



Internship Accomplishments

May – August 2025

Henry Warfield

Grid Modernization Internship

About Me:

- ❑ Junior E.E. Major at Virginia Tech with a Concentration in Power Systems
- ❑ Intern at Boston Office since May 2025
- ❑ 
- ❑ Vocational Degree in Electrical Engineering (4 Years) 

Generic Microgrid Testbed Demo

Assigned by



Woodward EasYGen
3500XT GenSet

SEL 751 Feeder
Protection Relay

HIL606

HIL Connect

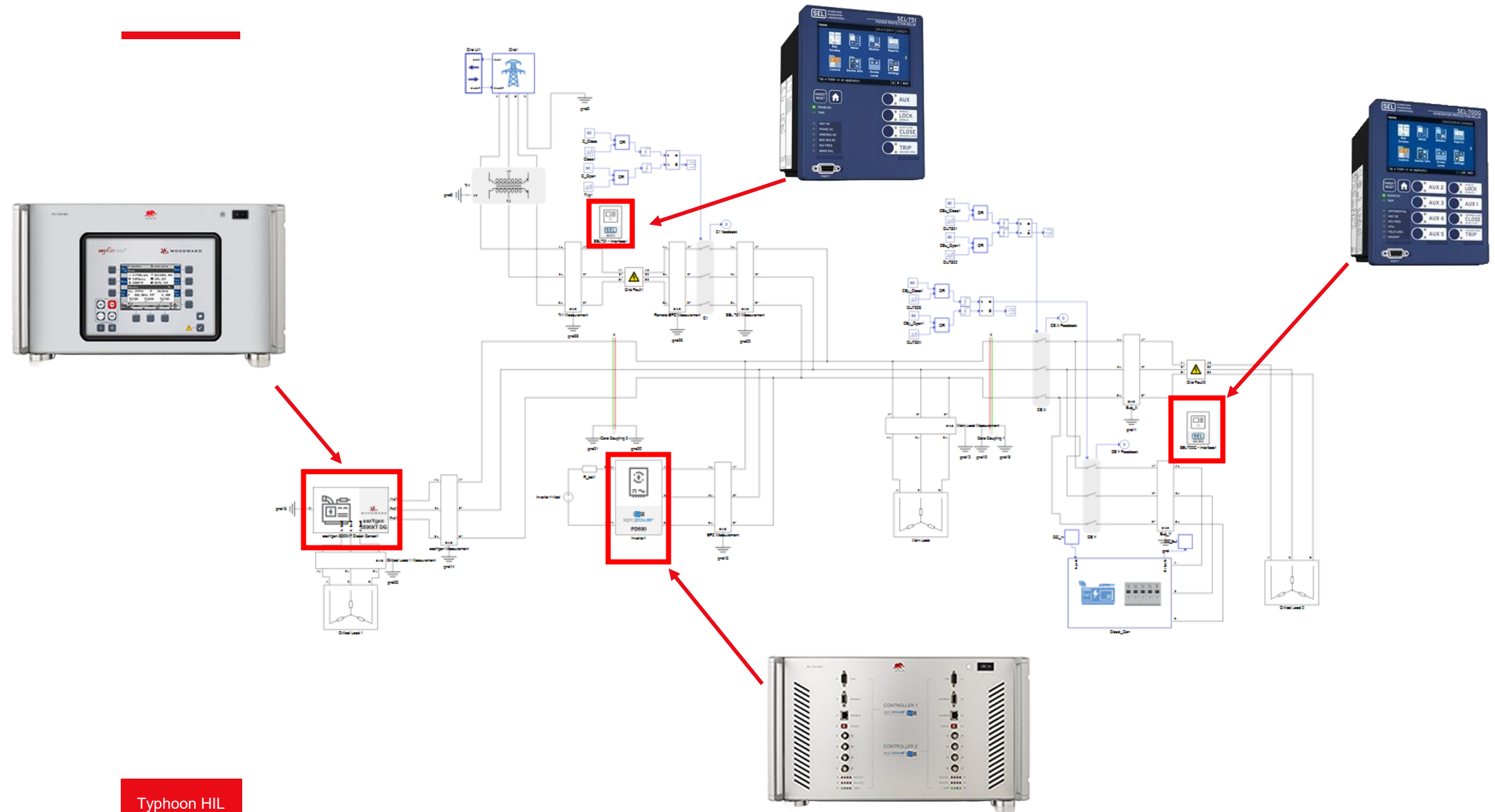
HIL606

EPC Power
Inverter

SEL 700G Generator
Protection Relay



Microgrid Circuit



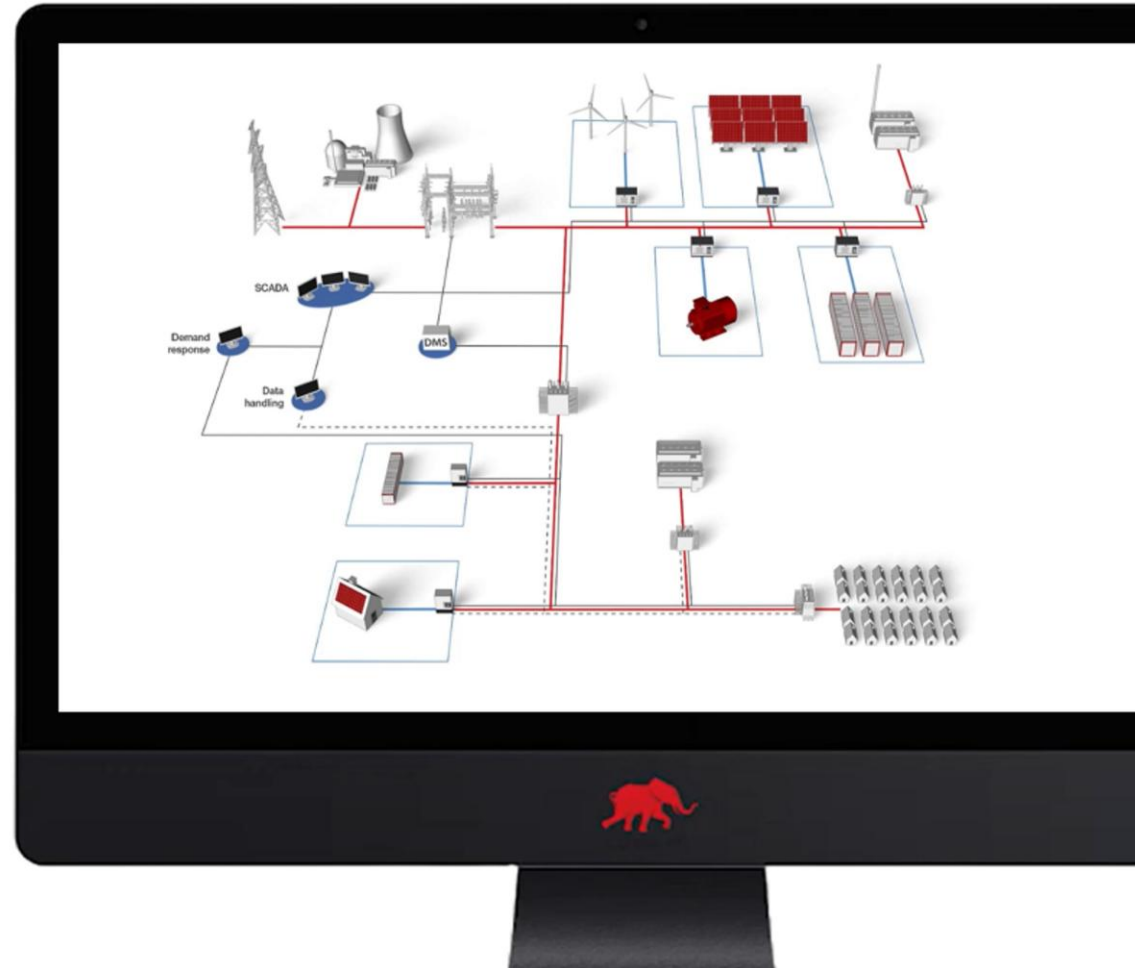
Tests Overview

- ❑ Showed normal grid-connected operation with generator and EPC inverter in grid-following mode.
- ❑ Simulated grid faults to verify selective breaker operation and fault isolation.
- ❑ Operated EPC inverter in grid-forming mode during main grid loss, with gensets supporting in following mode.
- ❑ Demonstrated islanded operation of virtual genset for critical load supply.
- ❑ Verified safe reconnection through synchronization checks on SEL-700G and SEL-751.
- ❑ Compared transition effects between operating modes to assess system stability.
- ❑ Tested equipment fault response (virtual genset overspeed) with protection logic isolating the fault while keeping loads powered.

