Modern Relay Protection
&
Control Applications

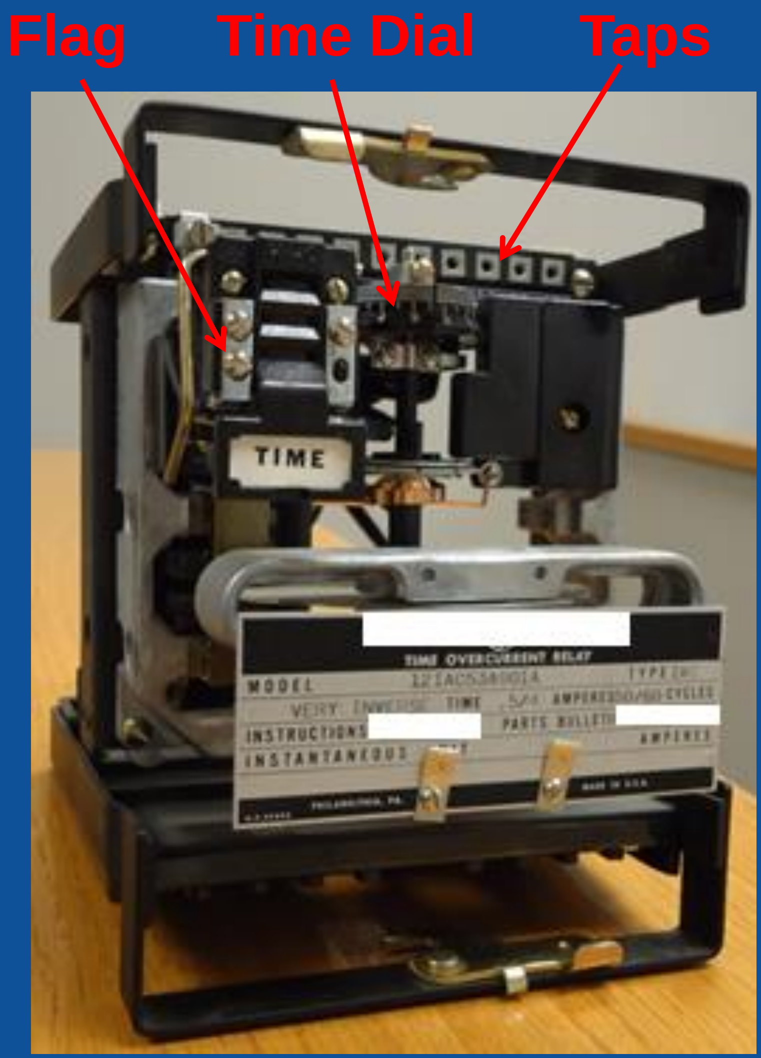
By: Wheeler O’Harrow, P. Eng.

Outline

- Brief Background & Historical overview of relay protection in 3 technological generations
- Case studies of microprocessor based relay applications as it pertains to:
  1. Enhancing personnel safety
  2. Minimizing equipment damage
  3. Maximized reliability and expedited root cause analysis
- Conclusion / Q&A

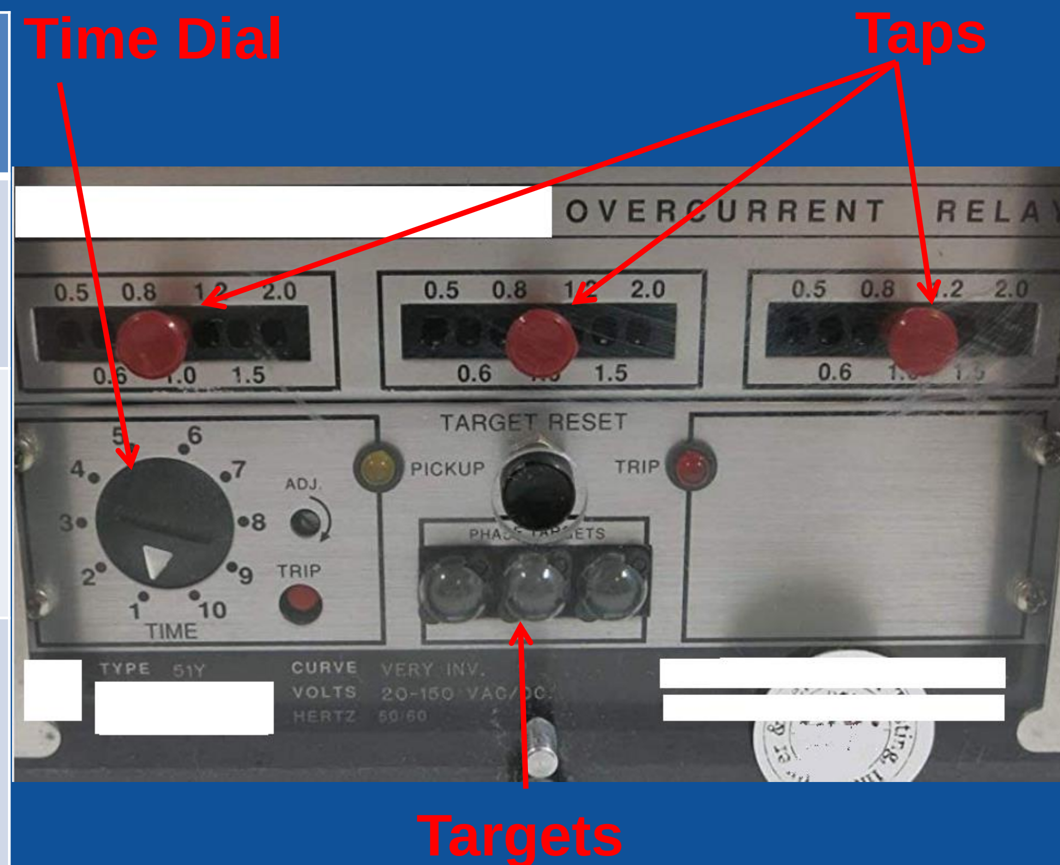
Electro-Mechanical Relays

Advantages	Disadvantages
No Computer needed to change settings	Slower and not as accurate as new relays
Mechanical (don't need to be a computer whiz)	Only performs one function
	Needs to be calibrated more frequently
	Takes up more space



Solid State Relays

Advantages	Disadvantages
No Computer needed to change settings	Targets for trips give little information
Performs 51 for all 3 phases not just 1	Still need multiple relays for other functions
No moving mechanical parts; reliability improved	



Microprocessor Relays

Advantages	Disadvantages
Multiple IEEE ANSI device functions available in 1 relay	Typically computer and cable required for event information or setpoint creation
Can record sequence of events and perform additional logic or control	Detailed design on implementation is more involved than previous technologies
No moving mechanical parts; reliability improved	Not recommended to be in service as long as most electro mechanicals have typically served

Relay Protection & Control Applications

1. Enhancing Personnel Safety

Equipment Damage

- Clearing time of arc event & proximity are manageable factors

EM Relay Example (1 relay per function)

Relay Reduction and Centralization

Relay Reduction and Centralization

49 relays to 7 + 1 data concentrator & remote i/o
All controls and IED’s outside the AFB

Arc Flash Hazard Mitigation with Relays

What if having the protection and/or controls of electrical equipment placed remotely from AFB (Arc Flash Boundary) is not feasible?

1. Maintenance Switch to activate more aggressive overcurrent settings engineered according to calculated arcing fault current.
2. Zone Selective Interlocking (ZSI) scheme allows for upstream and downstream protective devices to have identical trip settings with an established delay to allow for point to point communication between the two devices to determine whether upstream device will be blocked from tripping or in absence of this block be able to trip in a greatly reduced clearing time.

Arc Flash Hazard Mitigation with Relays

What if having the protection and/or controls of electrical equipment placed remotely from AFB (Arc Flash Boundary) is not feasible?

3. Addition of light sensors monitored by a relay with extremely fast operate contacts (1/2 cycle or less) either with or without current supervision that acts in parallel with existing protection systems.

AF Mitigation with Relays (Pros & Cons)

	Advantages	Disadvantages
1. Maint. Sw.	Material and labour req'd to install is economical with minimal extra programming on an IED	Effectiveness directly linked to calculated arcing current setpoint. Can cause nuisance tripping on large motor start if not disabled.
2. ZSI	Can achieve extremely fast clearing times with high level main breaker devices that typically require time for downstream selectivity.	Typically require same topology of trip units on each end of the ZSI scheme for communication assisted scheme to work. Not always simple with retrofit applications.
3. Light detection	Mitigation system can be independent of existing protection thus no threat to protective coordination. OC Setpoint usually set to twice load current. Fastest system of the three.	Can be the most costly of the three options to integrate with existing systems. Usually requires additional operational gain to warrant this retrofit.

Many other great papers covering 1. and 2., for sake of time we will look at 3.

