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Testing of Busbar Protection in IEC 61850-Based Digital Secondary System

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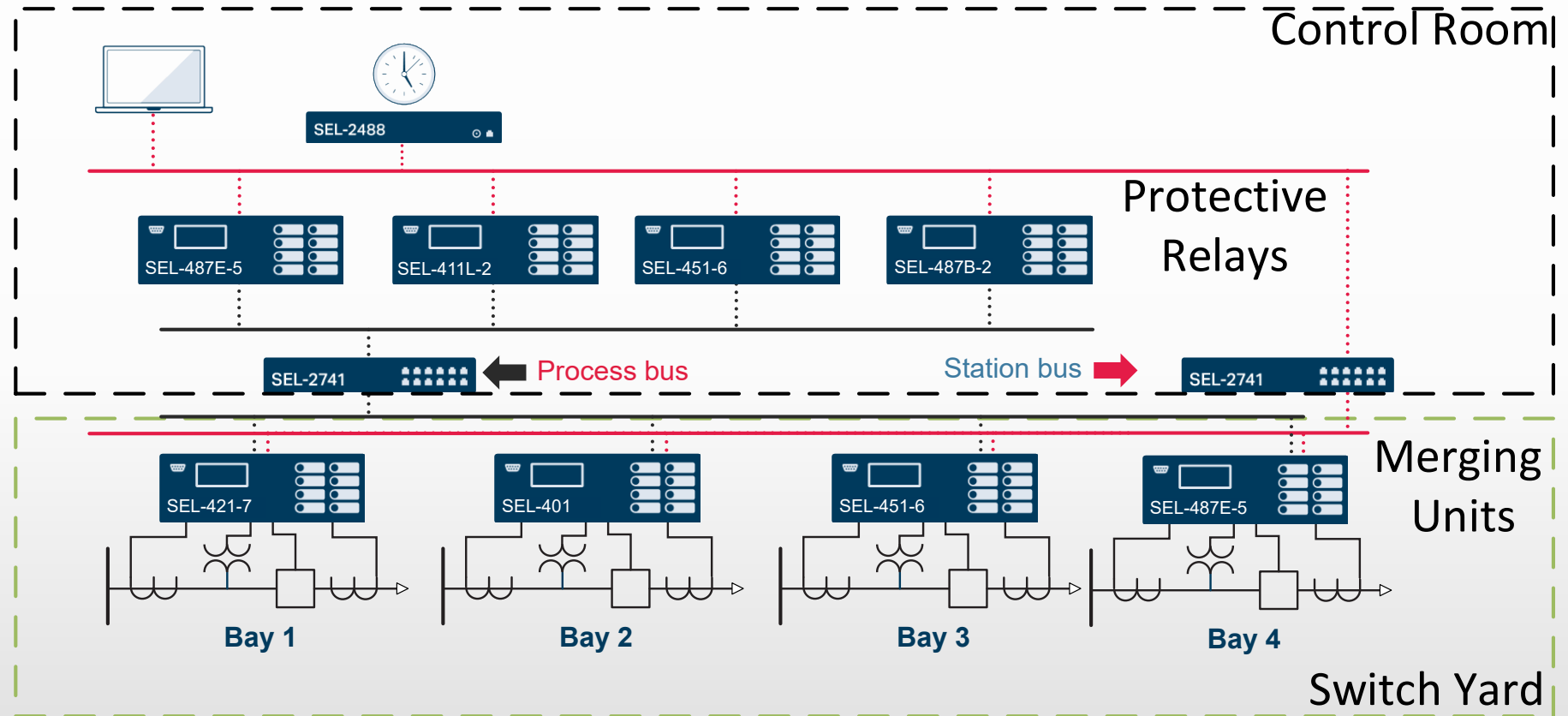


APPLICATIONS & TECHNOLOGY CONFERENCE 2025
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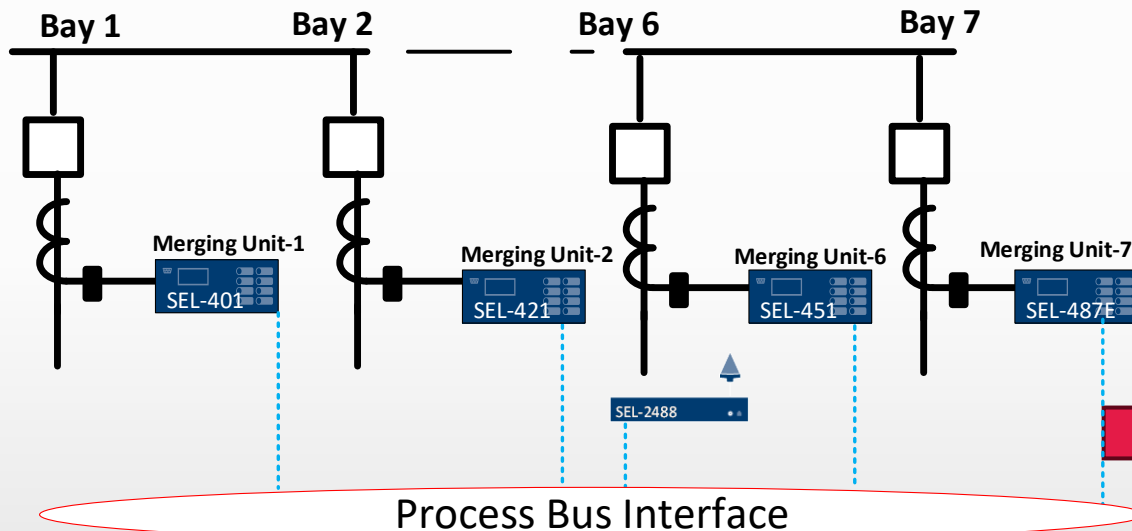
IEC 61850 –Based Digital Secondary System (DSS)

- Sampled values
- GOOSE
- PTP
- MMS

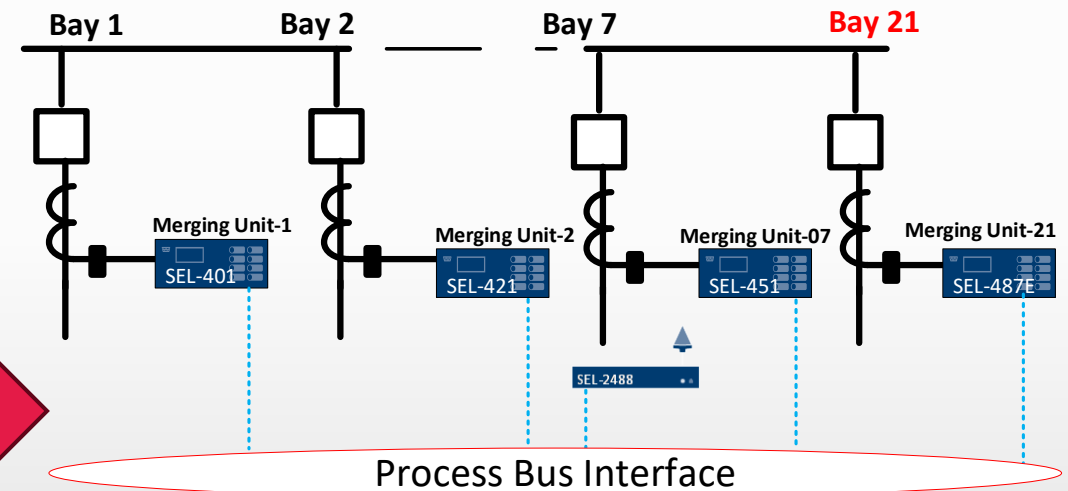


Busbar Differential (87B)-DSS Enhancement

Existing 7-bays DSS for 87B



Enhanced 21-bays DSS for 87B



24 SV Stream Subscriptions
SEL-487B-2
A-Phase SV Subscriber
24 SV Stream Subscriptions
SEL-487B-2
B-Phase SV Subscriber
24 SV Stream Subscriptions
SEL-487B-2
C-Phase SV Subscriber
21 Current Terminals and 3 Voltage Terminals

