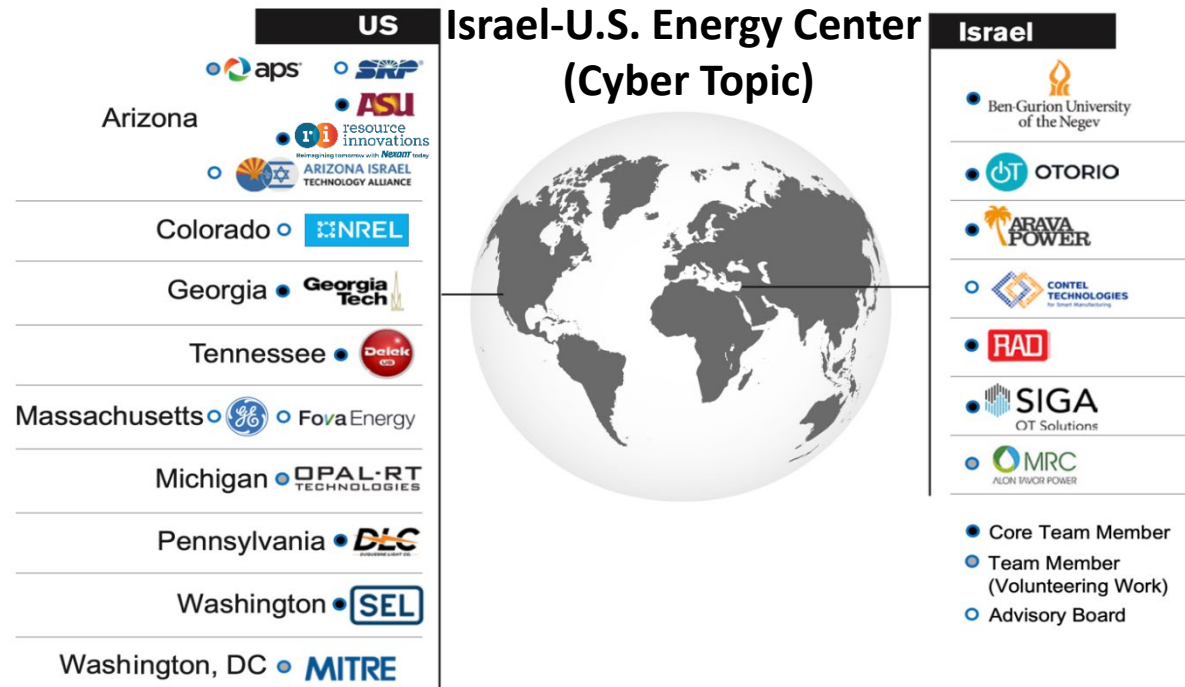


# Comprehensive **Cybersecurity** Technology for Critical Power Infrastructure **AI-Based** Centralized Defense and Edge Resilience

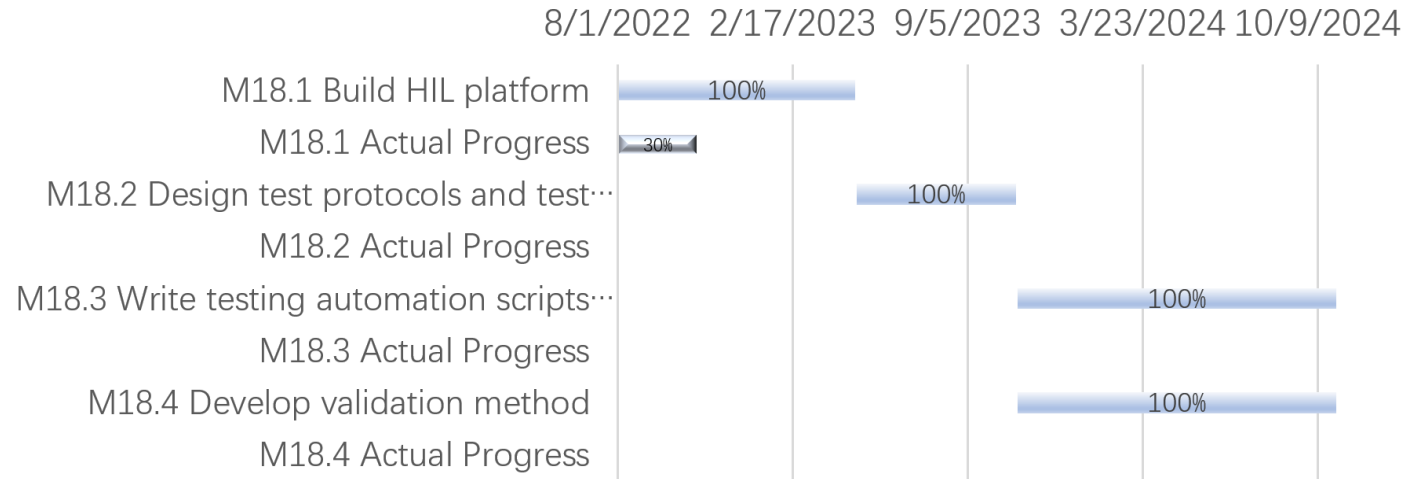


## Task 18 Hardware-in-the-loop Validation

Prepared by Qiushi Cui, Yang Weng

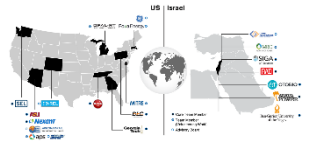
Aug. 21, 2022

# Gantt chart



#	Milestones	Milestone Date (MM/YY)
1	Task 18.1: Develop Software Models and Build HIL Platform	04/23
#	Deliverables Plan	Available Date (MM/YY)
1	HIL Platform Setup and Activation	04/22
2	HIL Platform Connection Setup	04/22
3	Simulation on IEEE C37.118 Slave Model	09/22

