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Protection System Redundancy Criteria for NERC TPL-001.5 Footnote 13

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NERC TPL-001.5.1 Footnote 13

- NERC Standard TPL-001.5.1 is a Transmission System Planning Performance Requirement
  - It requires an annual assessment of stability during specific fault conditions with delayed fault clearing due to failure of non redundant components of the Protection System
- Footnote 13 documents the components that must be considered for redundancy and if exceptions for monitoring and reporting are allowed.
- TPL-001.5.1 requires studies but does not require redundancy of Protection Systems
  - It does require identifying where redundancy requirements are not met
- Where we do not meet redundancy tests, we need to provide backup clearing times, breakers, fault currents and thevenin impedances.
  - Providing these values is complicated for ground faults if you use 67N elements. Multi-stage sequential clearing.
- Planning groups need to run stability studies with this information and determine where instabilities may occur.
- Exceptions/Exclusions are allowed for 13 b-d and are heavily used.

Timeline

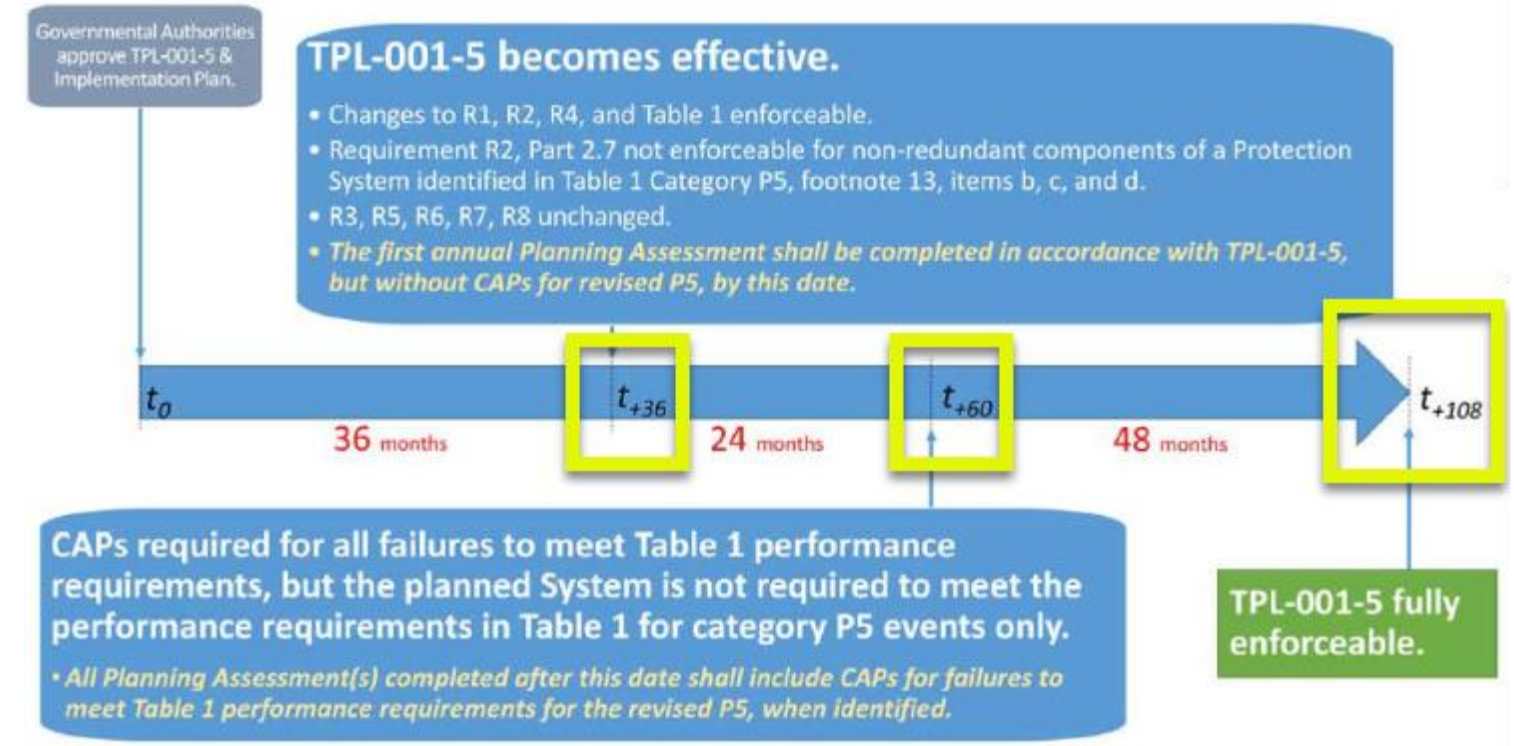


Figure 1 Implementation Plan Timeline

Figure from NERC TPL-001-5.1 Requirement Training

While there is some time until effective dates, the level of work requires action now.

- T+36 months: **Studies must be completed by 7/1/2023** (majority of TPL-001-5.1 R2). Studies must consider these footnotes.
- T+60 months: **Corrective action plans must be developed by 7/1/2025** (TPL-001-5.1 R2.7).
- T+108 months: **Corrective Action Plans must be completed by 7/1/2029** .