Why We Need HIL Simulator for Busbar Protection Laboratory Testing?

- Power system components modeling
- Realistic simulation of faults and switchgear controls
- **Dynamic zone configuration testing for busbar differential protection**
- **Closed loop feedback for GOOSE message performance test**



Busbar Protection- Percentage Differential Protection

- Operating current :

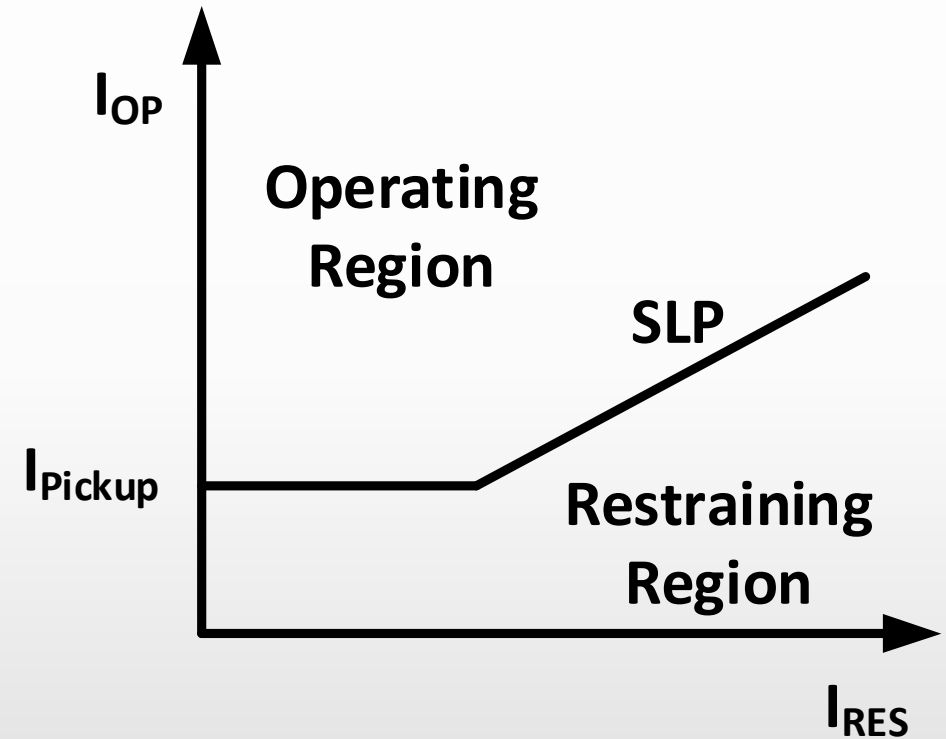
$$I_{OP} = |\bar{I}_1 + \bar{I}_2 + \dots + \bar{I}_n|$$

- Restrain current :

$$I_{RES} = |I_1| + |I_2| + \dots + |I_n|$$

- Relay 87B element operates:

$$I_{OP} > SLP \cdot I_{RES} \text{ AND } I_{OP} > I_{Pick_Up}$$

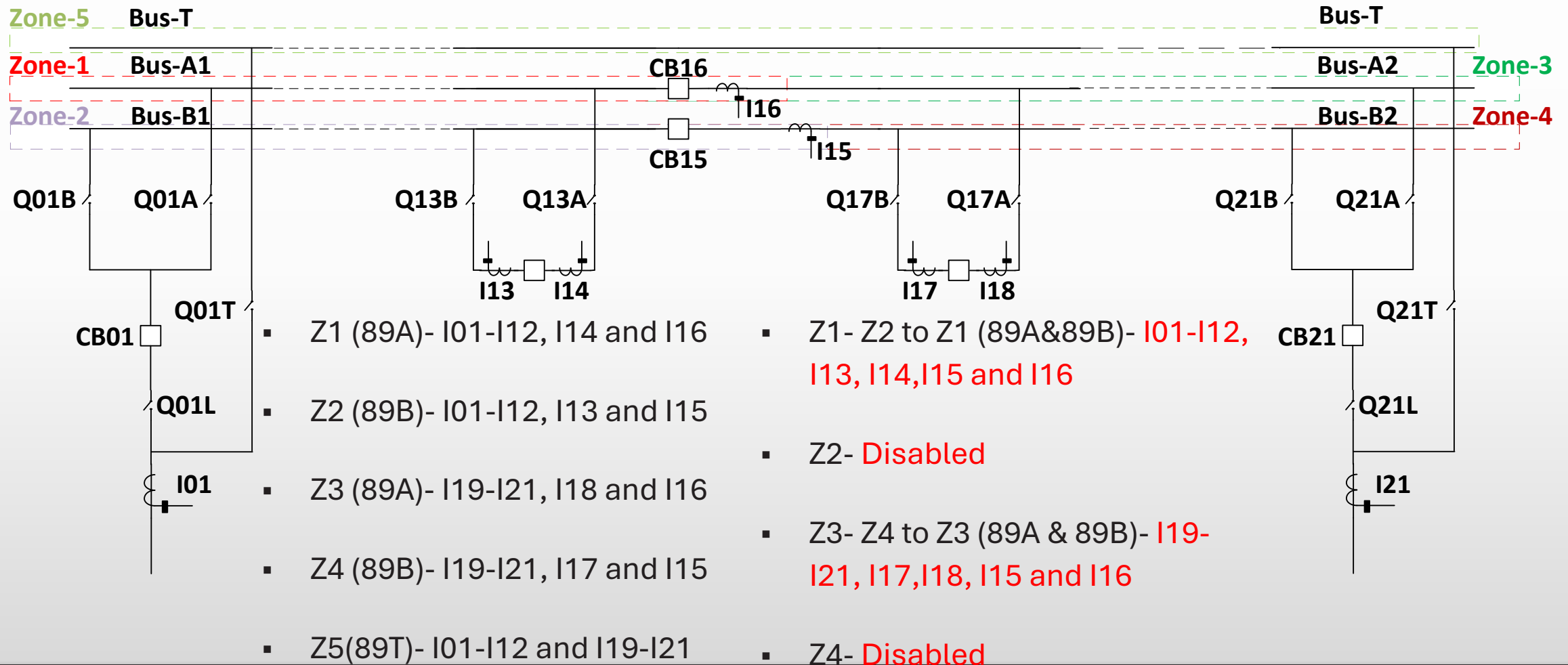


Busbar Protection Zone – Busbar Arrangement

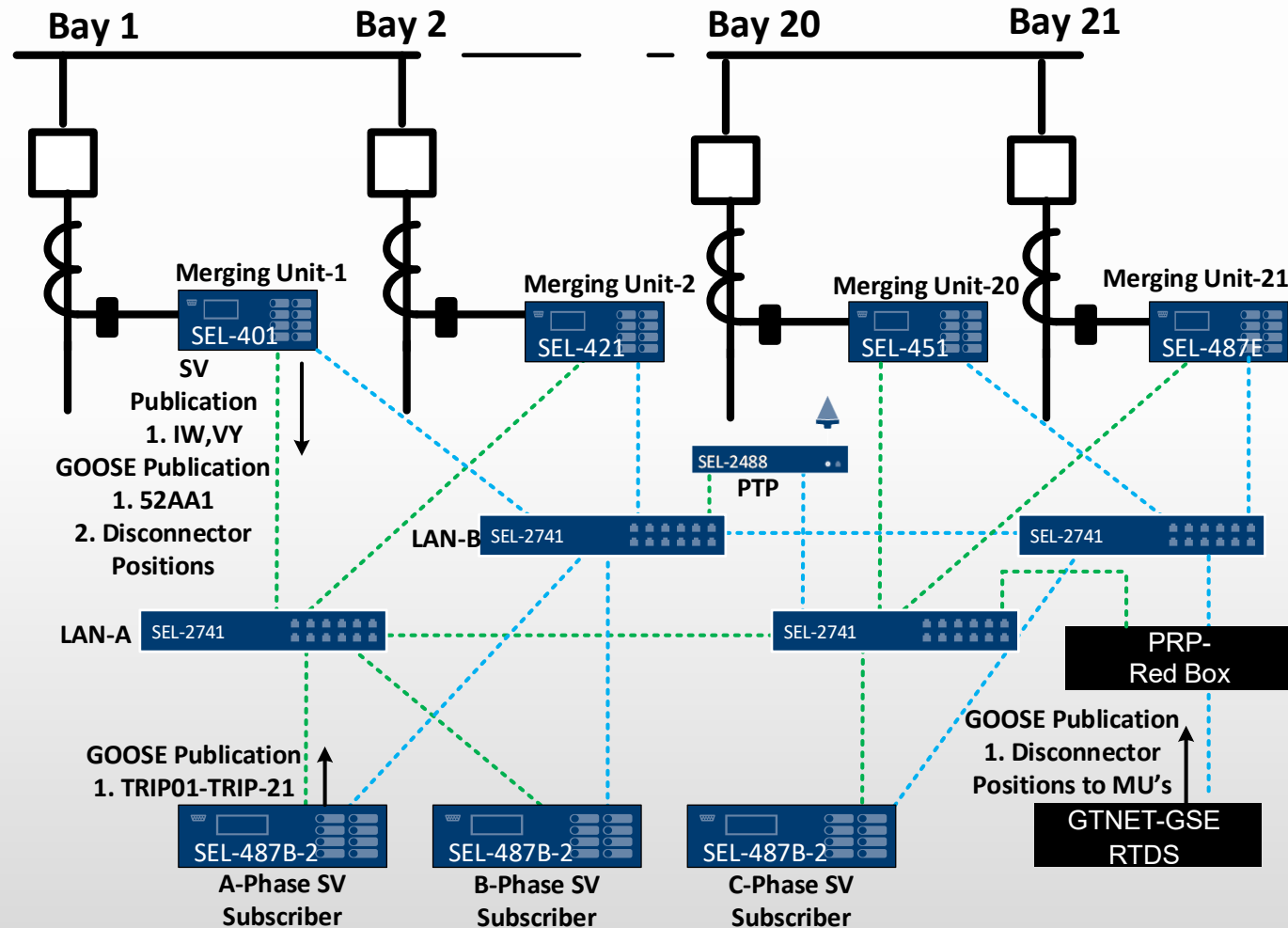
- Bus types for fixed zone of protection
 1. Single bus
 2. Breaker and a half
 3. Double bus, double breaker
- Bus types for dynamic zone of protection
 1. Double bus, single breaker
 - 2. Double bus, single breaker with transfer bus**



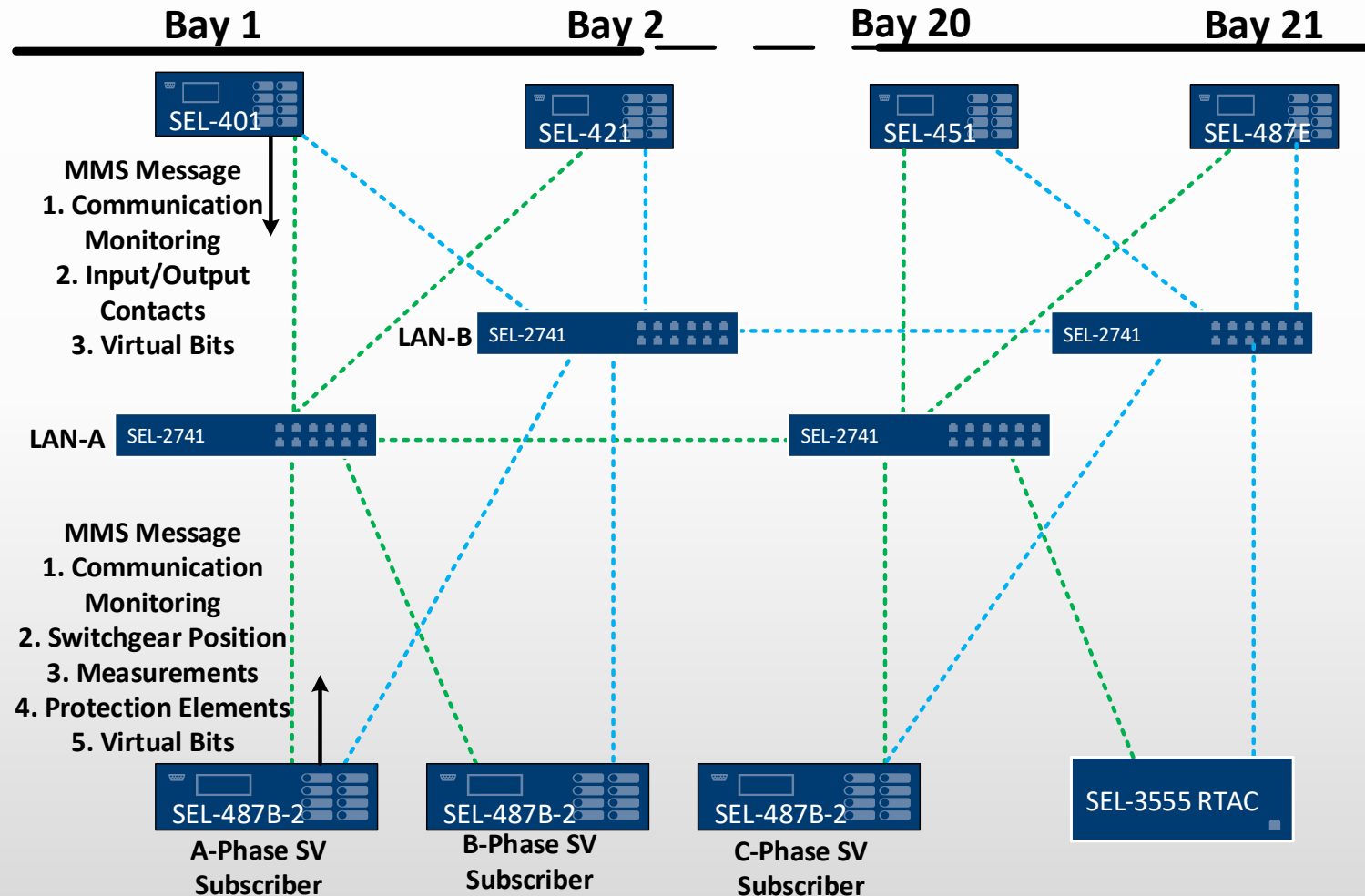
Dynamic Configuration: Double Bus-Single Breaker with Transfer Bus



