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

Qiushi Cui, Yang Weng, Zhihao Ma, Hao Yu, and Corey Mai

Prepared for

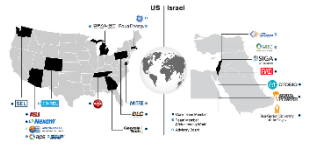**Eitan Yudilevich, Eynan Lichterman, and Tal Fischelovitch**

Task 18: Hardware in the Loop Validation

Milestones:

- **Task 18.1: Develop Software Models and Build HIL Platform**

- Task 18.2: Design Test Protocols and Test Plans with the Help of Industrial CMs

- Task 18.3: Write and Develop Testing Automation Scripts

- Task 18.4: Develop Validation Method for Detecting of Cyberattack Events

Develop Software Models and Build HIL Platform

Achievements:

- HIL Platform Setup and Activation

- HIL Platform Connection Setup

- Software Connection Setup

- Simulation on IEEE 39-bus System

- Simulation on IEEE C37.118 Slave Model

- C37.118 Slave to HIL Applications
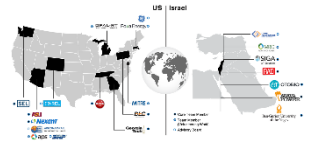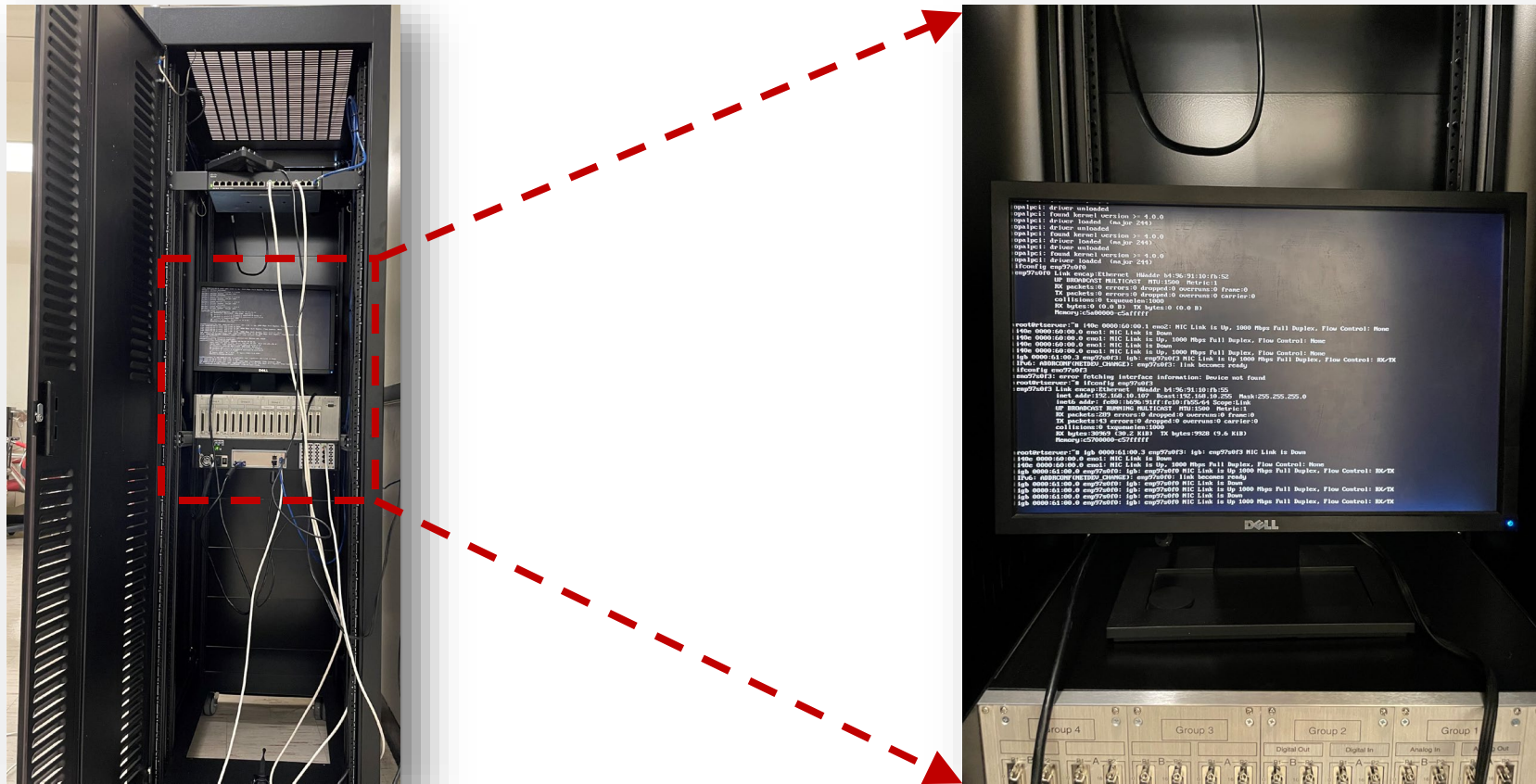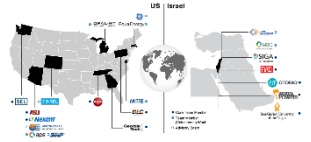
HIL Platform: Unbox & Set Up
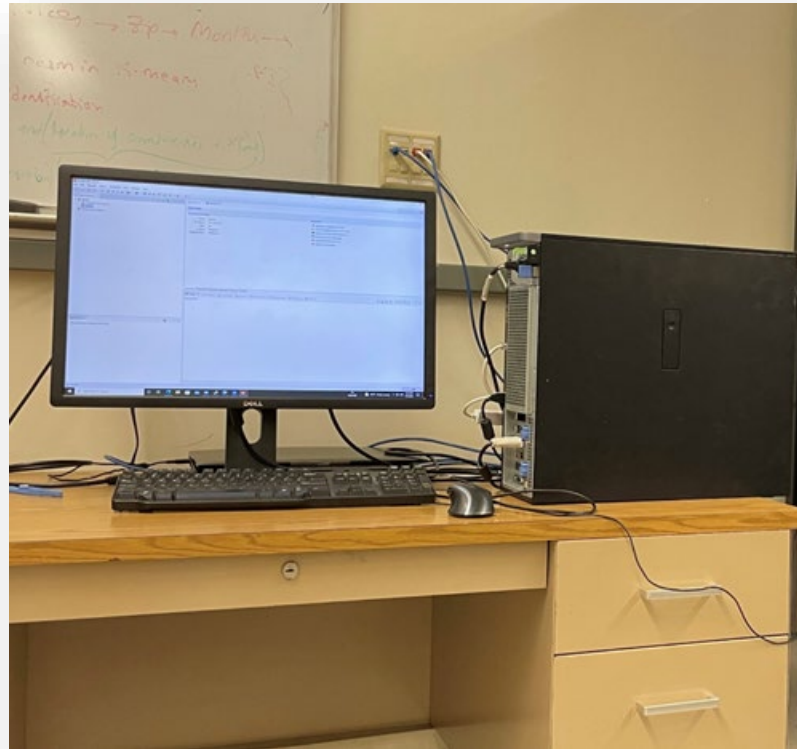