# Outline and Peripheral Devices



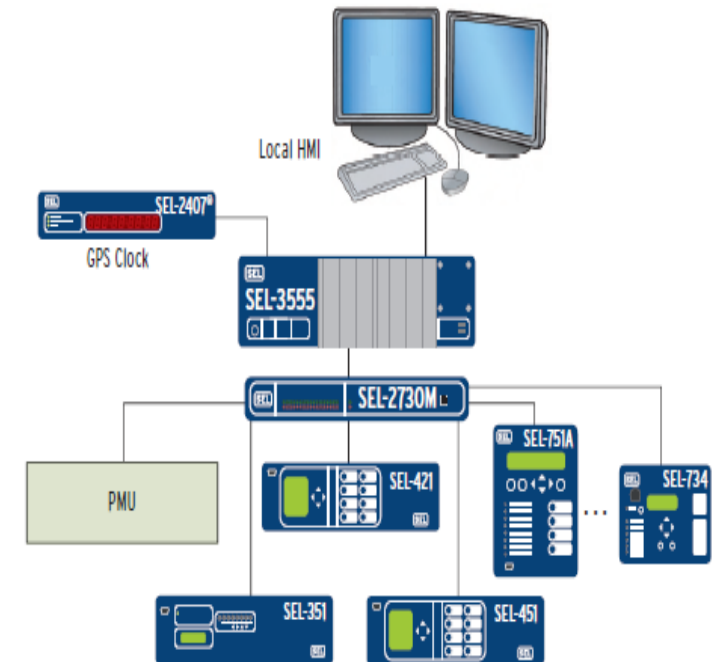
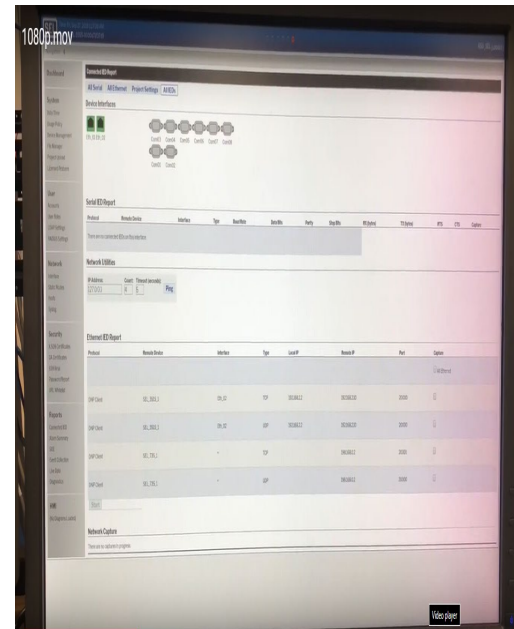
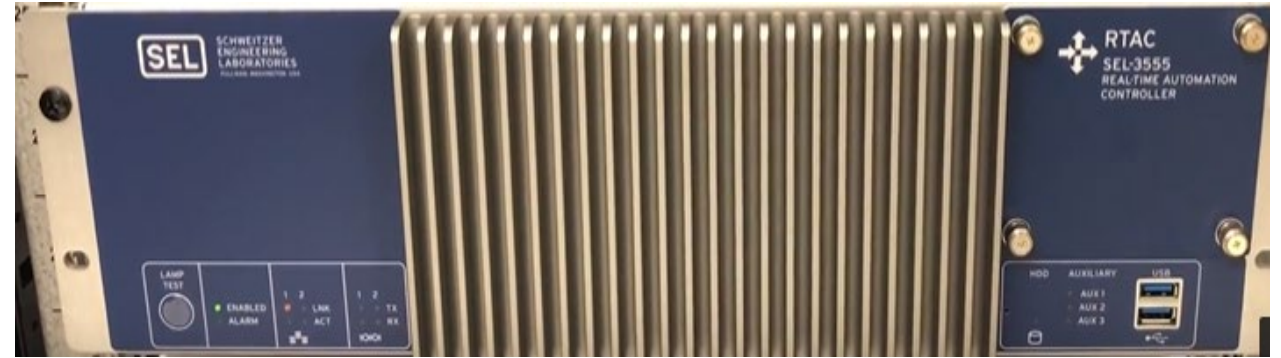
1. Peripheral devices preparation
2. HIL platform simulator
3. HIL platform connection to the local host
4. Realization of the IEEE C37.118 slave model to data output

## Major components:

1. Grid Connected PV system
2. Real-Time Automation Controller (SEL-3555)
3. Phasor Data Concentrator (SEL-3573)
4. Communication and Network Security Devices (SEL-2730, SEL-3620)
5. Intelligent Electronic Devices (SEL- 351s, SEL- 751 & SEL-735)
6. Satellite-Synchronized Clock (SEL-2401)
7. SEL Software: Rtac AcSELerator, PDC Assistant, AcSELerator QuickSet, SynchoWAVE Event.