System Architecture-Process Bus with PRP



System Architecture-Station Bus with PRP

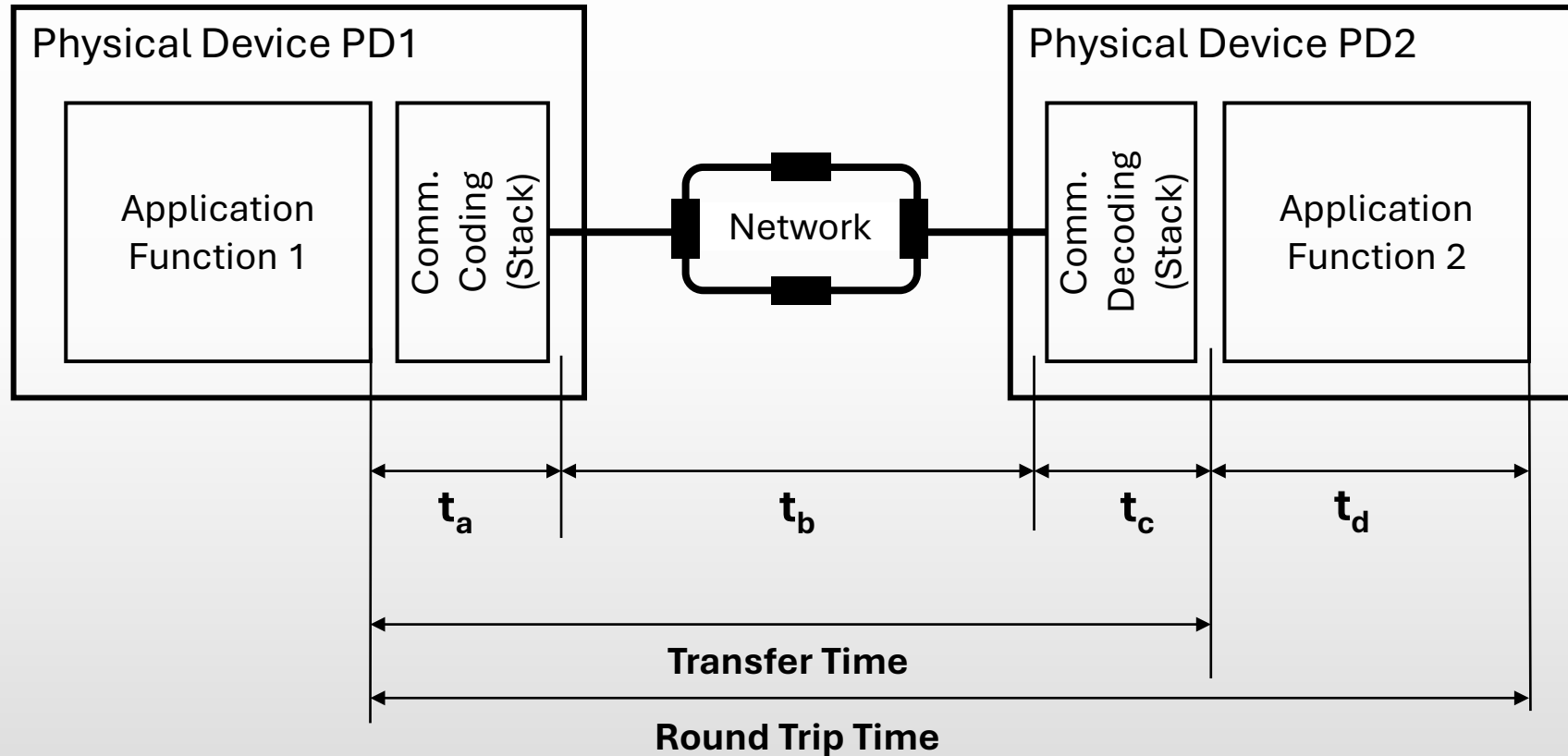


System Architecture– OT Software-Defined Networking (OT SDN)

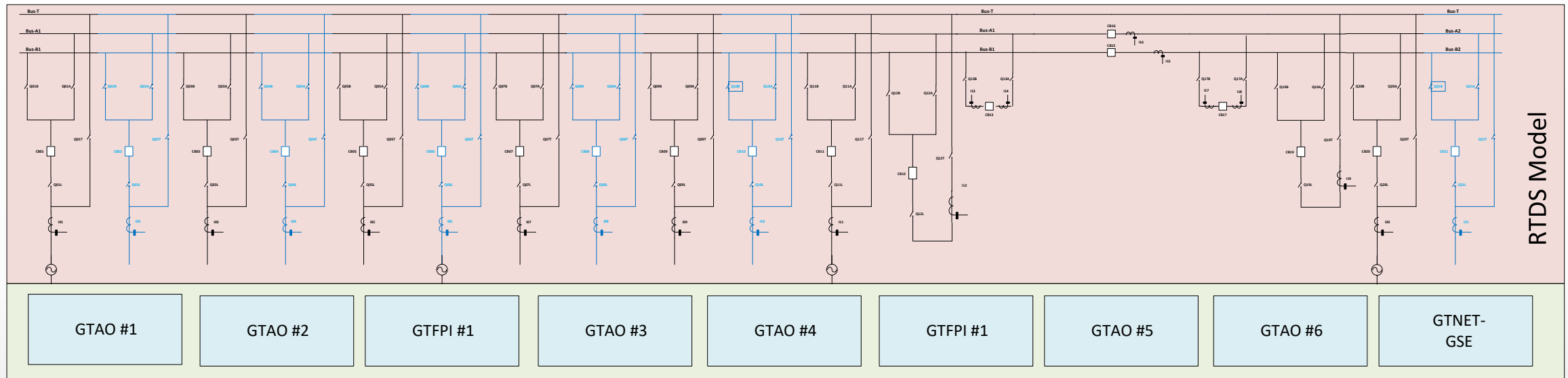
- Station and Process buses use SDN switches (SEL-2741)
 - Centralized configuration and monitoring
 - Multilayered traffic control (OSI layer 1 through 4)
 - Enhanced cybersecurity
 - Enhanced performance:
 - Complete traffic isolation
 - Traffic throttling per GOOSE and SV stream



