

# Experience with Point-to-Point Process Bus in a Substation Pilot

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# Agenda

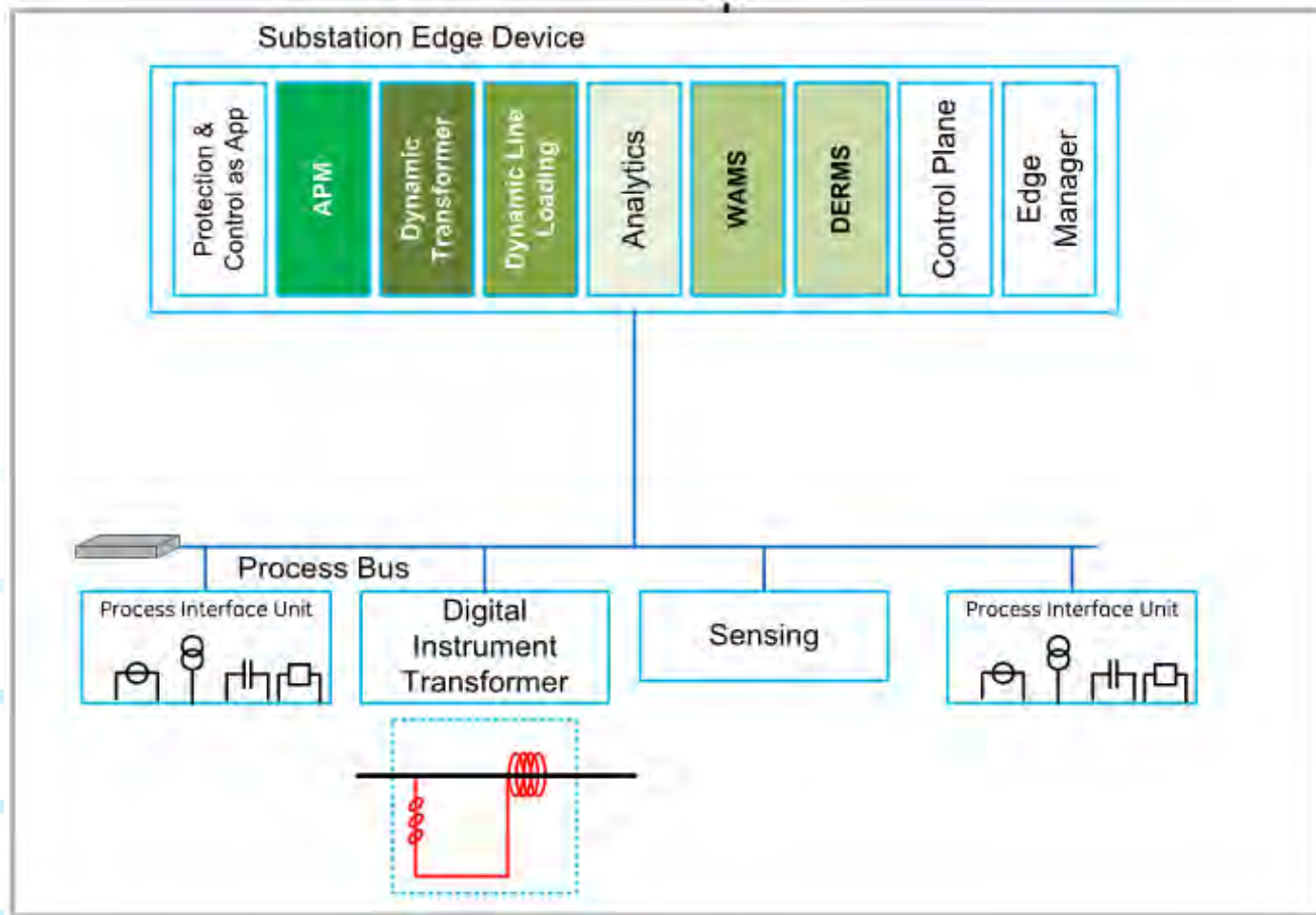
- Introduction
- What is Digital Substation?
- Process Bus Connections
- AltaLink's Point-to-Point Process Bus Deployment
- AltaLink's Point-to-Point Process Bus Experience
- Performance of Point-to-Point Process Bus Based Protection System
  - March 24, 2019 – Line L4 Fault
  - January 15, 2019 – Line L1 Fault
  - January 27, 2019 – Line L4 Fault
  - June 5, 2019 – Line L3 Fault
- Conclusion

# Introduction

- One of First Peer-to-Peer IED Communications (Late '90s): GOOSE using UCA
- GOOSE implemented with IEC 61850 since 2004
- Various GOOSE Applications: (Multi-Vendor)
  - Breaker Fail    Interlocking    Blocking    Cross-Triggering    Transfer Schemes    ect.
- Process Bus first deployed as Point-to-Point in late 2000's, then as Point-to-Many Networked IEC 61850-9-2LE early 2010's
- This allows for NCITs (e.g. Optical CTs) via MUs and PIUs to be used in P&C Applications
- Lots of Utility/Industrial Interest; First as Lab Testing, then Pilot Projects to gain experience (Evaluate, Learn, Pros, Cons) with Process Bus before full deployment
- AltaLink's 1<sup>st</sup> Pilot: Both Point-to-Point and Networked Process Bus and Station Bus

# What is Digital Substation?

- Digital Substation refers to using both IEC 61850 Process Bus and Station Bus
- Simplified Digital Substation:

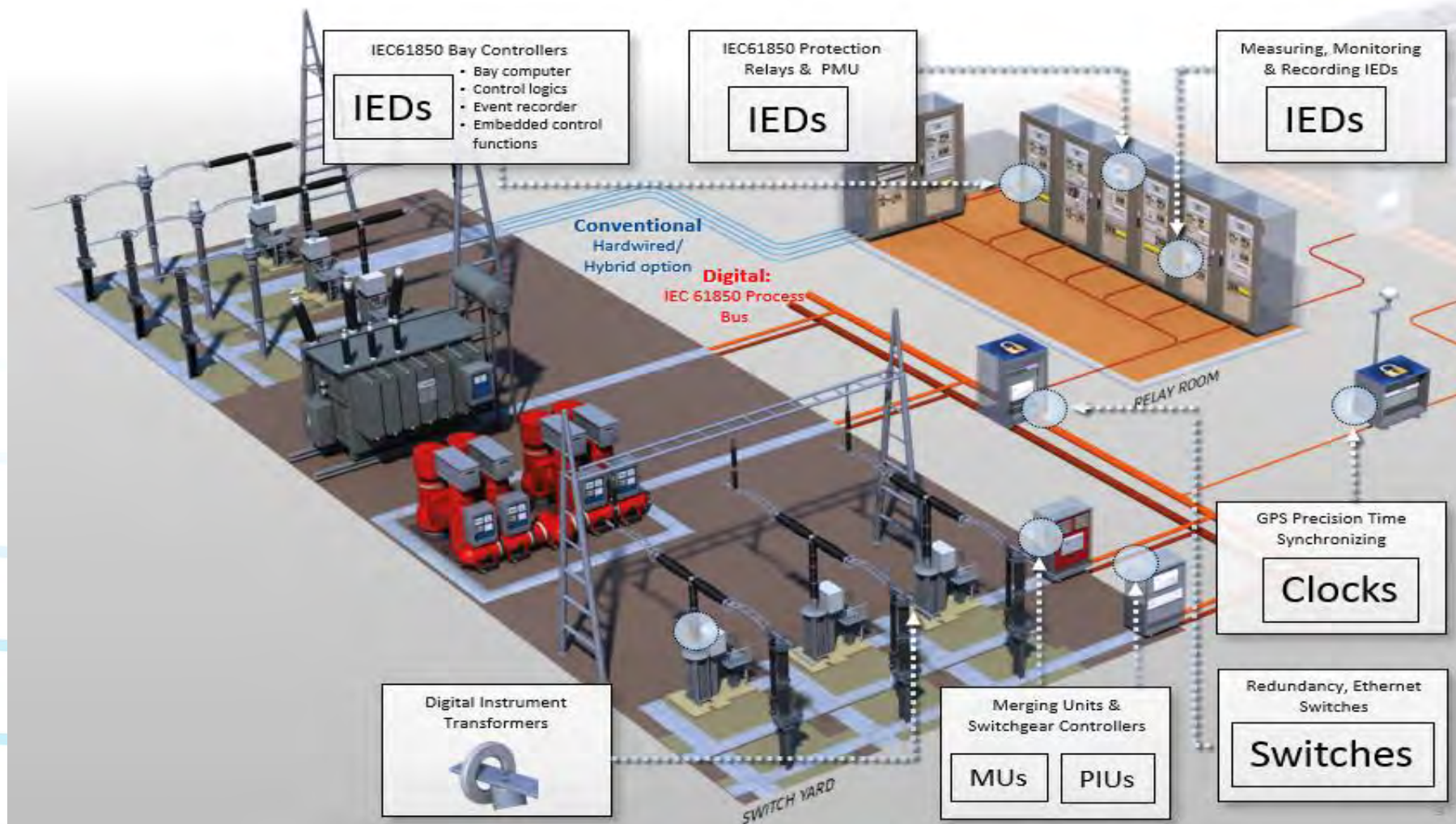


- Goal:
- Digitize & Communicate Volts & Currents to IEDs
- Facilitate status, alarms and Control Points between Primary Equipment & IEDs
- Field Level Devices: MU, PIU & RIO
- Substation Process Device: IED, RTU, DFR
- Comms can be Point-to-Point or Networked
- Perform Substation Applications: P&C, APM, Substation Analytics, dynamic trfr/line rating, WAMS, DERMS, SCADA