Category	Initial Condition	Event [1]	Fault Type [2]	BES Level [3]	Interruption of Firm Transmission Service Allowed [4]	Non-Consequential Load Loss Allowed
P5 Multiple Contingency *(Fault plus non-redundant component of a Protection System failure to operate)*	Normal System	Delayed Fault Clearing due to the failure of a non-redundant component of a Protection System[13] protecting the Faulted element to operate as designed, for one of the following: 1. Generator 2. Transmission Circuit 3. Transformer[5] 4. Shunt Device[6] 5. Bus Section	SLG	EHV	No[9]	No
				HV	Yes	Yes
P6 Multiple Contingency *(Two overlapping singles)*	Loss of one of the following followed by System adjustments.[9] 1. Transmission Circuit 2. Transformer [5] 3. Shunt Device[6] 4. Single pole of a DC line	Loss of one of the following: 1. Transmission Circuit 2. Transformer[5] 3. Shunt Device[6]	3Ø	EHV, HV	Yes	Yes
		4. Single pole of a DC line	SLG	EHV, HV	Yes	Yes

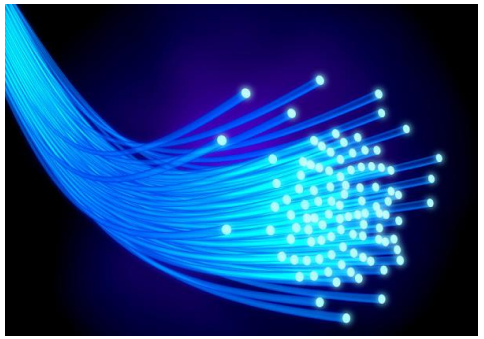
- TPL-001.5.1 Footnote 13:
- For purposes of this standard, non-redundant components of a Protection System to consider are as follows:

  - a. A single protective relay which responds to electrical quantities, without an alternative (which may or may not respond to electrical quantities) that provides comparable Normal Clearing times;
  - b. A single communications system associated with protective functions, necessary for correct operation of a communication-aided protection scheme required for Normal Clearing (an exception is a single communications system that is both monitored and reported at a Control Center);
  - c. A single station dc supply associated with protective functions required for Normal Clearing (an exception is a single station dc supply that is both monitored and reported at a Control Center for both low voltage and open circuit);
  - d. A single control circuitry (including auxiliary relays and lockout relays) associated with protective functions, from the dc supply through and including the trip coil(s) of the circuit breakers or other interrupting devices, required for Normal Clearing (the trip coil may be excluded if it is both monitored and reported at a Control Center).

13a. A single protective relay which responds to electrical quantities, without an alternative (which may or may not respond to electrical quantities) that provides comparable Normal Clearing times

- At BES voltages all utilities likely apply two levels of microprocessor protective relays
- No exclusion for protective relays for monitoring or alarming is given
- Common problem areas
  - **Most electromechanical relays** and some solid state and microprocessor relays are not redundant.
  - Many older bus differential relay schemes are not redundant
  - Bank differential relaying needs to be checked for delayed clearing in some cases.
- Do we need to check for redundancy in breaker failure protection?
  - Footnote 13 does not apply to breaker failure protection, but the main standard includes a “stuck breaker” reference. This likely requires identifying any BES breakers without breaker failure.

13b. A single communications system associated with protective functions, necessary for correct operation of a communication-aided protection scheme required for Normal Clearing (an exception is a single communications system that is both monitored and reported at a Control Center);



- A single communication system used to be the norm below EHV lines
- With digital communications it is now inexpensive to have redundant communication schemes.
- To rely on redundant digital communications, we now need to check for redundancy in the “cloud”, components and redundant DC supplies to telecom equipment.
- An exception is given for a single scheme that is monitored and reported at a Control Center.
- Can you produce evidence that every communication system is monitored and reported to a Control Center?

13c. A single station dc supply associated with protective functions required for Normal Clearing (an exception is a single station dc supply that is both monitored and reported at a Control Center for both low voltage and open circuit)

- Some utilities have redundant DC batteries on some or all of their BES.
- Many utilities do not have redundant DC batteries on all BES.
- The exception for a single battery can be used but is complicated.
- **Monitoring and alarming from the battery charger is generally not sufficient to meet the exception**.

DC Supply Monitoring

- Most companies have DC UV alarms
- New Battery Chargers have sophisticated monitoring/alarms but do not detect open Battery Cells or connectors.
- Typical Battery charger monitoring cannot detect an open cell if DC load is still connected.
- Battery Monitoring Systems are generally required to meet the monitoring exception.

