Understanding Ground Fault Detection Sensitivity and Ways to Mitigate Safety Hazards in Power Distribution Systems

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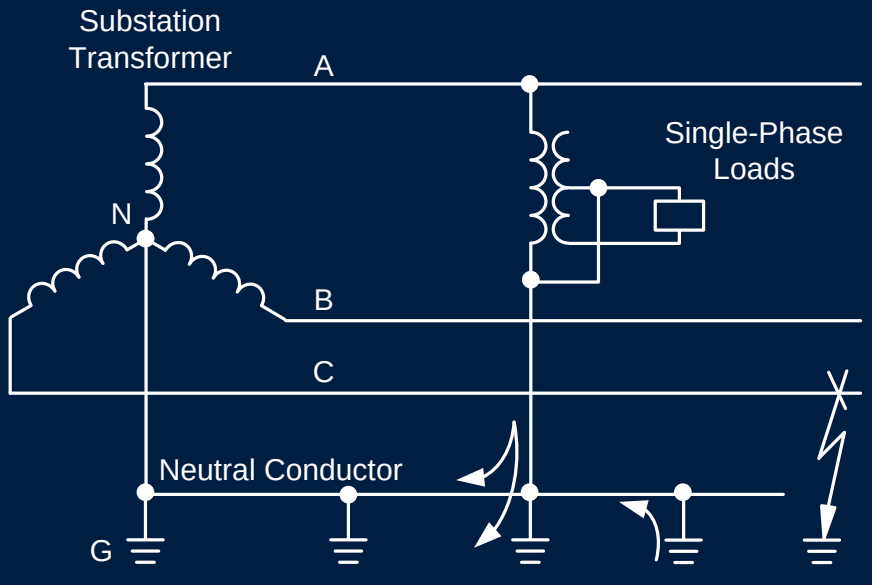
Overview

- Ground fault detection and sensitivity
- System grounding and impact to sensitivity
  - Multi-grounded systems
  - Uni-grounded systems
  - Ungrounded systems
- Dynamic process of fire ignitions
- Fire ignition versus released energy from faults

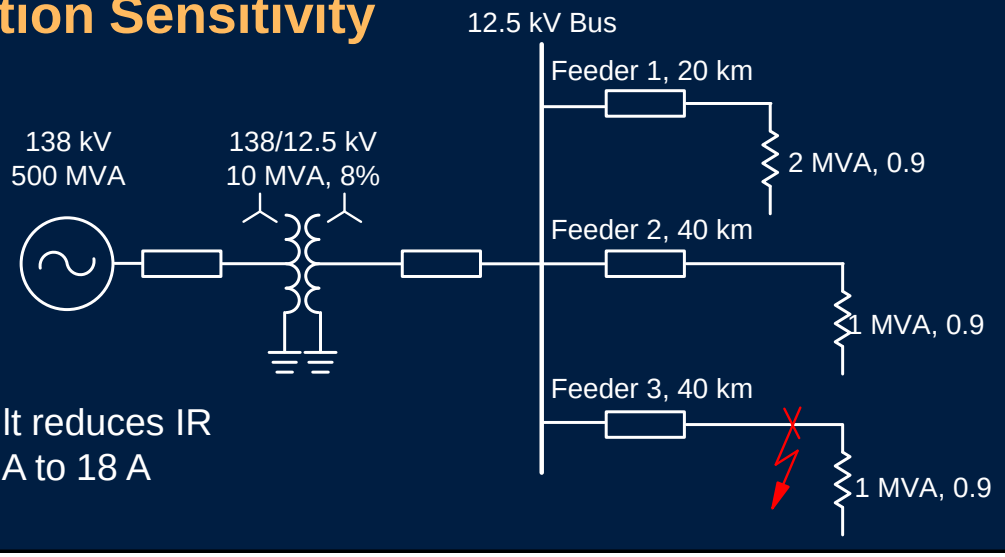
Ground Fault Detection in Distribution Systems