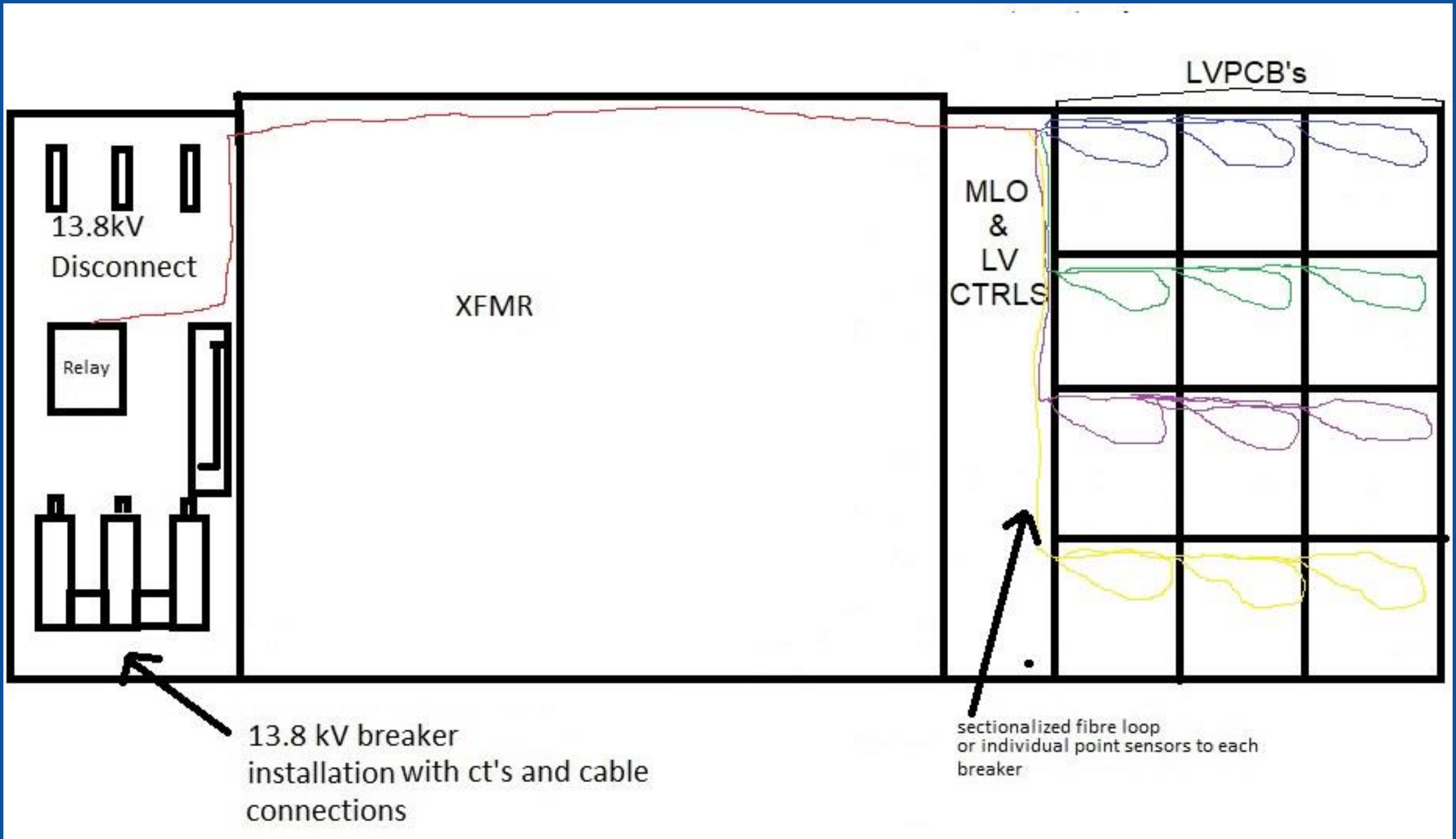
Light Detection Systems

Point Sensors

Light Detection Systems

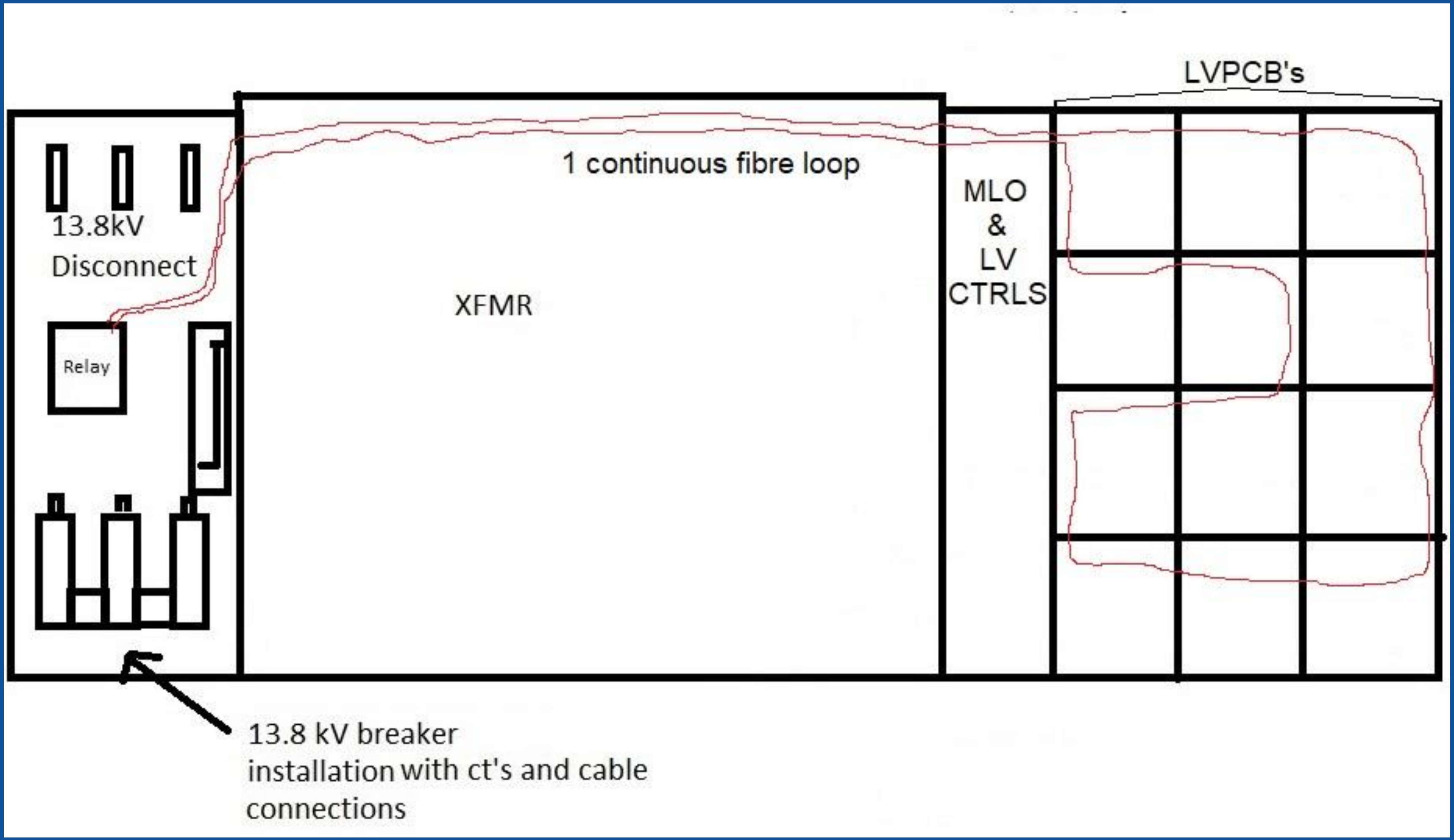
Fibre Loop Sensors

Light Detection Systems on TX Blind Spots



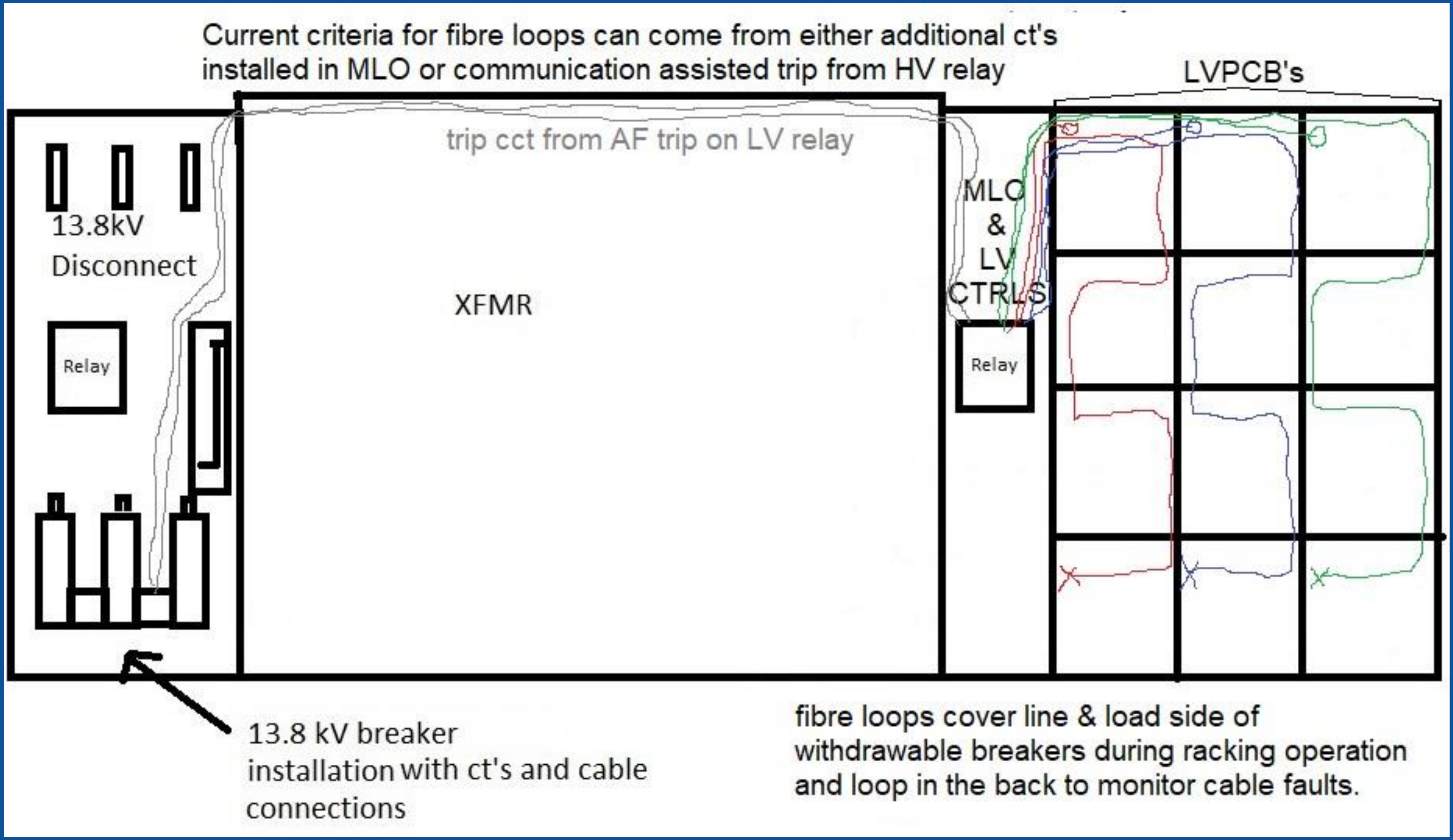
Can be cost prohibitive with the amount of routing and holes in switchgear