Video



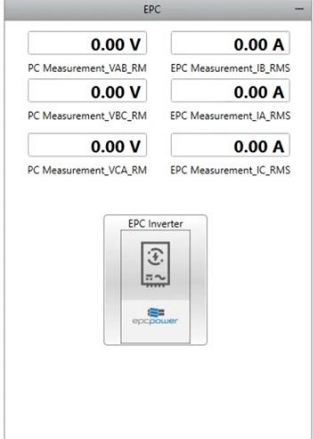
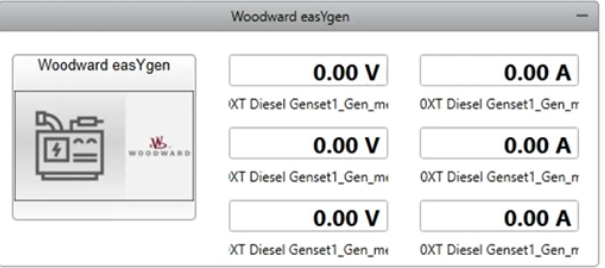
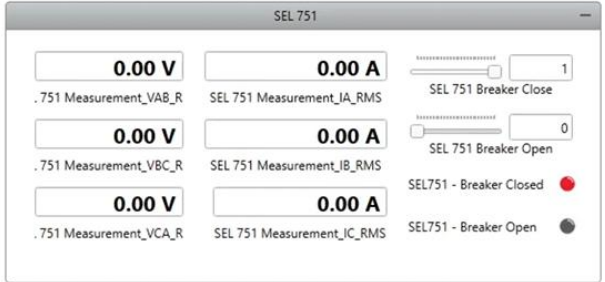
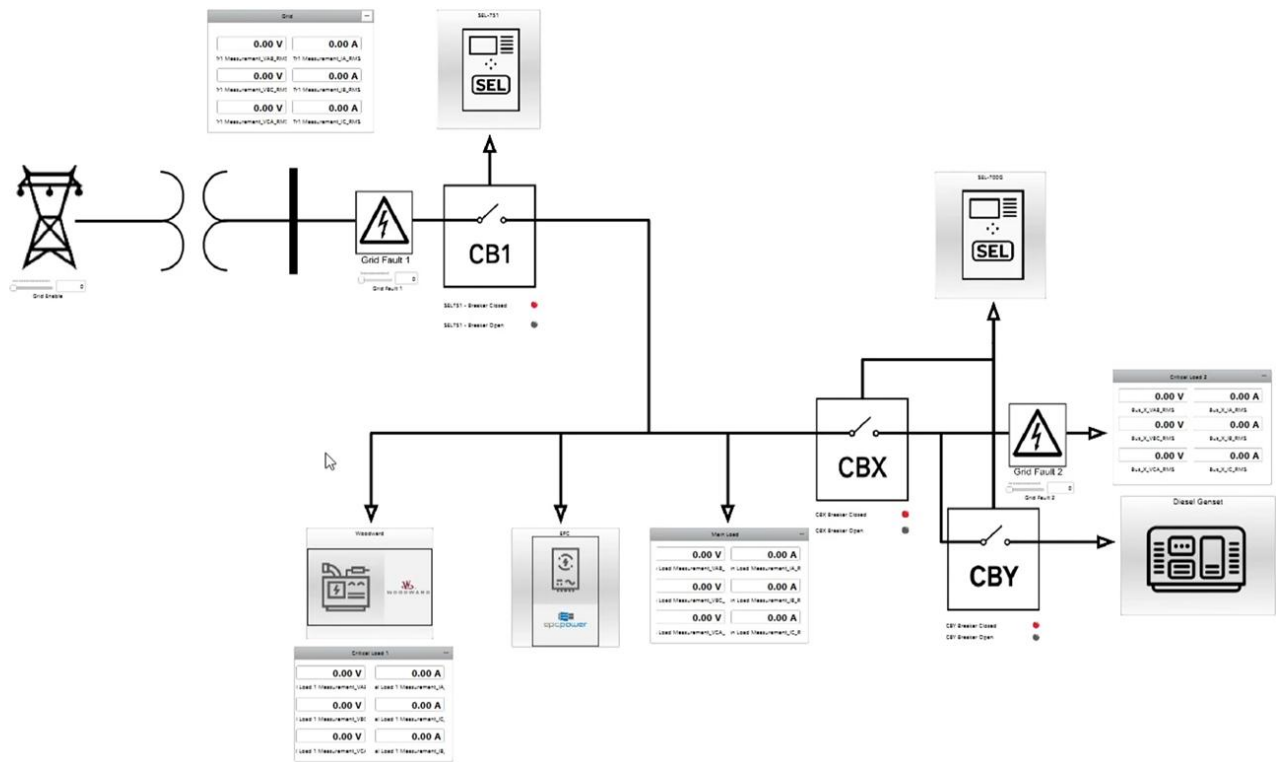
Full Microgrid Testbed Demo



Original SCADA Panel

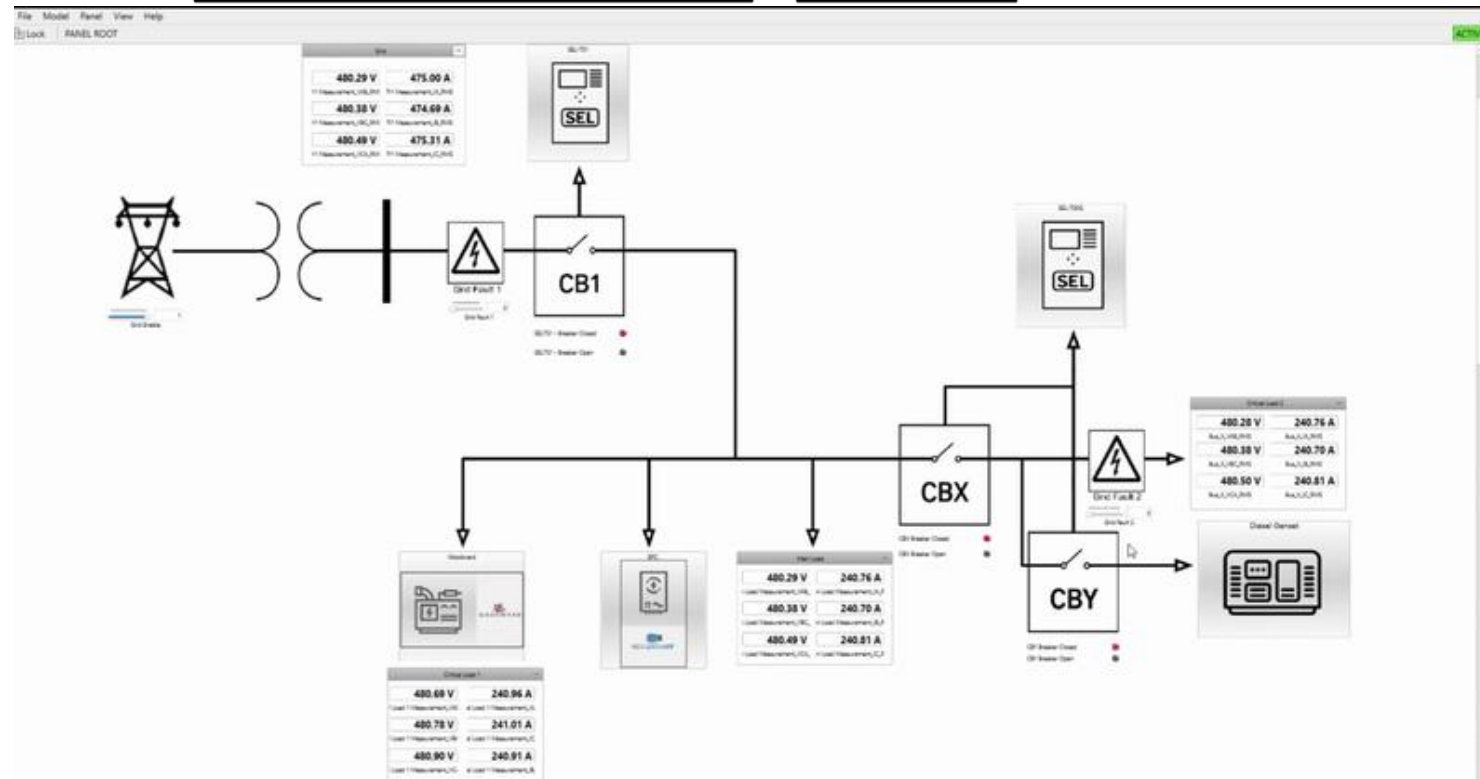


New SCADA Panel



Microgrid Testbed Demo – Why?

- ❑ **Shows Real-World Capability** – Demonstrates how Typhoon HIL can simulate an entire microgrid with real hardware, controllers, and protection devices in real time.
- ❑ **Demonstrates Integration** – Shows seamless operation between different devices (SEL relays, EPC inverter, Woodward genset controller) under one HIL platform.
- ❑ **Already show to be useful in presentations with** [REDACTED] & [REDACTED]
- ❑ **Builds Trust & Credibility**
- ❑ **Reusable Resource**
- ❑ **Covers Diverse Scenarios**



Boston VPAC

Assigned by

&



Boston VPAC

- ❑ Assembled the physical rack, including secure mounting and cable management for all devices.
- ❑ Installed, configured, and calibrated each component — including protection relays, control units, network equipment, and precision time synchronization devices.
- ❑ Verified communication across IEC 61850, PTP/NTP, and other relevant protocols to ensure accurate time stamping and event correlation.
- ❑ The rack is designed to support **voltage protection and control simulations**, enabling the testing of complex power system scenarios such as fault detection, isolation, load transfer, and system restoration.
- ❑ Demo already proven to be useful in presentation with [REDACTED]