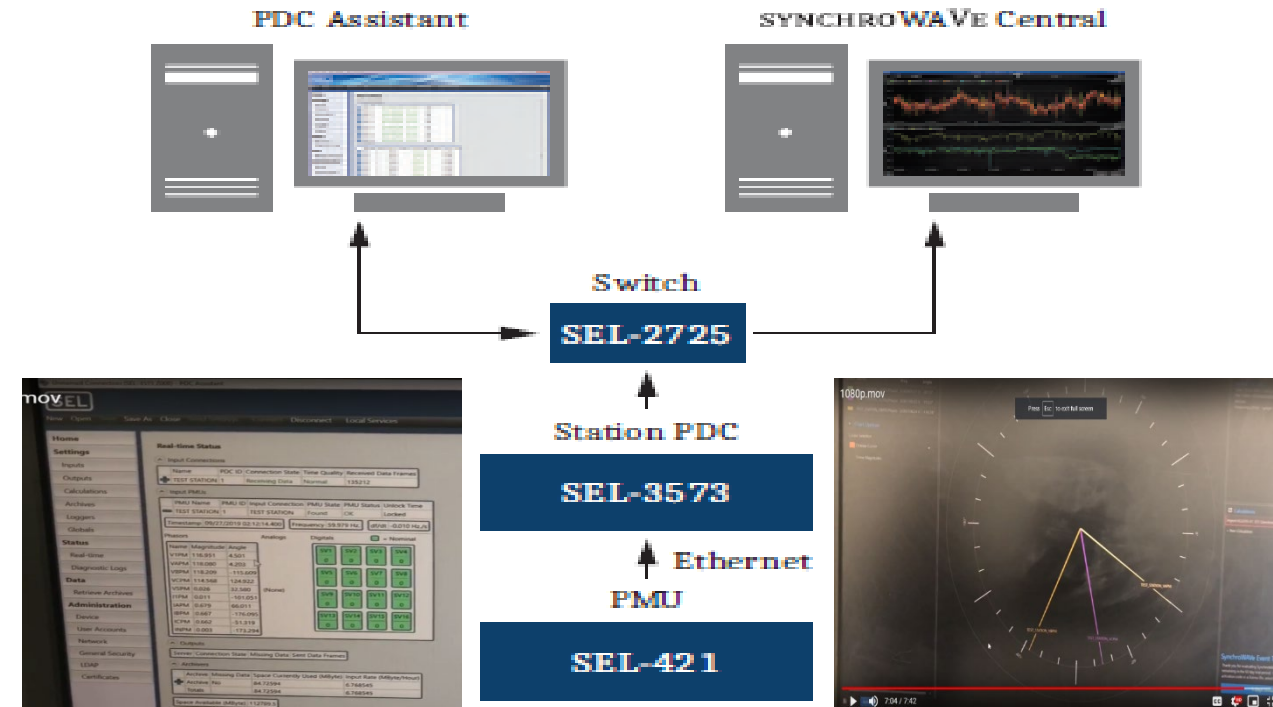
# Real-Time Automation Controller (SEL-3555) Software: Rtac AcSELerator

- RTAC login - Web Interface to Configuration IP addresses
- RTAC Data Base login - Rtac AcSELerator
- Select Communication Protocol (DNP) And Add Devices (SEL-351s) to create a project
- Add Binary/Analog input and output tags
- Go online, make sure offline pin is false under DNP Controller tab



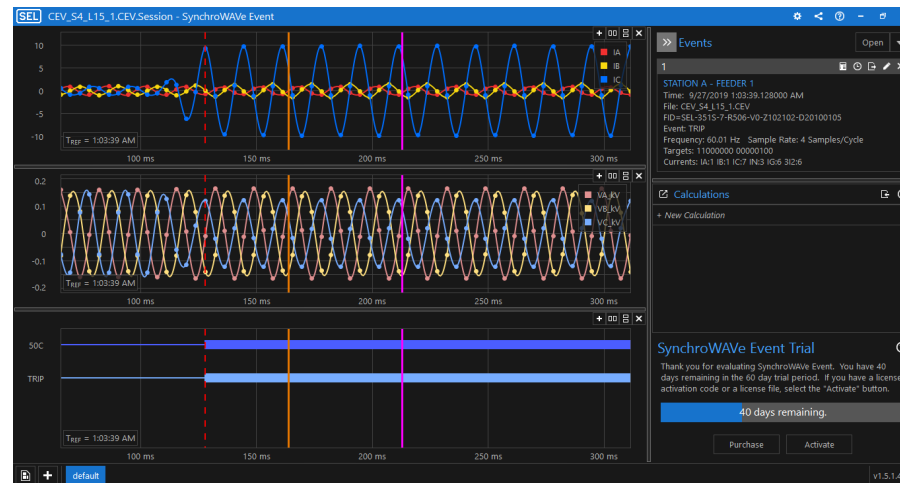
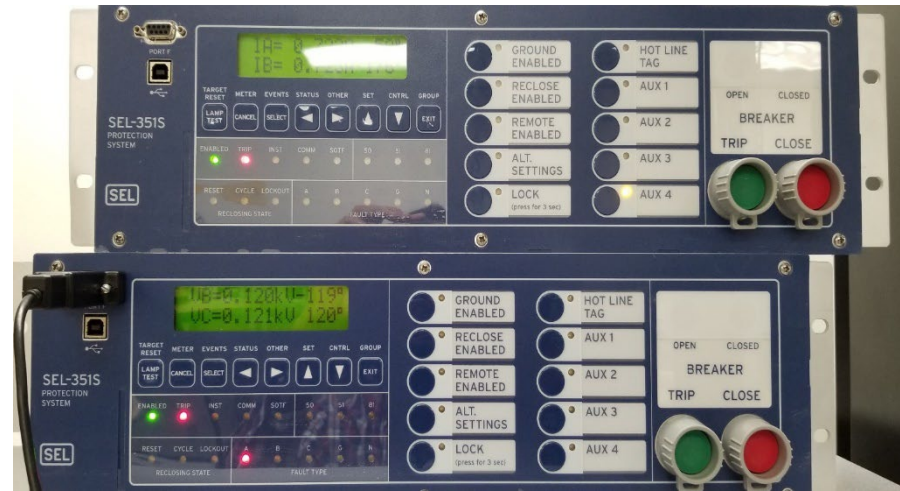
# Phasor Data Concentrator (SEL-3573), Software: PDC Assistant