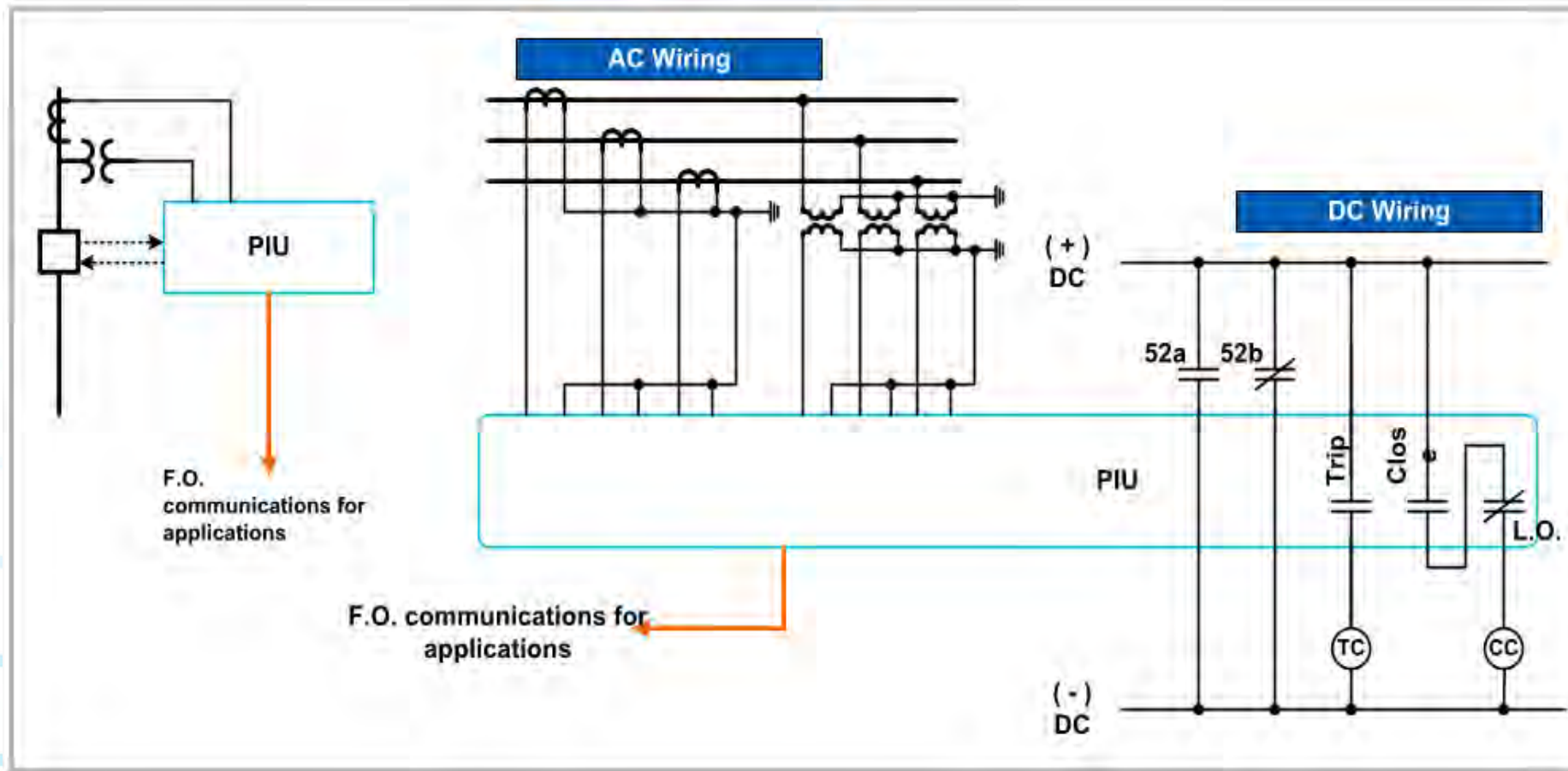
# Digital Substation Architecture

- Distributed Architecture of a Digital Substation

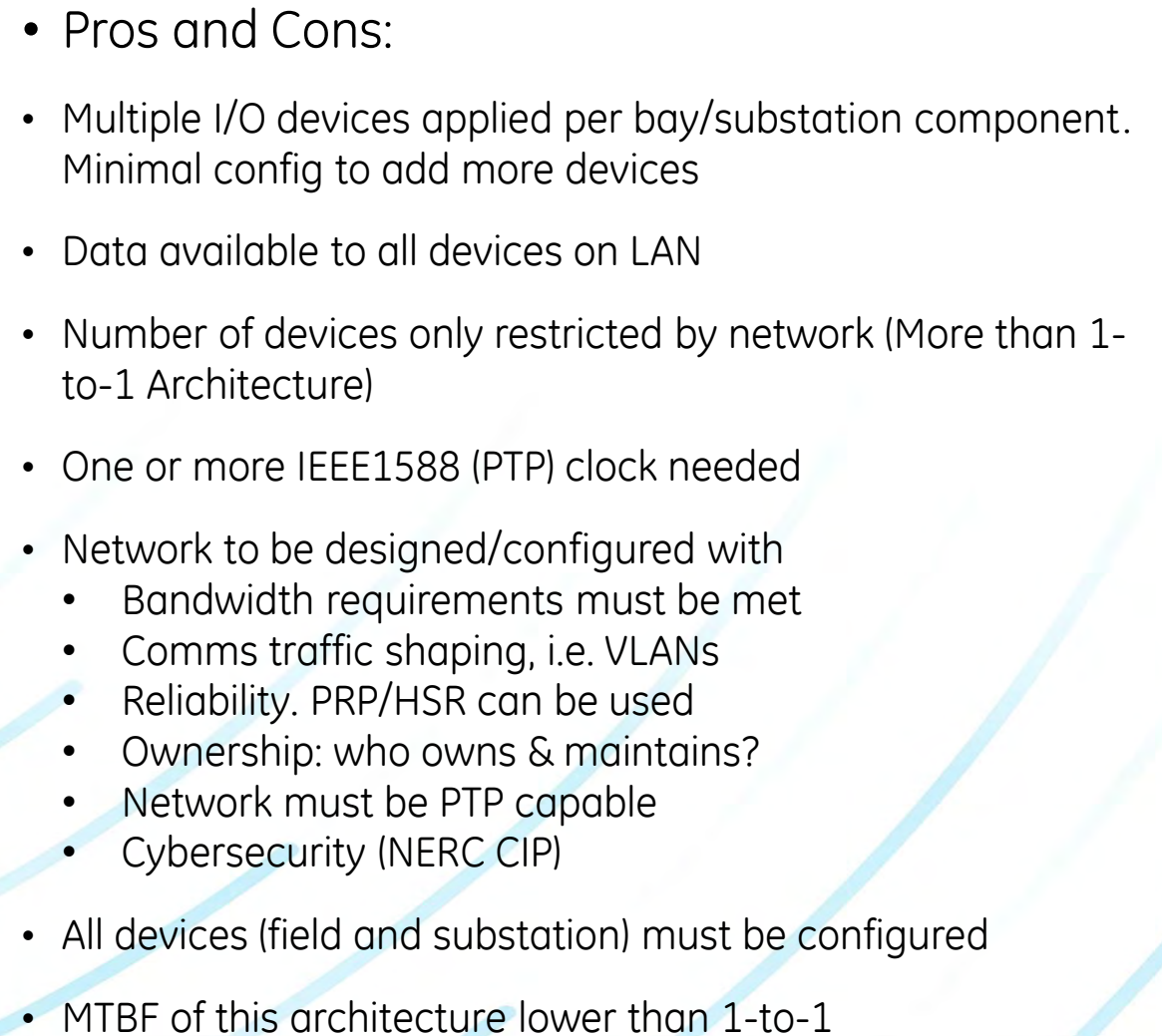


# Field Level Devices Example

- PIU has both AC and DC wiring; MU only AC and RIO only DC



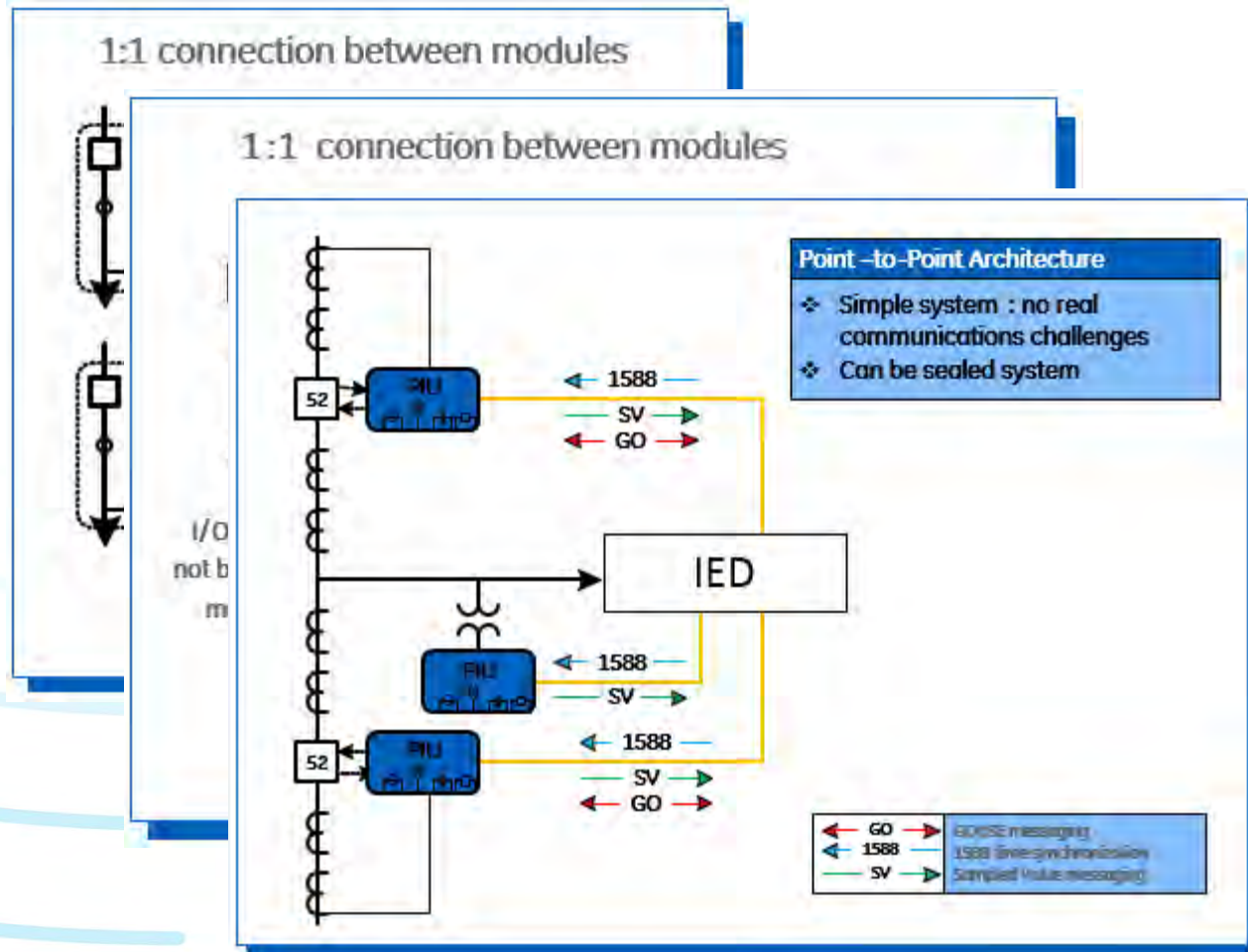
- Two methods for connections between Field Devices and Substation Application Devices:
- 1:Many or Many:1 Architecture (LAN)
- Pros and Cons:





# Process Bus Connections (2)

- 1:1 Architecture (Point-to-point)

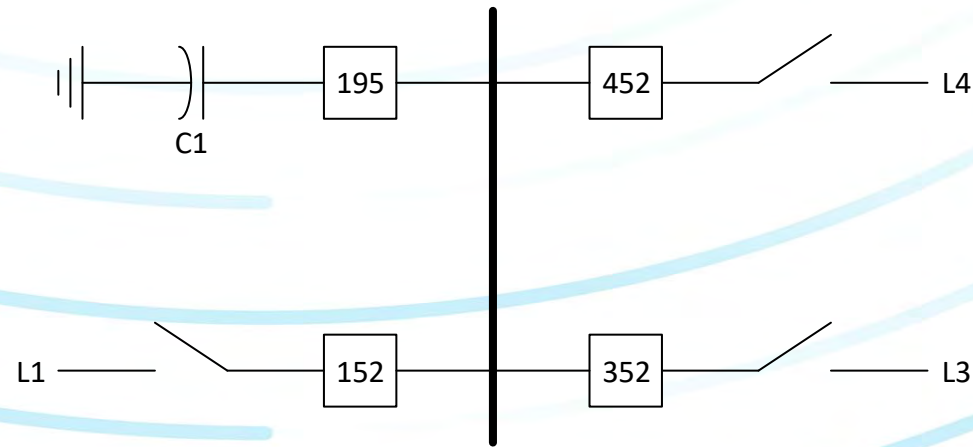


- Pros and Cons:
- One to one correlation between field device & IED
- Communications point-to-point; enclosed, simple, intuitive
- Field devices configuration free; all done from IED
- No IEEE1588 (PTP) clock needed; IED applies time synch
- No Network required, hence:
  - No network equipment with time synch (PTP)
  - No Cybersecurity (NERC CIP) concerns; closed network
- Best MTBF for process bus solutions
- I/O devices and IEDs must support multiple connections
- More fiber cables/connections required; redundancy
- Field devices must meet point count requirement, else more needed
- Data from field devices can't be readily shared



