  - Understand how to properly set up and use test blocks on energized relays

Tools

- **Computer**
  - Security Updates
  - Application Updates
  - Hardware Updates
  - Physical Security
  - Peripheral Devices

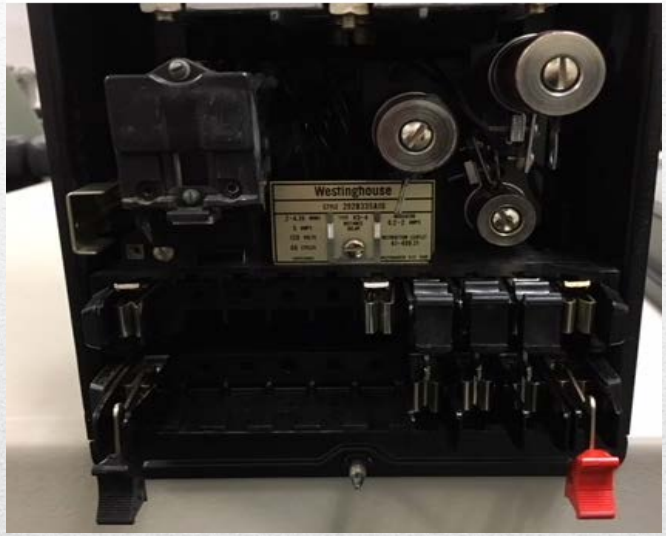
Tools

- **Your Brain**
  - Leave your comfort zone
  - Learn new techniques
  - Exposure to complex concepts
  - Learn new technologies
  - Know when to ask for help

Tools

Electromechanical Relay Testing Concerns

- **Removing in service relays from the case**
  - Cover
  - CT shorting
    - ABB shorting switch
    - GE shorting bars/paddle
  - Voltage restraint
    - Test switch sequence



Electromechanical Relay Testing Concerns

- **Removing in service relays from the case**
  - Adjacent relays
  - Vibration concerns

Electromechanical Relay Testing Concerns

- **Removing in service relays from the case**
  - Compromised protection
  - Temporary replacement relay

Electromechanical Relay Testing Concerns

- **Removing in service relays from the case**
  - Target reset mechanisms
    - Removed from cover
    - Requires qualified person to reset targets

Electromechanical Relay Testing Concerns

- **Cleaning the relay**
  - Canned air
    - Keep can upright
  - Soft bristle brush
    - Keep clean
  - Burnishing tools
  - No Solvents!

Electromechanical Relay Testing Concerns

- **Adjustments and repair**
  - Use of proper/improper tools
  - Fine wire resistors
  - Springs
  - Parts replacement
    - Capacitors
    - Stripped threads
    - Soldered connections
    - ICS/Target repair
    - IL parts list

Electromechanical Relay Testing Concerns

- **Relay replacement**
  - Pretested replacement
    - Change out bad relay for an even worse relay?
    - Thoroughly inspect replacement relay
    - Easier to repair than replace

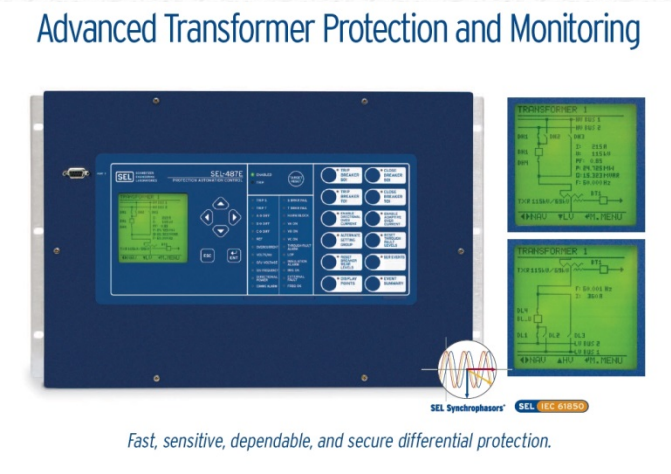
Electromechanical Relay Testing

- **Relay replacement**
  - Sometimes exact model must be used
  - Specific characteristic
  - Model numbers are different for a reason!

Electromechanical Relay Testing Concerns

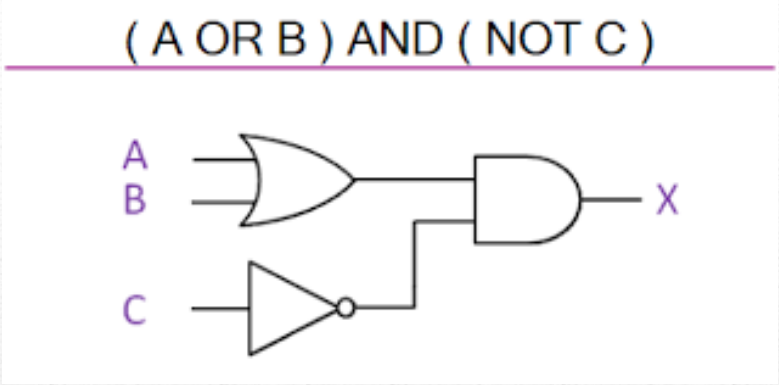
Electromechanical Relay Testing Concerns

- **Relay replacement**
  - Sometimes a slightly different model relay can be adjusted to work
    - Beware of relay components at the very end of operational spectrum



Microprocessor Relay Testing

- **Logic and element testing**
  - Handmade logic diagrams/truth table
  - Yellow line completed paths
  - Investigate confusing results