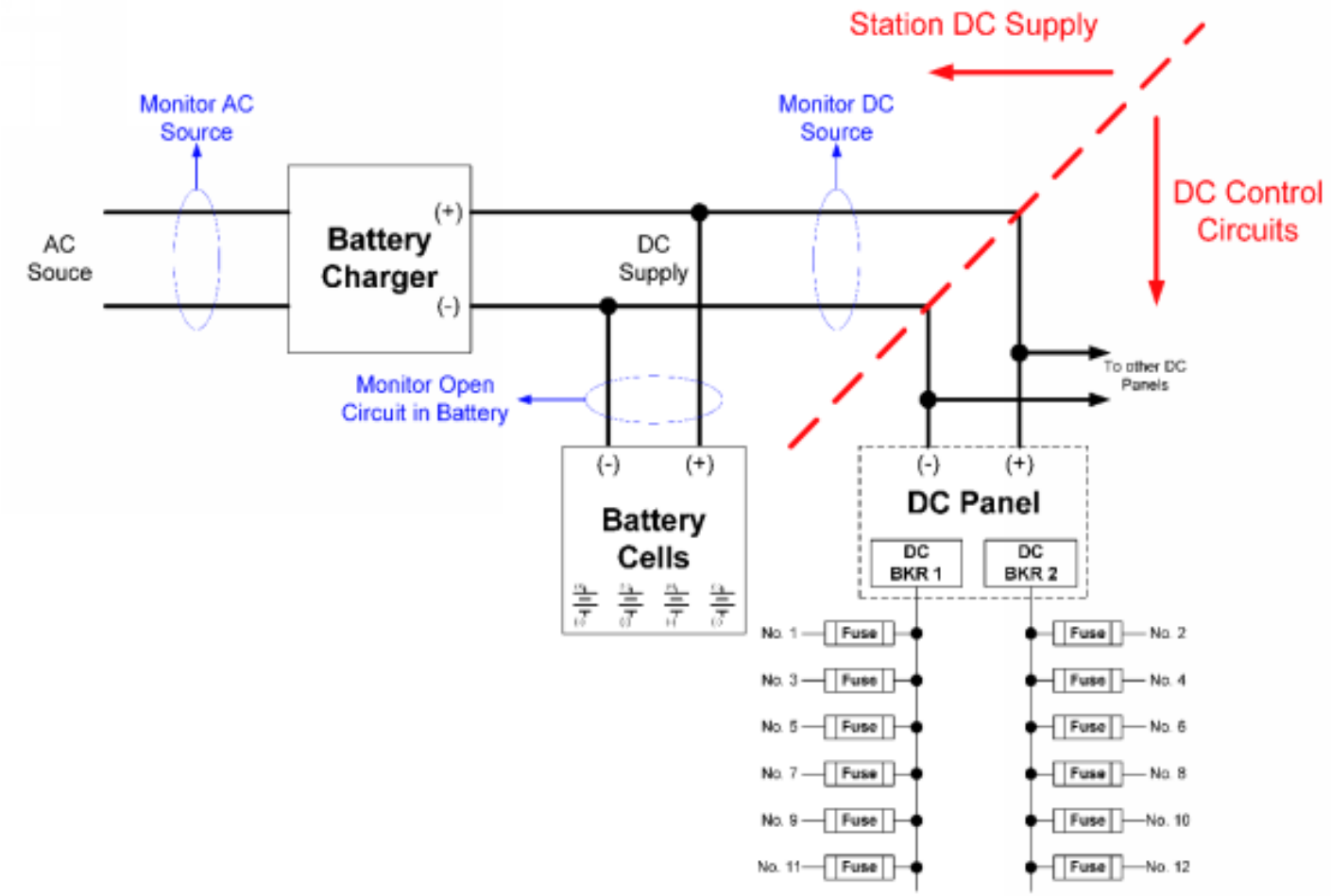
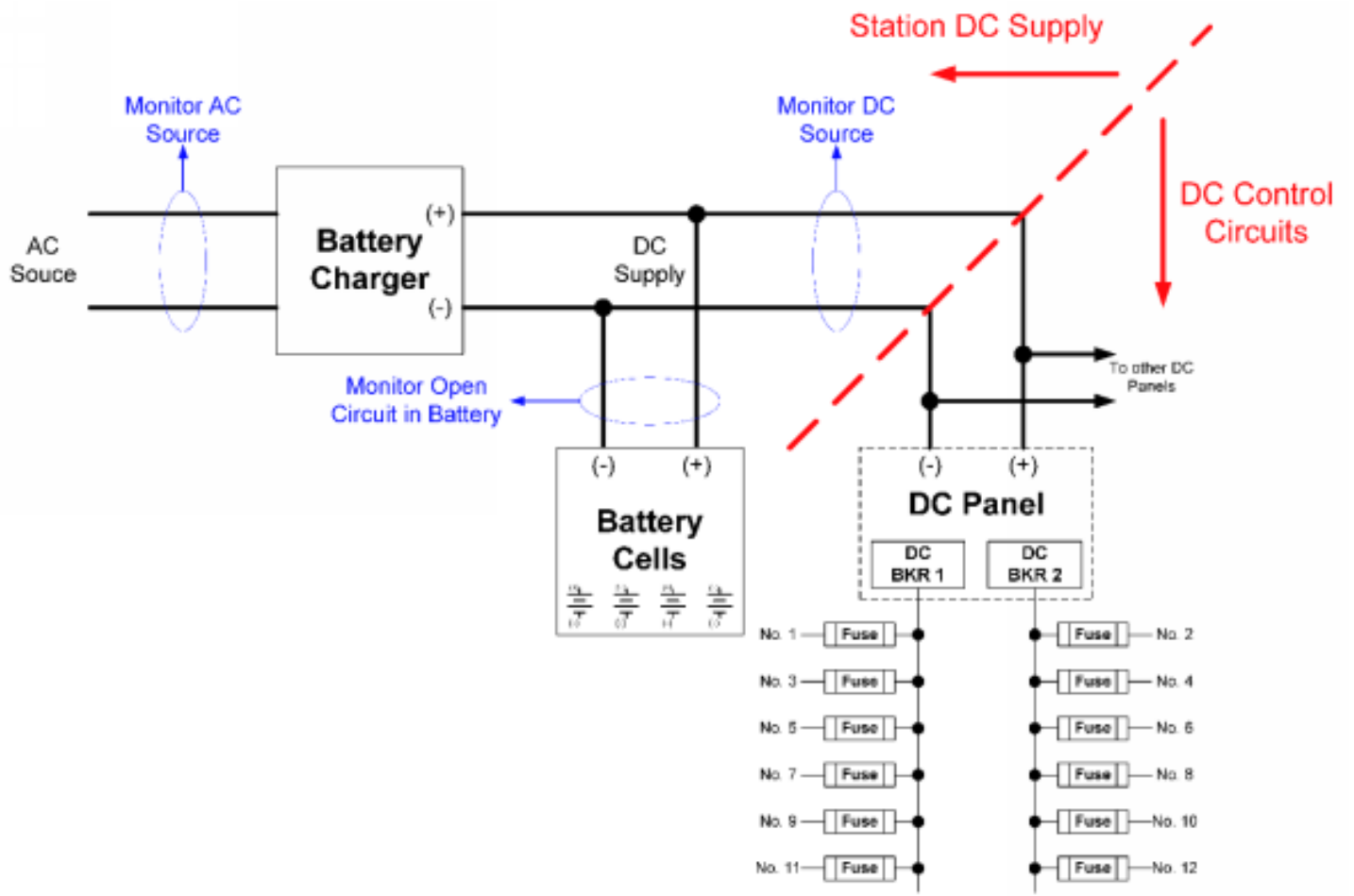


Figure from FERC Order No. 754 and NERC Technical Paper and Technical Rational for TPL-001.5

13d. A single control circuitry (including auxiliary relays and lockout relays) associated with protective functions, from the dc supply through and including the trip coil(s) of the circuit breakers or other interrupting devices, required for Normal Clearing (the trip coil may be excluded if it is both monitored and reported at a Control Center).