SMU615 and REF615

REX640

Cisco IE9320 Switch

M1000 Time-Server

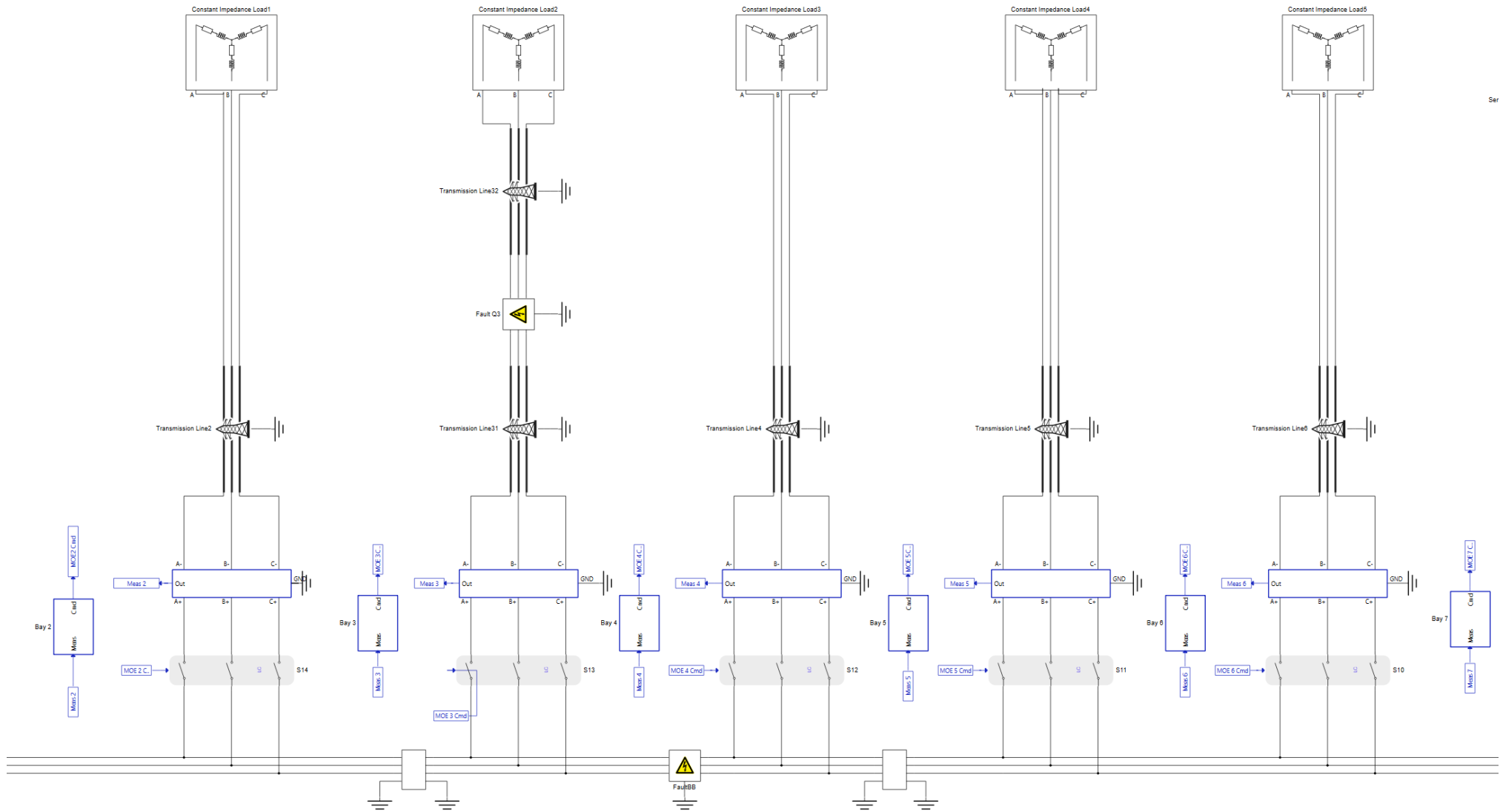
ABB SSC600

HIL606

HIL Connect



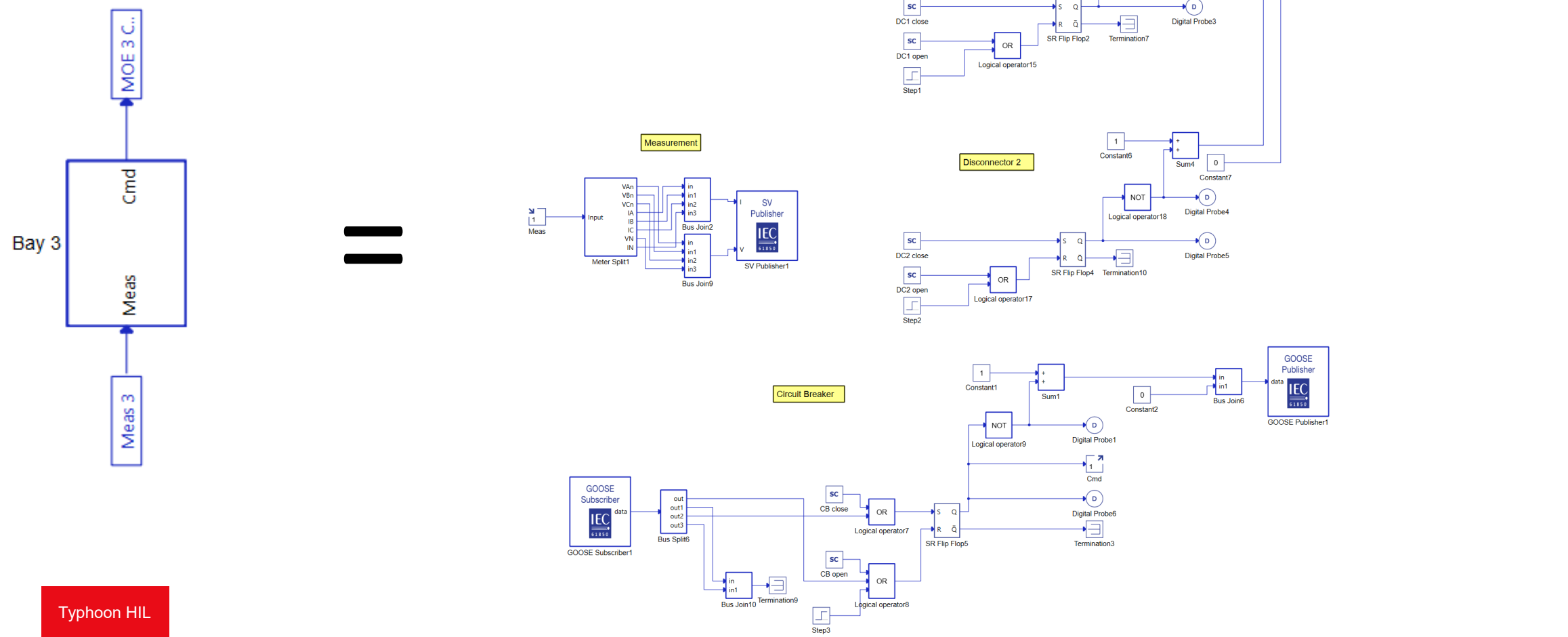
Section of the test circuit



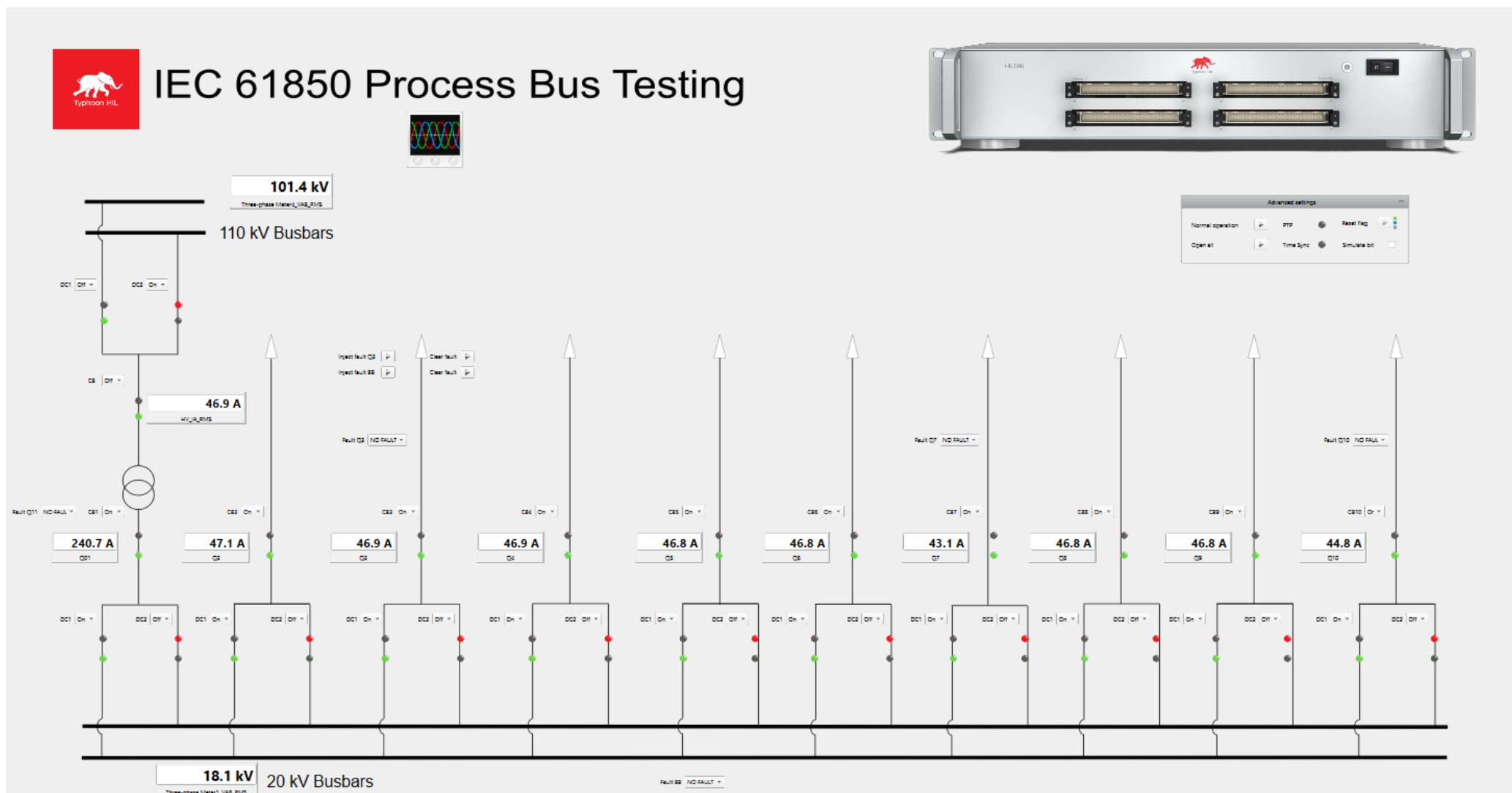
Ser

Bay Simulation Protocol

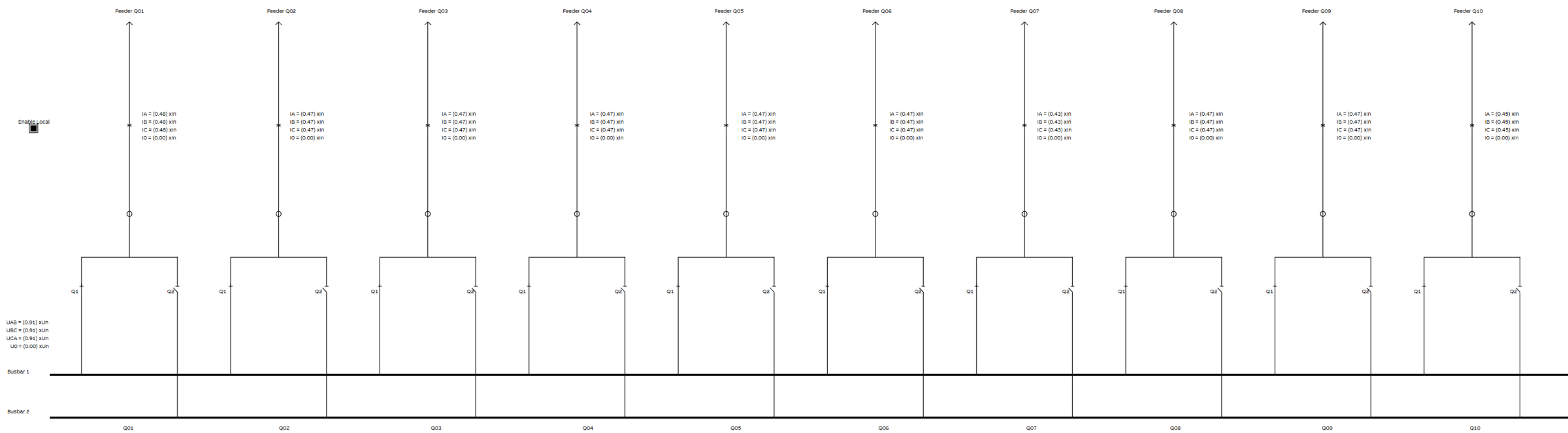