- Residual overcurrent for ground fault detection
- Sensitivity: capability to differentiate faults from normal system conditions
- Selectivity: allow downstream devices to trip their faults
- Security: no operation for transformer inrush, cold load pickup, and other emergency conditions
- Service dependability: trade-offs

Multi-Grounded Distribution Systems

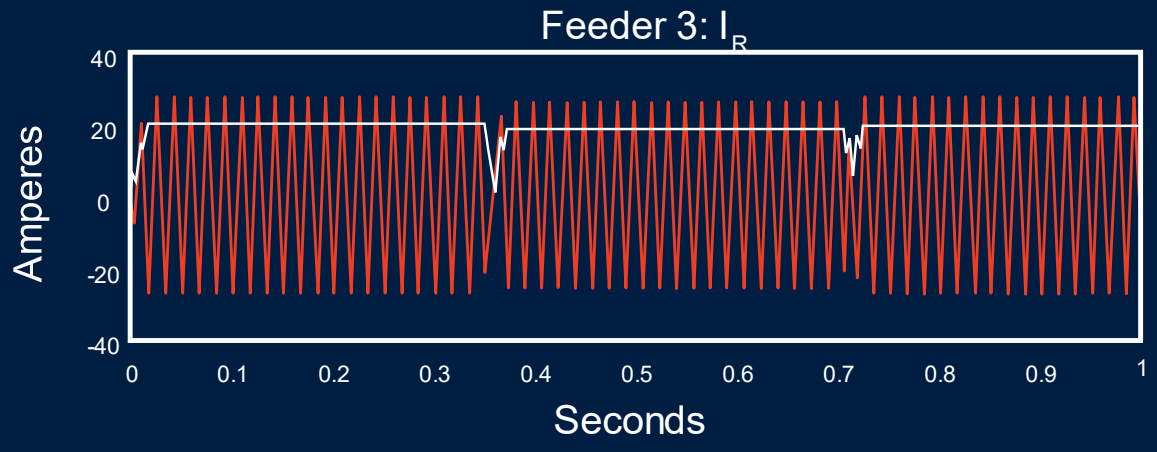