GOOSE Performance- Round Trip Time



RTDS Configuration: Power System Modeling and Interfaces to the Merging Units



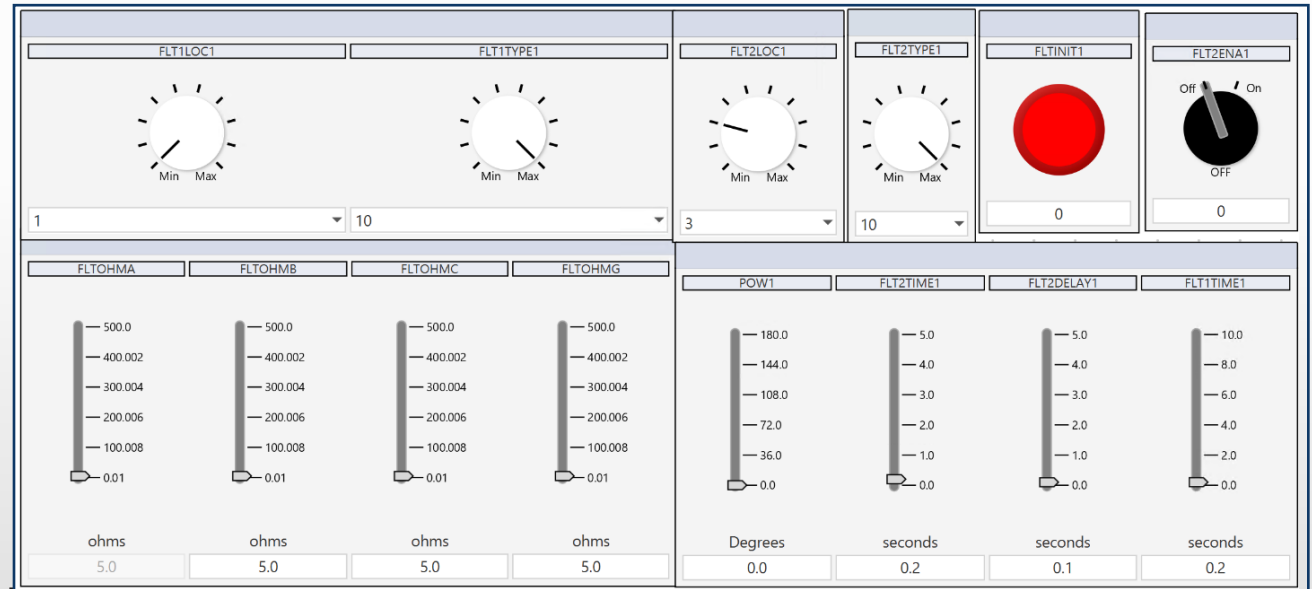
- Low Level Interface for Analog signals.
- Hardwired connections for breaker monitoring and control
- GOOSE for disconnecter positions

RTDS Configuration: Faults, Switchgear and Zone Controls

- Circuit breaker and disconnecter controls
- Control logic for the five zones selection

- Fault control:

1. Selection of fault location
2. Ten different types of faults
3. Configurable fault resistance
4. Point on wave fault simulation
5. Evolving fault simulation



RTDS and SEL DSS: Lab Setup



Commissioning: Process Bus Monitoring with RTAC HMI

SEL

Time: Wed, Apr 30, 2025, 6:07:56 PM

admin [ACTIVATE HMI READ-ONLY MODE] [LOGOUT]

Project Outline

Trending

SOE

ALARMS

DSS Monitoring

Status:

Project Info

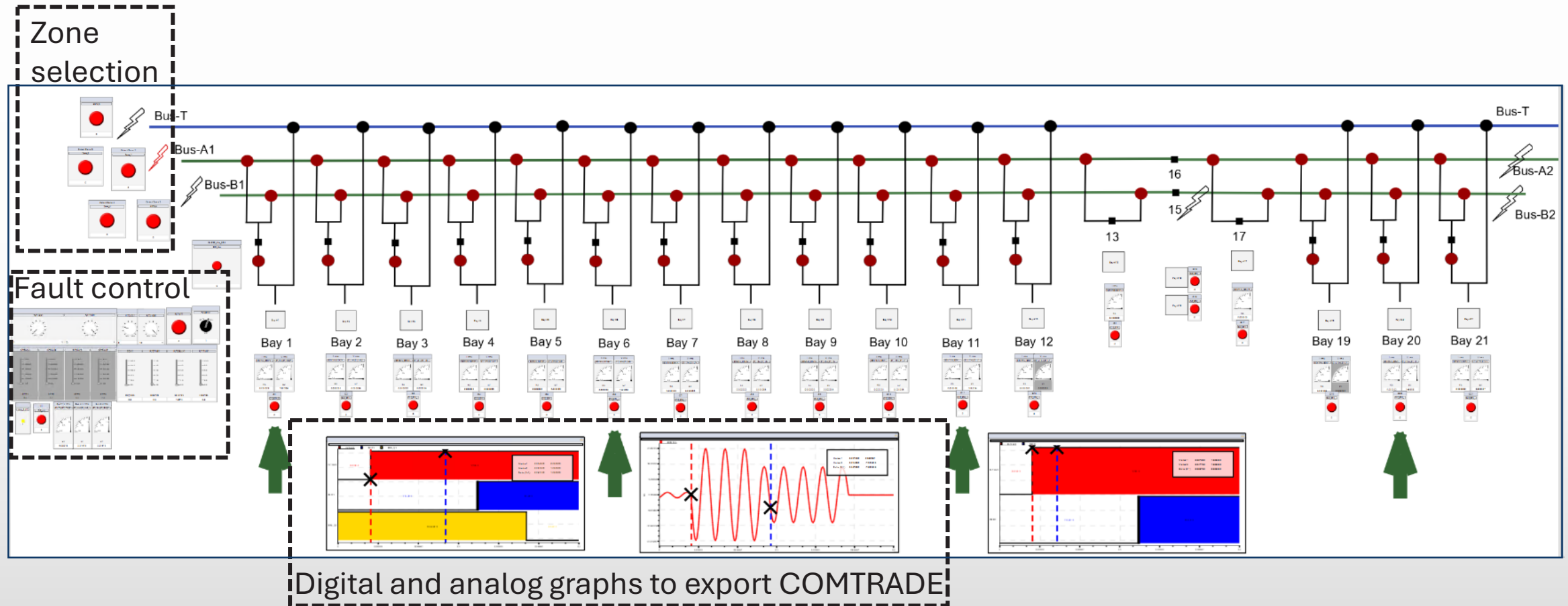
06 - PROCESS BUS - Slide x

 **PROCESS BUS** | UUT_487B_1_010

Application	Reference	Value	Description
Interface port 5A statistics	ETH1GGIO1.Ind01.stVal (ST)	TRUE	Port 5A ready
	ETH1GGIO1. Ind02.stVal (ST)	TRUE	Link status of port 5A connection
Interface port 5B statistics	ETH1GGIO1.Ind03.stVal (ST)	TRUE	Port 5B ready
	ETH1GGIO1.Ind04.stVal (ST)	TRUE	Link status of port 5B connection
PRP port 5A	PRP1GGIO1.Ind01 (ST)	TRUE	PRP port 5A GOOSE status
	PRP1GGIO1.Ind05 (ST)	TRUE	PRP port 5A SV status
	SEL_FP_P5ASVDUPNRCVD	0	Duplicate SV PRP packets not received
	SEL_FP_P5ASVDUPNRCVD	0	Duplicate GOOSE PRP packets not received
	SEL_FP_P5ADWNCNT	0	Link down counter
	SEL_FP_P5ADWNTIM	0	Link downtime (s)
PRP port 5B	PRP1GGIO1.Ind02 (ST)	TRUE	PRP port 5B GOOSE status
	PRP1GGIO1.Ind06 (ST)	TRUE	PRP port 5B SV status
	SEL_FP_P5BSVDUPNRCVD	0	Duplicate SV PRP packets not received
	SEL_FP_P5BSVDUPNRCVD	0	Duplicate GOOSE PRP packets not received
	SEL_FP_P5BDWNCNT	0	Link down counter
	SEL_FP_P5BDWNTIM	0	Link downtime (s)
Time master supervision	LTMS1.TmAcc.stVal (ST)	20	Number of significant bits in the second fraction
	LTMS1.TmSrc.stVal (ST)	0030A7FFFE1459C9	Time source identity
	LTMS1.TmSrcTyp.stVal (ST)	PTP	Timing source type (IRIG-B, PTP, SNTP, or Unknown)
	LTMS1.TmSyn.stVal (ST)	GlobalAreaClock	Timing source traceability (Global, Local, or Internal)
	LTMS1.TmSynLkd.stVal (ST)	Locked	Clock synchronization status

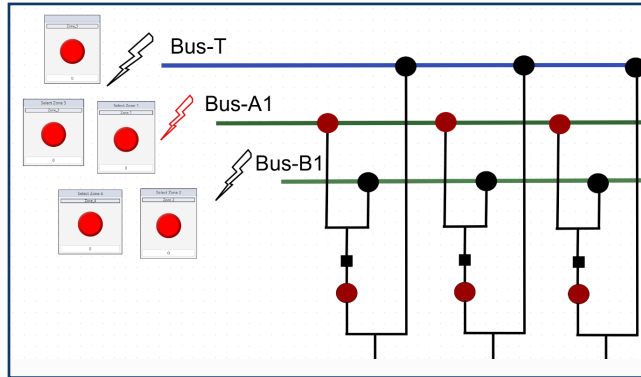


Commissioning: RSCAD Run Time View



Commissioning: Dynamic Zone Configuration

ZONE-1/3



Terminal

Serial Number: 1234567890

487B-A

Terminals in Protection Zone 1

I01I02I03

I04I05I06

I07I08I09

I14I16I12

Bus-Zones in Protection Zone 1

BZ1

Terminals in Protection Zone 2

I15

Bus-Zones in Protection Zone 2

BZ2

Terminals in Protection Zone 3

I16I18I19

I20I21

Bus-Zones in Protection Zone 3

BZ3

Terminals in Protection Zone 4

I15

Bus-Zones in Protection Zone 4

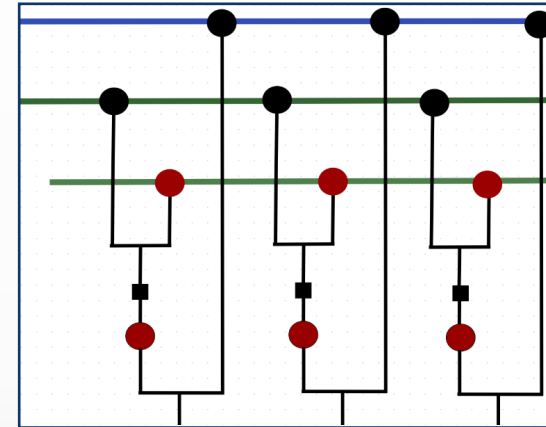
BZ4

Terminals in Protection Zone 5

BZ5

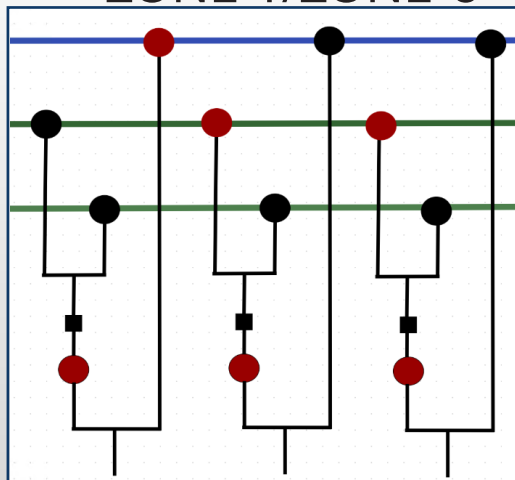
Protection Zone 6 is inactive

ZONE-2/4



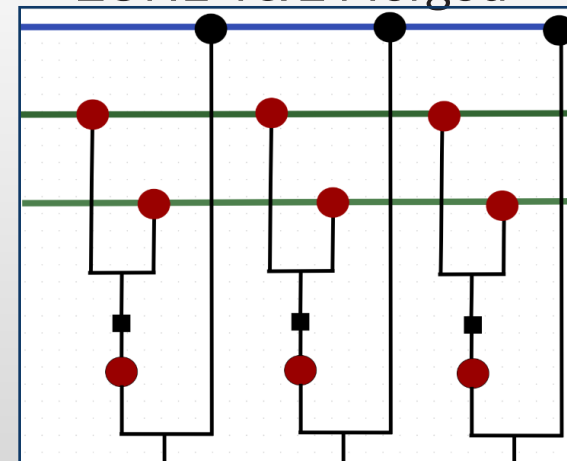
487B-A			Serial Number: 1234567890				
Terminals in Protection Zone 1							
I16							
Bus-Zones in Protection Zone 1							
BZ1							
Terminals in Protection Zone 2							
I01	I02	I03	I04	I05	I06		
I07	I08	I09	I10	I11	I12		
I13	I15						
Bus-Zones in Protection Zone 2							
BZ2							
Terminals in Protection Zone 3							
I16							
Bus-Zones in Protection Zone 3							
BZ3							
Terminals in Protection Zone 4							
I15	I17	I19	I20	I21			
Bus-Zones in Protection Zone 4							
BZ4							
Terminals in Protection Zone 5							
BZ5							
Protection Zone 6 is inactive							