- Allows to time-align and concentrate IEEE C37.118-compliant phasor data from PMU
- Integrated archiving capability of all PMU data
- Set up the relays PMU with AcSELeerator Team
- Configure SYNCHROWAVE PDC Assistant Settings
- PDC Assistant: perform different calculations on streaming phasor data



# Intelligent Electronic Devices (SEL- 351s, 751, 735, 2401, C662) Software: AcSELERator QuickSet, SynchoWAVE Event

- Comprehensive feeder and overcurrent protection
- Reliable Class A measurements
- Accurate Time Synchronization to PMUs
- AcSELERator QuickSet: Set up Relays, Meter and GPS settings
- SynchoWAVE Event: Analysis of events gather though QuickSet



# Communication and Network Security Devices (SEL-2730M, 3620)

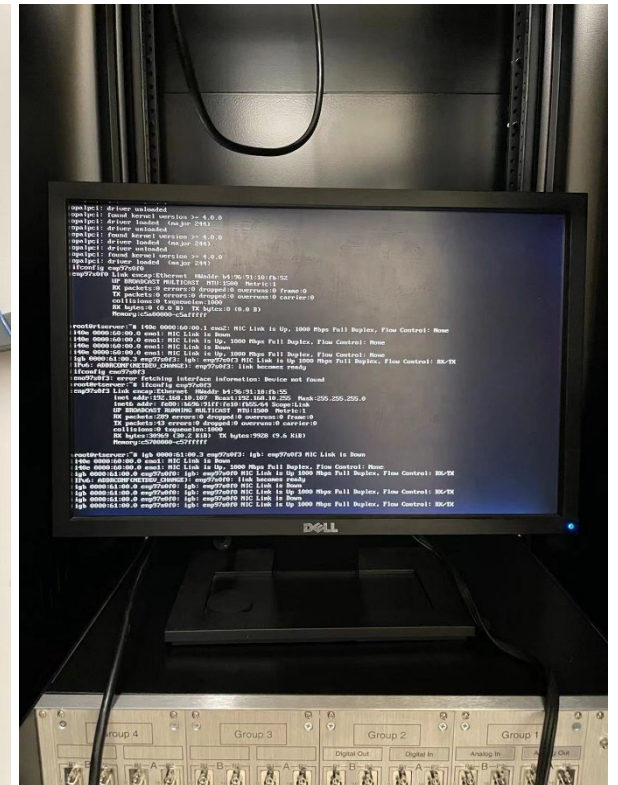
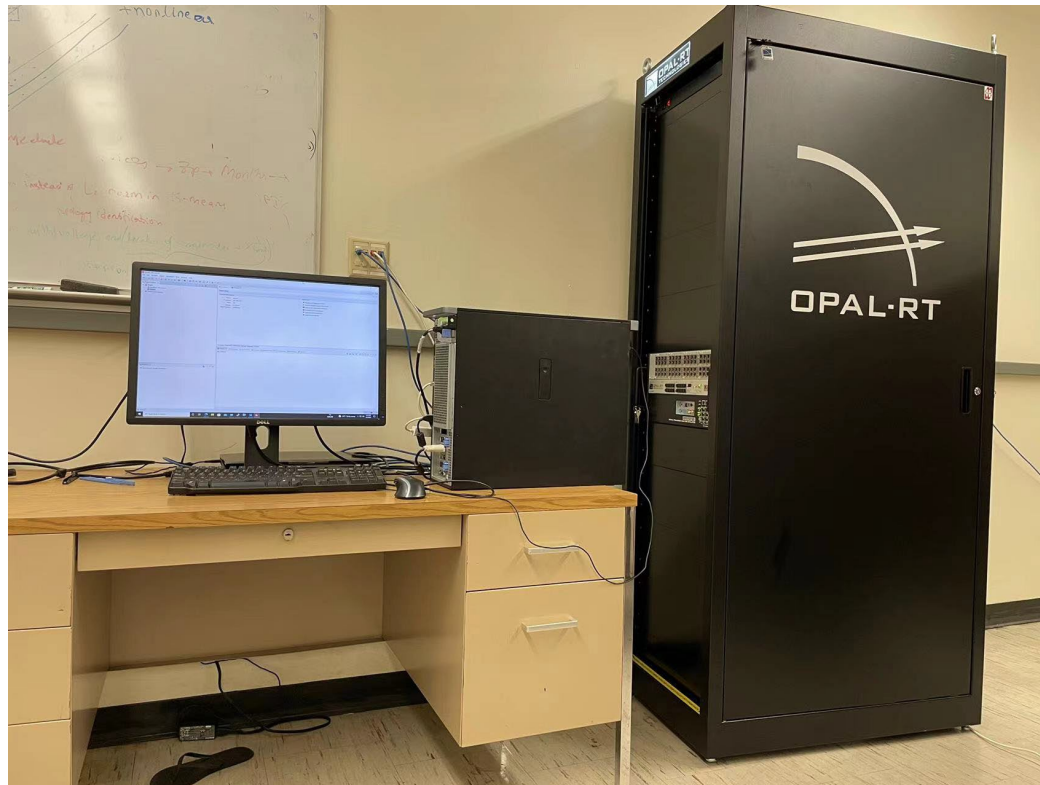
- Perform secure and proxy user access for serial-and Ethernet-based intelligent electronic devices (IEDs)
- Ethernet connectivity for SCADA, engineering access, and control, and it offers the same reliability found in SEL protective relays.