# AltaLink's Point-to-Point Process Bus Deployment

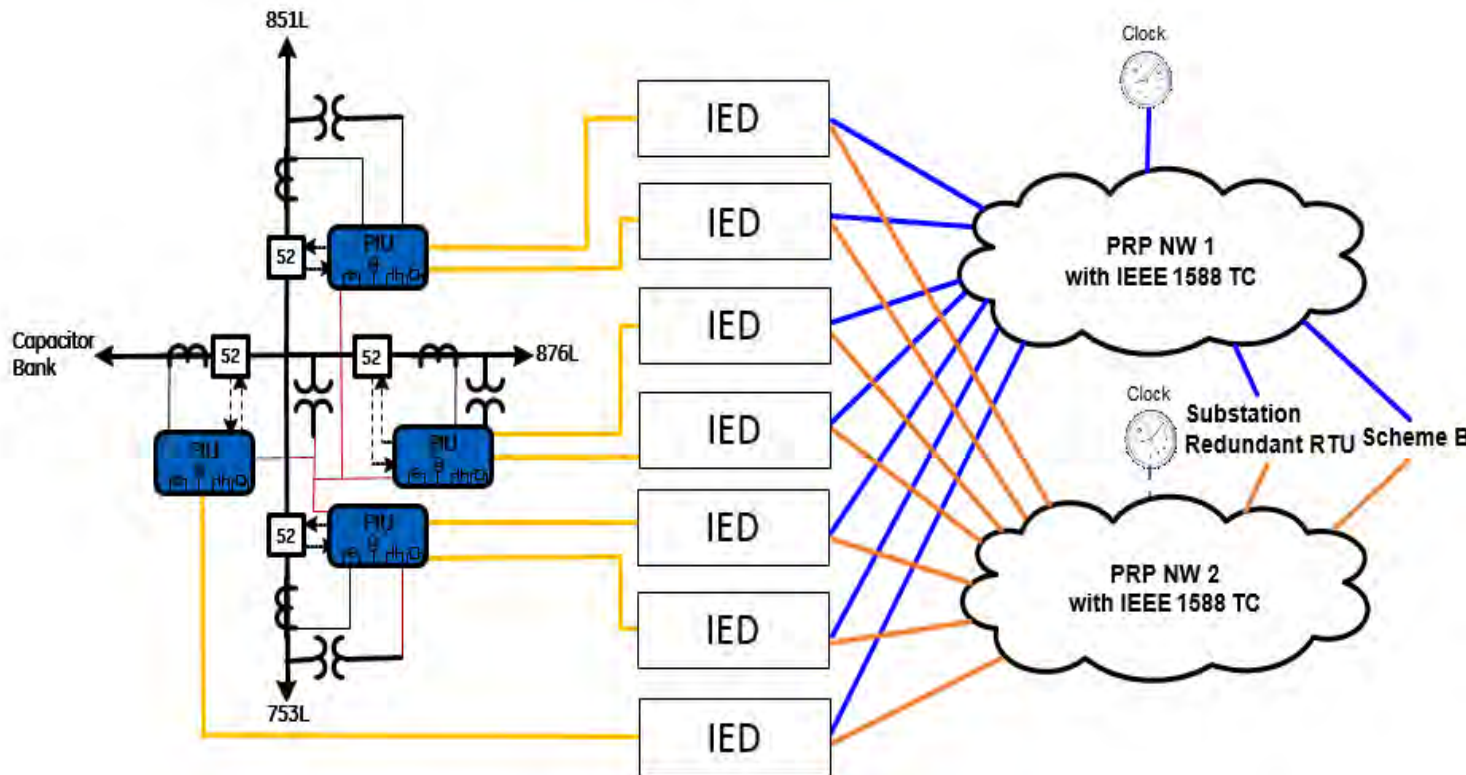
- In 2016, scheduled control building replacement at Blackie leveraged to deploy pilot Digital Substation
- Blackie was selected; scheduled to be upgraded, small foot print and close to Engineering & Field Office
- Blackie is a 138kV switching station, simple bus with three lines and capacitor bank
- Pilot consisted of: Install new Protection Relays & SCADA equipment; retain primary & telecom equipment
- All P&C upgraded from old Electromechanical equipment to IEDs with IEC 61850 sample values & GOOSE messaging at process bus and GOOSE messaging at station bus



- Operational since November 2018
- P&C systems mostly redundant, consists of two Architectures:
  - System B: LAN process bus covering three distance-based line protection, capacitor bank and bus protection
  - System A: Point-to-point process bus covering three distance-based line protection and four breaker management IEDs, one for each breaker.

# Blackie Protection System A Architecture

- System A consists of four PIUs connected point-to-point to three line protection IEDs and four breaker management IEDs
- Breaker management IEDs used for breaker fail and reclosing. Capacitor bank protection is incorporated in associated breaker management IED to provide redundancy



- All IEDs connected to redundant PRP LAN, to each other & redundant RTU
- All PIUs (system A), MUs, RIOs (system B) installed in junction boxes in HV yard
- Two station bus LANs fully redundant using PRP and PTP
- System A uses Irig-B and system B, RTUs uses PTP
- Two PTP clocks with fail-over

# Station Bus GOOSE Applications

- Breaker management not redundant. Two station bus GOOSE schemes were deployed to provide backup and enhance reliability utilizing:

- Breaker failure

All Protection IEDs associated with line/bus/capacitor trip through PIUs or RIOs initiate Breaker Fail to associated breaker management IED

Breaker management IED issue retrip and breaker fail trip to other breaker management IEDs

Eg. L3 line protection IEDs system A and system B trip breaker 352 via PIUs/RIOs and initiate breaker fail in breaker management IED 352

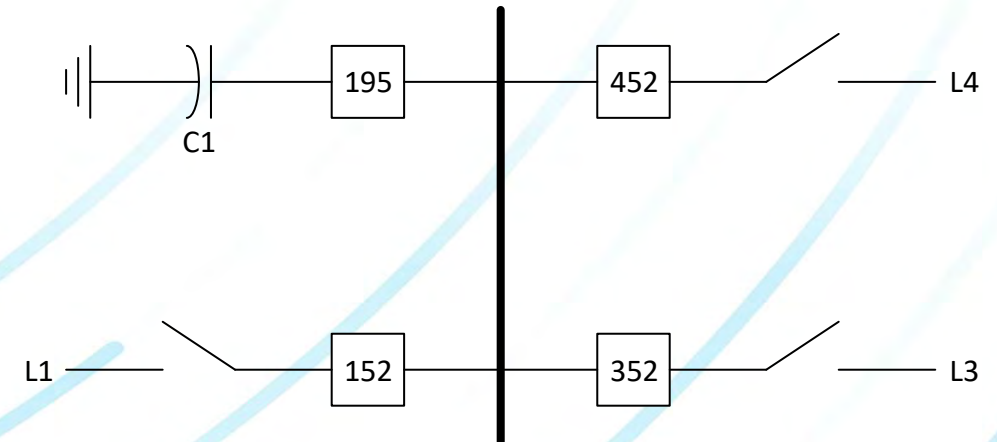
- Station Digital Fault Recording

All breaker management IEDs, upon breaker fail initialization, issue waveform capture (cross-trigger) to other breaker management IEDs

Eg. Line protection trip from System A and System B for L1 issue breaker fail initiate to breaker management IED 152

Breaker management IED 152 then cross-trigger breaker management IEDs 352, 452 and 195 if breakers are closed

All IEDs time synchronized, hence all waveforms can be merged into one station DFR record.



# AltaLink's Point-to-Point Process Bus Experience

- Prior to selection of process bus solutions, lab testing was done on available solutions
- Two different systems selected to compare: installation, configuration, testing, operation & performance
- Observations and advantages of point-to-point process bus:
  - Programming of IEDs similar to conventional IEDs. PIU extension of IED
  - No process bus network/LAN required, only direct fiber
  - No process bus time synch clock needed. IED performed time synch with PIU
  - Much fewer copper cables needed – kept external to substation control building
- Challenges of point-to-point process bus and system A
  - PIUs selection had to ensure adequate volts, currents & digital I/O for each power system component
  - PIUs had to be connected to multiple IEDs, hence enough connections/fiber needed
  - Station bus GOOSE interoperability between A & B; e.g. how IEDs handle one GOOSE data quality
  - Testing of GOOSE had to be deployed in logic since not equivalent implementation between A and B
  - New injection testing strategy deployed; i.e. PIU wired in relay room and connected to IED under test