Unbalanced Single-Phase Load Reduces Fault Detection Sensitivity

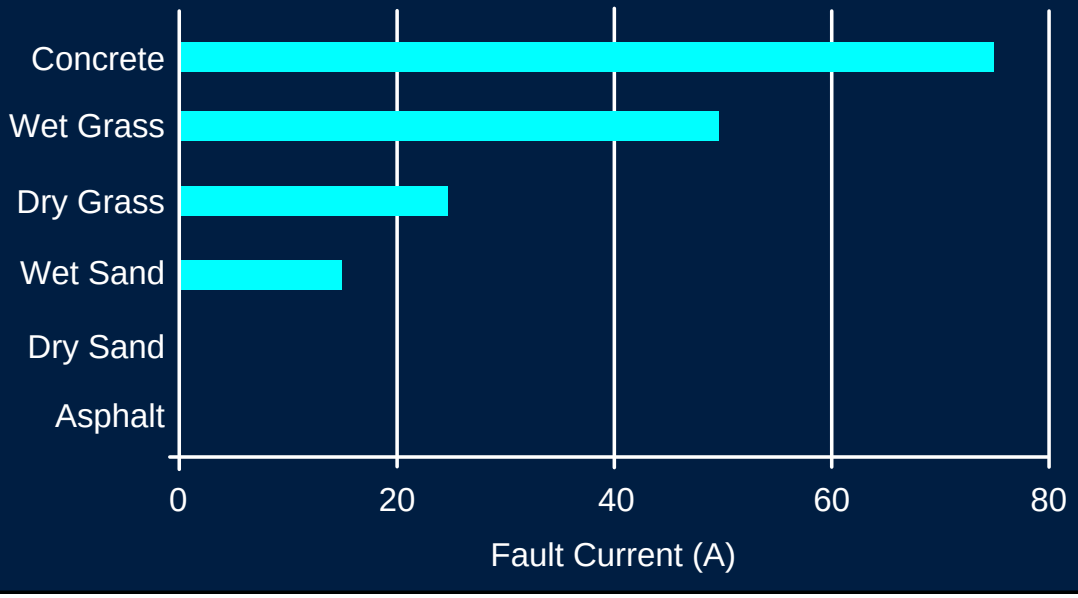


A 200 Ω fault reduces IR from 20 A to 18 A

Unbalanced Single-Phase Load Reduces Fault Detection Sensitivity

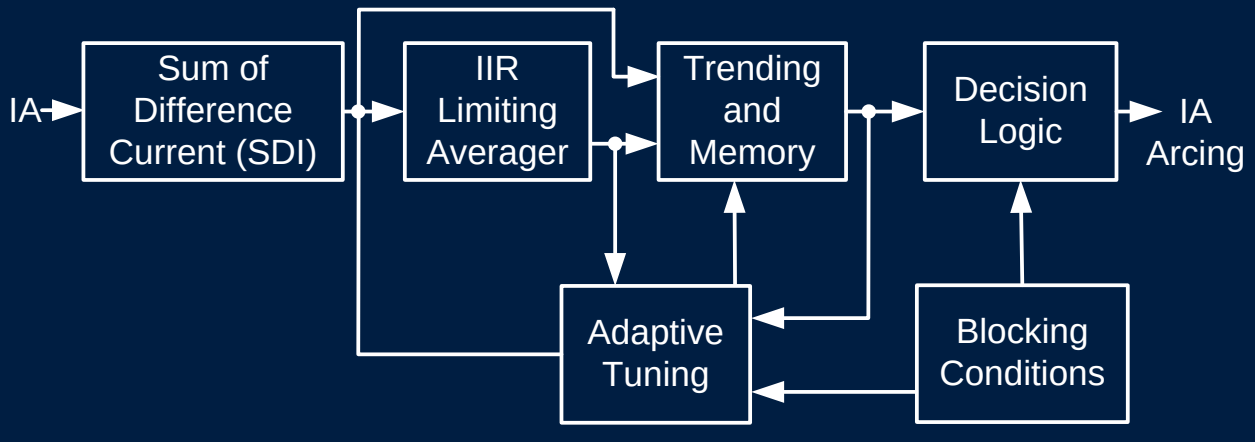


High-Impedance Faults (HIFs)



Purpose-Designed HIF Detection

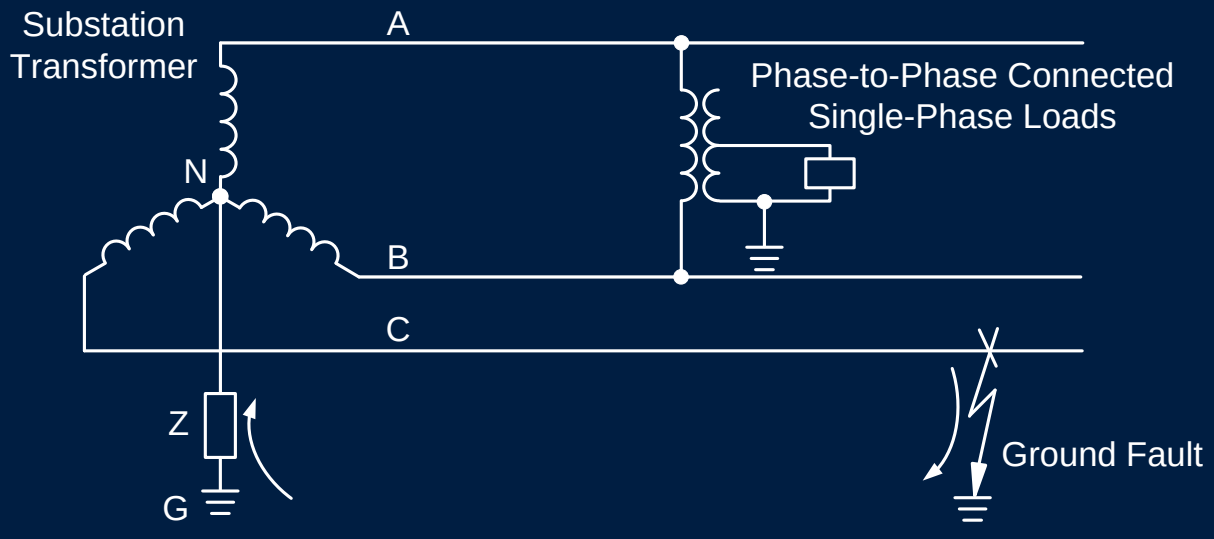
To Increase Ground Fault Detection Sensitivity