Sends IEC61850 Commands to act like the SMU615 station monitoring and control unit to monitor and protect substations



SCADA Panel



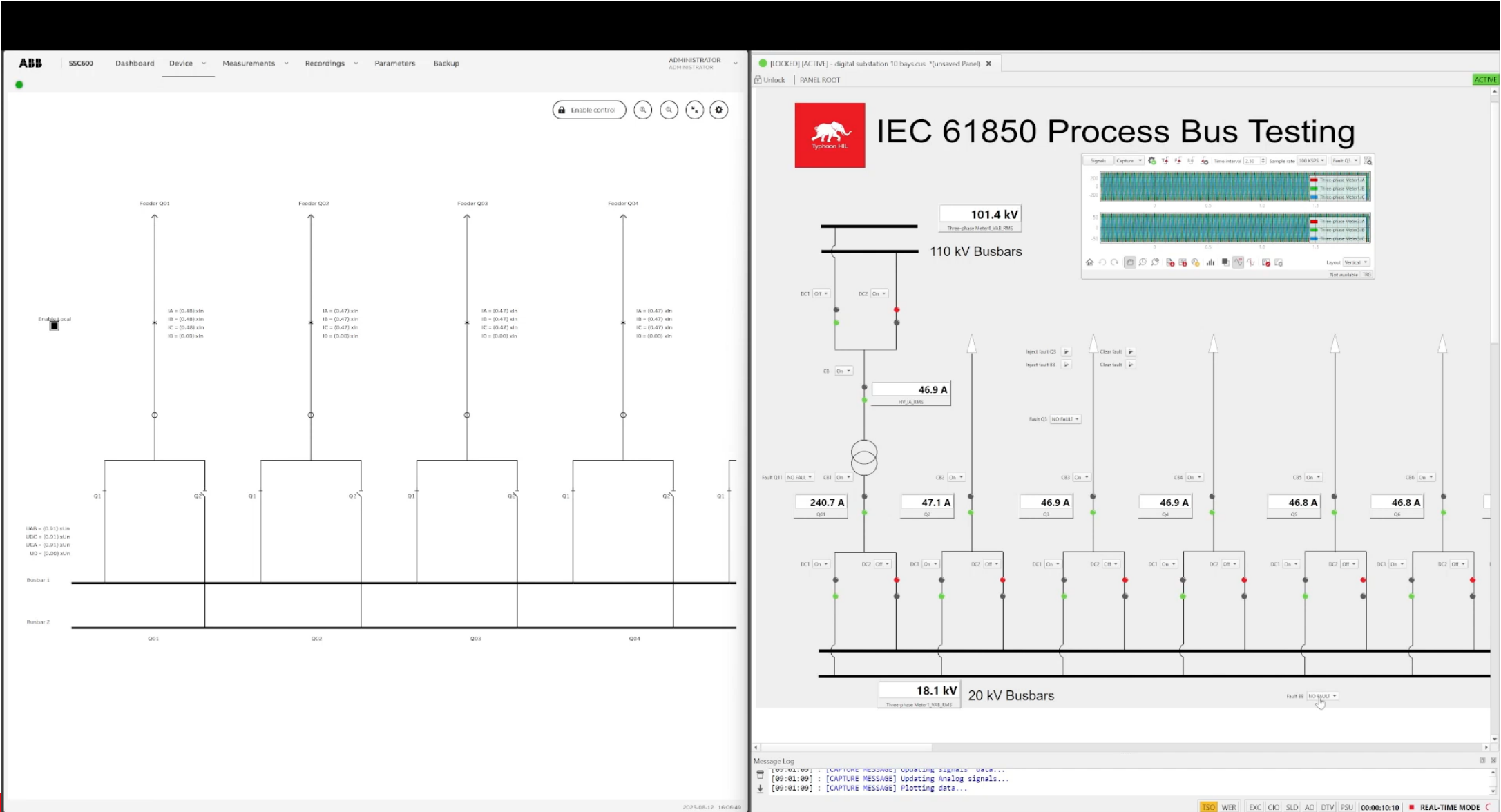
SSC600 Web HMI



Operation

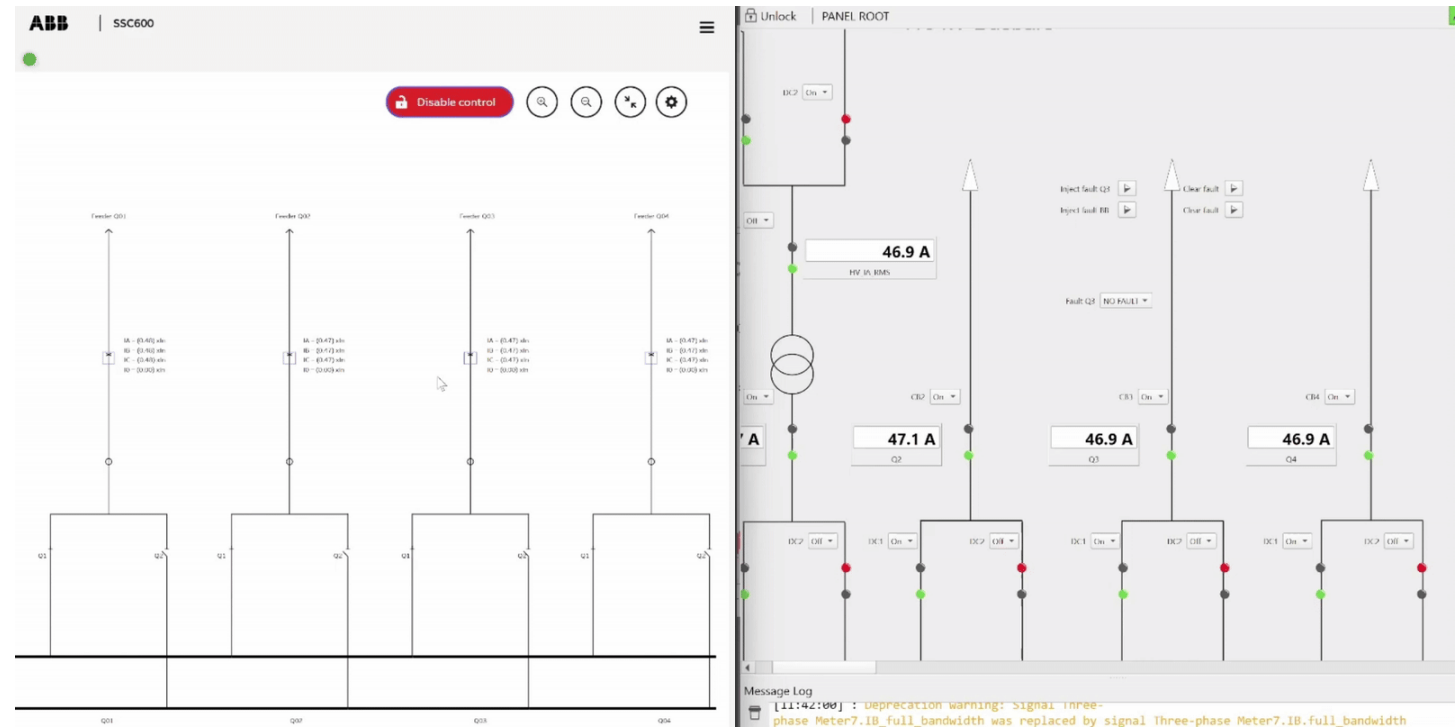
Active alarms

STATUS	NUMBER	DESCRIPTION
	1	BB_Diff_OPERATE



Boston VPAC – Why?