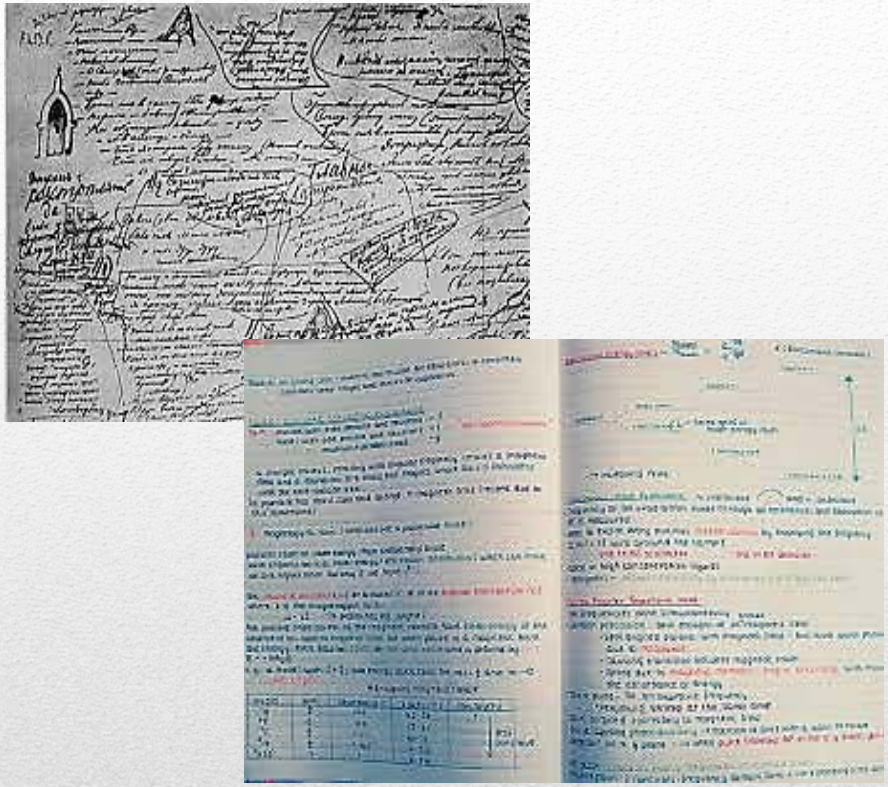


all possible states

(inputs) (outputs)			
A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

Microprocessor Relay Testing

- **Logic and element testing**
  - Personal notes that can be deciphered in the future
  - Write testing procedures for future use

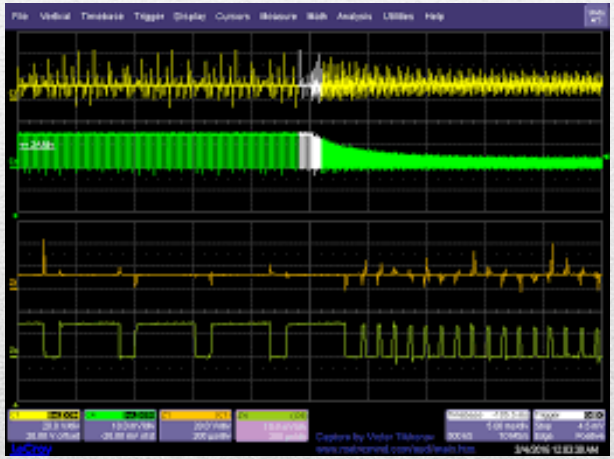


Microprocessor Relay Testing

- **Logic and element testing**
  - Scrutinize all test results
  - Double check math/formulas
  - Document test results

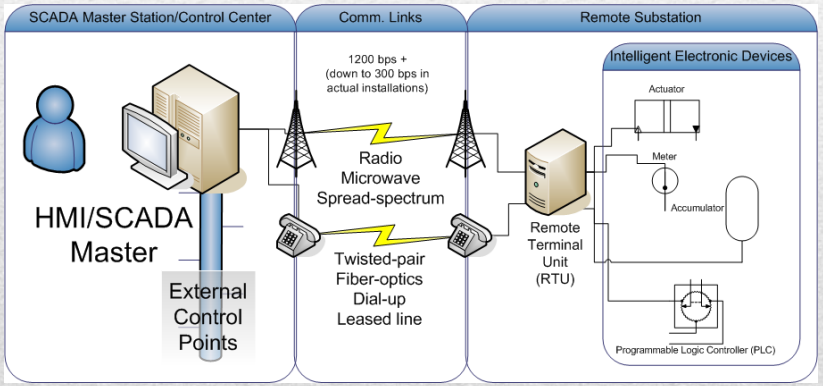
Microprocessor Relay Testing

- **Logic and element testing**
  - Fault simulation for trip checks and reclose testing
  - Fault simulation for communication assisted trip schemes