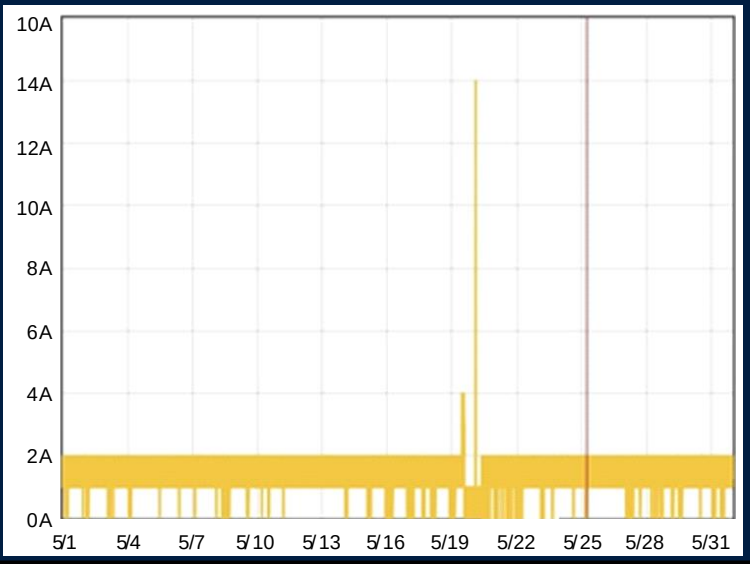
Uni-Grounded Distribution Systems

- Solidly grounded system
- Impedance-grounded system
- Compensated system (Petersen-coil grounded)