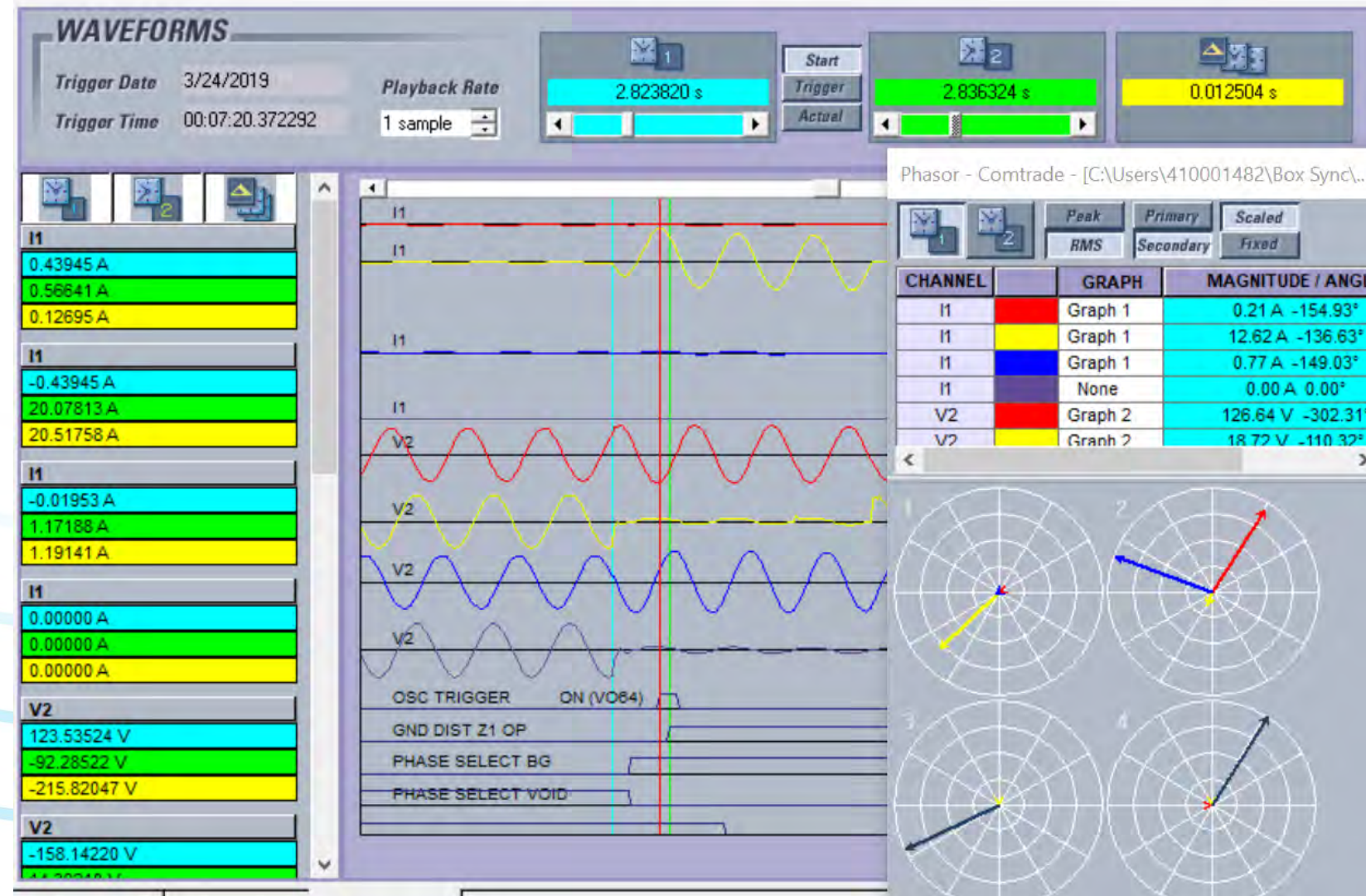


# Performance of Point-to-Point Process Bus

- Since commissioning/cut-over, four faults occurred; two on L4, one on L1 and one on L3
- All line protection systems utilize redundant stepped-distance – no pilot schemes
- Remote end of L1 is redundant, only one is IED
- L3 has redundant stepped-distance with IEDs at both ends
- Remote end of L4 also redundant; only electromechanical (events/waveforms not available
- In all cases both protection systems A and B operated with very similar performance
- Fault 1: March 24, 2019 – Line L4 Fault
  - Permanent B-G occurred close to Blackie-end. Pre-fault current was 59A and B-phase fault current 2.6kA
  - Fault well within reach of Gnd Dist Zone 1
  - System A operated in 12.5ms; System B very equivalent time. Fault cleared after 56.8ms

# Performance of Point-to-Point Process Bus (Fault 1)

- System A L4 distance protection IED waveforms:

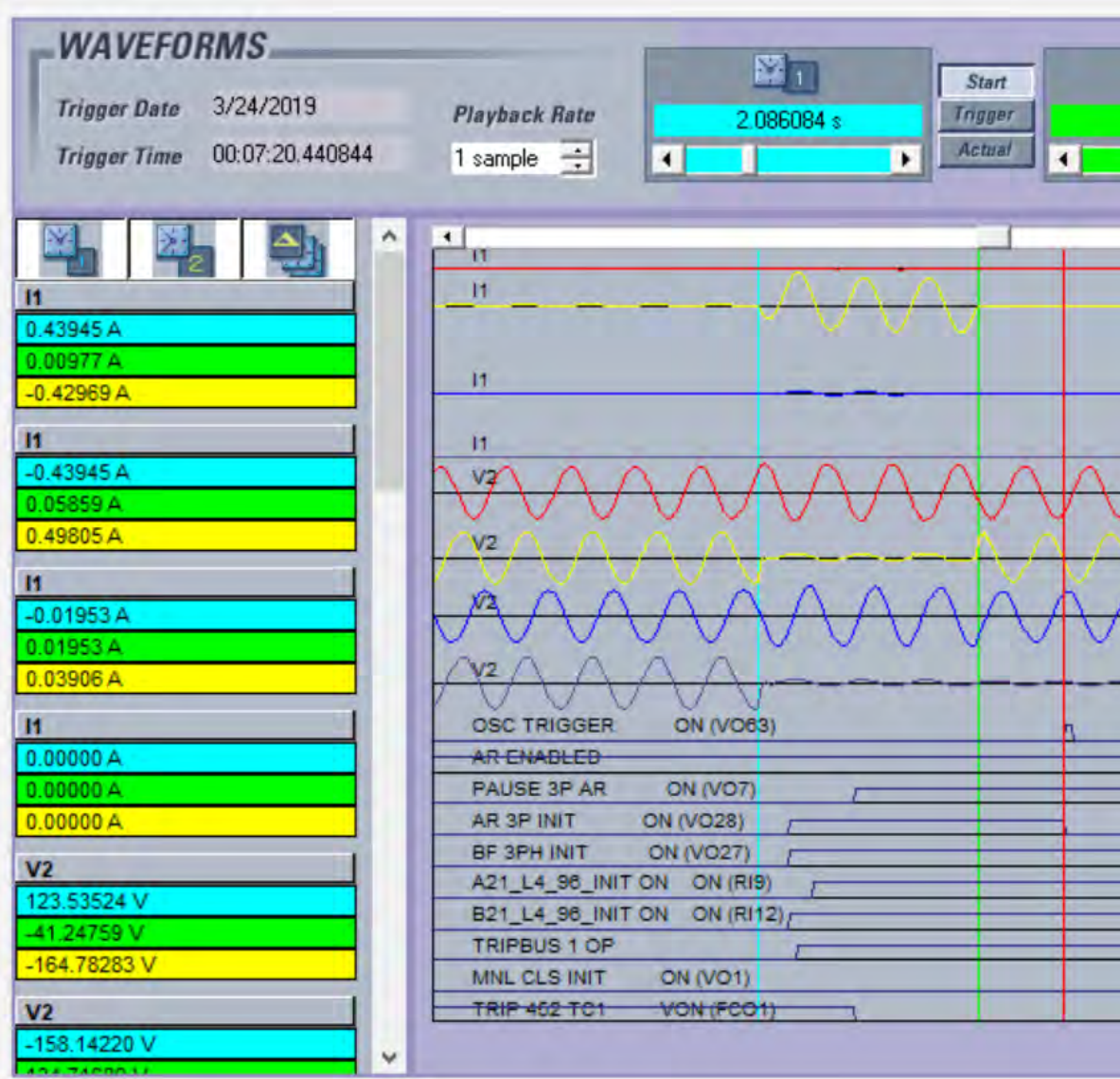


- Performance of process bus based protection systems very comparable to conventional protection systems
- Remote end cleared by Gnd Dist Zone 2
- Since distance protection IEDs initiate breaker fail & reclosing in breaker management IED S452, waveforms available
- Breaker management IED S452 cross-trigger the other breaker management IEDs, hence its waveforms available too
- Capacitor bank was out of service, hence no waveforms from IED 195