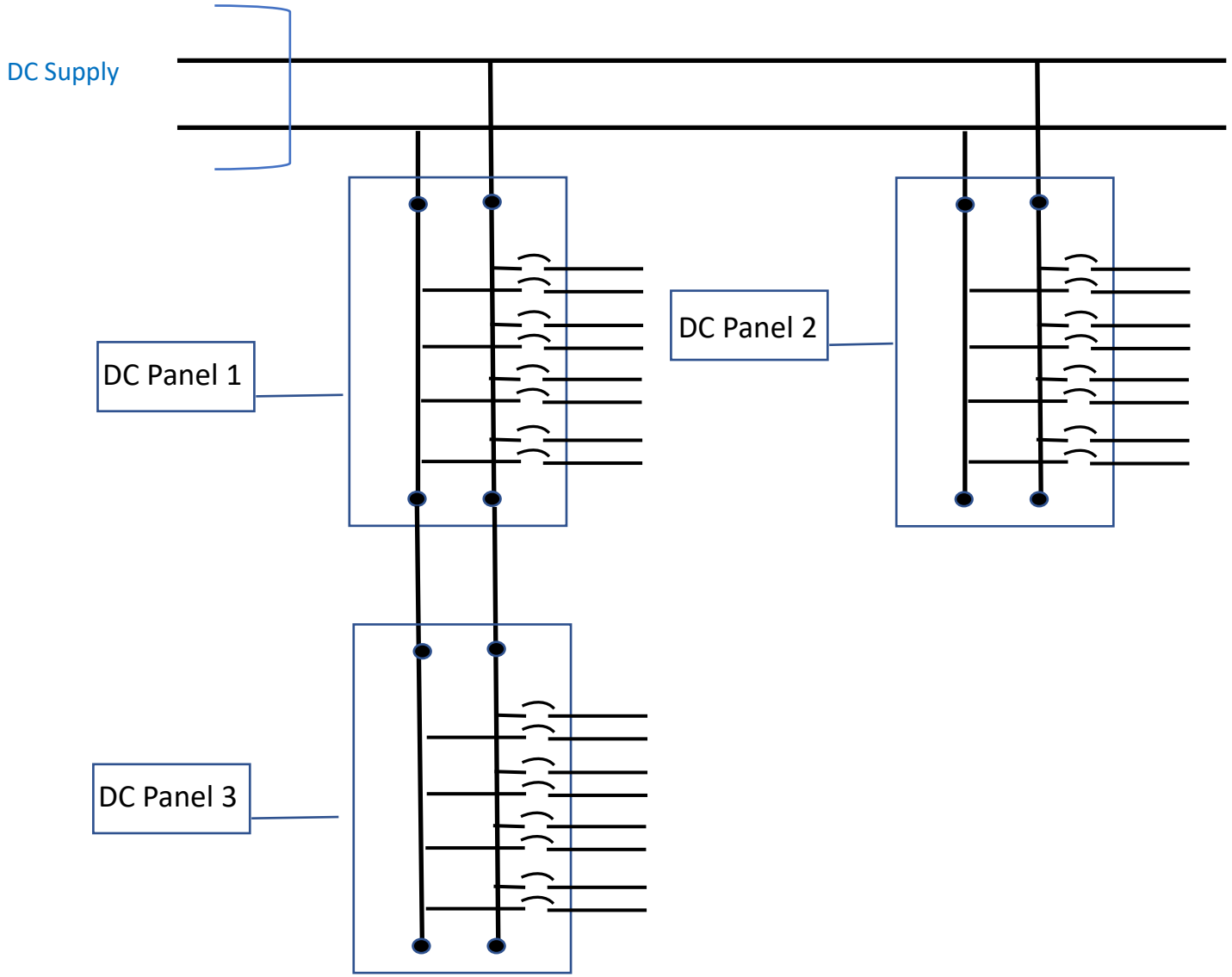
- Control circuitry in 13d is the most challenging part of footnote 13.
- Note the monitoring exclusion is **only for the trip coil** and no other components of the control circuit.
- The authors company has submitting a NERC Standard Authorization Request to change 13d to allow excluding all components of the control circuit that are monitored and reported.
- See following figures

Decide Where to Draw the Line



- Can you draw the line of demarcation between DC Supply (13 c) and Control Circuits (13) anywhere?
- There should be no gap between DC Supply and Control Circuits
- Have you had complete failure of a DC panel?