- ❑ **Demonstration Tool** – Provides a ready-made platform for customer demos and proof-of-concept testing
- ❑ **Protocol & Testing** – Validates IEC 61850, PTP/NTP, and other communication protocols across multiple vendors before deployment.
- ❑ **Flexible Scenario Testing** – Supports grid faults, islanding, synchronization, reclose logic, and recovery in a repeatable and safe environment.



SEL 751/700G Modbus Interface

Assigned by [REDACTED]



SEL 751/700G Modbus Interface

- ❑ Developed Modbus TCP link between SEL-751 & SEL-700G and Typhoon HIL via HIL Client.
- ❑ Created SCADA Panels for both based on HIL Client
- ❑ Mapped key measurements, breaker states, and trip/alarm signals from SEL Modbus register maps.
- ❑ Implemented control commands (Close/Open/Target Reset) with status feedback.
- ❑ Also created separate SCADA Panels based on both using a class-based structure via Modbus API



SEL751ModbusClient



SEL700GModbusClient

The image shows two side-by-side configuration windows for Modbus clients. The left window is titled 'Component (SEL751ModbusClient1) prop...' and the right window is titled 'Component (SEL700GModbusClient1) pr...'. Both windows have a 'Edit the description' field at the top. Below this, there are two sections: 'SEL751' for the left window and 'SEL700G' for the right window. Each section contains fields for 'IP Address', 'port', and 'Slave ID'. Below these, there is a section for 'HIL Device' with fields for 'Modbus Client IP Address', 'Netmask', 'HIL Device ID' (a dropdown menu), and 'Execution rate'. The 'HIL Device ID' is set to '0' in both. The 'Execution rate' is set to '100e-6' in both. At the bottom of each window are 'OK' and 'Cancel' buttons.

Field	SEL751ModbusClient1	SEL700GModbusClient1
IP Address	12.168.204.202	12.168.204.202
port	502	502
Slave ID	1	1
Modbus Client IP Address	12.168.204.102	12.168.204.102
Netmask	255.255.255.0	255.255.255.0
HIL Device ID	0	0
Execution rate	100e-6	100e-6

1. *Journal of Management Studies*, 1991, 28, 1, 1-13.



1. *Journal of Management Studies*, 1997, 34, 1, 1-14.



SEL 751 Panels

SEL 751 HIL Client

Device Current

IA = 0.00 A

IB = 0.00 A

IC = 0.00 A

IN = 0.00 A

IG = 0.00 A

UBI = 0.00 %

UBV = 0.00 %

FREQ = 0.00 Hz

FREQS = 0.00 Hz

Device Voltage

VAB = 0.00 kV

VBC = 0.00 kV

VCA = 0.00 kV

VS = 0.00 kV

VDC = 0.00 kV

P = 0.00 kW

Q = 0.00 kVAR

S = 0.00 kVA

PF = 0.00

Modbus Status

1

Enable Modbus

Target Reset

ENABLED

TRIP

INST OC

PHASE OC

GND NEU OC

NEG SEQ OC

OU FREQ

BRKR FAIL

CONTACT I/O

00000000

Contacts

Breaker

Close

Open

NOTE: Current Resolution is 1A and Voltage is 10V

SEL 751 API Client

Device Current

IA = 0.00 A

IB = 0.00 A

IC = 0.00 A

IN = 0.00 A

IG = 0.00 A

UBI = 0.00 %

UBV = 0.00 %

FREQ = 0.00 Hz

FREQS = 0.00 Hz

Device Voltage

VAB = 0.00 kV

VBC = 0.00 kV

VCA = 0.00 kV

VS = 0.00 kV

VDC = 0.00 kV

P = 0.00 kW

Q = 0.00 kVAR

S = 0.00 kVA

PF = 0.00

Modbus Connect

Enter IP

192.168.32.81

Modbus Status

Target Reset

ENABLED

TRIP

INST OC

PHASE OC

GND NEU OC

NEG SEQ OC

OU FREQ

BRKR FAIL

CONTACT I/O

00000000

Contacts

Breaker

Close

Open

NOTE: Current Resolution is 1A and Voltage is 10V

SEL700G Panels

SEL 700G HIL Client

Device Current

IAX = 0.00 A

IBX = 0.00 A

ICX = 0.00 A

IAY = 0.00 A

IBY = 0.00 A

ICY = 0.00 A

FREQX = 0.00 Hz

FREQY = 0.00 Hz

FREQS = 0.00 Hz

Device Voltage

VAX = 0.00 kV

VBX = 0.00 kV

VCX = 0.00 kV

VAY = 0.00 kV

VBY = 0.00 kV

VCY = 0.00 kV

VS = 0.00 kV

P3X = 0.00 kW

Q3X = 0.00 kVAR

S3X = 0.00 kVA

P3Y = 0.00 kW

Q3Y = 0.00 kVAR

S3Y = 0.00 kVA

1

Enable Modbus

Target Reset

Modbus Status

CONTACT I/O

00000000

Contacts

Breaker X

Close

Open

Breaker Y

Close

Open

ENABLED

TRIP

DIFFERENTIAL

INST OC

OU FREQ

V OVER HZ

FIELD LOSS

DIR POWER

NOTE: Current Resolution is 1A and Voltage is 10V

SEL 700G API Client

Device Current

IAX = 0.00 A

IBX = 0.00 A

ICX = 0.00 A

IAY = 0.00 A

IBY = 0.00 A

ICY = 0.00 A

FREQX = 0.00 Hz

FREQY = 0.00 Hz

FREQS = 0.00 Hz

Device Voltage

VAX = 0.00 kV

VBX = 0.00 kV

VCX = 0.00 kV

VAY = 0.00 kV

VBY = 0.00 kV

VCY = 0.00 kV

VS = 0.00 kV

P3X = 0.00 kW

Q3X = 0.00 kVAR

S3X = 0.00 kVA

P3Y = 0.00 kW

Q3Y = 0.00 kVAR

S3Y = 0.00 kVA

Modbus Connect

Enter IP

192.168.32.80

Target Reset

Modbus Status

CONTACT I/O

00000000

Contacts

Breaker X

Close

Open

Breaker Y

Close

Open

ENABLED

TRIP

DIFFERENTIAL

INST OC

OU FREQ

V OVER HZ

FIELD LOSS

DIR POWER

NOTE: Current Resolution is 1A and Voltage is 10V

Contacts Subpanel

SEL700G

IN				OUT			
IN101		IN102		OUT101		OUT102	
IN301		IN302		OUT 301		OUT 302	
IN303		IN304		OUT 303		OUT 304	
IN305		IN306		OUT 401		OUT 402	
IN307		IN308		OUT 403		OUT 404	
IN401		IN402		OUT 501		OUT 502	
IN403		IN404		OUT 503		OUT 504	
IN405		IN406					
IN407		IN408					
IN501		IN502					
IN503		IN504					
IN505		IN506					
IN507		IN508					

SEL751

IN				OUT			
IN101		IN102		OUT101		OUT102	
IN301		IN302		OUT 301		OUT 302	
IN303		IN304		OUT 303		OUT 304	
IN305		IN306		OUT 305		OUT 306	
IN307		IN308		OUT 307		OUT 308	
IN401		IN402		OUT 401		OUT 402	
IN403		IN404		OUT 403		OUT 404	
IN405		IN406		OUT 405		OUT 406	
IN407		IN408		OUT 407		OUT 408	
IN501		IN502		OUT 501		OUT 502	
IN503		IN504		OUT 503		OUT 504	
IN505		IN506		OUT 505		OUT 506	
IN507		IN508		OUT 507		OUT 508	