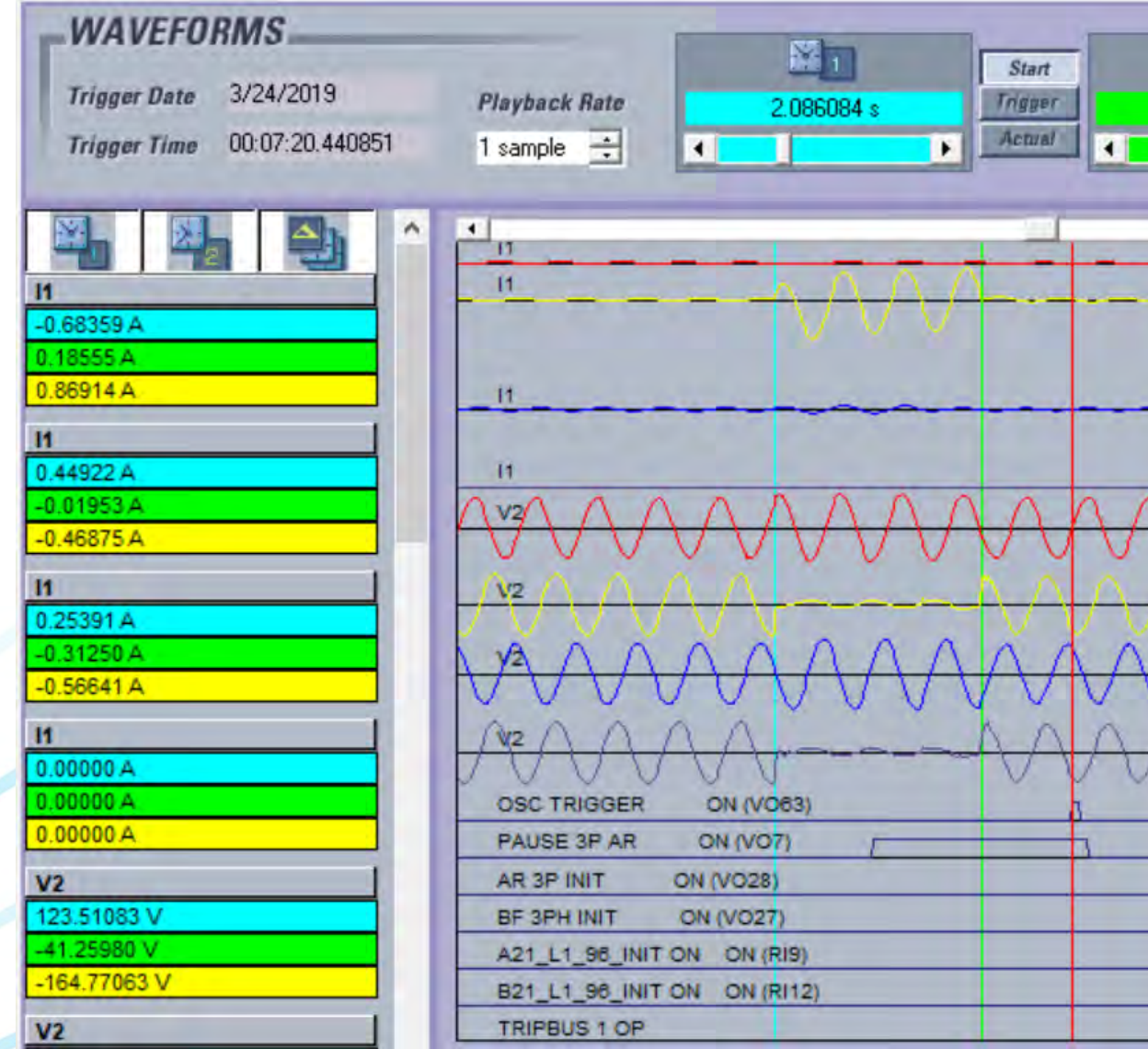


# Performance of Point-to-Point Process Bus (Fault 1)

- Breaker Management S452 waveforms (L4)



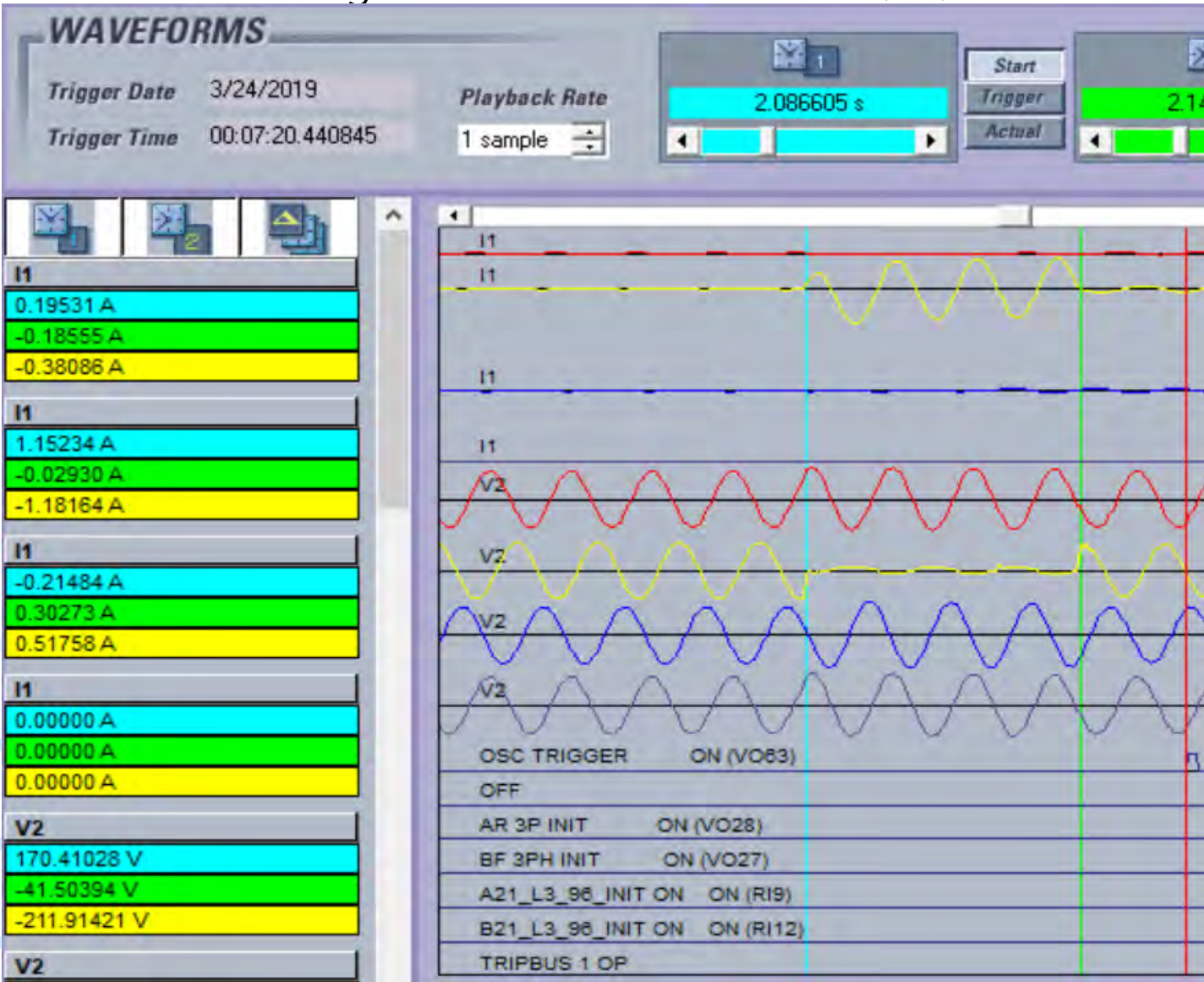
- Breaker Management S152 waveforms (L1)





# Performance of Point-to-Point Process Bus (Fault 1)

- Breaker Management S352 waveforms (L3)