# Software preparation



1. Download the RT-lab installation pack from the OPAL-RT website
2. Install it on our secondary hard drive for better software performance
3. Set up the software workspace at that drive—all of the models and simulation files will be stored in that workspace folder.

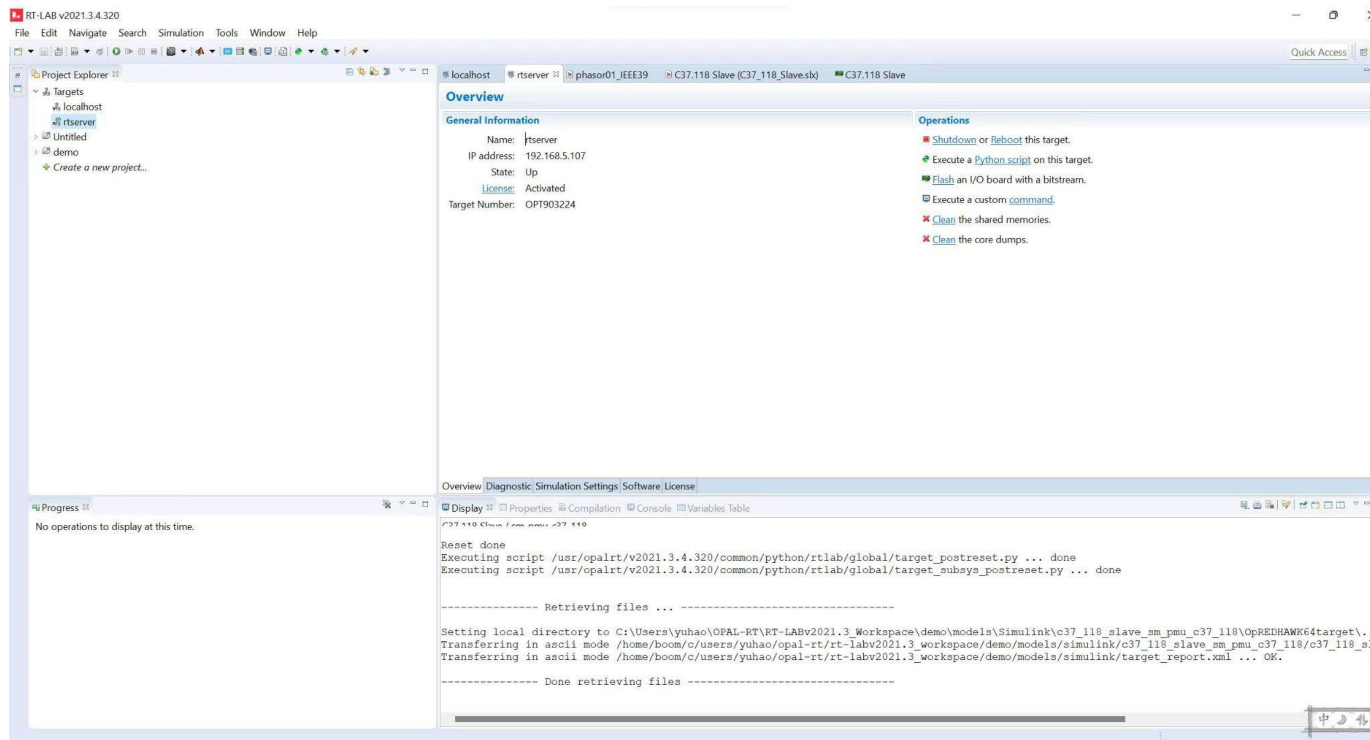




# Software configuration



1. Add localhost in the target tag, which has the IP address of 127.0.0.1 to indicate the local computer
2. Activate multiple RT Lab software in different local computers for multi-tasking.
3. Directly utilize an ethernet cable to connect the OPAL-RT simulator and lab server
4. Utilize the USB ethernet adapter for the lab server & the ENO 1 port on the simulator for remote control
5. Configure the same IP address of our USB ethernet port as the simulator port, which allows successful communication between the simulator and the lab sever



The interface of RTlab software shows a successful connection to the simulator.

# Streaming data visualization



To further verify the simulator's output, we connected RT-LAB with two different software to visualize the streaming data.

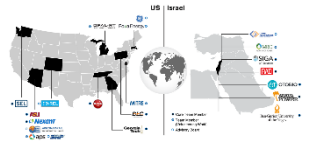
1. The first software is PMU Connection Tester, which is a Grid Protection Alliance (GPA) developed Windows GUI application used to validate connections from phasor measurement devices.