ZONE-1/ZONE-5



487B-A			Serial Number: 123456789		
Terminals in Protection Zone 1					
I02	I03	I04	I05	I06	I07
I08	I09	I10	I11	I14	I15
Bus-Zones in Protection Zone 1					
BZ1					
Terminals in Protection Zone 2					
I15					
Bus-Zones in Protection Zone 2					
BZ2					
Terminals in Protection Zone 3					
I16	I18	I19	I20	I21	
Bus-Zones in Protection Zone 3					
BZ3					
Terminals in Protection Zone 4					
I15					
Bus-Zones in Protection Zone 4					
BZ4					
Terminals in Protection Zone 5					
I01	I12				
Bus-Zones in Protection Zone 5					
BZ5					
Protection Zone 6 is inactive					

ZONE-1& 2 Merged



Terminal

487B-A

Serial Number: 1234567890

Terminals in Protection Zone 1

I01I02I03I04I05I06

I07I08I09I10I11I12

I13I14I15I16

Bus-Zones in Protection Zone 1

BZ1BZ2

Protection Zone 2 is inactive

Terminals in Protection Zone 3

I15I16I17I18I19I20

I21

Bus-Zones in Protection Zone 3

BZ3BZ4

Protection Zone 4 is inactive

Terminals in Protection Zone 5

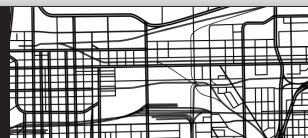
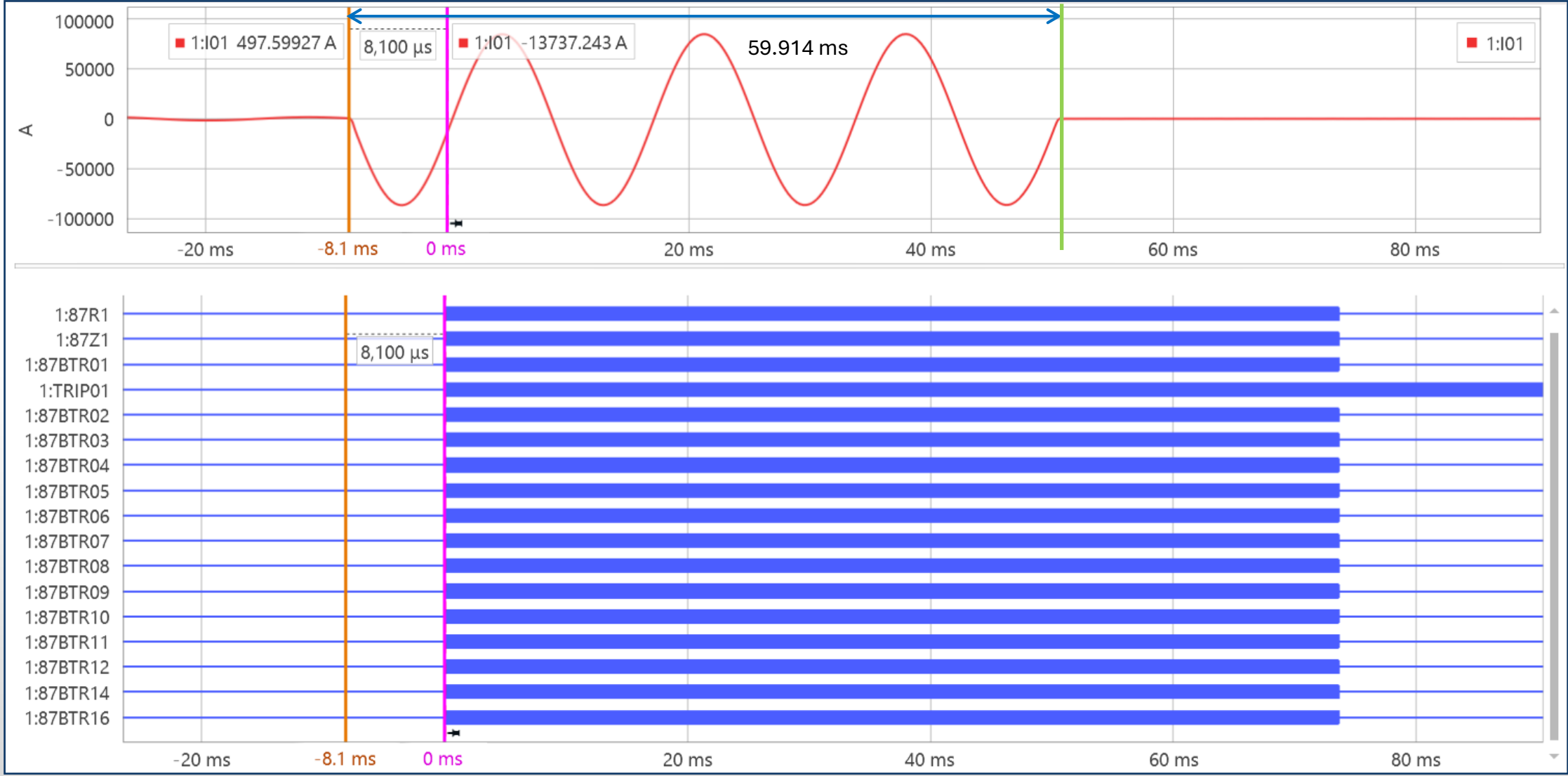
Bus-Zones in Protection Zone 5