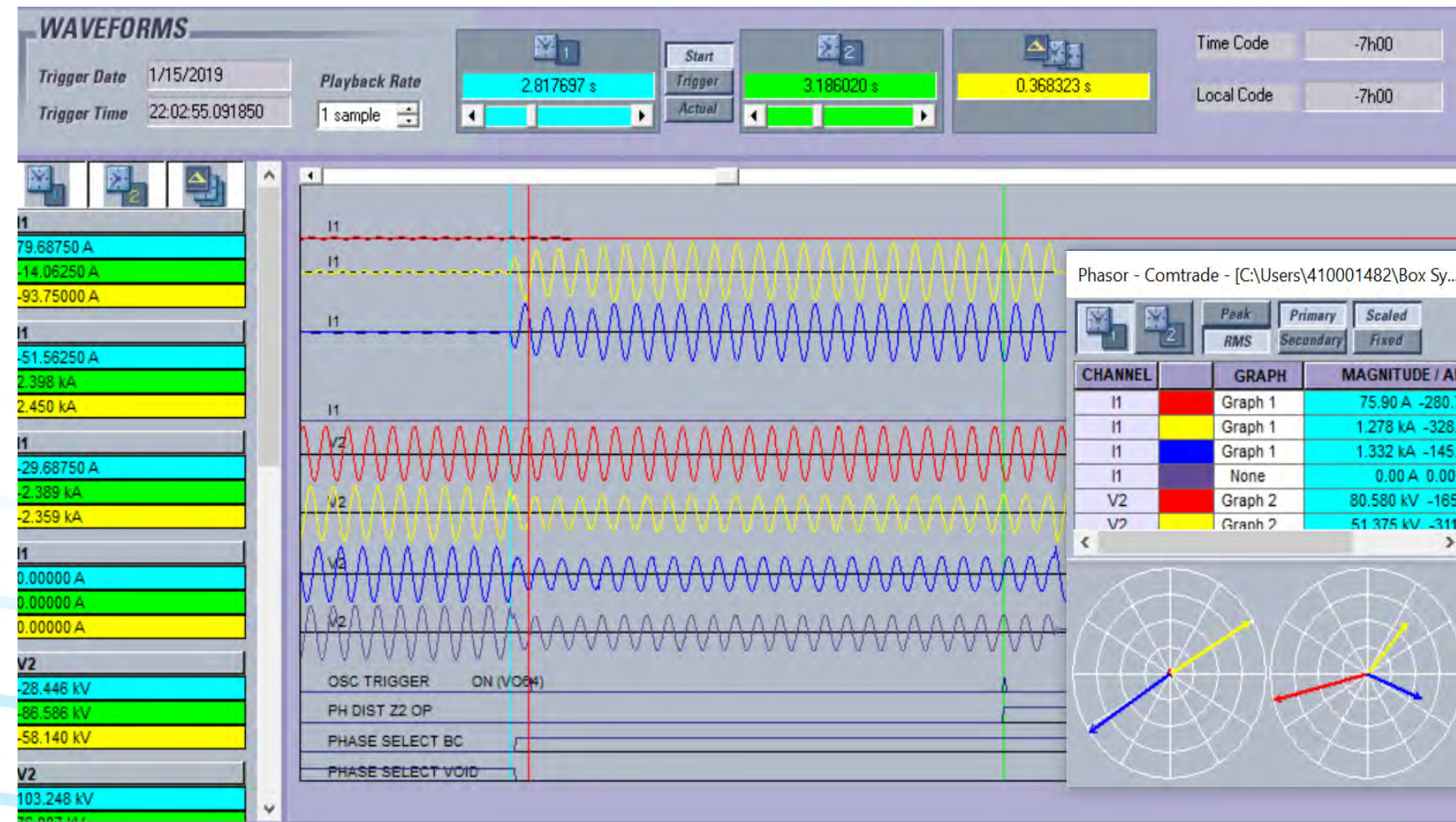


- Distance lines L1 and L3; and bus protection systems did not operate and remained secure during this event.
- Remote end cleared by Gnd Dist Zone 2
- Capacitor bank was out of service, hence no waveforms from IED 195



# Performance of Point-to-Point Process Bus (Fault 2)

- System A L1 distance protection IED waveforms:



- January 15, 2019 permanent BC fault on L1 within Phase Distance Zone 2
- Pre-fault current 71A and fault current 1.8kA, System A operated in 368ms (system B comparable) fault cleared in 408ms (Stepped distance)
- Performance of process bus based protection systems again very comparable to conventional protection systems
- Remote end cleared by Ph Dist Zone 1 (IED data not available)

# Performance of Point-to-Point Process Bus (Fault 2)

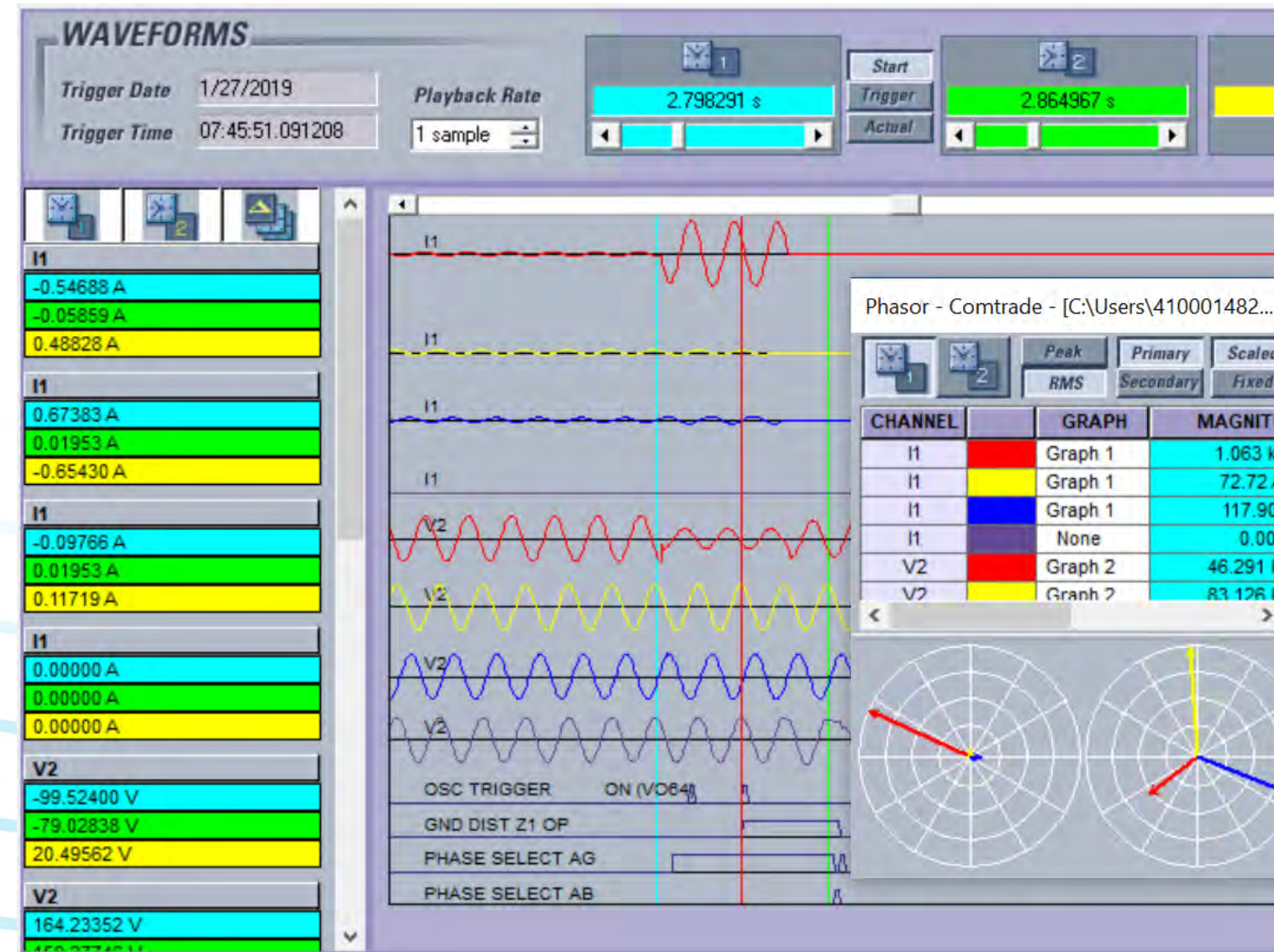
0 days 0 h : 0 m : 0.341827 s		
Event Number	Date/Time	
1596	Jan 15 2019 22:03:55.503825	AR DISABLED
1595	Jan 15 2019 22:03:55.503825	AR LO
1594	Jan 15 2019 22:03:55.499657	BLOCK AR On (VO6)
1593	Jan 15 2019 22:03:55.499657	DUMP TIMER On (VO5)
1592	Jan 15 2019 22:03:00.188758	PAUSE 3PAR On (VO7)
1591	Jan 15 2019 22:03:00.188758	AUX OV1 DPO
1590	Jan 15 2019 22:03:00.140965	AR 3-P/2 RIP
1589	Jan 15 2019 22:03:00.138762	PAUSE 3PAR Off (VO7)
1588	Jan 15 2019 22:03:00.138762	AUX OV1 OP
1587	Jan 15 2019 22:03:00.138762	AUX OV1 PKP
1586	Jan 15 2019 22:02:55.798344	TRIP 152 TC1 DOff (FCO1)
1585	Jan 15 2019 22:02:55.794150	TRIP 152 TC1 Off (FCO1)
1584	Jan 15 2019 22:02:55.652448	BF 3PH INIT Off (VO27)
1583	Jan 15 2019 22:02:55.650245	A21_L1_96_INIT ON Off (RI9)
1582	Jan 15 2019 22:02:55.644114	B21_L1_96_INIT ON Off (RI12)
1581	Jan 15 2019 22:02:55.512727	AR 3P INIT Off (VO28)
1580	Jan 15 2019 22:02:55.510757	A21_L1_79_INIT ON Off (RI8)
1579	Jan 15 2019 22:02:55.504390	B21_L1_79_INIT ON Off (RI11)
1578	Jan 15 2019 22:02:55.502424	Osc Trigger Off (VO63)
1577	Jan 15 2019 22:02:55.500220	OSCILLOGRAPHY TRIG'D
1576	Jan 15 2019 22:02:55.500220	Internal Osc Trigger Off (VO64)
1575	Jan 15 2019 22:02:55.500220	Osc Trigger On (VO63)
1574	Jan 15 2019 22:02:55.498273	Internal Osc Trigger On (VO64)
1573	Jan 15 2019 22:02:55.498273	BREAKER 1 OPEN
1572	Jan 15 2019 22:02:55.492465	52b_152 On (FCI2)
1571	Jan 15 2019 22:02:55.485747	TRIP 152 TC1 IOff (FCO1)
1570	Jan 15 2019 22:02:55.481603	BREAKER 1 PHASE A INTERM
1569	Jan 15 2019 22:02:55.474967	52a_152 Off (FCI1)
1568	Jan 15 2019 22:02:55.458540	TRIP 152 TC1 VOff (FCO1)
1567	Jan 15 2019 22:02:55.454397	B21_L1_79_INIT ON On (RI11)
1566	Jan 15 2019 22:02:55.452409	B21_L1_96_INIT ON On (RI12)
1565	Jan 15 2019 22:02:55.452409	AR RIP
1564	Jan 15 2019 22:02:55.450205	TRIP 152 TC1 IOn (FCO1)
1563	Jan 15 2019 22:02:55.450205	TRIP 152 TC1 DOn (FCO1)
1562	Jan 15 2019 22:02:55.450205	TRIP 152 TC1 On (FCO1)
1561	Jan 15 2019 22:02:55.450205	TRIPBUS 1 OP
1560	Jan 15 2019 22:02:55.450205	TRIPBUS 1 PKP
1559	Jan 15 2019 22:02:55.448264	AR 3P INIT On (VO28)
1558	Jan 15 2019 22:02:55.448264	BF 3PH INIT On (VO27)
1557	Jan 15 2019 22:02:55.446037	A21_L1_79_INIT ON On (RI8)
1556	Jan 15 2019 22:02:55.446037	A21_L1_96_INIT ON On (RI9)
1555	Jan 15 2019 22:02:55.104210	PAUSE 3PAR On (VO7)
1554	Jan 15 2019 22:02:55.104210	AUX OV1 DPO