The screenshot displays the PMU Connection Tester application. The main window is titled "PMU Connection Tester" and shows the following details:

- Connection Parameters:** Host IP: 192.168. 5.107, Port: 8900, Protocol: IEEE C37.118-2005, Device ID Code: 235.
- Configured frame rate: 60 frames/second** graph showing a fluctuating blue line.
- Real-time Frame Detail:** Frame Type: DataFrame, Time: 2022-05-03 18:27:54.966, Frequency: 60.0000 Hz, Angle: 0.00572957795130823°, Magnitude: 0.0123 (0.0214) kV.
- Hex Dump:** AA 01 00 3E 00 EB 62 71 74 2A 0F 0E BF C8 00 00 30 39 00 01 30 38 34 D7 30 38 CB 27 22 19 00 00 04 D2 00 01 04 D1 34 D7 04 D1 CB 27 03 68 00 00 00 00 3E C8 01 0D 00 63 00 0A 01 0D 8B 21

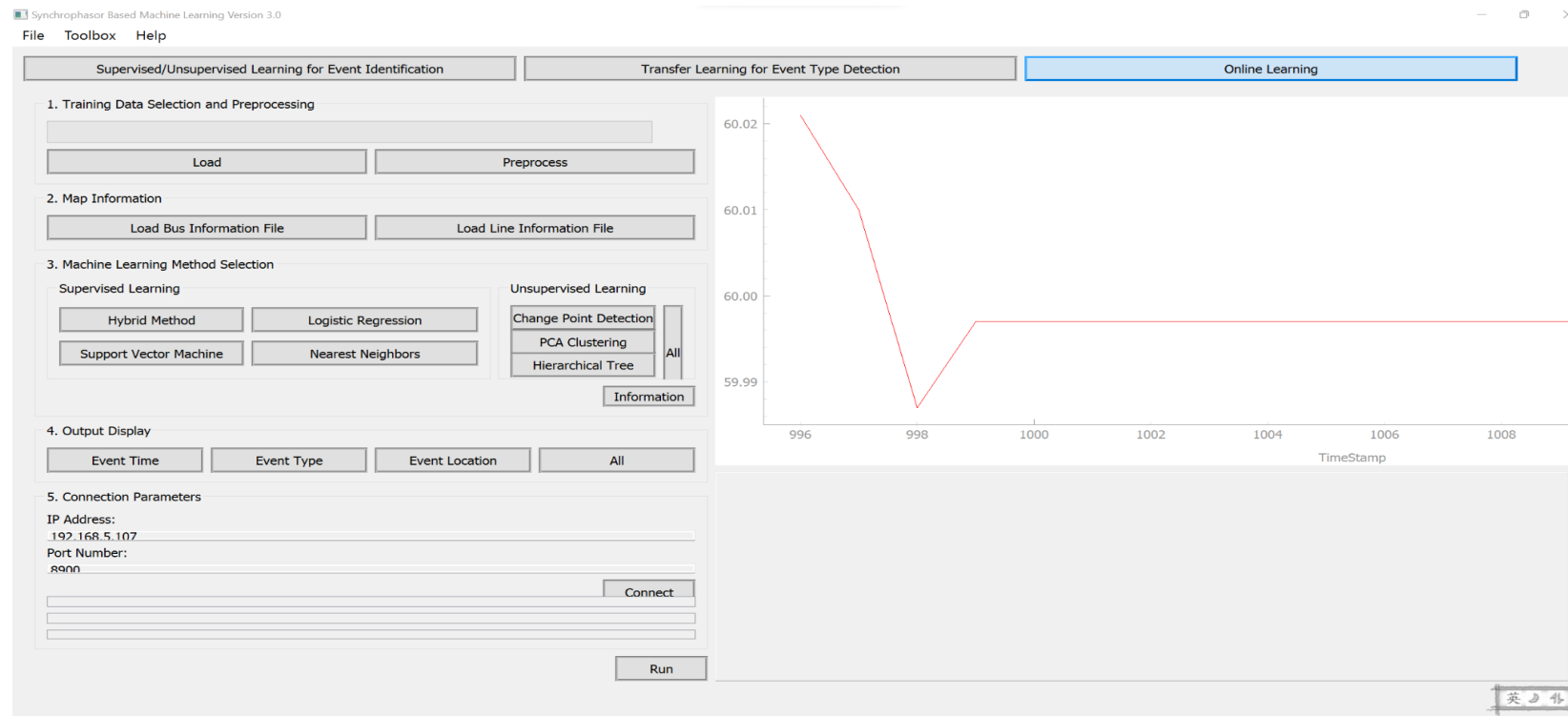
Screenshot of successful connection on PMU Connection Tester

# Streaming data visualization



2. The second software is Synchronphasor Based Machine Learning (SBML) software which is developed by our group for streaming data fault detection.

By inputting the same IP address and the port number of the C37.118 Slave model from the simulator to two different software, both software can successfully communicate and plot the streaming data.