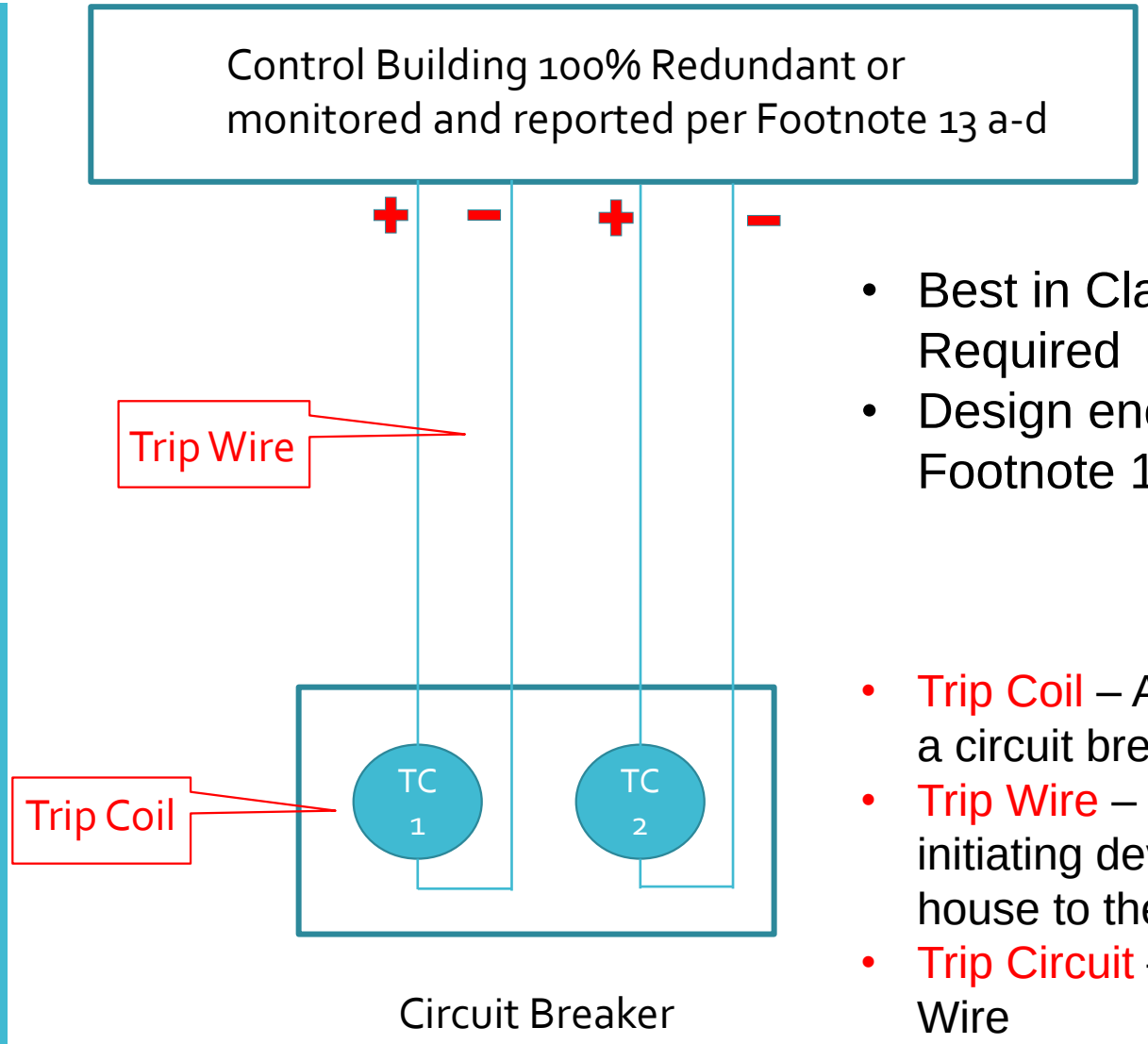
Control Circuitry – DC Panels



- Look for Single Points of Failure
- If Primary and Backup Relays are both fed from the same DC Circuit they **fail** redundancy
- If Primary and Backup Relays are fed from separate circuits on DC Panel 1 they **fail** redundancy
- If Primary Relay is fed from DC Panel 1 and Backup Relay is fed from DC Panel 3 they **fail** redundancy
- If Primary Relay is fed from DC Panel 1 and Backup Relay is fed from DC Panel 2 they **pass** redundancy

Control Circuitry –

Dual Trip Wires and Dual Trip Coils



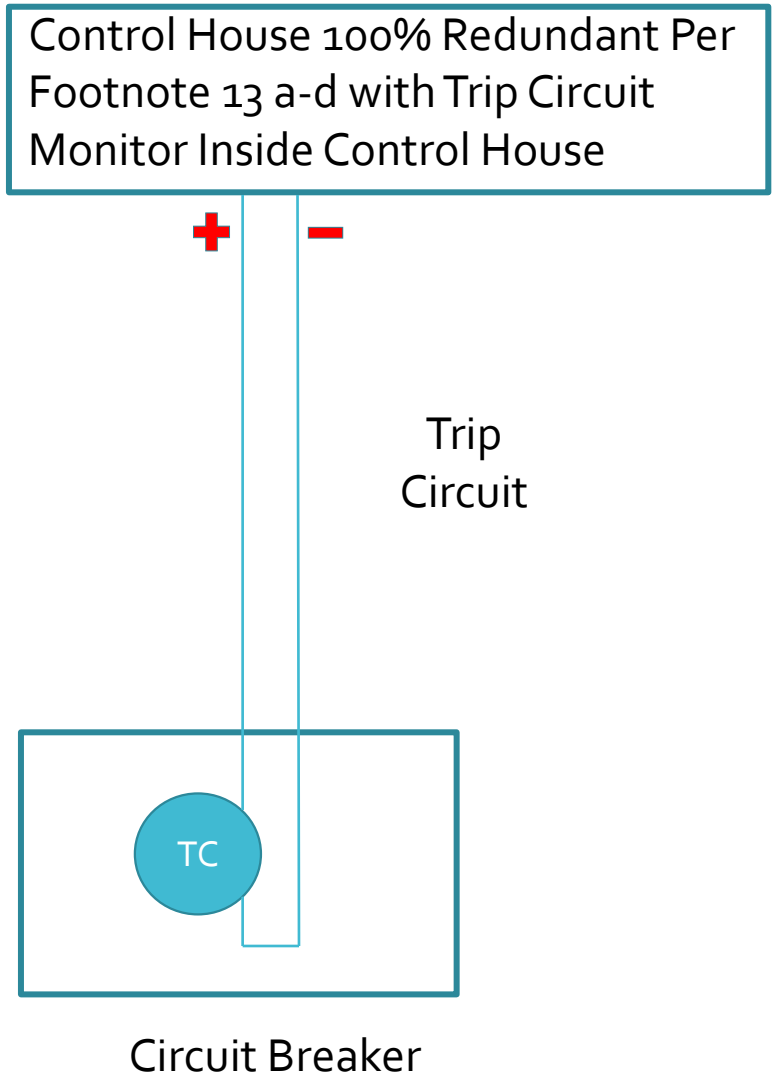
- Best in Class / NPCC Required
- Design encouraged by Footnote 13d.