Light Detection Systems on TX Blind Spots



Still somewhat labour intensive but some improvement on # of holes req'd & single routing

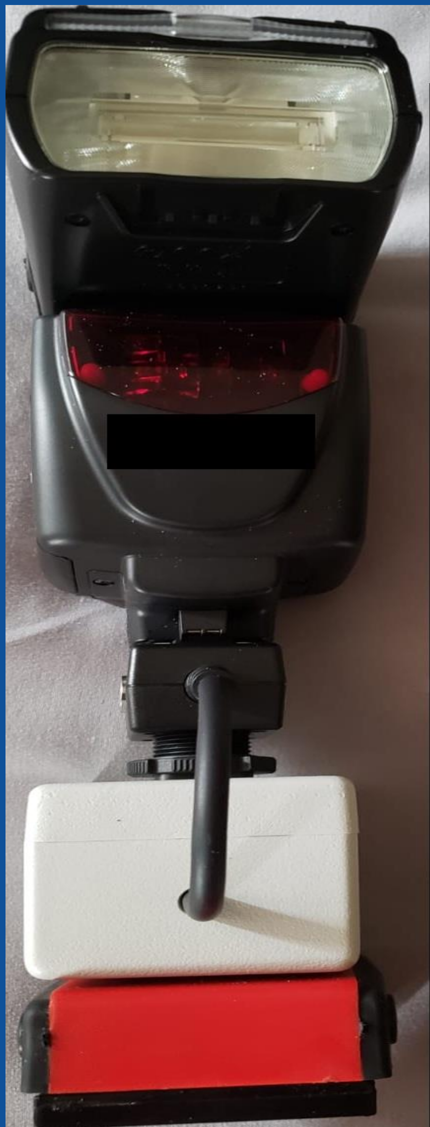
Light Detection Systems on TX Blind Spots



Extra relay but overall savings in simplified shorter loops with cable coverage.

Light Detection Systems on TX Blind Spots

Testing of Light Detection Systems



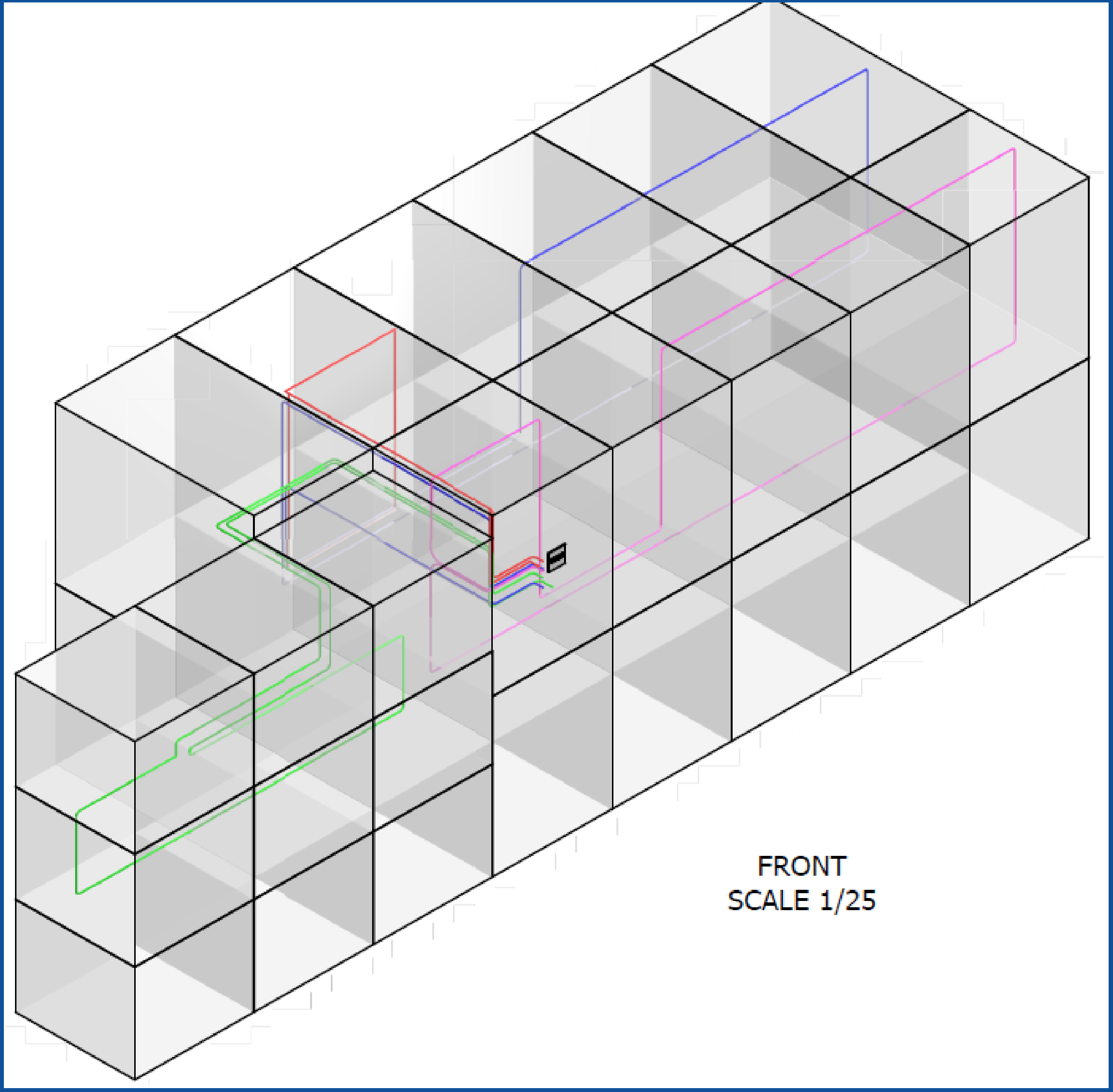
Relay Protection & Control Applications

2. Minimizing Equipment Damage

Light Detection Systems

- Light fibre loops run in 4 sections of coverage:

1. Breakers (pink)
2. Starters (green)
3. Cable and Busway (blue)
4. Line side of main (orange)



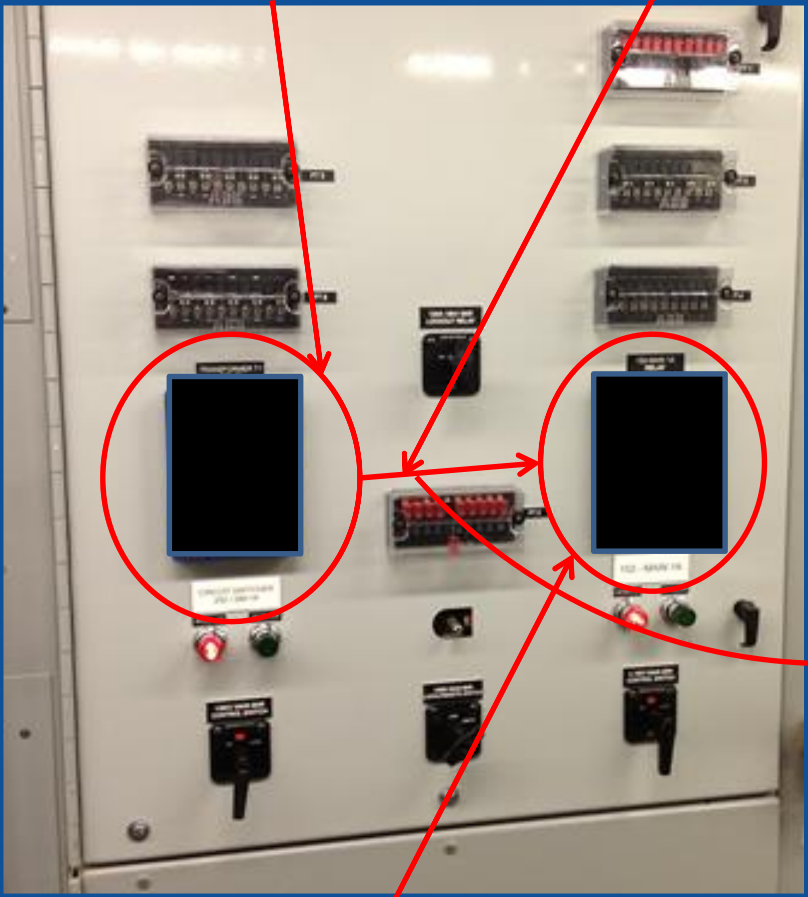
Sensor Management

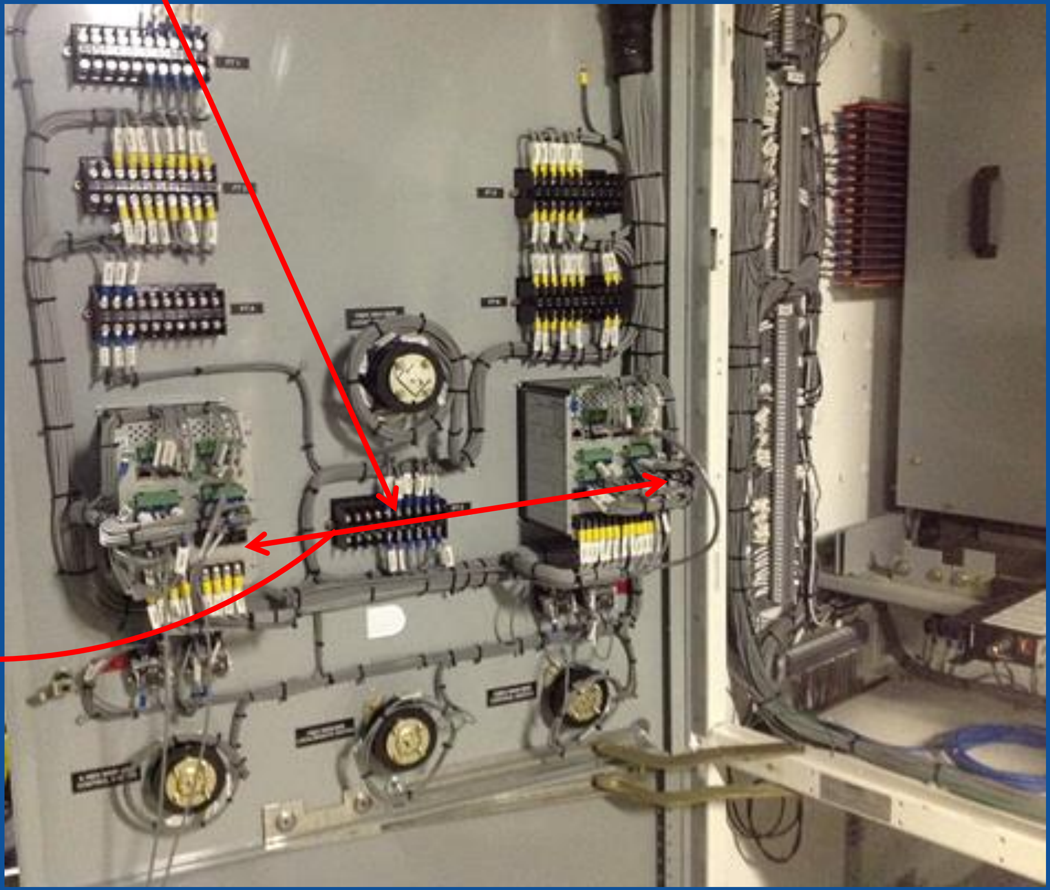
- Modular runs allows for ease of replacement
- Single marshalling point before landing to relay

Light Transfer Trip Technique

Light Detection

Light trip sent



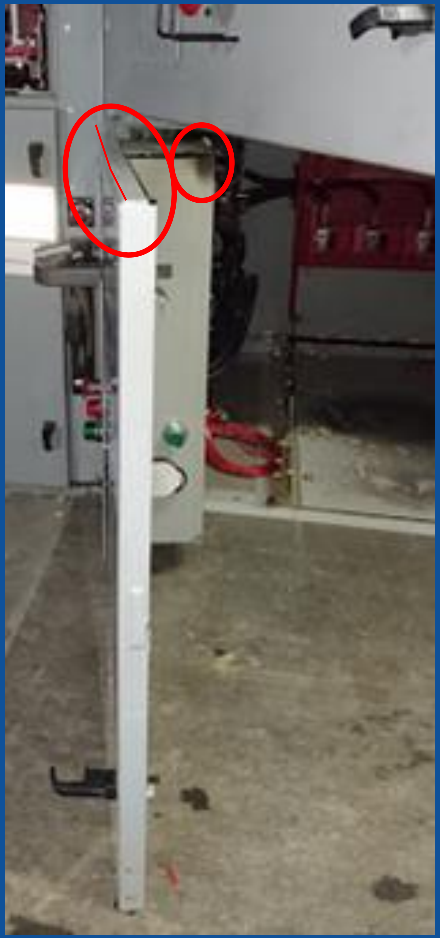


Arcing O/C Setpoint Trip

Upstream trip to circuit switcher for approx. 100ms trip total

Light & Current Event Trip

- Relay transfer trip operate and breaker clearing time approximately 100ms
- Door deflection and damaged fibre



Light & Current Event Trip

- At approximately 100ms of arcing time, insulating barriers and fuses were replaced and contactor returned to service in 6 hours.
- Considerable downtime saved by limiting arcing time.

Light & Current Event Trip

- Control cables, power cables, and control devices not affected by lessened arc flash.

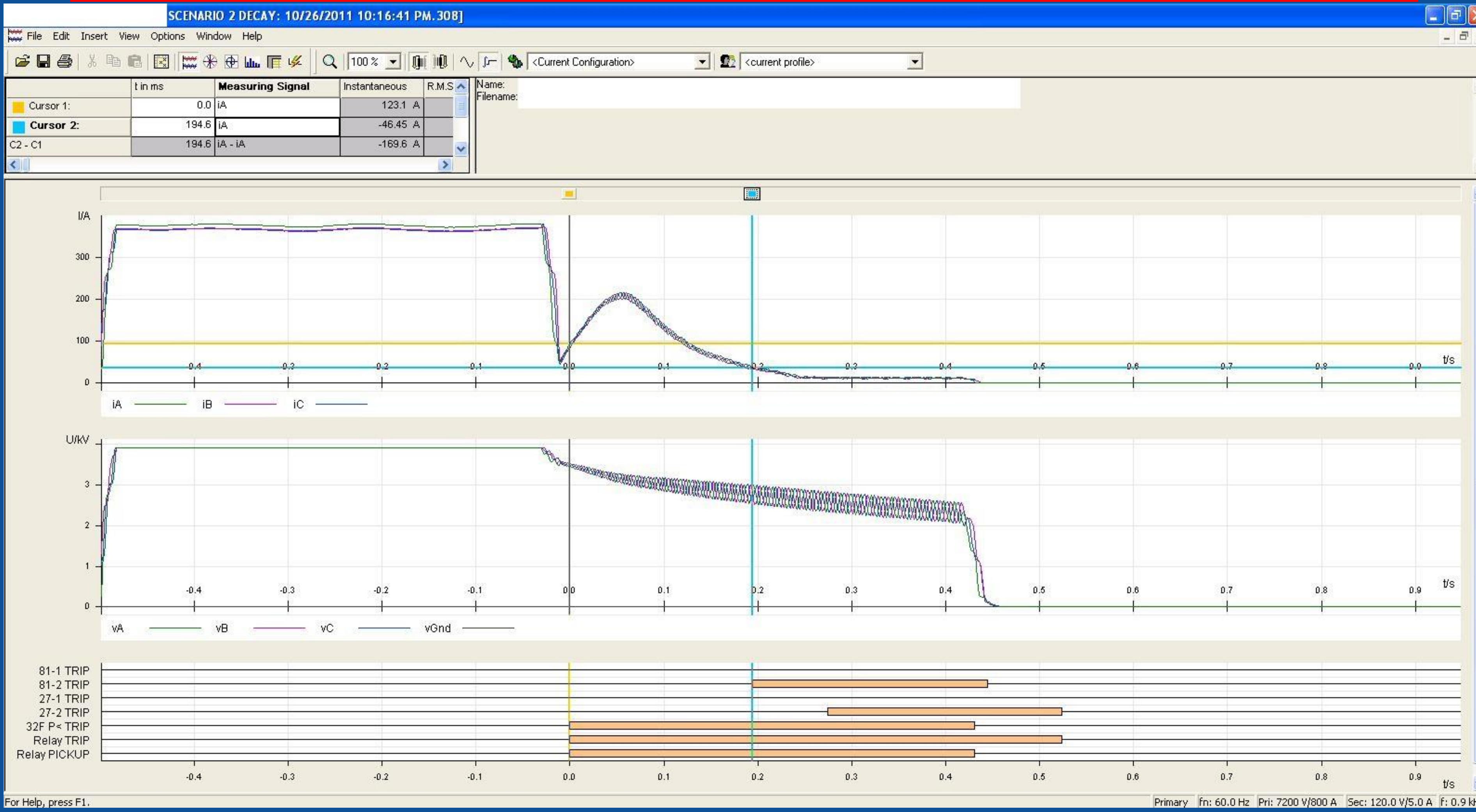
32F Minimum Forward Power

- Large MV induction motors coupled to pumps in the order of 4000hp to 6500hp.
- Concern discovered during commissioning of default settings for function enabled with no philosophy or narrative on why the setting was required and what should be the appropriate designed setpoints.

32F Minimum Forward Power

- Utility providers were verified to have reclosing enabled with intervals as short as 200ms posing potential harm to motors out of sync with utility but still connected through bypass contactors.
- Subsequent testing observed the immediate reversal of the voltage waveform but gradual current and frequency decay upon simulation of loss of utility power.