Uni-Grounded Distribution Systems



System Standing Unbalance Limits Fault Detection Sensitivity

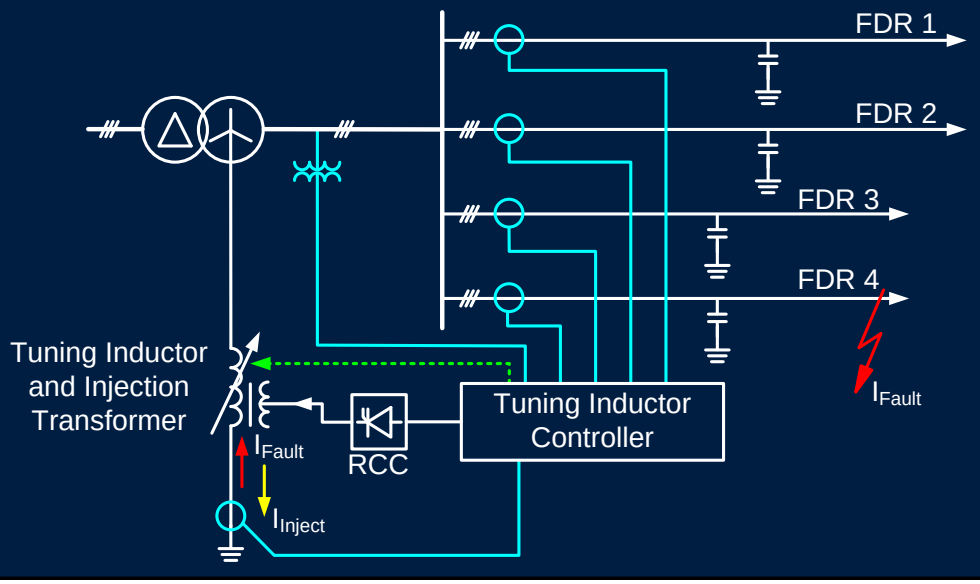


Improving Ground Fault Detection Sensitivity

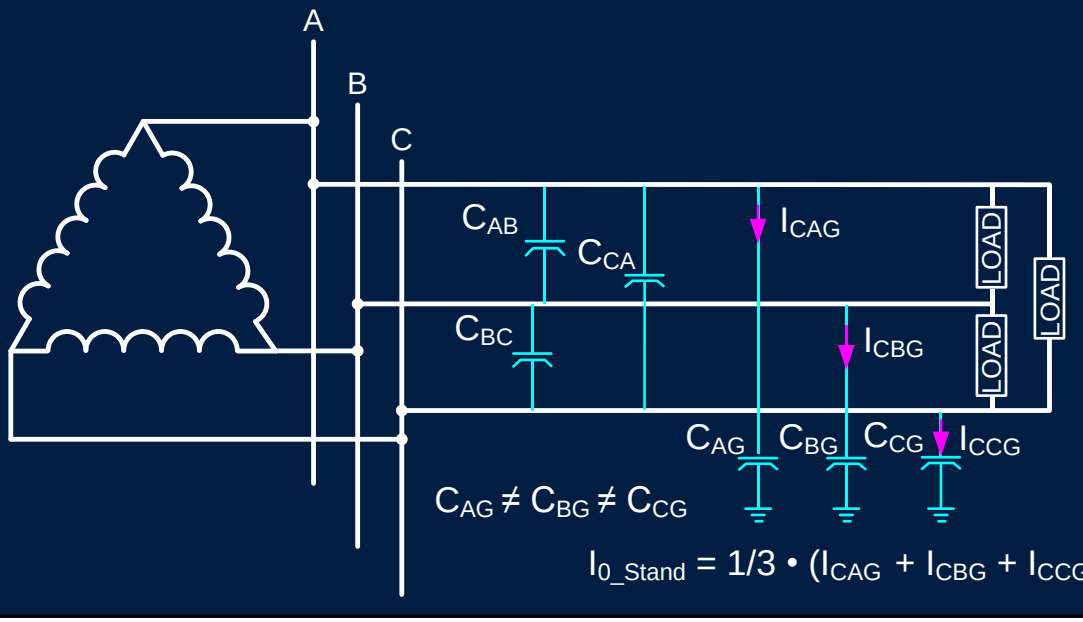
- Use incremental conductance element for resonant-grounded systems
- Use flux summation CTs (core-balanced CTs) – not always practical for existing outdoor breakers
- Employ low CT ratio (e.g., 50:5)
- Use sensitive relay residual current input

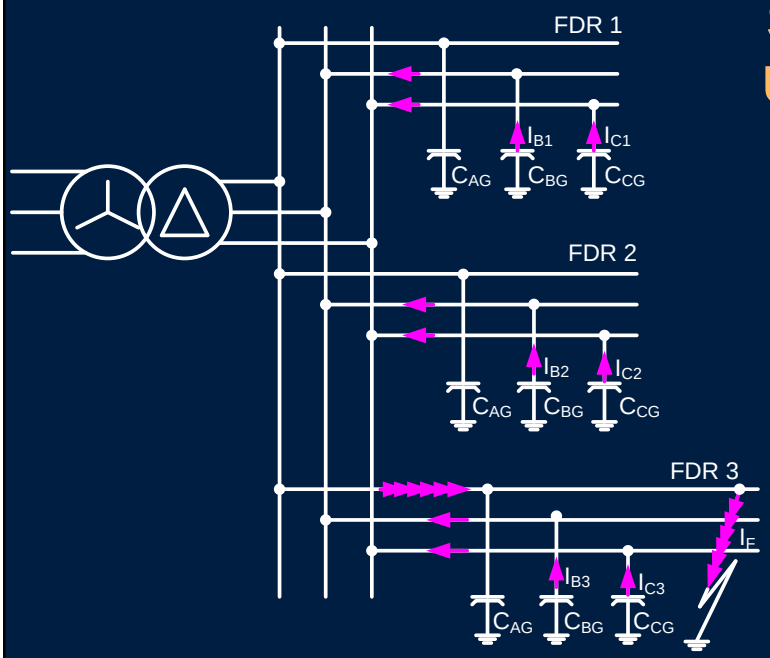
Rapid Earth Fault Current Limiter (REFCL)