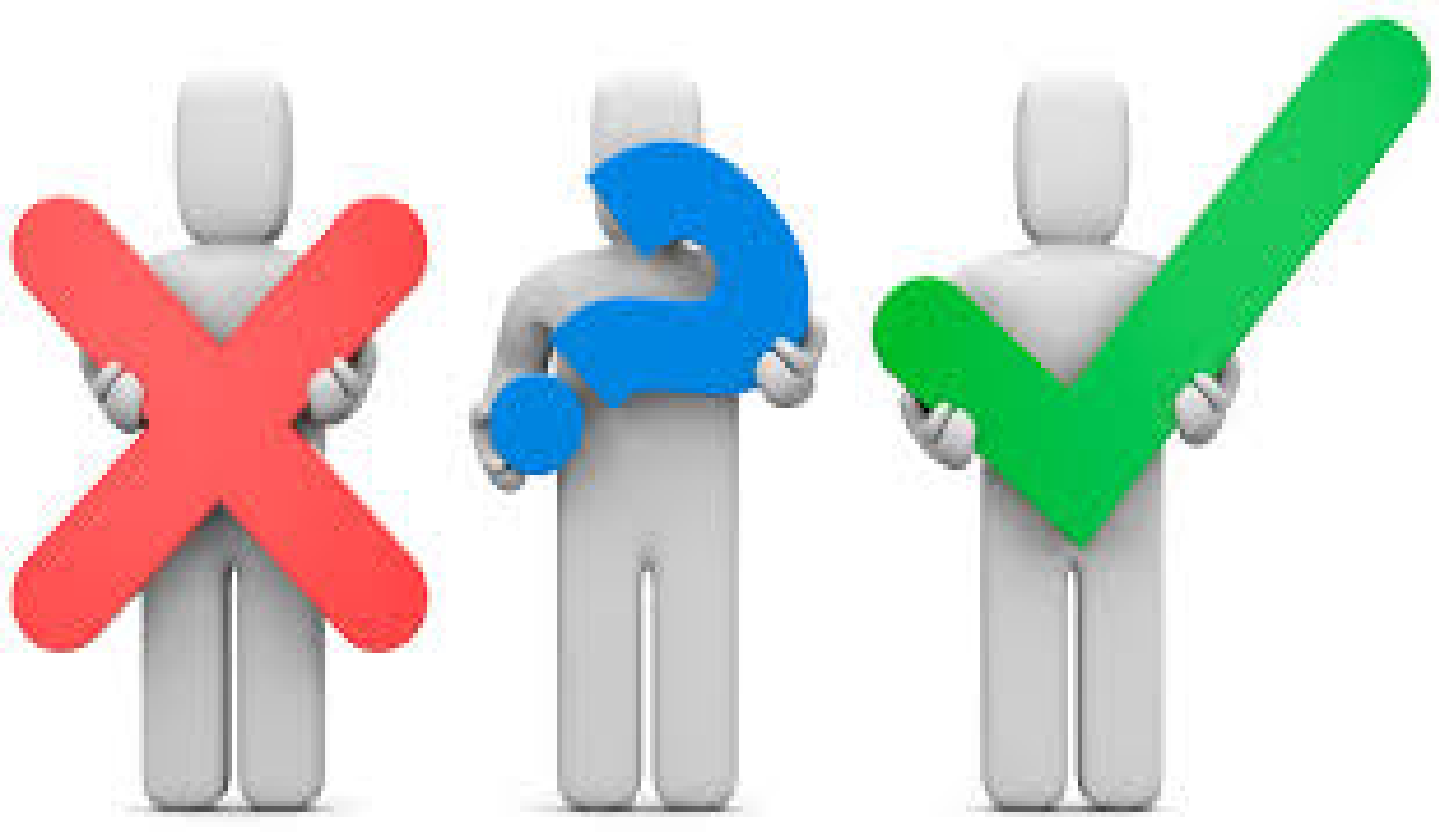


Microprocessor Relay Testing

- **Logic and element testing**
  - Operations Center to Substation Communication testing
  - Relay to Relay Communication testing



Microprocessor Relay Testing



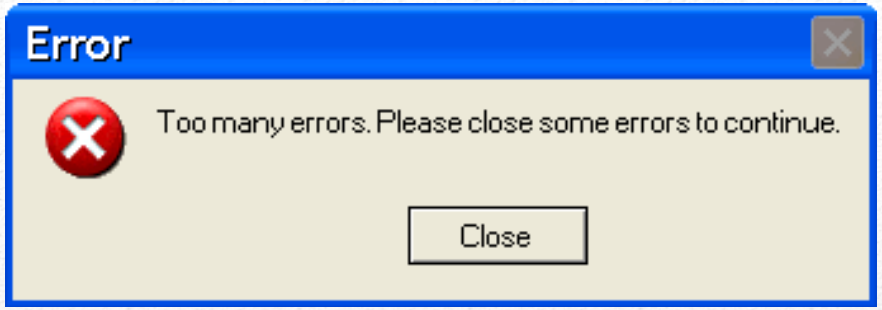
Results

Anticipated Results

- **Anticipated**
  - Testing (ATV)
    - Relays
    - Voltage/Current Circuits
    - Trip Testing
  - Switching
    - High Voltage
  - Metering
    - Proper values

Unanticipated Results

- **Unanticipated**
  - Causes
    - Proper procedure?
    - Safety issue?
    - Lack of focus?
  - Clean up
    - Physical and Professional
  - Stress