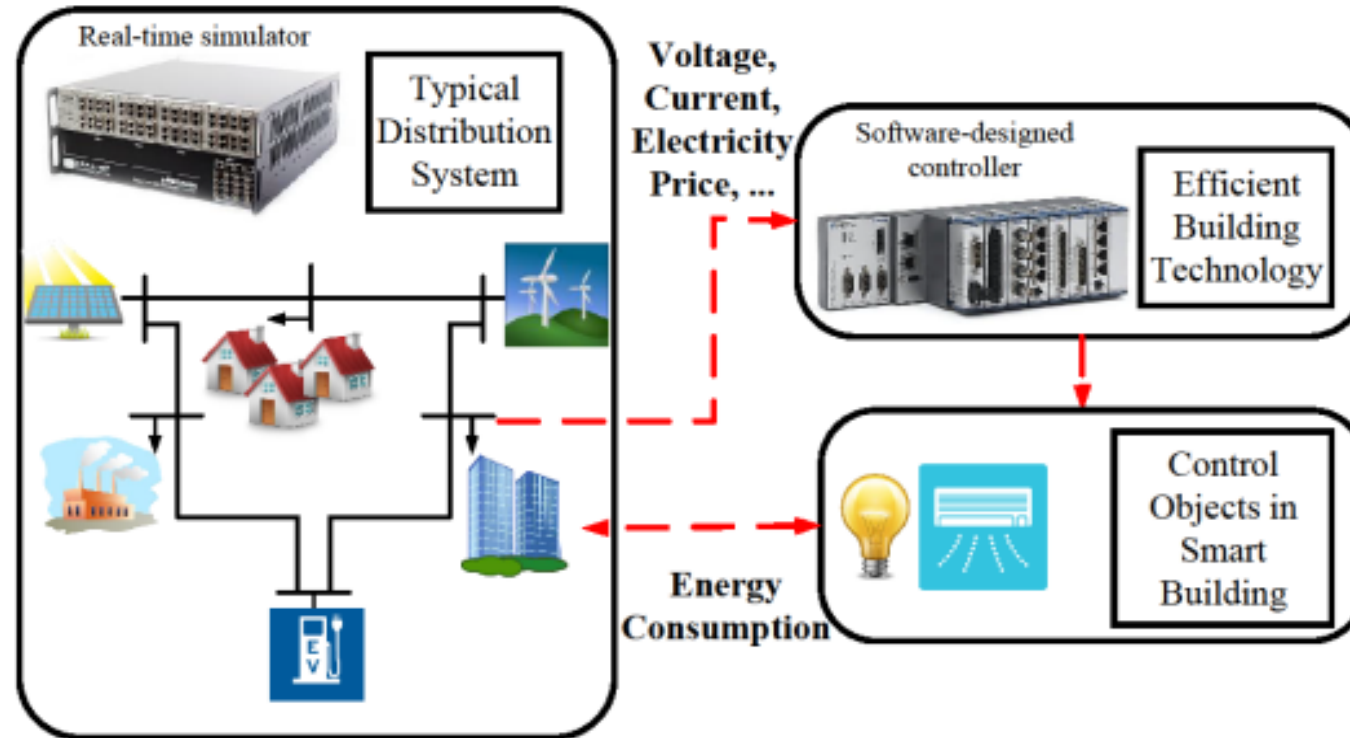


Screenshot of successful connection on SBML software

# Case study



## 1. Real-Time Performance Monitoring of Load-Flexible, Grid-Connected Buildings



Hardware setup of the EBT applications for data generation and verification

# Validation (Utility-Connected Grid and Hardware-In-the-Loop)

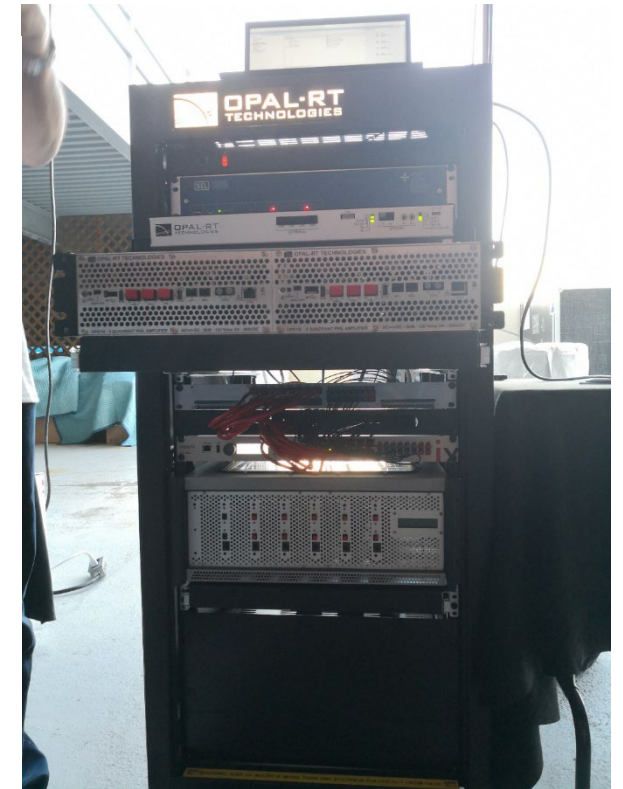
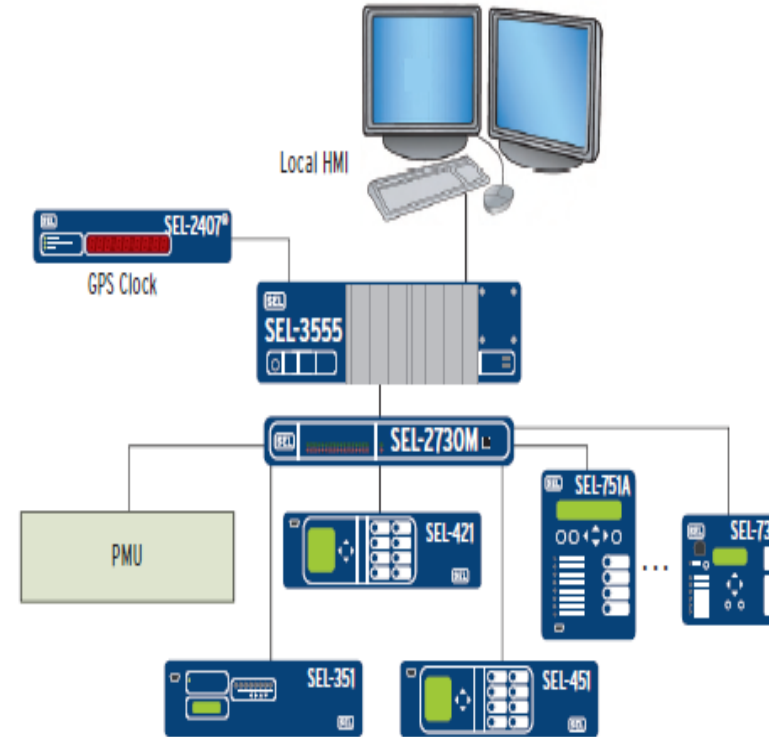