32F Minimum Forward Power



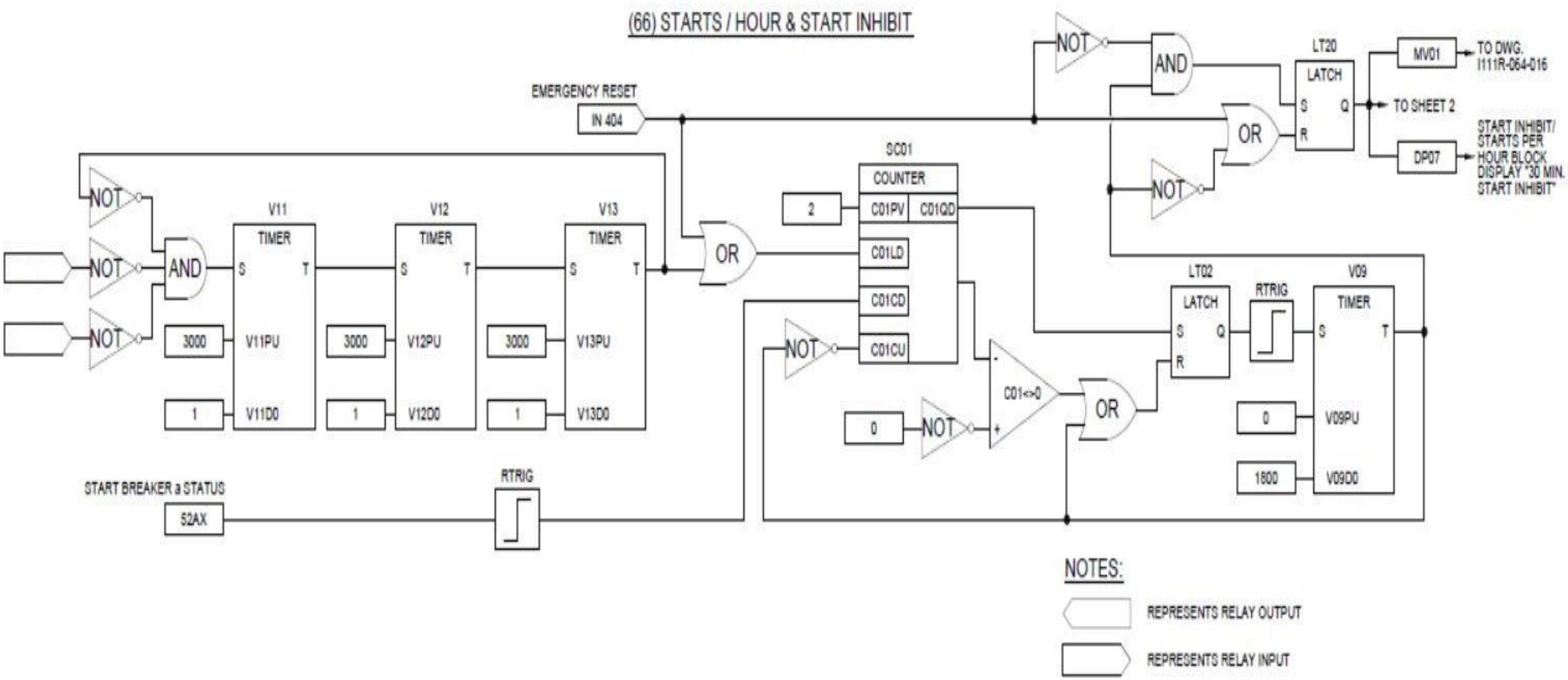
Current active for almost 0.5s after power severed, 81/27 elements slow and unpredictable to respond to loss of utility situation. Proposed 32F element instant.

IED Limitations

IED did not have a native 66 function
No panel room or budget for another 3 relays for a single function that could prevent destruction of machine

IED Limitations

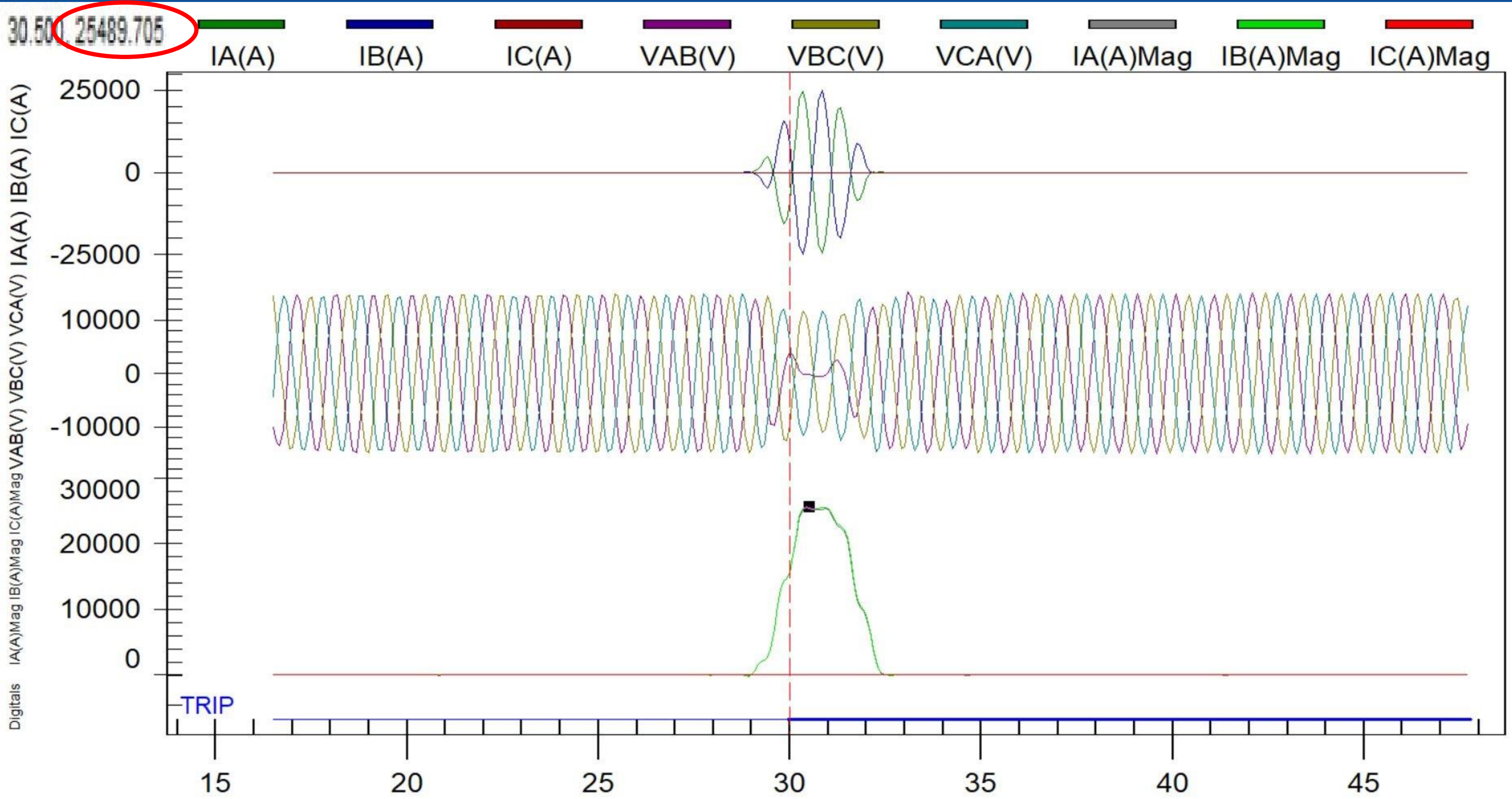
Make your own function with available logic, and TEST it to ensure reliable performance.



Human Performance Limitations

With significant changes in protection and controls, training of all staff that could potentially start any of these machines was highly recommended, but….