- Trip Coil – A Solenoid and latch in a circuit breaker to initiate a trip
- Trip Wire – Wire from any trip initiating device in the control house to the circuit breaker
- Trip Circuit – Trip Coil and Trip Wire

Control Circuitry

Single Trip Wire and Single Trip Coil

The only way to meet 13 d is to add a second trip wire and trip coil



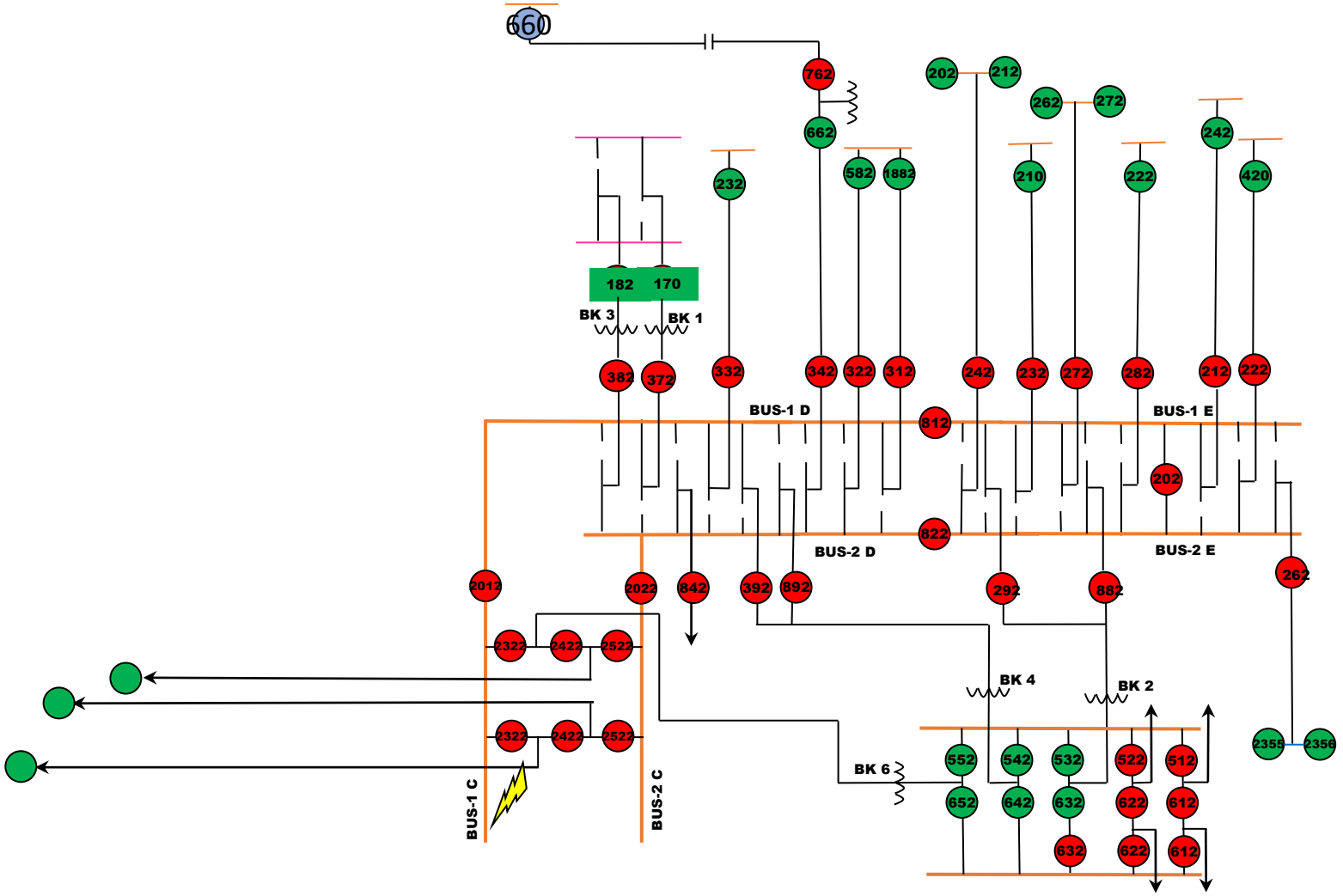
- Many Companies have some legacy breakers with single Trip Coils.
- Breakers with one Trip Coil generally have one Trip Circuit
- Trip Circuit Monitor - A device/ function that monitors an associated circuit breaker's trip circuit for continuity and for the presence of tripping voltage and sets an externally readable alarm when continuity or tripping voltage is lost (a surrogate for the traditional red light on relay and control panels). IEEE Std 3004.8-2016
- A Trip Circuit Monitor In the Control House Monitors the entire Trip Circuit (Trip Wire + Trip Coil).
- This does not meet TPL-001.5 Footnote 13d for monitoring.