## 1. Microgrid controller

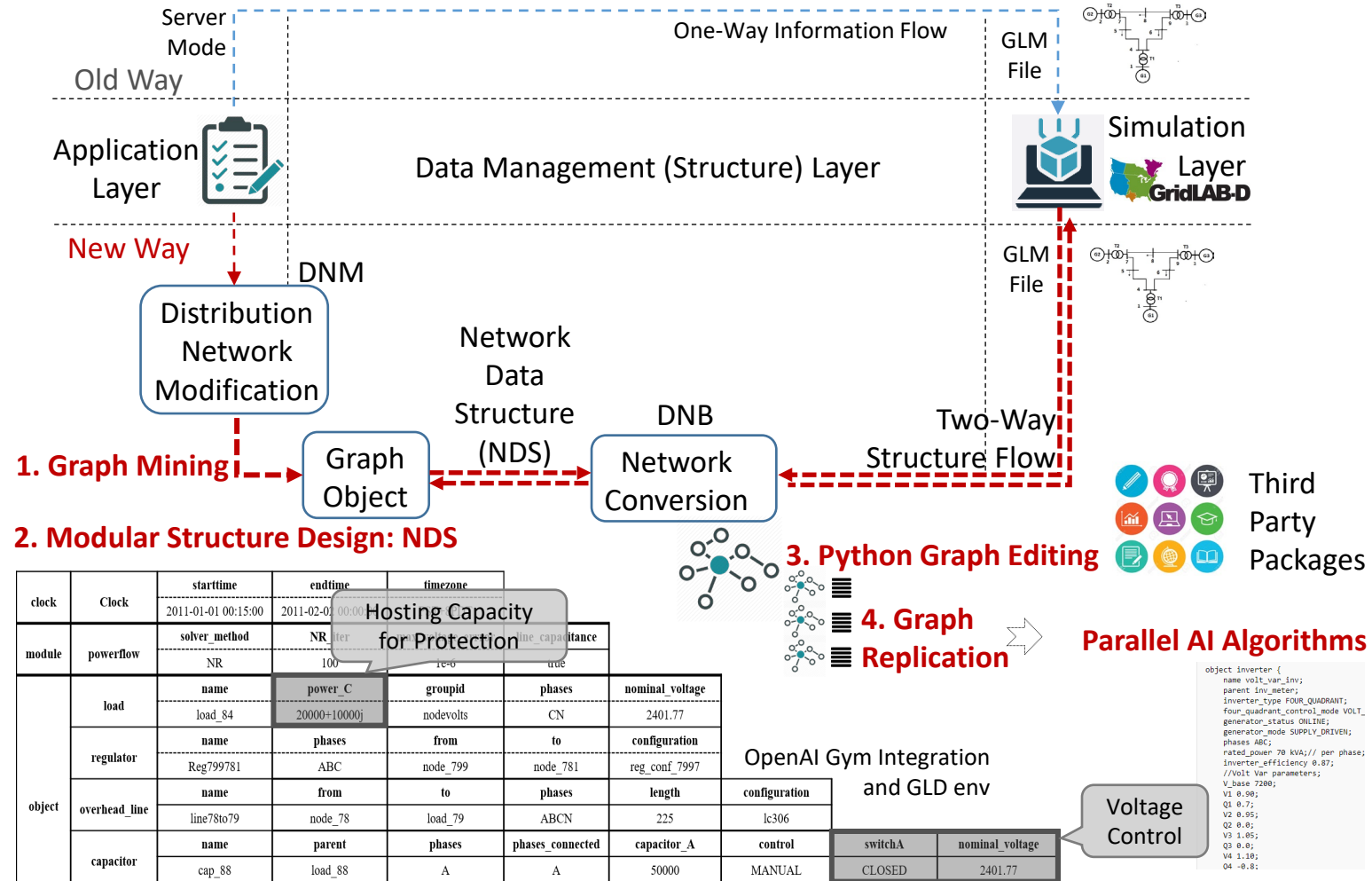
1. More IEDs interfacing with RTAC through available communication protocol and ports
2. Instruments and Control Circuits system with reclosers and breakers

## 2. SCADA HMI

## 3. Power-HIL



# Preliminary Co-Simulation Platform



# Thanks for your attention!