Human Performance Limitations

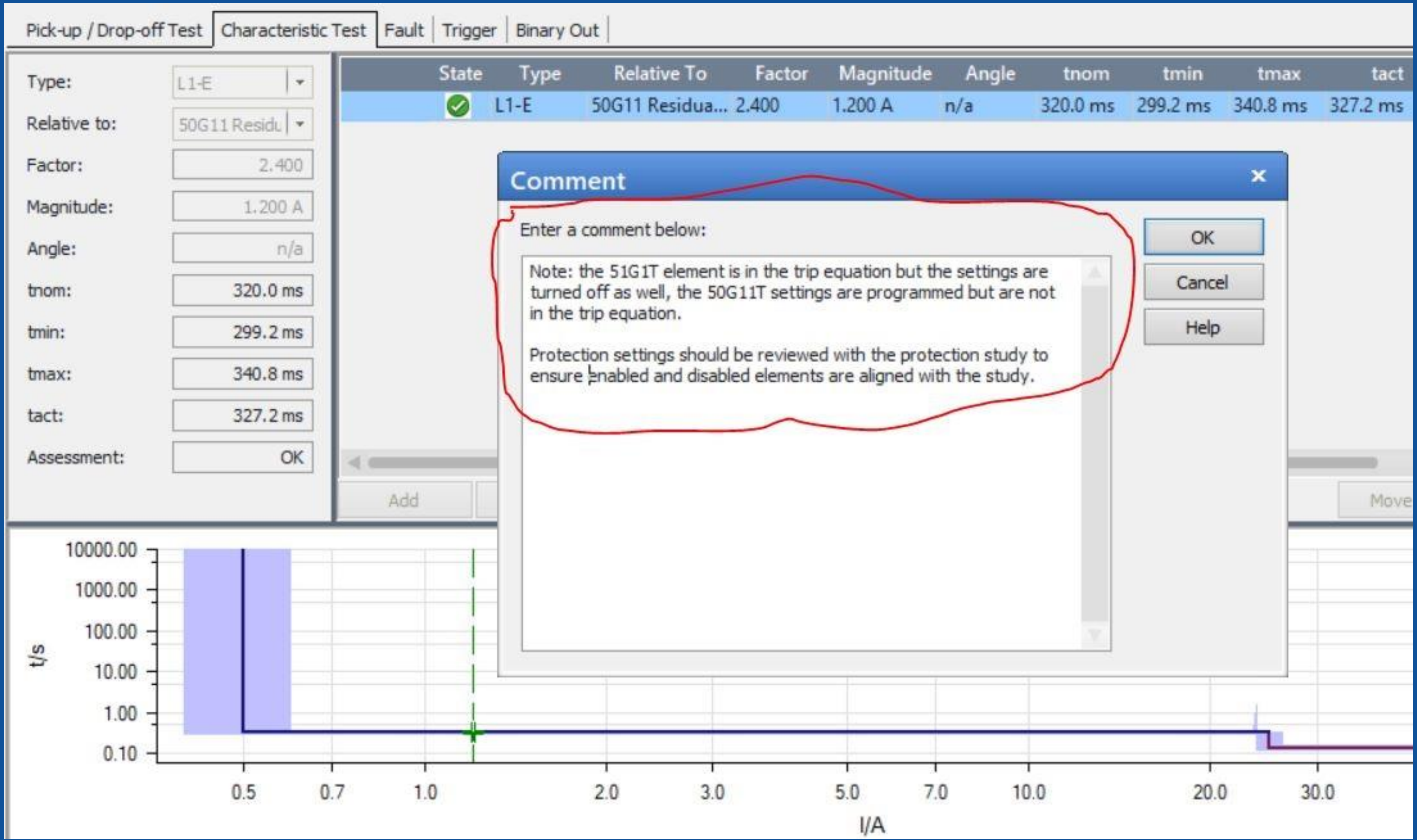


It just didn't happen and as result the machine req'd a complete re-wind after 5 attempted starts. Protection did block excessive immediate restarts

Relay Protection & Control Applications

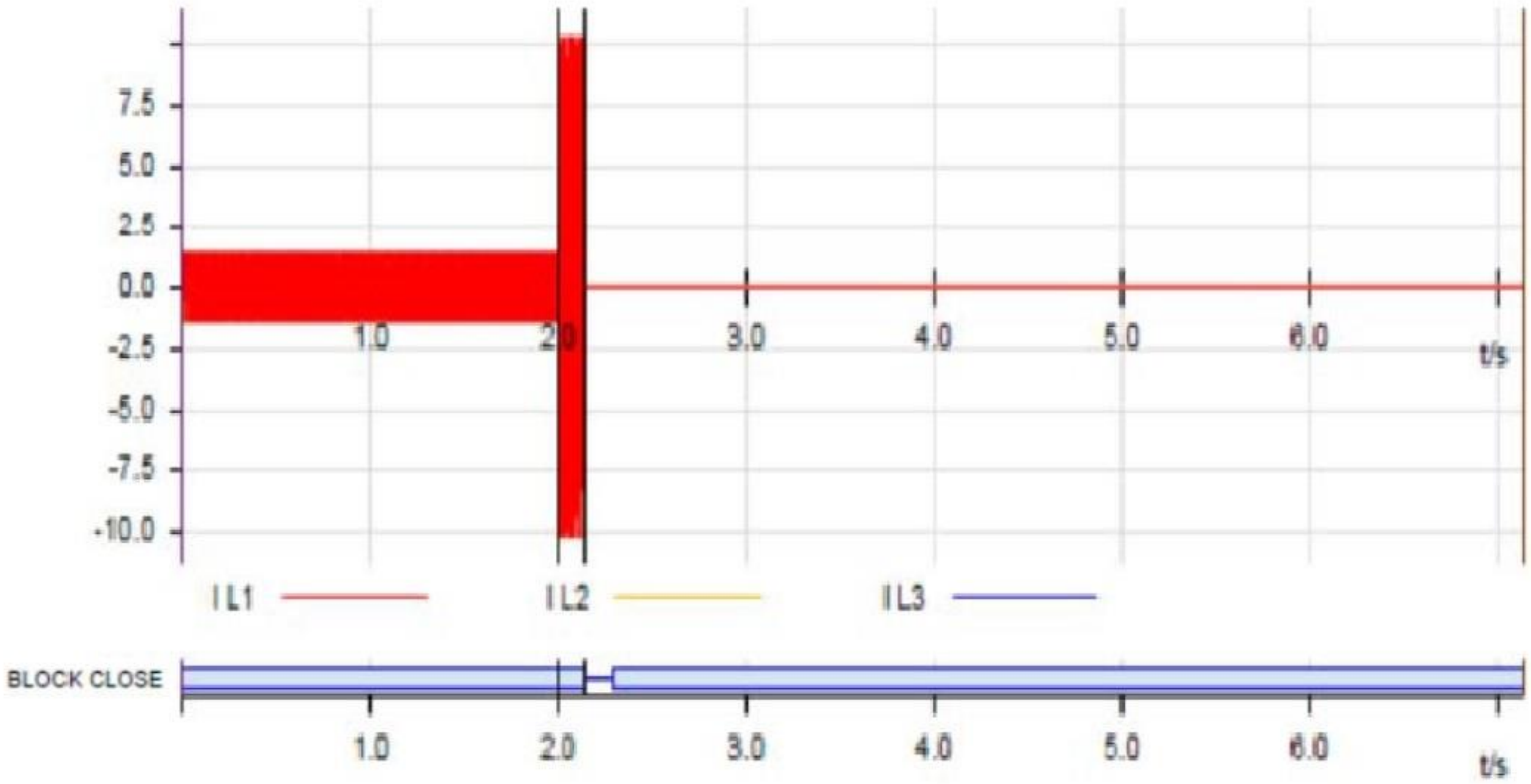
3. Maximized reliability and expedited root cause analysis

Vetted Protection & Control Schemes



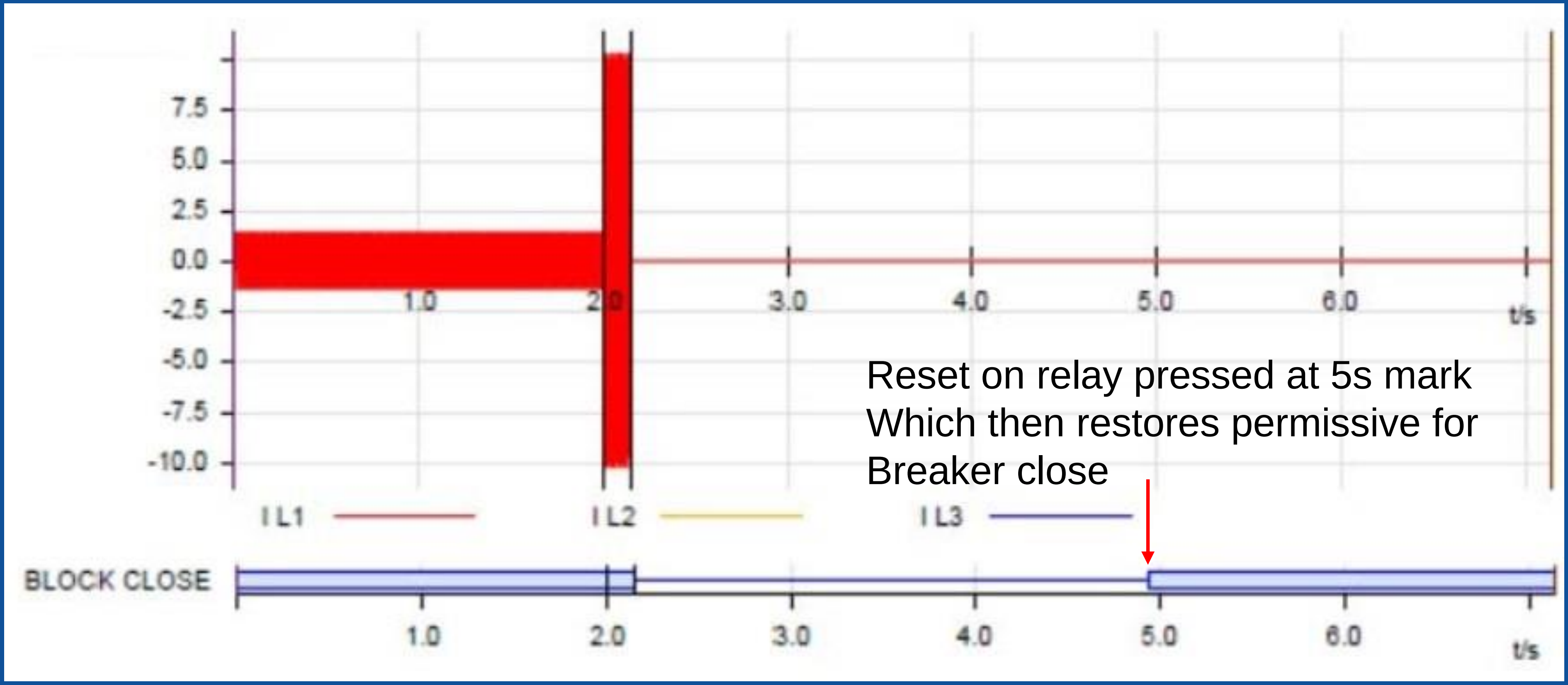
In service for several years with no ground fault protection. Protection survey revealed 50 deficiencies, several critical to production

Vetted Protection & Control Schemes



Close contact immediately returns to healthy after trip duration / dropout setting of which a trip toggles this block close permissive contact.