SEL700G in Action

SEL 700G API Client

Device Current

IAX = 233.00 A

IBX = 236.00 A

ICX = 236.00 A

IAY = 0.00 A

IBY = 0.00 A

ICY = 0.00 A

FREQX = 60.00 Hz

FREQY = 60.00 Hz

FREQS = 60.00 Hz

Device Voltage

VAX = 0.28 kV

VBX = 0.28 kV

VCX = 0.28 kV

VAY = 0.28 kV

VBY = 0.28 kV

VCY = 0.28 kV

VS = 0.00 kV

P3X = 195.00 kW

Q3X = -7.00 kVAR

S3X = 195.00 kVA

P3Y = 0.00 kW

Q3Y = 0.00 kVAR

S3Y = 0.00 kVA

Modbus Connect

Enter IP

192.168.32.80

Enabled

Target Reset

Modbus Status

CONTACT I/O

00000000

Contacts

ENABLED

TRIP

DIFFERENTIAL

INST OC

OU FREQ

V OVER HZ

FIELD LOSS

DIR POWER

Breaker X

Close

Open

Breaker Y

Close

Open

NOTE: Current Resolution is 1A and Voltage is 10V

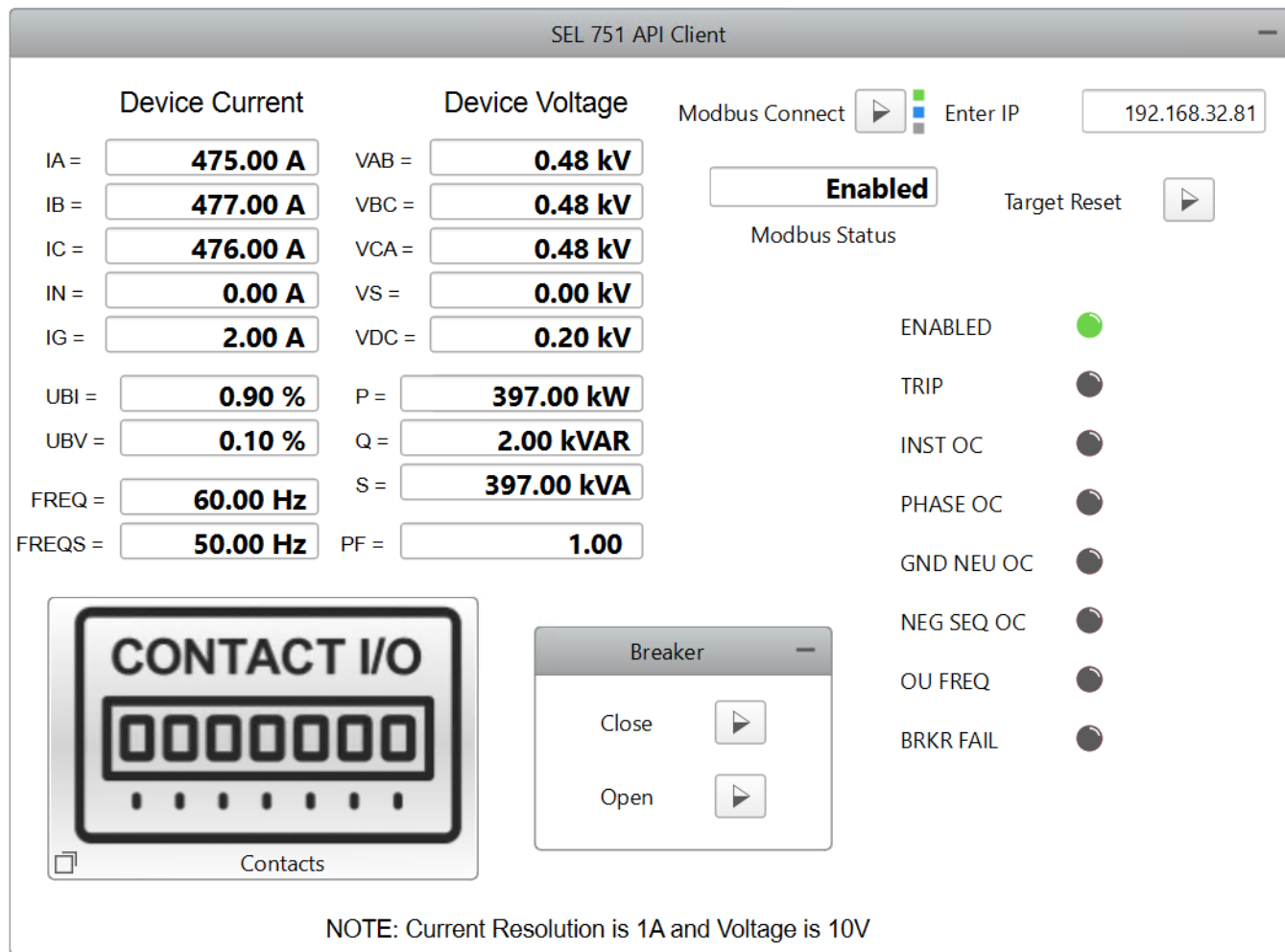
IN

IN101		IN102	
IN301		IN302	
IN303		IN304	
IN305		IN306	
IN307		IN308	
IN401		IN402	
IN403		IN404	
IN405		IN406	
IN407		IN408	
IN501		IN502	
IN503		IN504	
IN505		IN506	
IN507		IN508	

OUT

OUT101		OUT102	
OUT 301		OUT 302	
OUT 303		OUT 304	
OUT 401		OUT 402	
OUT 403		OUT 404	
OUT 501		OUT 502	
OUT 503		OUT 504	

SEL751 in Action

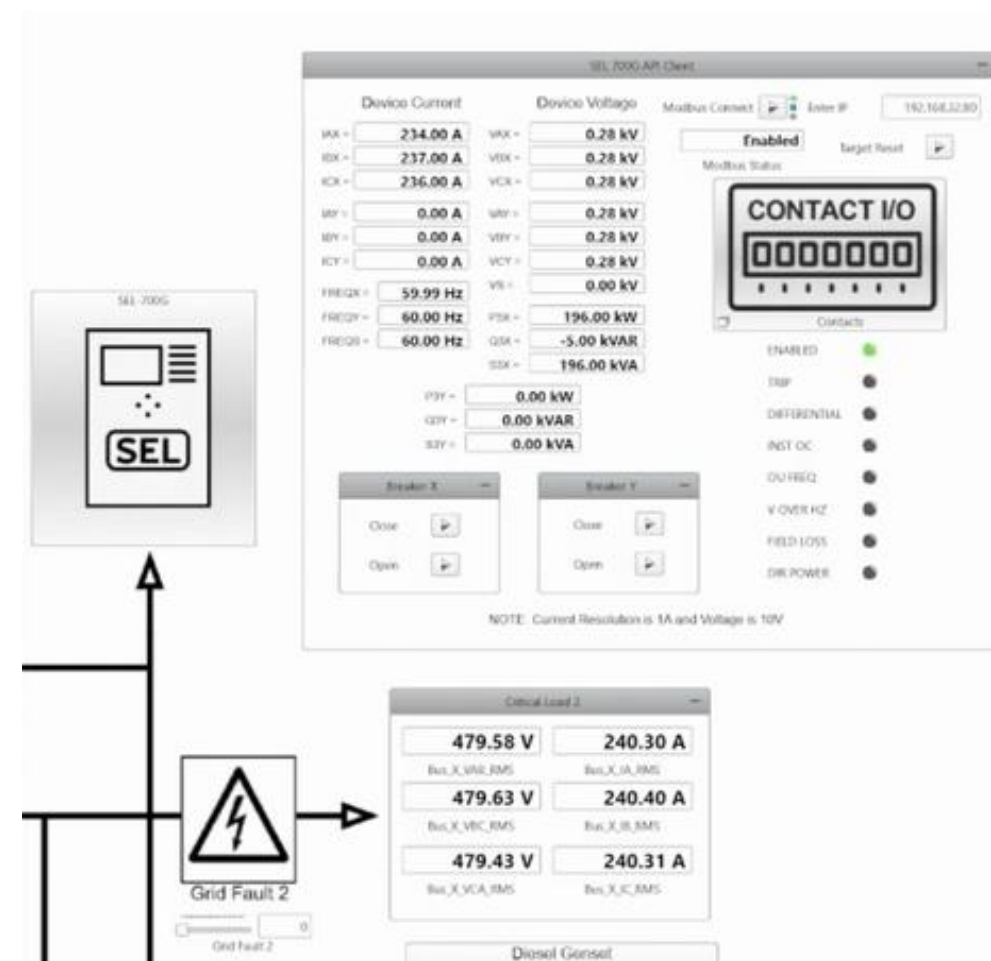


IN					
IN101		IN102			
IN301		IN302			
IN303		IN304			
IN305		IN306			
IN307		IN308			
IN401		IN402			
IN403		IN404			
IN405		IN406			
IN407		IN408			
IN501		IN502			
IN503		IN504			
IN505		IN506			
IN507		IN508			

OUT					
OUT101		OUT102			
OUT 301		OUT 302			
OUT 303		OUT 304			
OUT 305		OUT 306			
OUT 307		OUT 308			
OUT 401		OUT 402			
OUT 403		OUT 404			
OUT 405		OUT 406			
OUT 407		OUT 408			
OUT 501		OUT 502			
OUT 503		OUT 504			
OUT 505		OUT 506			
OUT 507		OUT 508			

SEL 751/700G Modbus Interface – Why?

- ❑ **Streamlined SCADA Integration** – View real-time values, breaker status, and trip signals directly in Typhoon HIL SCADA panels.
- ❑ **One-Stop Control & Monitoring** – No need to switch between SCADA and SEL's AcSELeator for target resets or breaker X/Y operations.
- ❑ **Class-Based API Structure** – Organized, reusable Python code for fast integration into future Typhoon HIL projects.
- ❑ **Centralized Operations** – Control commands (close/open/reset) and status verification all from a single dashboard.
- ❑ **Time-Saving & User-Friendly**



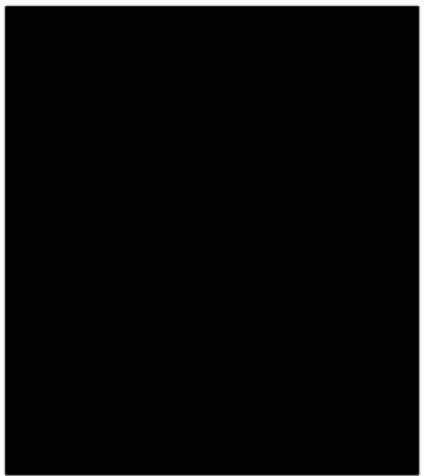
EPC Modbus on SEL RTAC

Assigned by [REDACTED]