GFN or RCC



Ungrounded Distribution Systems





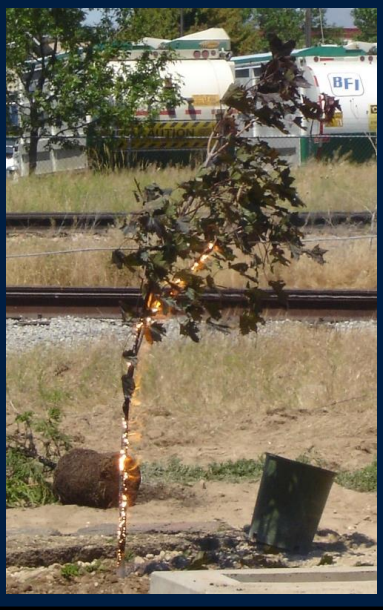
System Standing Unbalance Limits Fault Detection Sensitivity

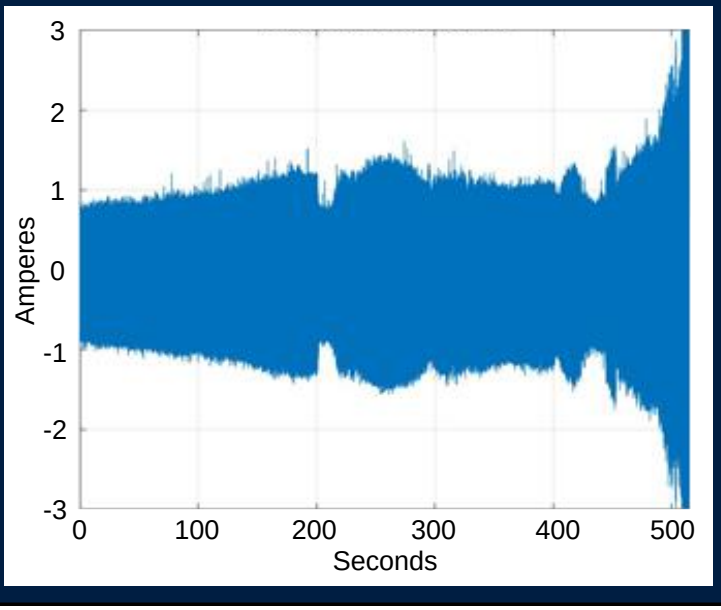
Use flux summation CTs with low CT ratios

Dynamic Process of Fire Ignitions

- Weather factors: wind speed, humidity, temperature
- Ground fuel factors: types, humidity, reserves
- Arcing fault characteristics
- Right time with right conditions

