Protection Challenges of a Resistance Grounded Distribution Feeder with Fused Taps

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Redacted, Inc. Chemical Plant experiences a fault on one of several transformers fed from a fused tap on a distribution circuit.

The circuit is low-resistance grounded with two grounded sources, a utility transformer and a generator.
Fused taps are the de-facto standard on overhead utility distribution circuits.

They’re fairly common on insulated distribution circuits as well.

Yes, this is a picture of a fused contactor, not a fused switch. It’s the best I had without stealing one off the internet.
Fault is initiated as a phase-to-phase-to-ground fault. Peak magnitude in first 2 cycles is approximately 4 kA on C-phase.

Feeder breaker relay trips on ground overcurrent and breaker interrupts the fault and all load on the feeder.

Phase C clears, leaving Phase A to ground. The measurement is at the feeder, not the fused tap, so load can still be seen.

Ground fault current (approx. 600 amps) continues to flow.
“Fuses do a pretty good job...”

- Matt Proctor, former sales manager for relays
300 amps total clear time is between 8 and 9 seconds.

400 amps total clear time is approximately 600 ms.

800 amps total clear time is approximately 85 ms.

Amps in excess of 6kA clear in approximately 8 ms.

Fuses do a pretty good job when current magnitude is high.

They can limit current too!

Not so great for low magnitudes.
Solution #1 – Fix the Mis-Coordination
Solution #2 – Solidly Ground the System

Instead of limiting current magnitude after one fuse blows, the 2nd fuse would have likely blown very fast.

Fixes coordination problem.

Increases fault energy, potential catastrophic damage to gen.
Solution #3 – Use IED’s to Locate Fault

IED’s fast 50G operates.

IED’s fast 50G is blocked. IED allows fuse to blow.
Solution #4 – Use IED’s to Trigger Fast Grounding Switch

IED protection detects transformer fault and actuates fast ground switch.

Fuses blow for 3LG fault in 8 ms.

Costly, but there’s an added benefit of arc flash reduction at LV equipment.
Solution #5 – Use Proactive Transformer Monitoring

Water line in the bottom of the tank.

Online monitoring might detect moisture in the transformer before a fault occurs.
Solution #6 – Install a breaker (or recloser)

A breaker is the most conventional solution, but there’s a reason a breaker wasn’t used in the first place.
Inference About Transformer Differential Pickup Setting
Ultra-conservative pickup = 2 x maximum loading

A-C-G fault yielded approx. 2kA RMS

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A fault with more turns between the source or a higher Zf reduces likelihood of 87 Trip.
Ultra-conservative pickup = 2 x maximum loading

In this case, it is highly unlikely that the 87 would have tripped if the fault were in the secondary winding unless pickup were set sensitively.

Ultra-conservative pickup = 2 x maximum loading
Conclusions

• Fuses can be very fast and effective at clearing faults but are prone to partially clearing.
• Coordinating 51G elements with fuses can require extremely long time delays on resistance grounded systems.
• With multiple sources, multiple scenarios must be considered in coordination.
• Setting an 87 sensitively does not always sacrifice reliability.
• Predictive maintenance is the closest thing we have to zero-cycle protection.
THANK YOU. QUESTIONS?