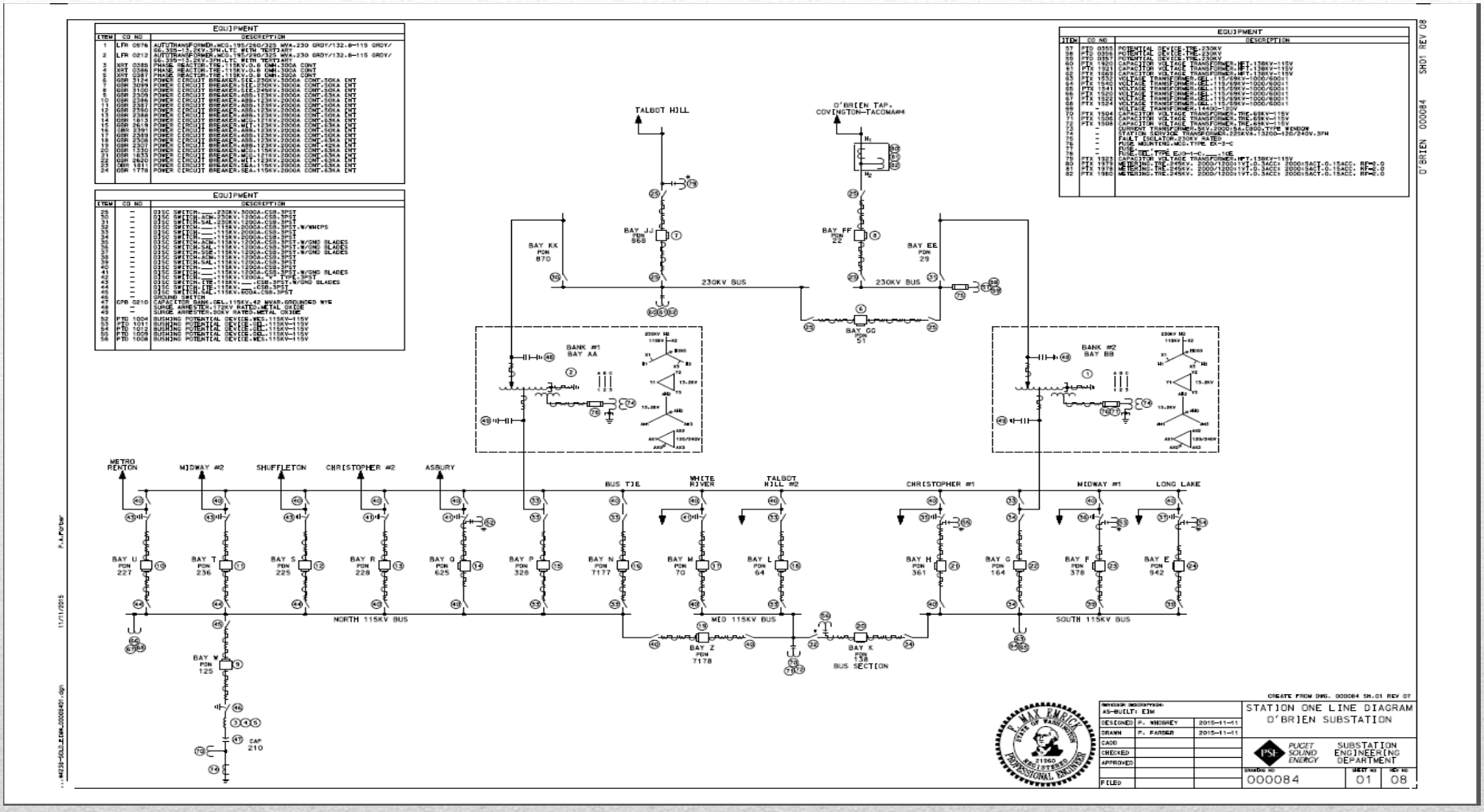
- **How/Why did this happen?**
  - Underlying causes
  - Observing a symptom or a cause?
  - Unfavorable results of RCA
    - Discipline
    - Procedure changes
    - How is easy
    - Why is not so easy

Root Cause Analysis

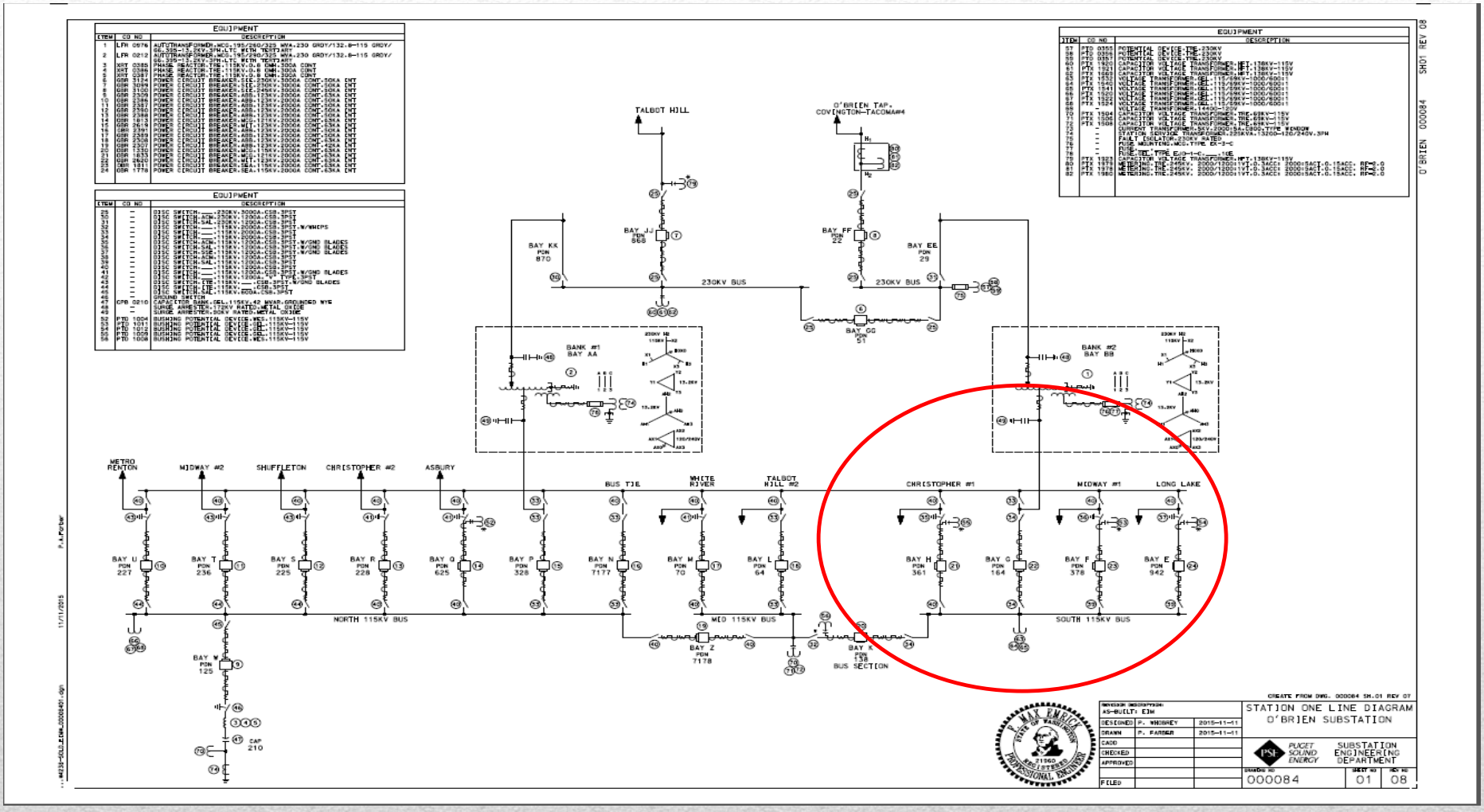
I swear it was there….