TPL-001.5.1 Footnote 13
Standards Authorization Request – Submitted by PG&E

Purpose of SAR

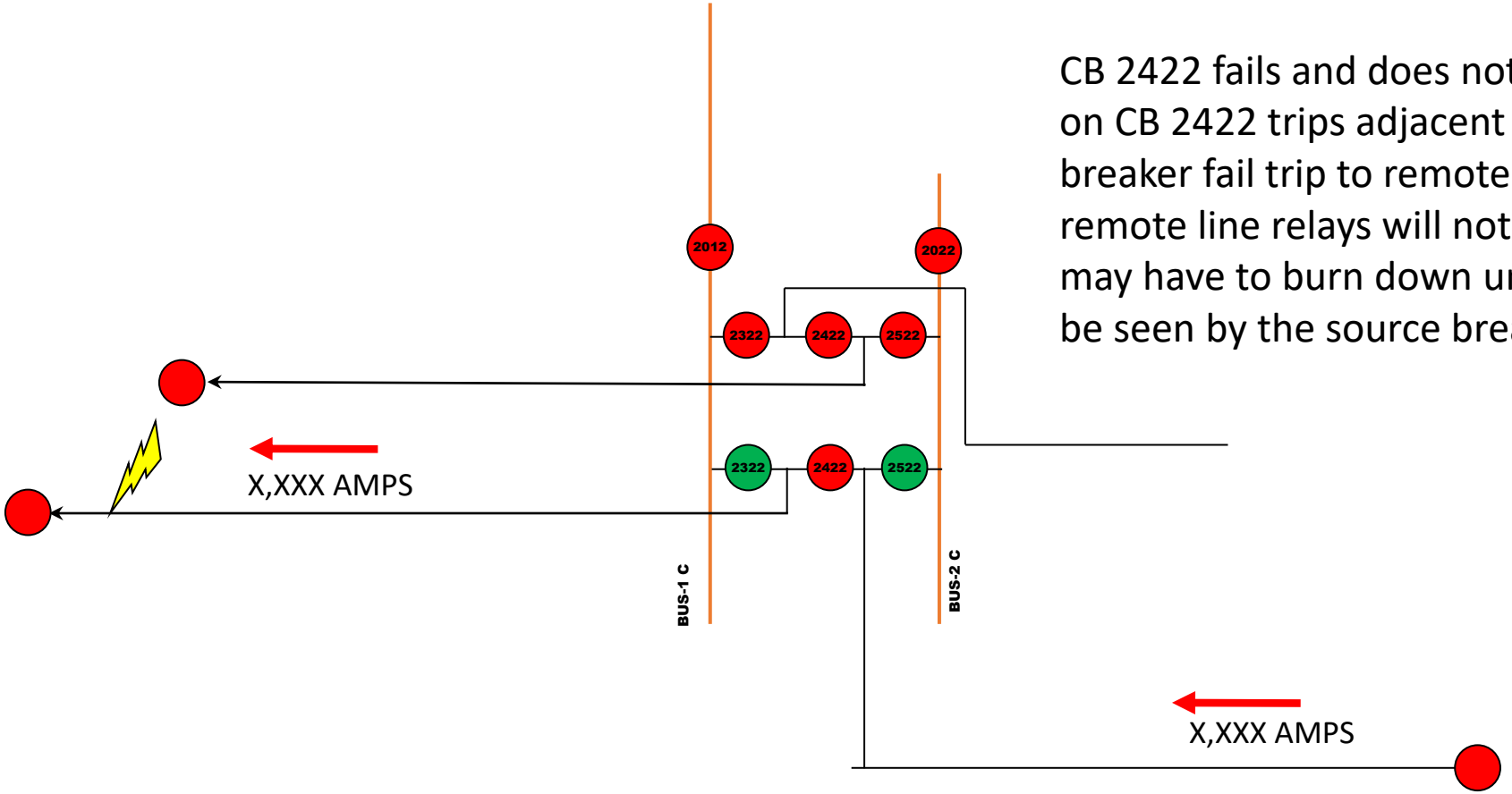
The goal is to enhance the language of the Footnote 13d exclusion to include "**any non-redundant components of the control circuitry that are both monitored and reported**" in addition to the current exclusion of the single trip coil. The proposed modification will reduce the burden on the DP, GO, and TO that would be required to install redundant control circuitry to ensure the BES will operate reliably over a broad spectrum of system conditions and following a wide range of probable contingencies that are studied under the TPL-001-5.1 Reliability Standard. This goal can be accomplished by modifying the exclusion language to include monitored and reported components of the control circuitry while reducing risk to BES performance by avoiding additional Protection System complexity.

The SAR has been accepted and assigned to a Standard Drafting Team (Project 2022-02).



BAAH bus fault. Non Redundant Bus Differential scheme fails

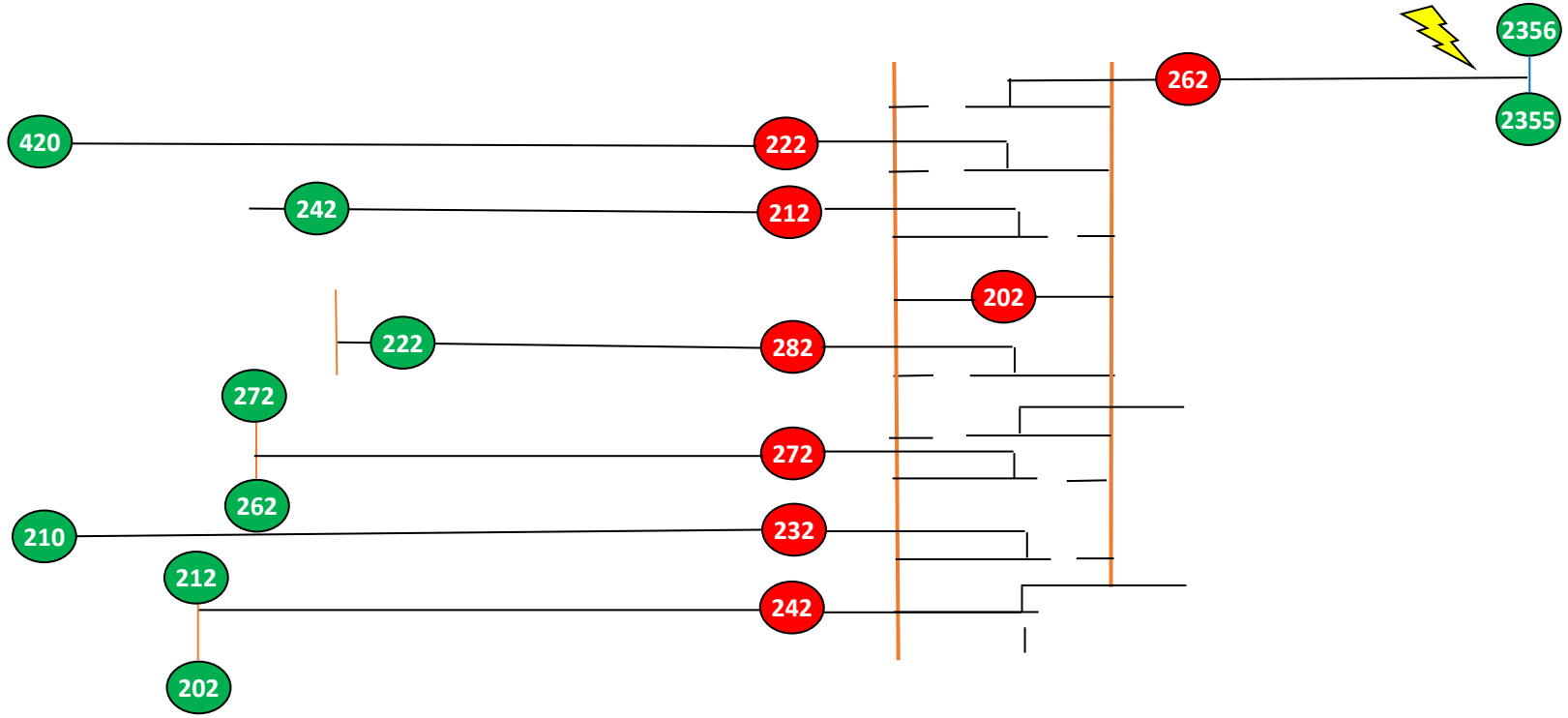
The Problem with BAAH and Ring Busses
Line fault with failed center breaker



CB 2422 fails and does not clear. Breaker failure relay on CB 2422 trips adjacent breakers. Unless we have breaker fail trip to remote line terminal (rare) the remote line relays will not see the fault. Conductor may have to burn down until the line impedance can be seen by the source breaker on the lower right.