BZ5

Protection Zone 6 is inactive

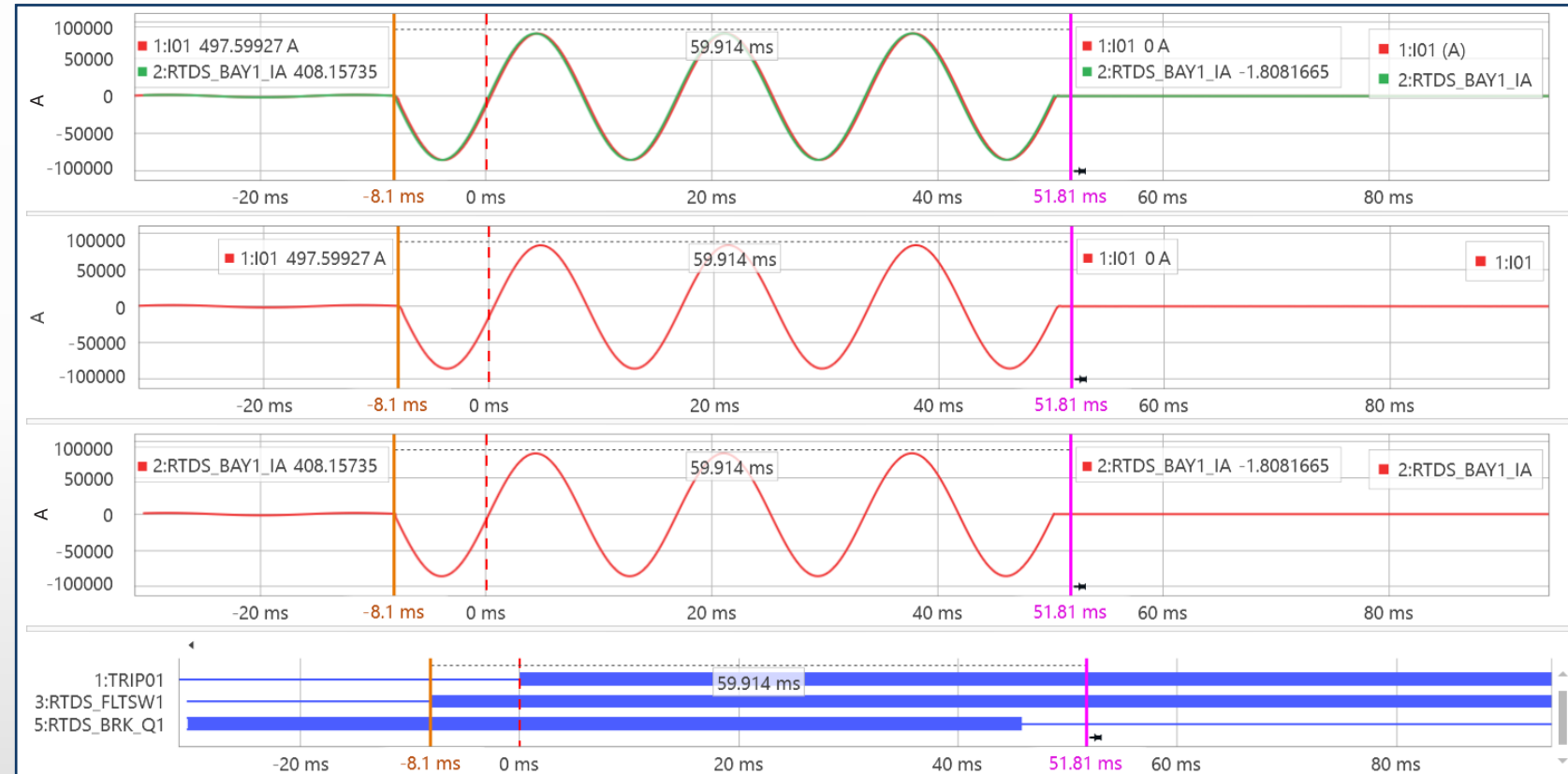


Fault Simulation 3ΦG on Bus-A1: Relay Results

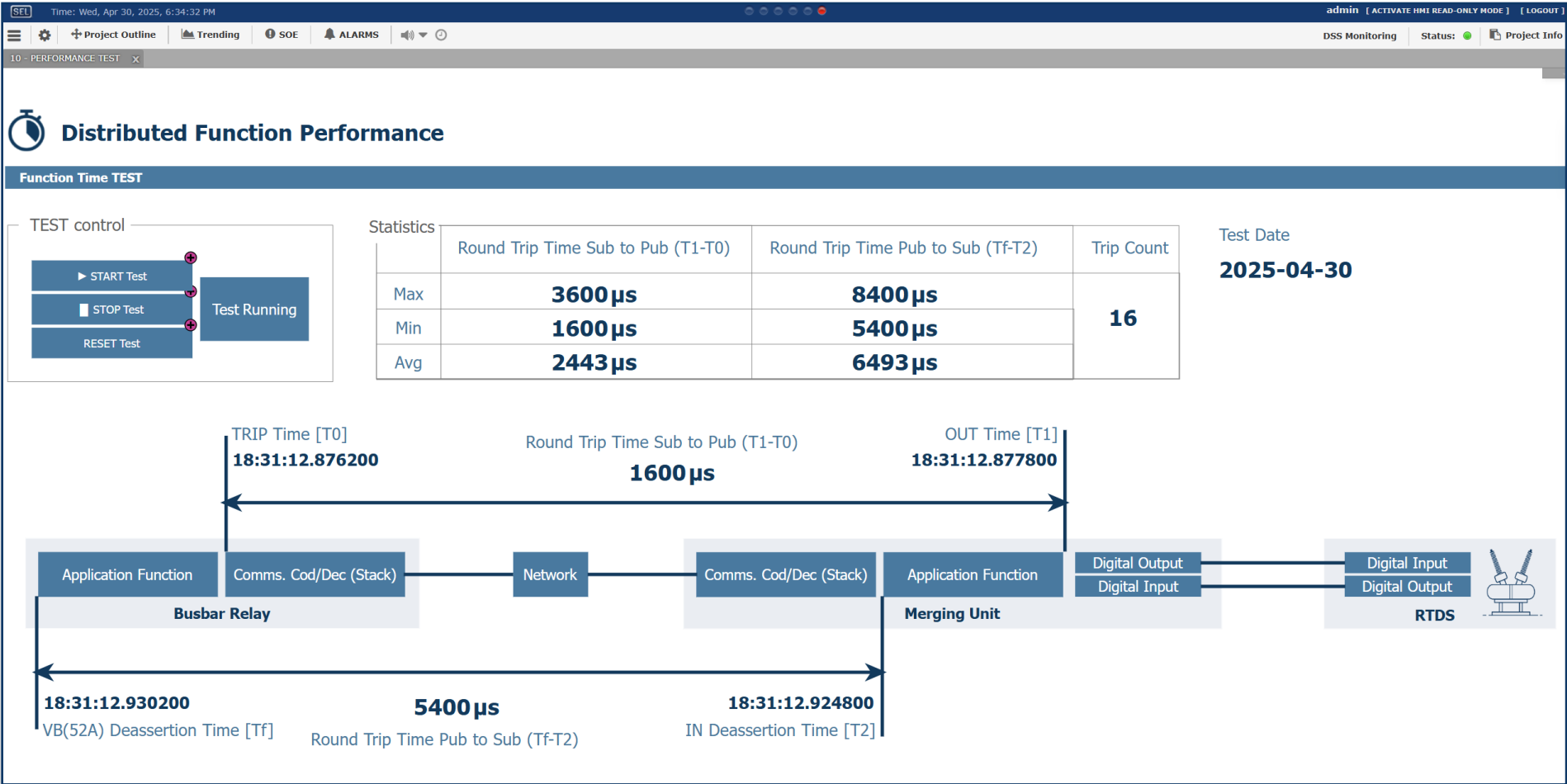


Fault Simulation 3ΦG on Bus-A1:RSCAD & Relay Results

- Total fault clearing time includes:
 - Trip time
 - **Communication Round trip time**
 - Input/output processing time on relay and RTDS
 - Delay time modeled in breaker control



Fault Simulation 3ΦG on Bus-A1: GOOSE Performance



Conclusions

- Concept of IEC 61850-based digital secondary system
- Reviewed concept of GOOSE performance testing
- Dynamic zone configuration for double bus-single breaker with transfer bus
- System configuration and laboratory test setup
- Commissioning procedure and fault simulation results were presented



Thank you