- 230Kv-115Kv
- 2-325 MVA transformers
- 2-230Kv circuits
- 12-115Kv circuits
- 115Kv Bus is split 2 times
- Mixture of Oil breakers and Gas breakers
- Mixture of electromechanical relays and microprocessor relays

Obrien Substation



Obrien Substation



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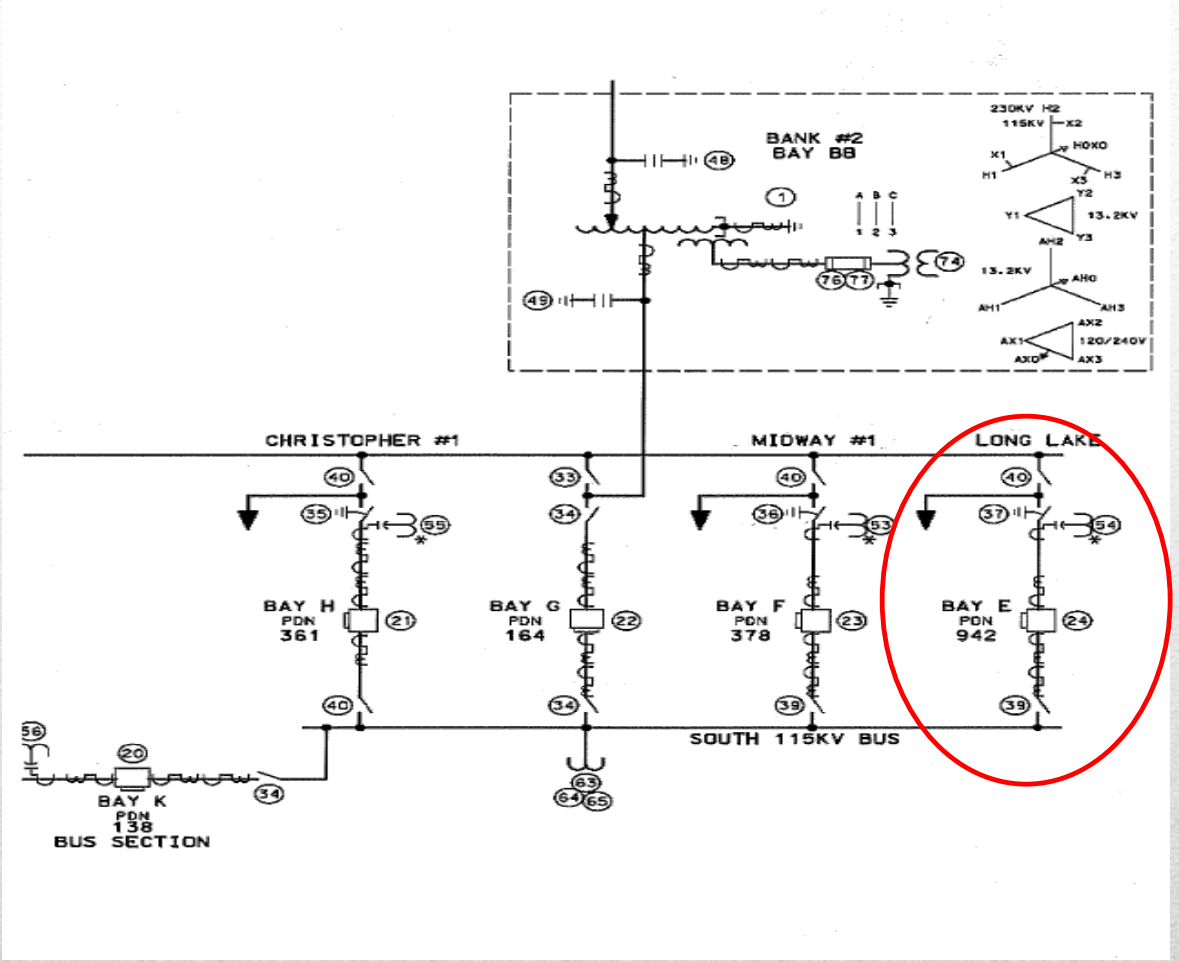