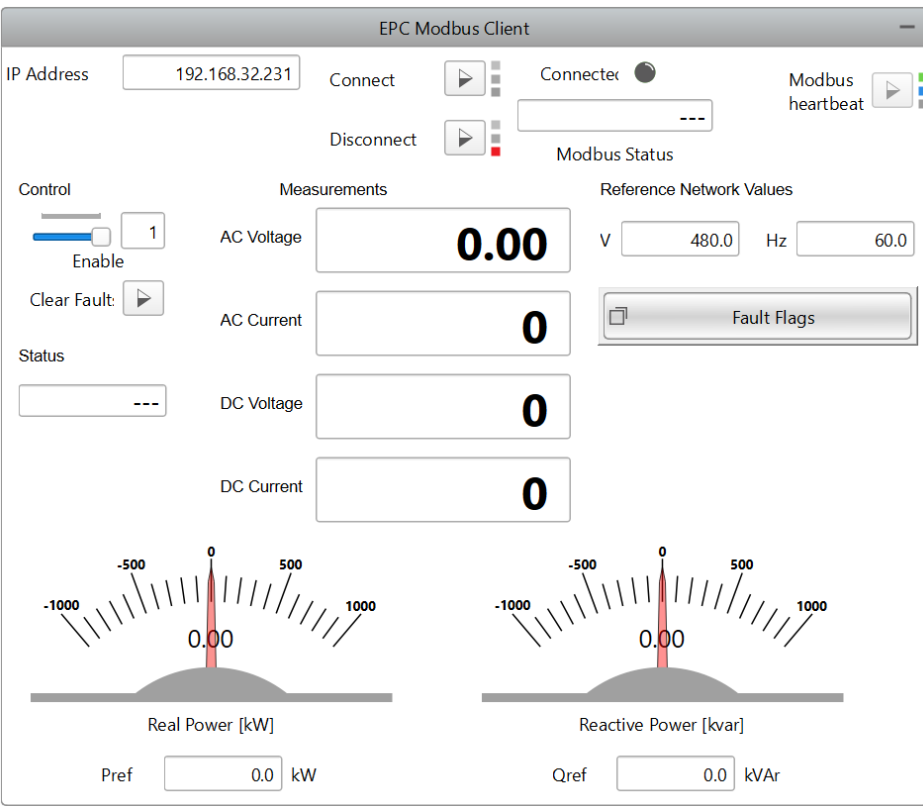


EPC Modbus on SEL RTAC

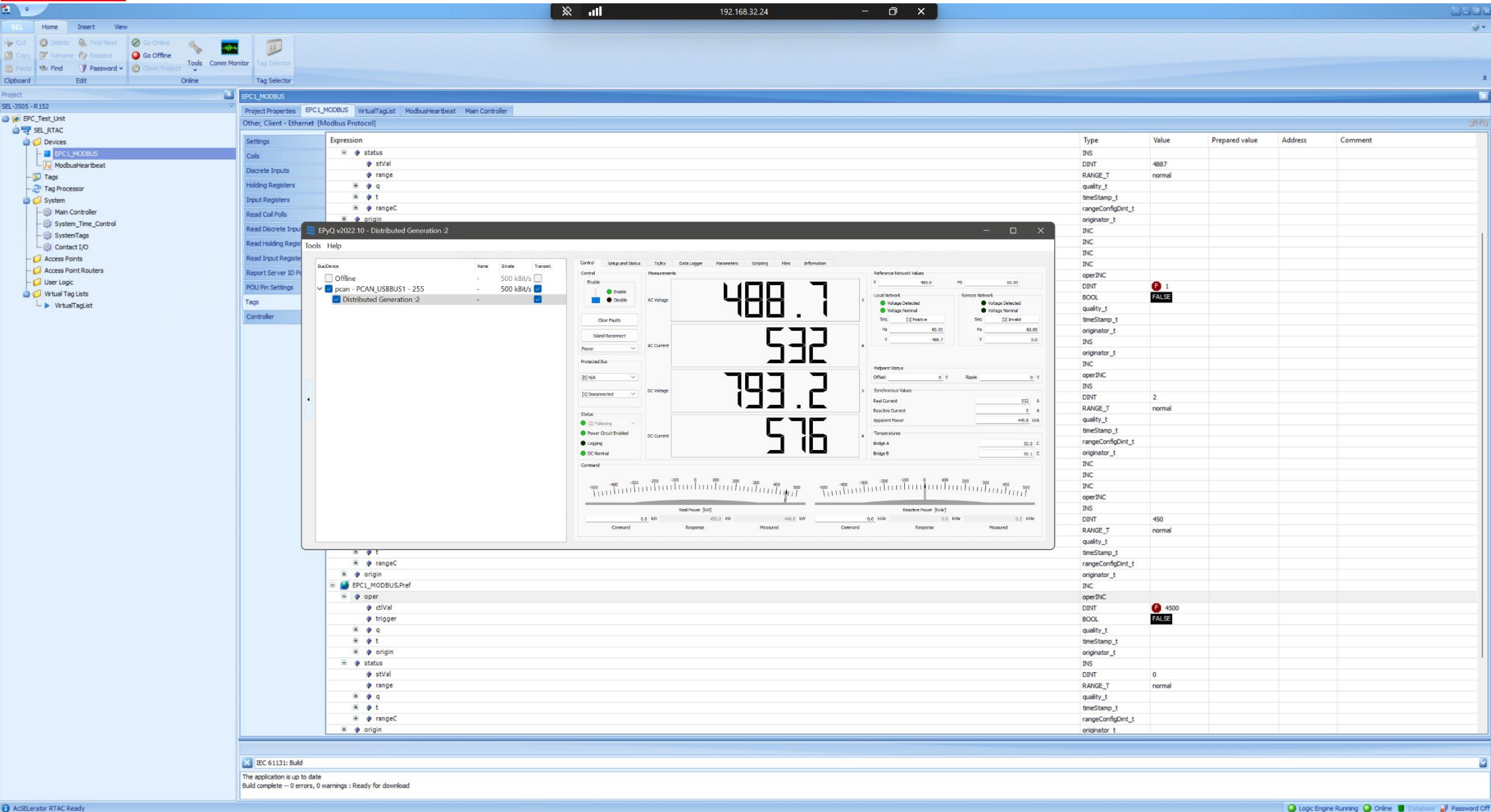
- ❑ Resolved long-standing issue where [REDACTED] could not read/write Modbus values from the EPC.
- ❑ Developed **SEL RTAC project file** capable of both reading and writing EPC Modbus registers.
- ❑ Implemented custom code to **enable/disable write triggers** dynamically, simulating a Modbus heartbeat for reliable communication.
- ❑ Created a reusable approach for future Modbus-based EPC integrations.



Undervoltage DC	☐	Ground Fault	☐
Overvoltage DC	☐	Control Bd. Undervo	☐
Overcurrent DC	☐	External Inhibit	☐
Overcurrent AC	☐	I2C	☐
Power Ch. Imbalance	☐	Control Message	☐
di/dt	☐	Illegal Transition	☐
Timed DC Overload	☐	E-Stop	☐
Timed AC Overload	☐	Condensation	☐
Timed AC Overvoltage	☐	Baseplate Overtemp	☐
Timed Circ. Current	☐	Internal Overtemp	☐
Fan Circuit	☐	Cooling System	☐
Fuse Open	☐	Low Cooling Flow	☐
AC Disconnect	☐	POR Timeout	☐



RTAC in Action

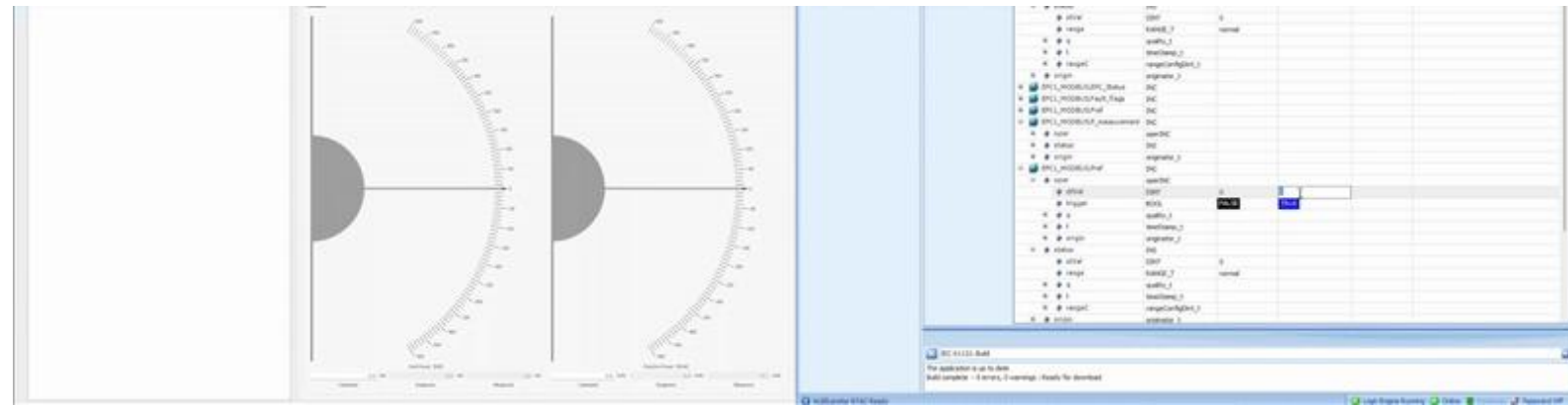


RTAC in Action

VirtualTagList.AC_Disconnect	BOOL	FALSE	Undervoltage DC		Ground Fault	
VirtualTagList.B_EE_S	BOOL	FALSE	Overvoltage DC		Control Bd. Undervol	
VirtualTagList.Bad_EE_Header	BOOL	FALSE	Overcurrent DC		External Inhibit	
VirtualTagList.CF	BOOL	FALSE	Overcurrent AC		I2C	
VirtualTagList.CmdMsg_Invalid	BOOL	FALSE	Power Ch. Imbalance		Control Message	
VirtualTagList.Conden	BOOL	FALSE	di/dt		Illegal Transition	
VirtualTagList.CR	BOOL	FALSE	Timed DC Overload		E-Stop	
VirtualTagList.CS	BOOL	FALSE	Timed AC Overload		Condensation	
VirtualTagList.Ctrl_Board_Voltage	BOOL	FALSE	Timed AC Overvoltage		Baseplate Overtemp	
VirtualTagList.E_Stop	BOOL	TRUE	Timed Circ. Current		Internal Overtemp	
VirtualTagList.External_Inhibit	BOOL	FALSE	Fan Circuit		Cooling System	
VirtualTagList.Fan_Circuit	BOOL	FALSE	Fuse Open		Low Cooling Flow	
VirtualTagList.Fuse	BOOL	FALSE	AC Disconnect		POR Timeout	
VirtualTagList.Ground_Fault	BOOL	FALSE				
VirtualTagList.I2C	BOOL	FALSE				
VirtualTagList.Illegal_Transition	BOOL	FALSE				
VirtualTagList.Overcurrent_AC	BOOL	FALSE				
VirtualTagList.Overcurrent_DC	BOOL	FALSE				
VirtualTagList.Overload_Thermal	BOOL	FALSE				
VirtualTagList.Overtemp_Baseplate	BOOL	FALSE				
VirtualTagList.Overtemp_Device	BOOL	FALSE				
VirtualTagList.Overtemp_Internal	BOOL	FALSE				
VirtualTagList.Overtemp_Inverter	BOOL	FALSE				
VirtualTagList.Overvoltage_AC	BOOL	FALSE				
VirtualTagList.Overvoltage_DC	BOOL	FALSE				
VirtualTagList.POR	BOOL	FALSE				
VirtualTagList.Power_Imbalance	BOOL	FALSE				
VirtualTagList.Timed_Circ_Current	BOOL	FALSE				
VirtualTagList.Timed_Overload_AC	BOOL	FALSE				
VirtualTagList.Timed_Overload_DC	BOOL	FALSE				
VirtualTagList.Undervoltage_DC	BOOL	FALSE				
VirtualTagList.UTM	BOOL	FALSE				