- Distance protection IEDs initiate breaker fail in IED S152 (Zone 2 so no reclosing)
- Breaker management IED S152 cross-trigger the other breaker management IEDs, hence its waveforms available too
- Only IED S152 events available
- Capacitor bank was out of service, hence no waveforms from IED 195



# Performance of Point-to-Point Process Bus (Fault 3)

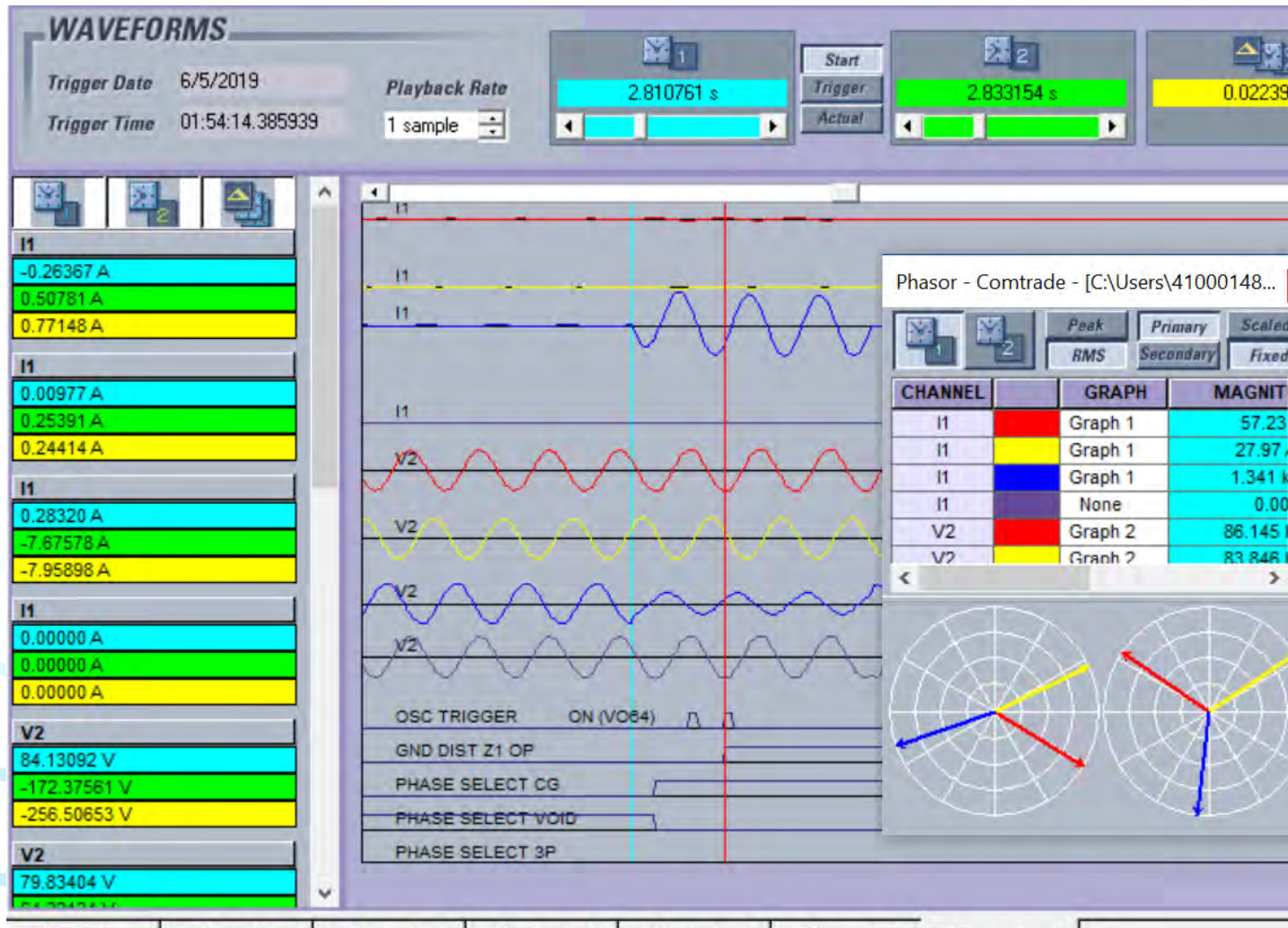
- System A L4 distance protection IED waveforms:



- January 27, 2019 permanent AG fault on L4 within Gnd Distance Zone 1 (End)
- Pre-fault current 80A and fault current 1.17kA, System A operated in 31.7ms (system B comparable) fault cleared in 50ms
- Performance of process bus protection again very comparable to conventional protection systems
- Remote end cleared by Gnd Dist Zone 1 (EM so no waveforms)
- Distance protection IEDs initiate breaker fail & reclosing in IED S452, cross-triggered and waveforms available

# Performance of Point-to-Point Process Bus (Fault 4)

- System A L3 distance protection IED waveforms:



- June 5, 2019 temporary CG fault on L3 within Gnd Distance Zone 1 (Both ends)
- Pre-fault I 35A and fault I 1.54kA, System A operated in 22.3ms (system B comparable) fault cleared in 57.3ms
- Remote end Gnd Dist Zone 1 operated in 21.8ms, pre-fault 33A and fault 1.6kA (conventional IED)
- Performance of process bus protection again very comparable to conventional protection systems
- Distance protection IEDs initiate breaker fail & reclosing in IED S352, cross-triggered and waveforms available
- Successful reclose



# Conclusions

- IEC 61850 process bus P&C systems can provide significant deployment savings; most impactful on greenfield/new installations vs brownfield/replacements
- Process bus implementations can impact various aspects during design/implementation/commissioning/operations/maintenance such as:
  - Protection & Control Engineering
  - SCADA and Telecom Engineering
  - Substation Engineering Design
  - Equipment Specifications
  - Substation Construction
  - Protection System Maintenance
  - Equipment Maintenance

# Conclusions (2)

- IEC 61850 station and process bus P&C systems bring new challenges to be reviewed during planning, specifications, design, installation and testing stages:
- All station bus GOOSE aspects (including descriptions and quality etc.) should be reviewed for interoperability between all IEDs to be used
- Testing and simulation of GOOSE messaging should be reviewed for all IEDs to ensure proper interoperability if it is intended to be used in system testing
- New commissioning and maintenance testing strategies must be adopted (Lots of papers on this)
- IEC 61850 is an evolving standard; ongoing additions/updates, which may impact interoperability between different vendor IEDs. Complete interoperability should be tested before deployment
- Process bus P&C systems installed at AltaLink's Blackie substation have proven with reliability and performance comparable to conventional P&C systems during normal operation and disturbances; whether using a point-to-point/LAN architecture. Using IEC 61850 capabilities, reduced copper wiring and allowed increased flexibility and interaction among IEDs at a substation

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Thank You

Questions?

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