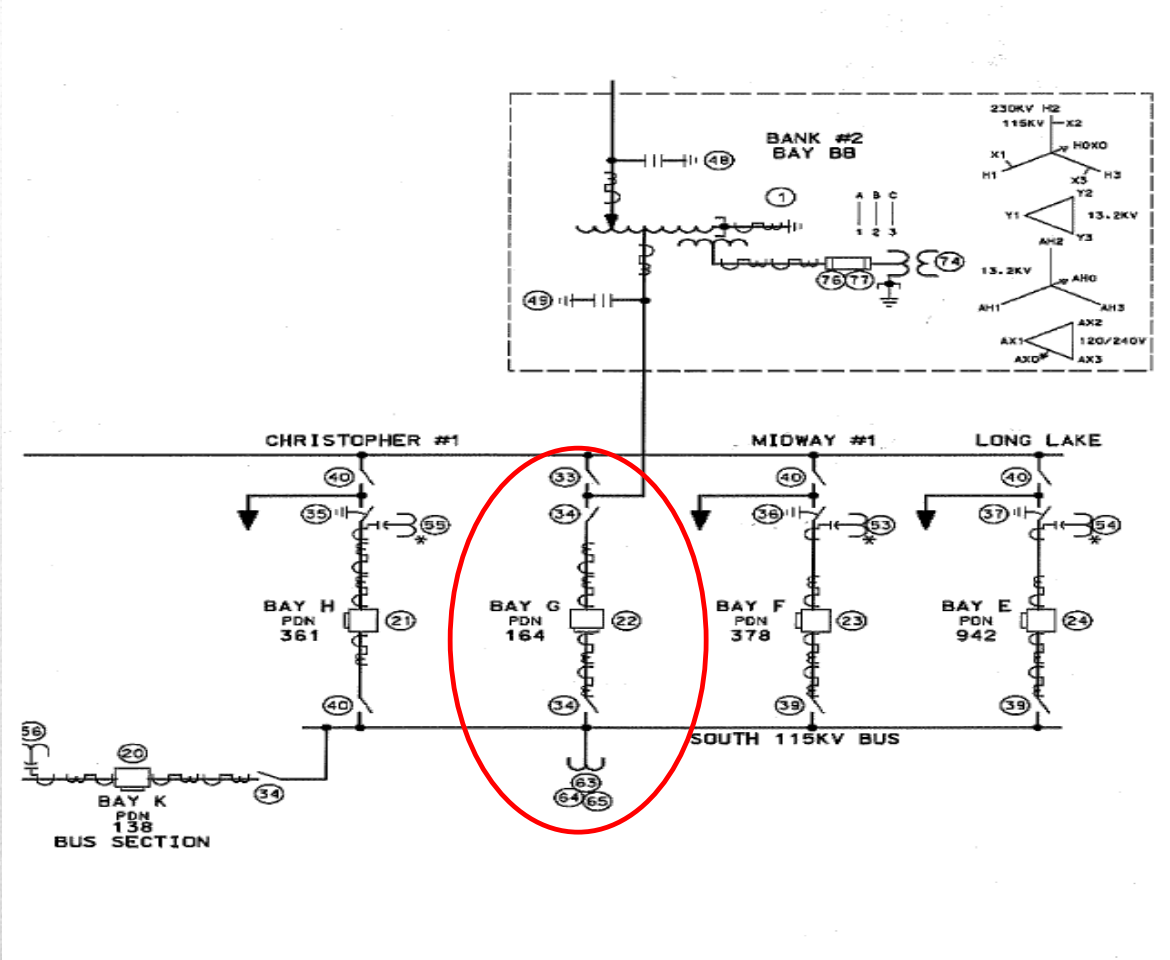
Obrien Substation

- PDN 0942
  - Oil breaker
  - 25 Years old
  - Operating almost every morning and every night for three months for line project across Vashon Island in Puget Sound
  - Operated properly in the morning, but breaker failed in the evening when switching back in
  - PSE breaker fail initiates for all trips, including supervisory

Obrien Substation

- 115Kv South Bus section cleared properly via the South Bus differential lock out relay
- Breaker fail at PSE is set to 10 cycles
- PDN 0942 opened in about 13 cycles
- Breaker fail appears to have worked properly, with the exception of PDN 0164 did not open
- No fault

Obrien Substation



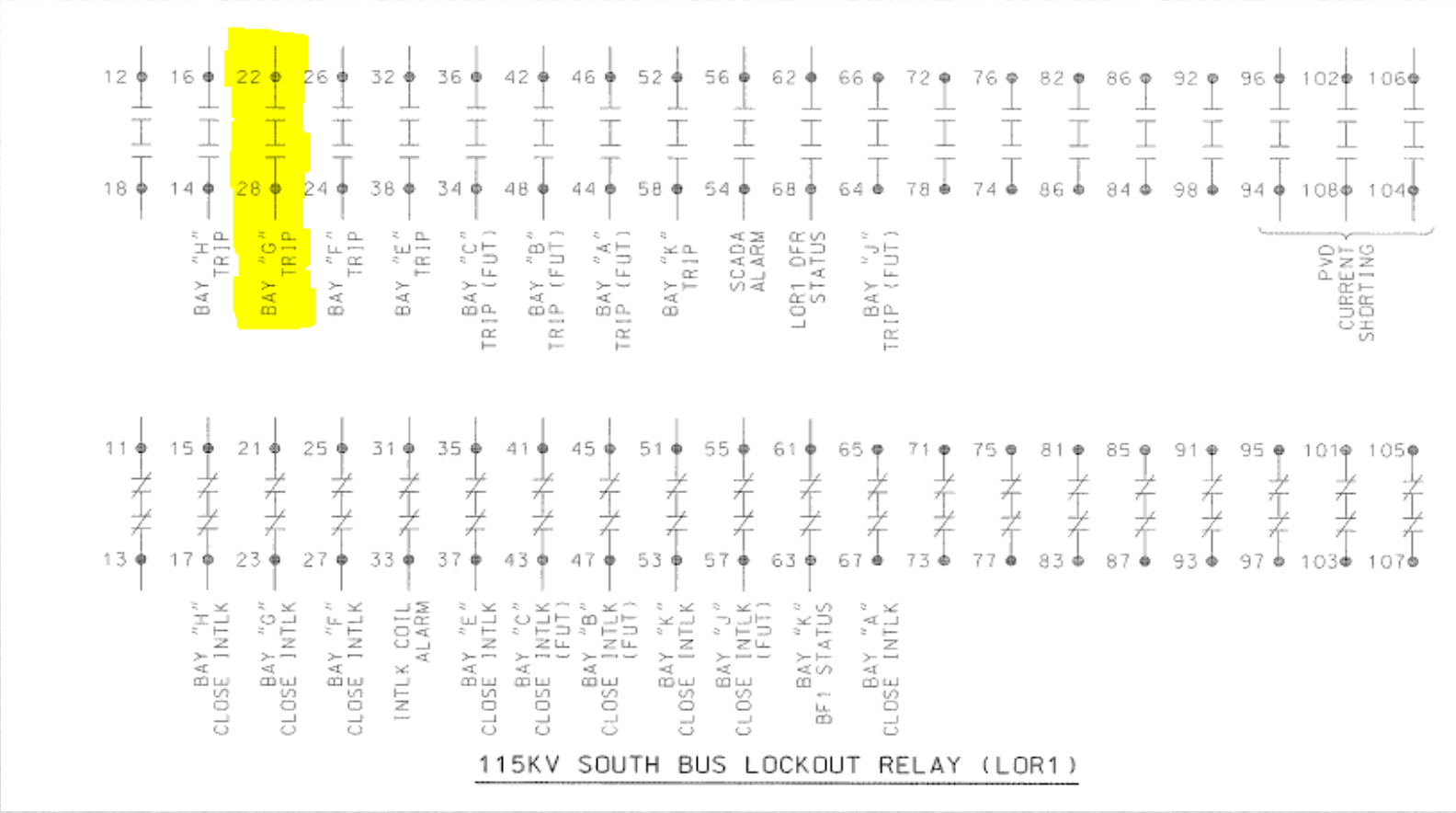
Obrien Substation

- What could have caused PDN 0164 to not open when the bus lock out relay clearly tripped?