Fire Ignitions From Staged Fault Tests

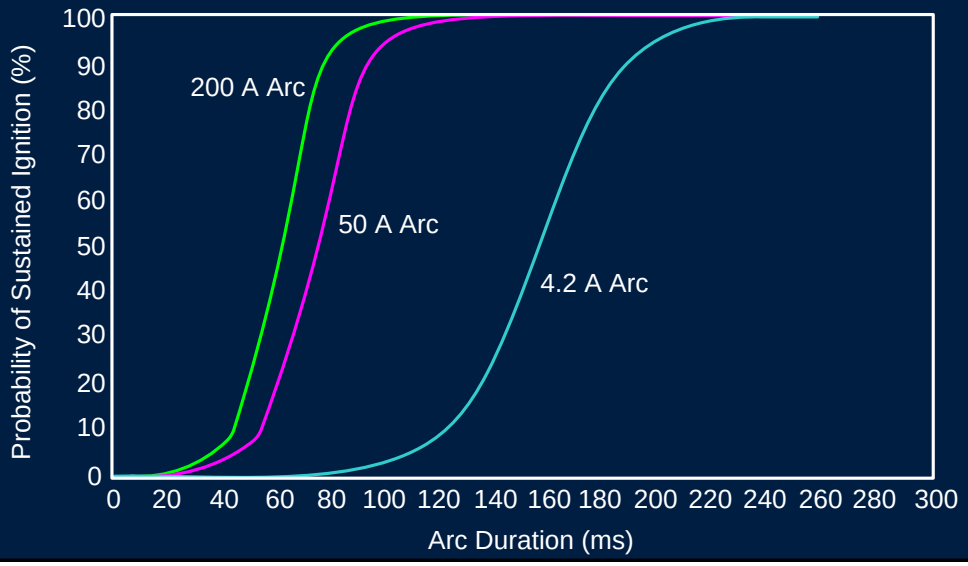




Fire Ignitions From Staged Fault Tests

Fire Ignition Versus Energy Released From Faults

Australian Bushfire Ignition Test Report



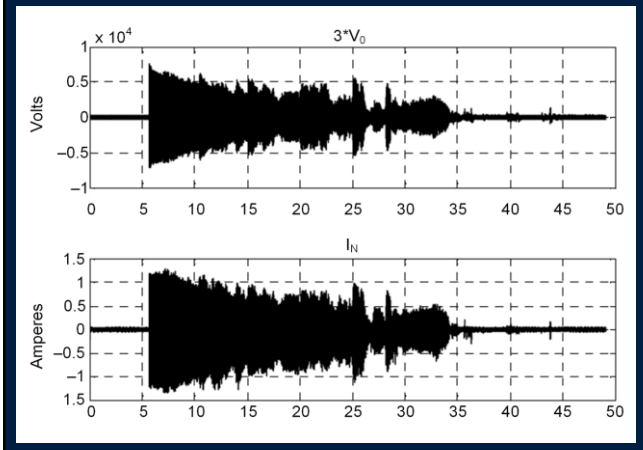
Fire Ignition Versus Fault Current Level

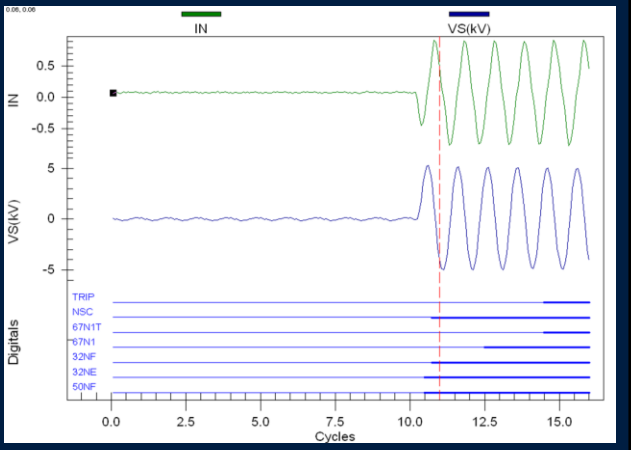
Australian Vegetation Ignition Test Report

- Branch-to-wire ground faults
  - 0.5 A primary pickup setting with 2-second delay
  - Tenfold reduction in ignition probability
- Wire-into-vegetation ground faults
  - 0.5 A primary pickup setting
  - 80% reduction in fire risk

Can We Close the Gap?

4.6 kV Ungrounded System





Conclusions

- Ground fault detection sensitivity depends on system standing unbalance
- Single-phase loads limit the sensitivity for multi-grounded systems
- Use purpose-designed detection algorithms for HIFs
- System standing unbalance comes from structure asymmetries and is much smaller for uni-grounded and ungrounded systems

Conclusions

- Use core-balance CTs with low CT ratios to improve sensitivity for uni- and ungrounded systems
- Wildfire ignition depends on many ambient conditions in addition to released energy from faults
- There is a potential to sensitively detect ground faults and reduce possibilities of fire ignitions
- We can reduce the probability of fire ignition, but we will likely never eliminate the risk

Questions?