Vetted Protection & Control Schemes

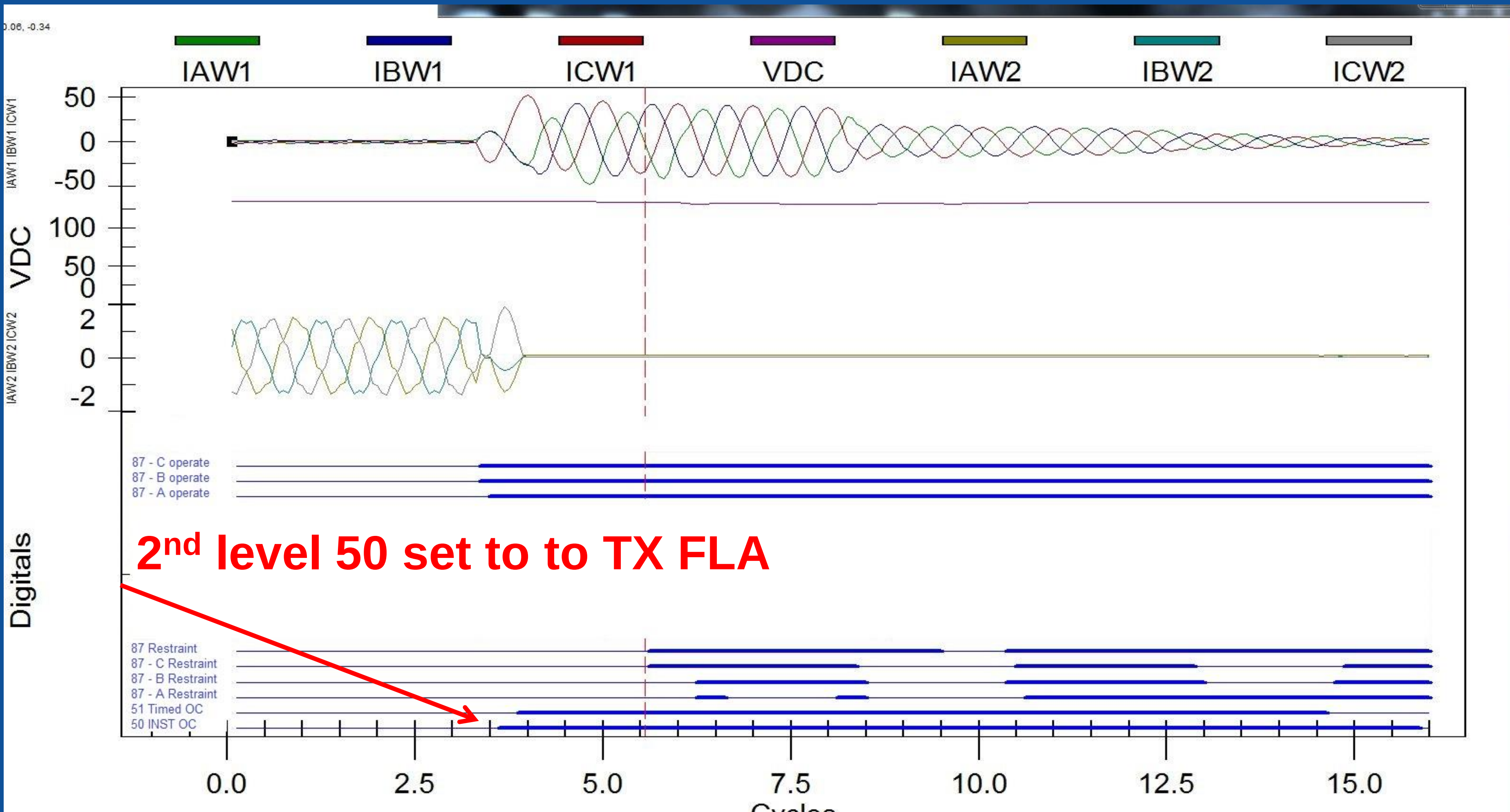


In service for several years with no block close protection. Complete interrupter failure due to closing into a fault multiple times.

Simplified yet Comprehensive

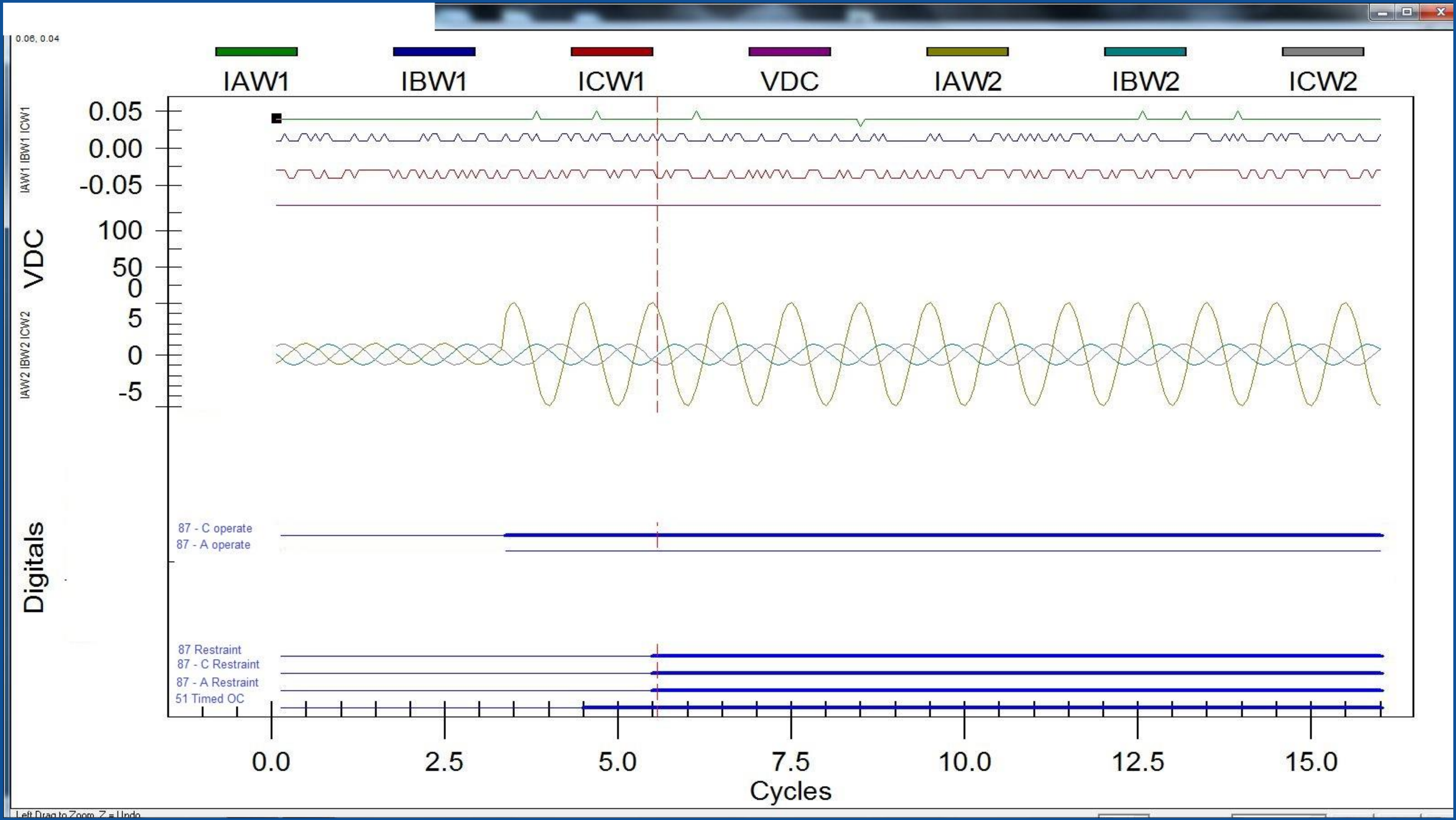
1 IED utilized to perform differential of mobile unit, monitor UPS voltage, BKR status, TX & SF6 instrument/mechanical protections with all statuses shown local and sent remote

FLA Monitor



This fault was a high impedance MV cable fault 3000 ft downstream that continue to extinguish itself with large presence of smoke. Not high enough current to be a 50.