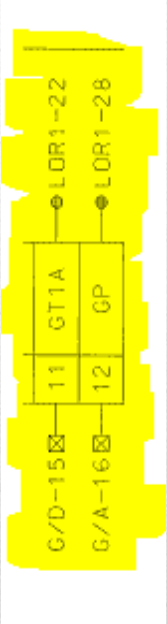
Obrien Substation

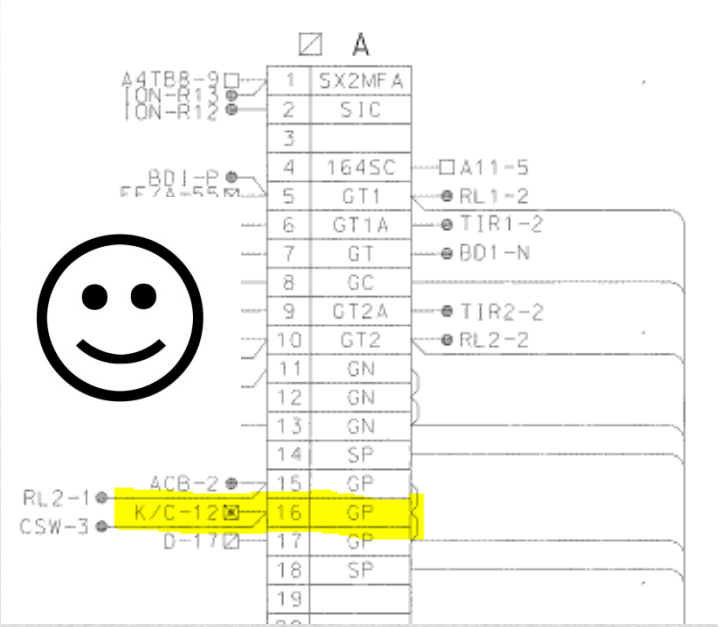
- What could have caused PDN 0164 to not open when the lock out relay clearly tripped?
  - It turns out the wires from the lock out relay to the trip circuit for PDN 0164 were never installed!

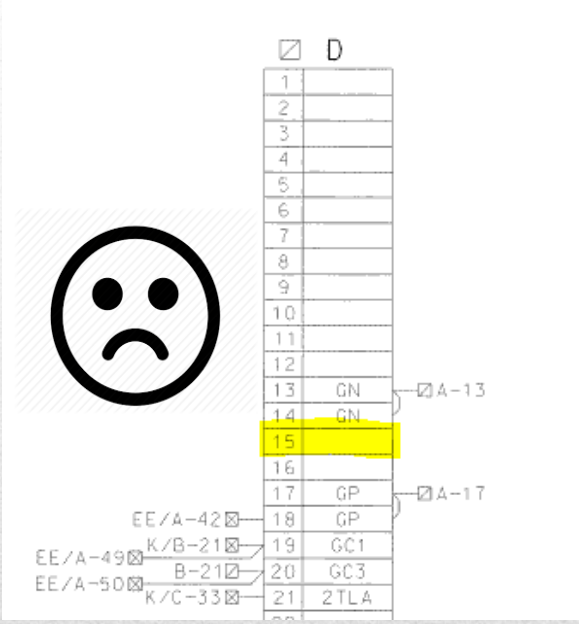
Obrien Substation



Obrien Substation







Obrien Substation

- What could have caused PDN 0164 to not open when the lock out relay clearly tripped?
  - It turns out the wires from the lock out relay to the trip circuit for PDN 0164 were never installed!

Which also means they were never tested!

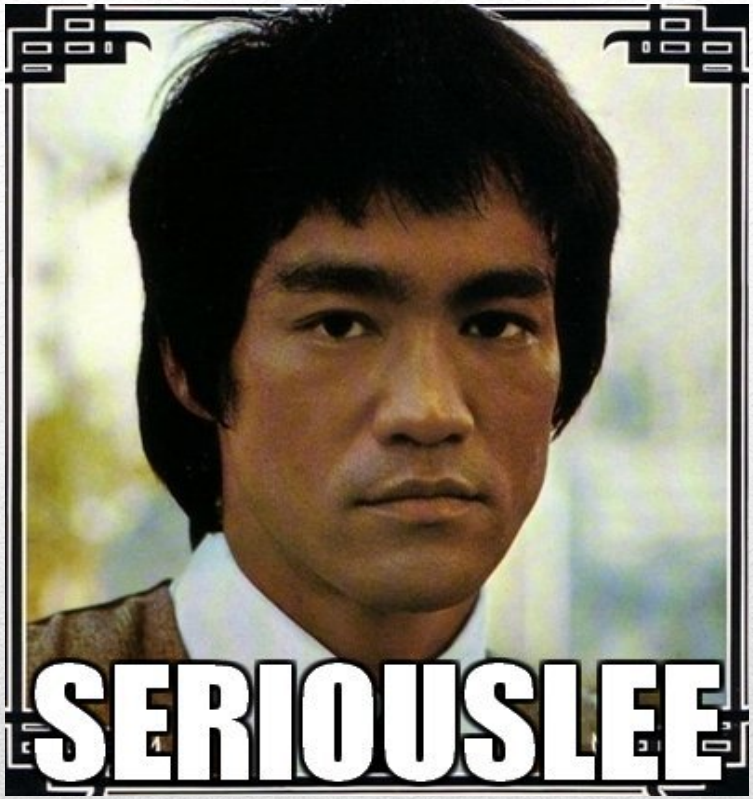
Obrien Substation

- New wires were ran and tested
- PDN 0942 was ready to be changed out as it obviously is not working properly, is old…
  - Trip checks proved the continuity of the trip circuit
  - Breaker fail was isolated during trip checks
  - One last look from the maintenance crews discovered a gummy trip latch
  - A little TLC and good as new