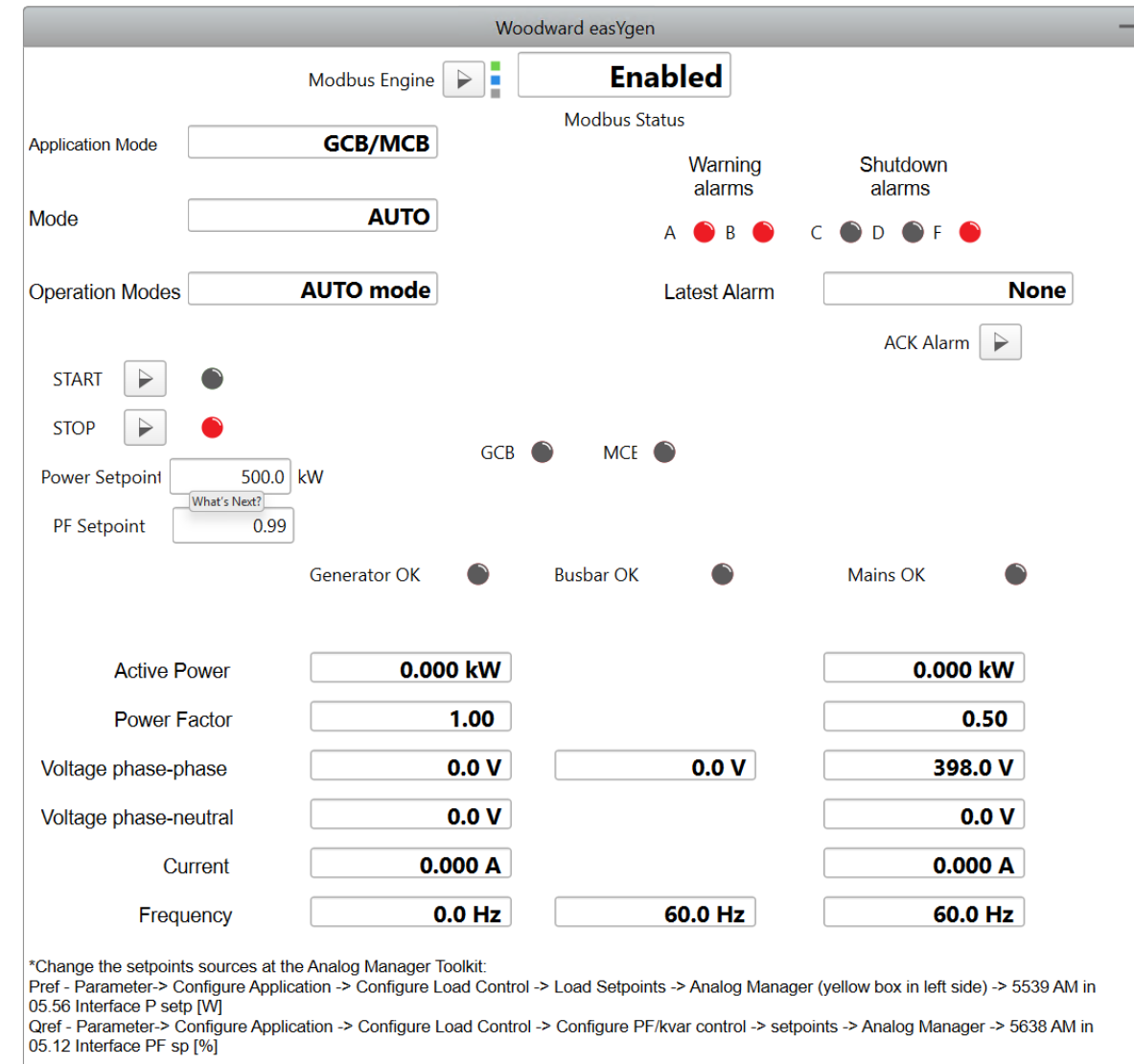
EPC Modbus on SEL RTAC – Why?

- ❑ **Direct Customer Impact** – Resolved a long-standing issue for Texas Tech where EPC Modbus values could not be read or written.
- ❑ **Enhanced Functionality** – Delivered an SEL RTAC project file enabling full read/write access to EPC Modbus registers.
- ❑ **Reusable Solution** – Created a framework that can be applied to other EPC Modbus integrations.
- ❑ **Builds Customer Trust** – Demonstrates Typhoon HIL’s ability to quickly solve real-world interoperability problems.

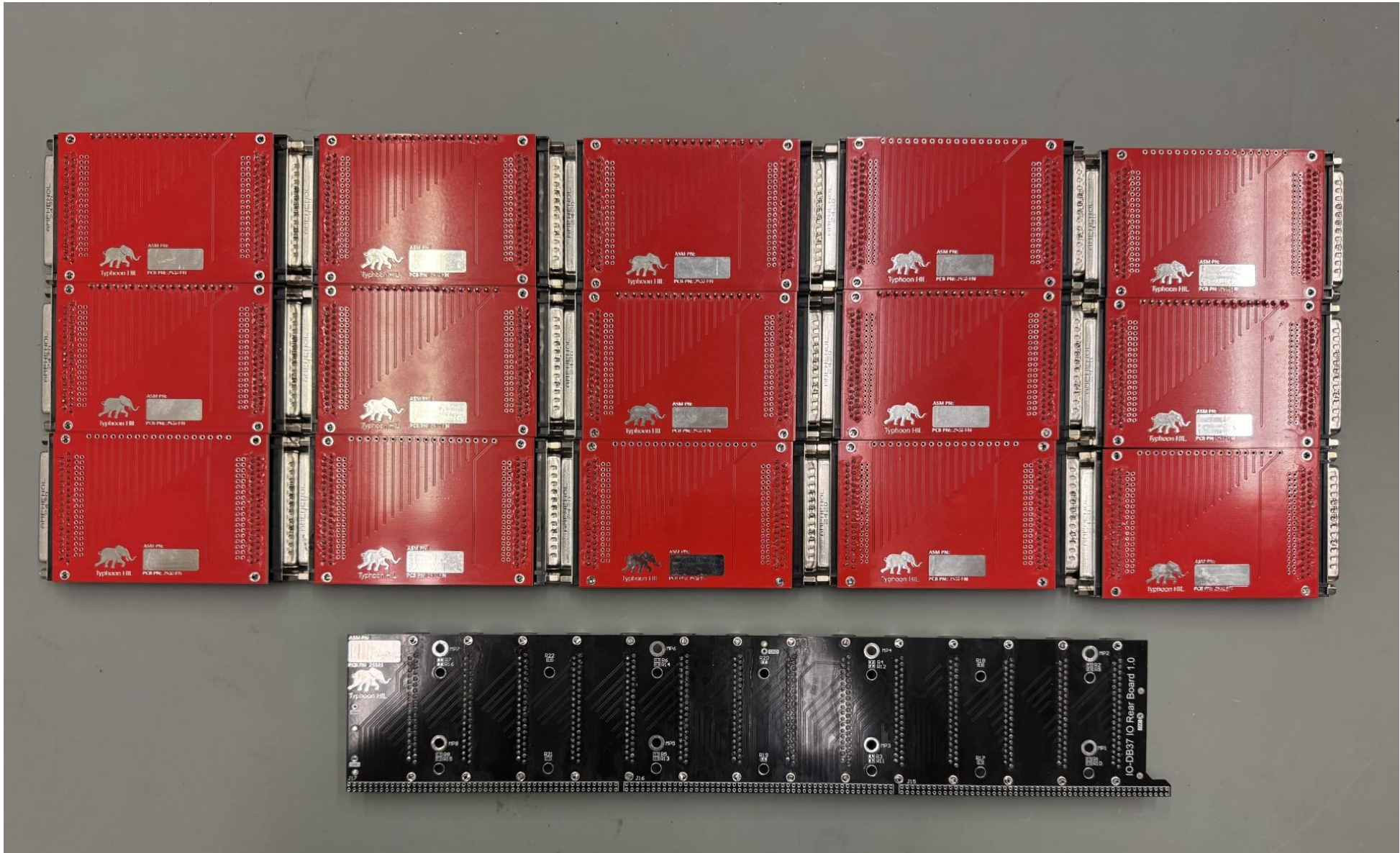


Miscellaneous Tasks

- ☐ Soldering
- ☐ Rack Construction, Shipping, and Receiving
- ☐ Created SEL 700G Unit Test Settings File
- ☐ Helped debug Woodward easYgen Modbus widget
- ☐ Helped with CNC machine project
- ☐ Presentations with [REDACTED] & [REDACTED]



Soldering



What's Next?

- ☐ Finish up my Junior & Senior year
 - Graduation: May 2027
- ☐ Plan to Stay in Greater Boston next Summer & the following Summer
- ☐ Hope to continue my learning
 - Through Work
 - 
 - Through Classes

Thank You!