FLA Monitor

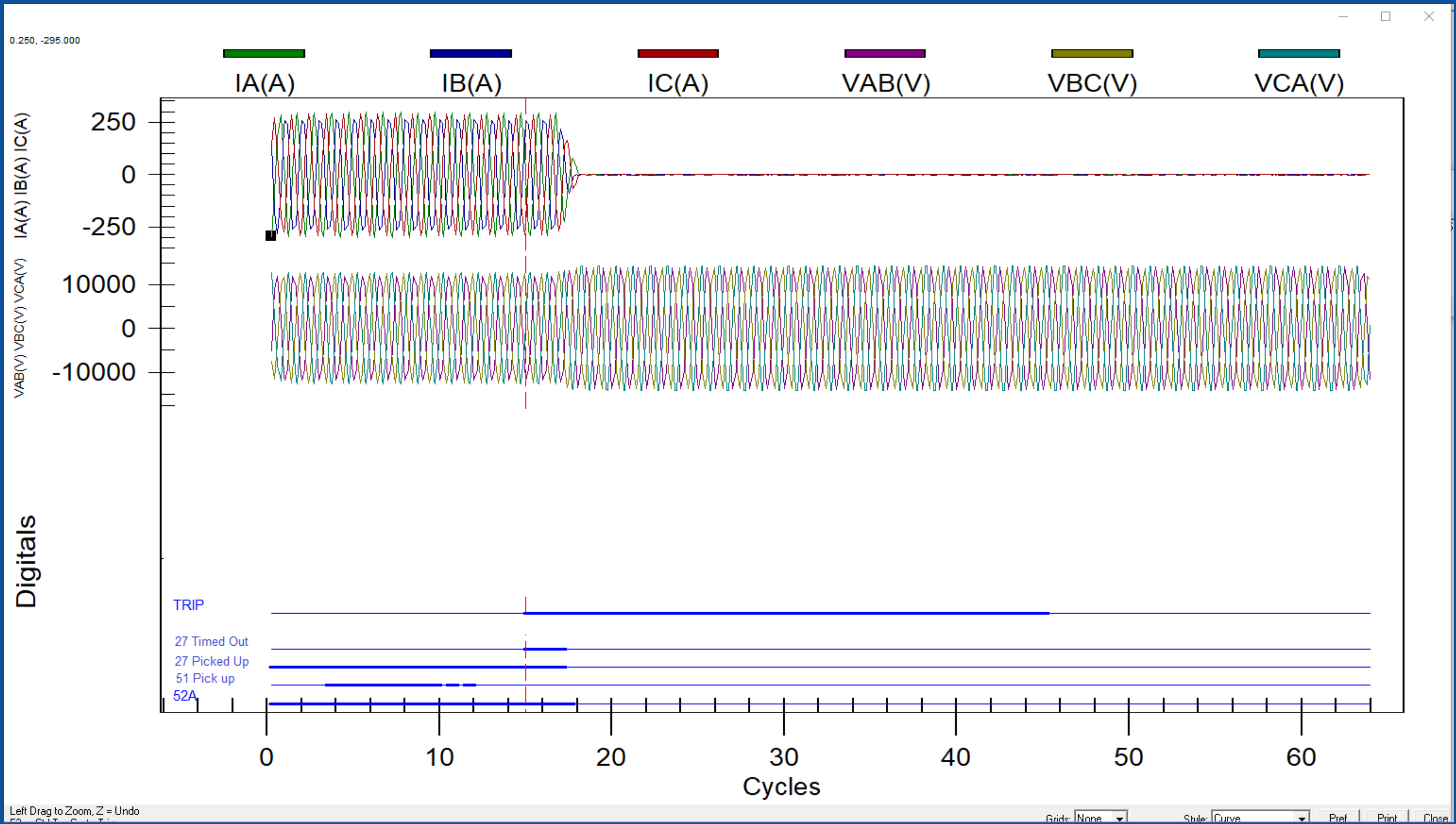


Fault escalates to ground fault, then goes line to line to trip entire facility

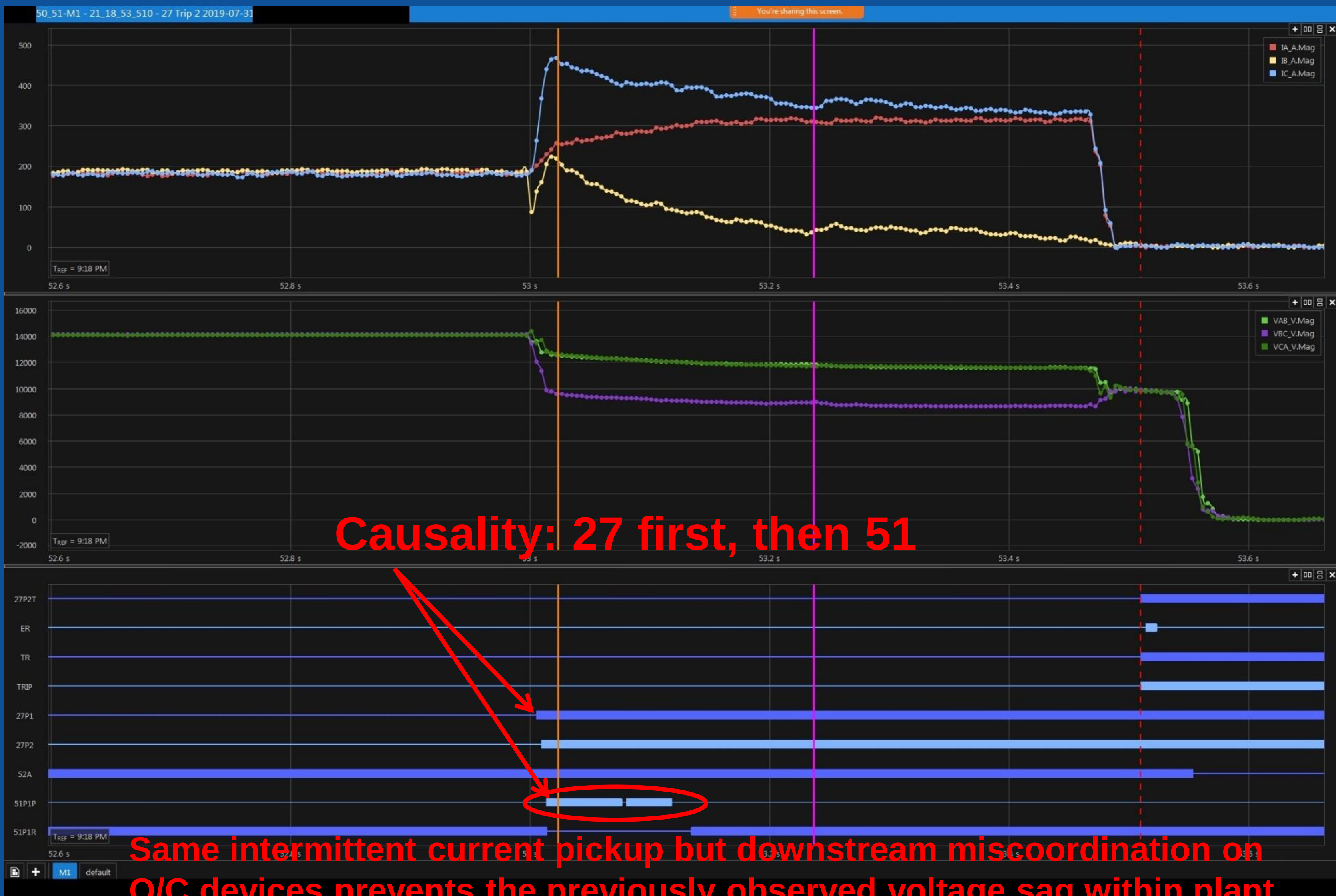
FLA Monitor

- Due to the trip cct accidentally left isolated causing this extended fault duration to which the primary protection had to isolate, largest question raised was remaining equipment life of the TX.
- Combination of years of FLA monitor logs downloaded routinely gave a better idea in combination with sequence of events from fault as well as transformer test results helped conclude how to proceed with manufacturer.

Data, Data, Data – Never Enough



Low utility fault level and unstable voltage stability forced operation to temporarily miscoordinate overcurrent to prevent loads that are likely to jam from causing a 27



Same intermittent current pickup but downstream miscoordination on O/C devices prevents the previously observed voltage sag within plant

Call Utility to Investigate

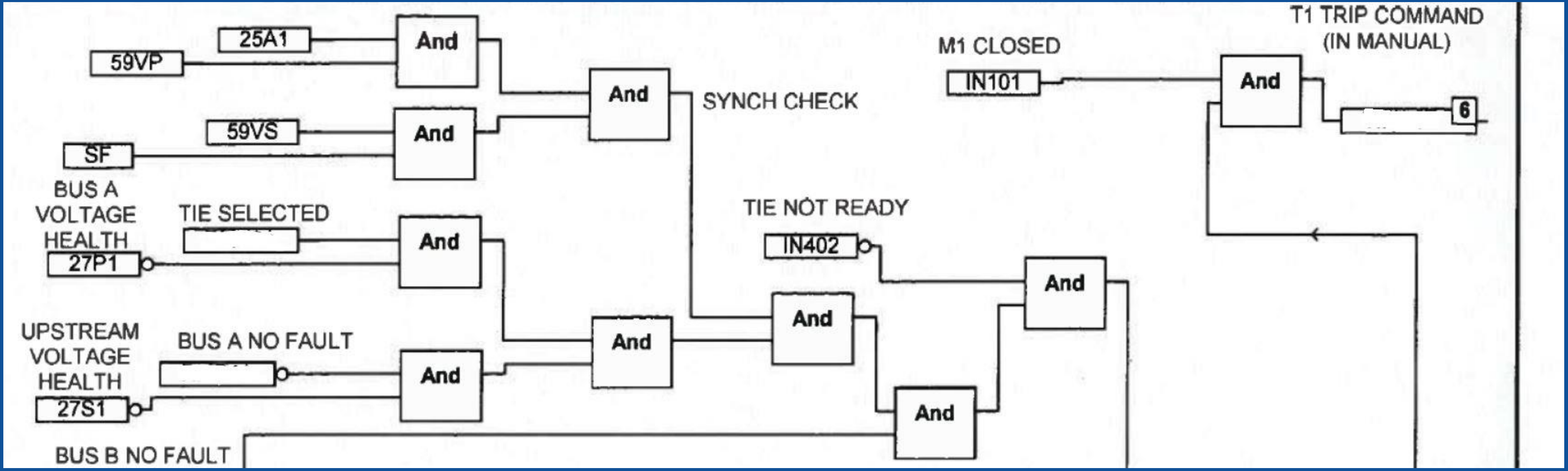
Found the undervoltage! (Line to Line fault upstream on utility's end)

Conclusions

- Significant improvements in reliability of protection systems with new microprocessor based relays
- Effective and efficient designs are now a product of the protection design and the programming (status messages on IED’s)
- No reason to be limited to application sheet for a particular IED, lots of logic options available

Conclusions

- Bench testing and/or commissioning activities are necessary activities to reduce the potential for equipment / personnel risk



- Relay event data is essential and should be analyzed and archived to help interpret future events.

Questions?

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