Obrien Substation

- Lessons Learned
  - Properly commission all aspects of the job
  - Bus was split years ago, and obviously no trip checks were ever done properly
  - Drill down to the actual cause of a failure
  - Don’t assume anything
  - This led to PSE redesigning the breaker fail logic to include breaker fail initiate from lock out relay trips and remove it from supervisory and control handle trips

Obrien Substation

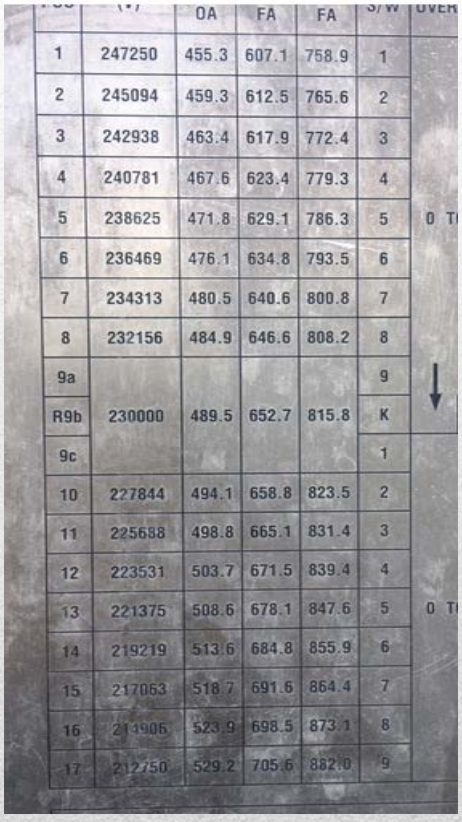


Our job is tough enough already….

LTC Fun

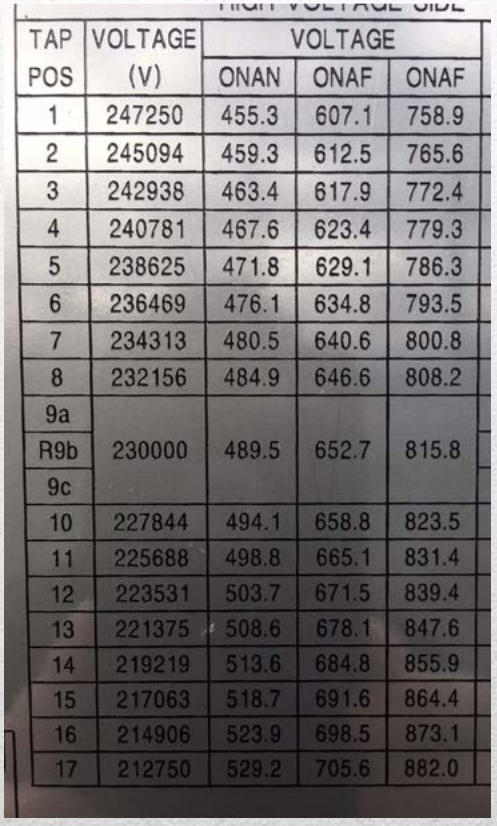
- Two identical transformers
  - Same rating (325MVA)
  - Same Transformer Manufacturer
  - Same LTC Manufacturer
  - One built in 1998 the other 2007
  - They are even the same color!

Bank #1 Nameplate



		OA	FA	FA	S/W	OVER
1	247250	455.3	607.1	758.9	1	
2	245094	459.3	612.5	765.6	2	
3	242938	463.4	617.9	772.4	3	
4	240781	467.6	623.4	779.3	4	
5	238625	471.8	629.1	786.3	5	0 T
6	236469	476.1	634.8	793.5	6	
7	234313	480.5	640.6	800.8	7	
8	232156	484.9	646.6	808.2	8	
9a					9	
R9b	230000	489.5	652.7	815.8	K	
9c					1	
10	227844	494.1	658.8	823.5	2	
11	225688	498.8	665.1	831.4	3	
12	223531	503.7	671.5	839.4	4	
13	221375	508.6	678.1	847.6	5	0 T
14	219219	513.6	684.8	855.9	6	
15	217063	518.7	691.6	864.4	7	
16	214906	523.9	698.5	873.1	8	
17	212750	529.2	705.6	882.0	9	

Bank #2 Nameplate



TAP POS	VOLTAGE (V)	VOLTAGE ONAN	ONAF	ONAF
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17	212750	529.2	705.6	882.0

LTC Fun

Bank #1 LTC Tap position indicator

Bank #2 LTC Tap position indicator

LTC Fun

Fredonia Generator 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

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 Generating 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

- 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

Fredonia Generating Station

Lessons Learned

- 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

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 P.U. X 200 = 500 amps x 132794 L-N = 66397000w
    - 66397000/1,000,000 = 66.397 MW X 3 = 199.191 MW
    - 199.191 MW = TRIP (we recorded just over 200MW)

- 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 X 200 = 1200 amps X 132794 = 159352800 watts
    - 159352800/1,000,000 = 159.353 MW X 3 = 478.058 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

Obrien Substation

Last Thoughts

- This week will be challenging
- Ask questions
- Meet new people
- Try something new

- It should also be fun!

Thank You