Short Line / Longer Line

- Short Line/Long Line can be an overtrip issue.
- Zone 2 on long lines may outreach Zone 1 on short lines.
- If a fault on a short line occurs with a DC supply failure or communication failure multiple lines may trip.



Evidence of Monitor and Reported to a Control Center

- Evidence should be a list of Alarm Points displayed for Control Center Operators tied to every exception taken for Monitor and Reporting.
- Telling an auditor it is your standard practice may not be acceptable.
- Looking at alarms wired to an RTU at a substation may not be acceptable.
- The author assumed that all required monitor and report elements were displayed at Control Center per company standards. This was determined to be inadequate due to SCADA mapping errors on numerous points.

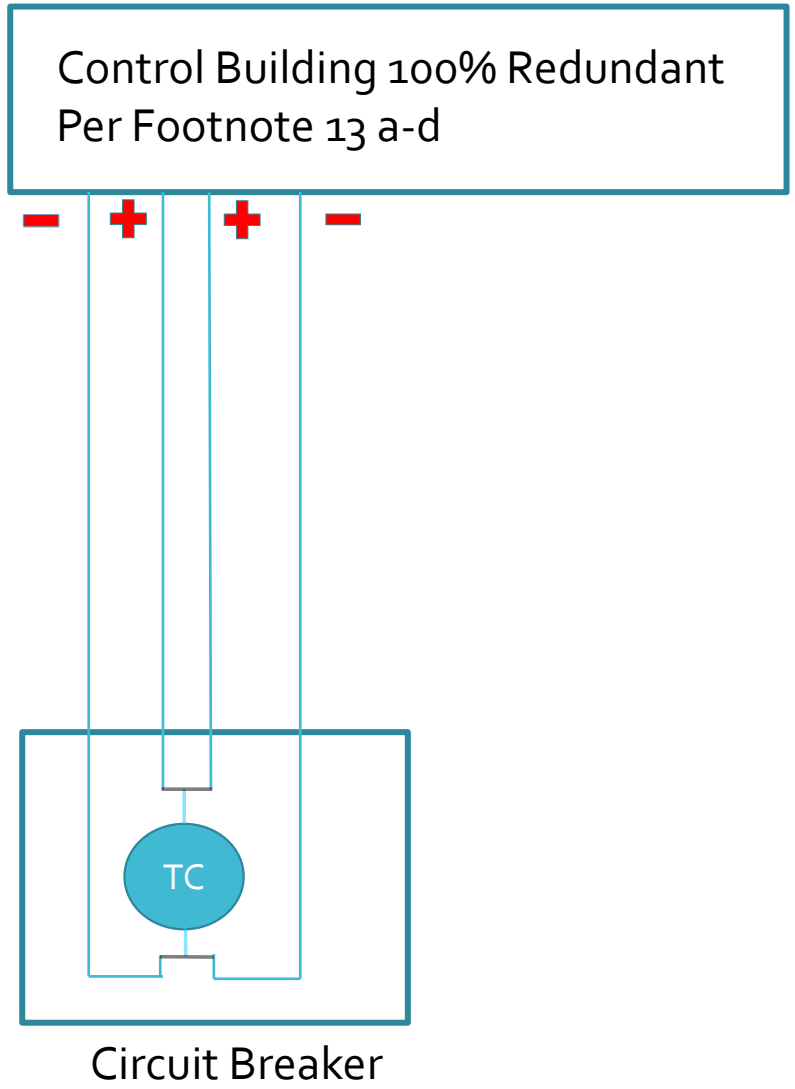
Track Future Changes to Your System

- Assuming your system is not perfect, and you have to document all the Single Points of Failure or Non Redundancies, how do you store this information and update it as new equipment is installed or replaced?
- Creating a process or database for this information will save huge amounts of labor as you perform this evaluation on an annual basis as part of your gap analysis.
- Footnote 13 a-d cover parts of the Protection System but do Protection Engineers manage or own all the assets covered?

Questions?

Control Circuitry –

Dual Trip Circuits and Single Trip Coil



- Many Companies have some legacy (old) breakers with Single Trip Coils.
- An Exclusion is Provided for a Single Trip Coil that is monitored and reported
- This design is not practical. It will require combining separate DC trip wires onto common terminals of the Trip Coil creating a single point of failure and creating a new non redundancy.
- A Trip Circuit Monitor in the control building will not detect a single open trip wire. It will detect if both trip wires are open at the same time.
- A Trip Circuit Monitor will detect an Open Trip Coil

Future Impacts Of Current Language

Current language in 13 d could require spending millions of dollars in a large substation with minimal benefit

Figure A: U/G Conduit Example

Figure B: Trench Example

- When TPL-001-5 R 2.7 becomes enforceable, it will require corrective actions for studies that do not meet stability criteria.
- Control circuits in scope of TPL-001-5 Footnote 13.d that are non redundant, could require corrective action such as installation of a redundant trip wire and trip coil.
- Some installations utilize underground conduit (fig A) and some use trenches (figure B).
- Underground conduit may be fully utilized, plugged with mud or collapsed in older substations.
- Adding new conduit in energized substations frequently requires hand digging, which can be extremely expensive with no significant reliability improvement.