**PACIFIC GAS AND ELECTRIC COMPANY**
**Wildfire Mitigation Plans Discovery 2023**
**Data Response**

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| DRU Index #: | | Requester: | Wendy al-Mukdad |

**SUBJECT: PG&E 2023 WMP – INQUIRIES (MAINLY REFCL & EPSS & SUPPORTING TECHNOLOGIES)**

**QUESTION 003**

EPSS & REFCL Inquiries:

a. EPSS vs REFCL – Describe the major similarities and differences.
   i. What are advantages and disadvantages?
      - In terms of capability, sectionalization, safety, and reliability?

b. Phase-to-Ground Faults vs Complex (Multiphase) Faults – What is the risk profile of existing ignitions on PG&E's system and how does REFCL & EPSS mitigate these risks?

c. Combination of REFCL with EPSS & Other Mitigations –
   i. Explain how these could work together, and
   ii. if PG&E has quantified combined risk-reduction benefits.

d. Explain the differences in fault energy for EPSS vs REFCL including for low and high impedance faults.
   i. Explain why EPSS is preferred if REFCL fault energy is less than 10% of EPSS fault energy for low impedance faults.
   ii. Explain the effectiveness of DCD vs REFCL on high impedance faults.

**ANSWER 003**

a. In concept, EPSS and REFCL are two very different approaches that share a common goal of attempting to reduce risk associated with ignitions on primary electric distribution systems.
   i. EPSS – advantages:
      - Can be implemented on mostly existing equipment and relays
      - Reduces incident fault energy across all types of faults (Three-phase, line-to-line, line-to-ground, etc.)
      - Reduces incident fault energy through fault clearing time reduction

- Helps to reduce backfeed issues associated with 3-wire distribution system by prioritizing gang trip behavior versus single phase fuse operation
- Incorporates various technologies for high impedance fault detection (Sensitive Ground Fault (SGF), Downed Conductor Detection (DCD), etc.)
- Does not require extensive field high speed measurements or communication beyond traditional SCADA and remote access. (I.e. does not rely on synchrophasor technology)
- Does not require changes to system grounding configuration or load connections to implement

REFCL – advantages:

- Potential for 90% ignition probability reduction for single line to ground faults (Victorian ignition testing). Considering all fault types, an overall ignition probability reduction can be calculated to approximately a 59% reduction.
- Fault current limited to 1 Amp for single line to ground faults based on 2022 field testing
- Greater sensitivity to high impedance faults ( > 5k ohm fault resistance)
- Lower short circuit forces for line equipment for ground faults

EPSS – disadvantages:

- Less capability to sectionalize the system during fault events as compared to traditional protective settings due to the minimal coordination time provided in which can result in lower reliability performance
- Fault current is not limited - fault energy is reduced by faster clearing times - and remains a function of existing system configuration. Re-energization after a fault event requires disabling of EPSS to avoid inrush trips
- Susceptible to trips associated with customer load inrush, CT error, capacitor bank switching, and other non-fault grid disturbances.

REFCL – disadvantages:

- No risk reduction for line-line faults or three-phase ground faults
- Complicated to install and operate
- Limits operational flexibility / switching for the distribution circuits
- Fault location is more difficult
- Increased line-ground voltage stress on equipment during fault
- Requires tuning, stress testing, and some proactive equipment replacement

b. PG&E will need to evaluate the occurrences of different types of faults at locations within HFRA to determine the risk profile of existing ignitions and risk mitigation for REFCL and EPSS.

c.

i. EPSS and REFCL can be effective companion technologies as they both augment the other technologies shortfalls in some areas. For example, EPSS can reduce fault incident energy associated with line-to-line and three-phase faults which REFCL does not provide any benefit for. On a similar point, REFCL can potentially reduce energy associated with high impedance and provide greater detectability of these conditions. At this time, PG&E does not believe there are any negative implications of having both systems online at the same time and plans to do so in 2023.

ii. PG&E has not assessed the combined risk-reduction benefits of REFCL with EPSS & Other Mitigations. Having actual operational data associated with operating REFCL will allow better understanding of the risk vs. benefits associated with the systems independently as well as combined.

d.

i. PG&E's REFCL demonstration project has not been in full operation yet due to equipment failures during testing and the need for more testing to finalize settings. EPSS does not require the same new complex hardware, system conditioning, and testing and tuning periods to implement on a circuit, as compared to REFCL. Once REFCL is online, its advantages will be limited to line-to-ground faults only. Therefore, EPSS will continue to be a part of the protection strategy regardless of REFCL being implemented.

ii. REFCL can be performance tested to dial in settings with staged fault testing, and fault sensitivity is expected to be approximately 1 Amp of fault current. DCD can be enabled in software in certain types of existing line recloser controllers to detect high impedance fault conditions down to approximately 1 Amp. Both technologies will continue to be evaluated to determine their effectiveness.