Shipment Arrived In
Protecting Crate

Simulator Unboxed
and Powered Up

- Set up an external monitor for direct system monitoring.
- Installed the operating system on OPAL-RT simulator.
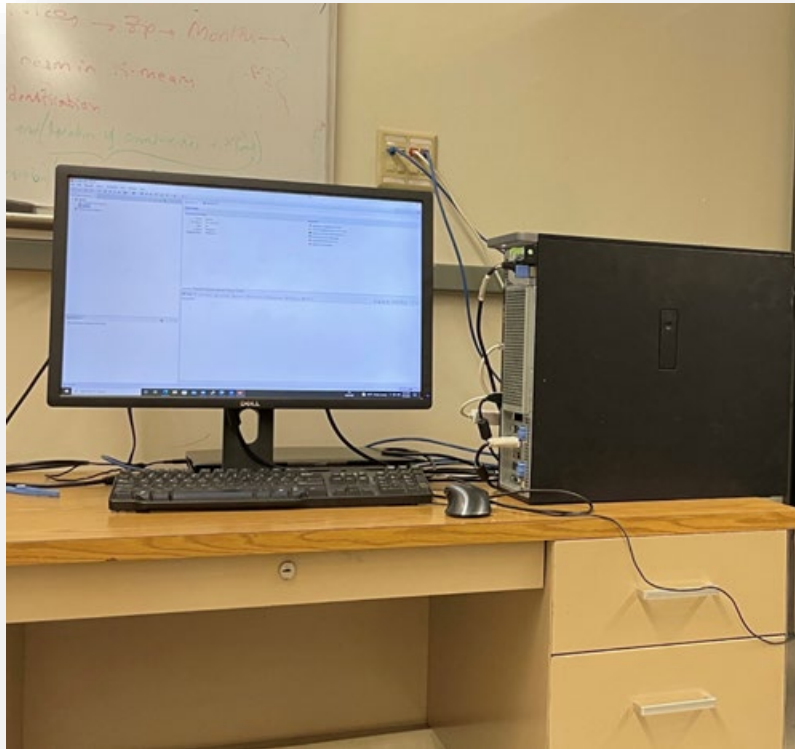
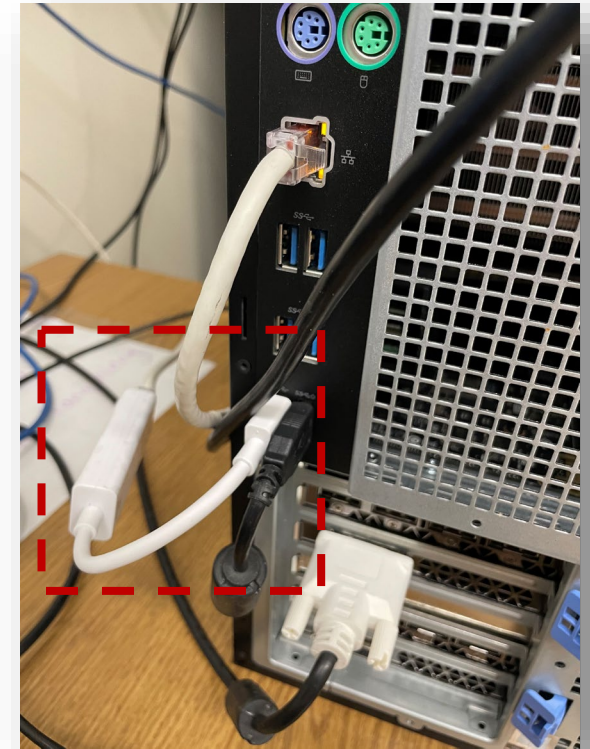# HIL Platform: Simulator License Activation

Activate

OPAL-RT Simulator

- Installed RT-Lab software to our lab server.
- Retrieved the license and activated our OPAL-RT simulator.

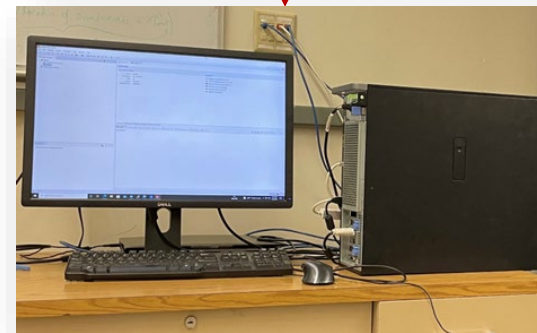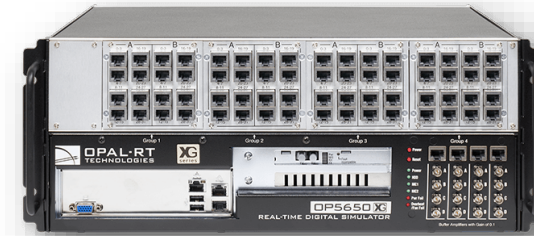# HIL Platform: Server Upgrade

Install

- Installed ethernet adapter to our server.
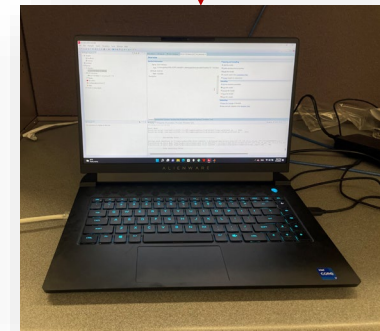
- Allowed our server for online/offline control.

Configure

Server

Laptop

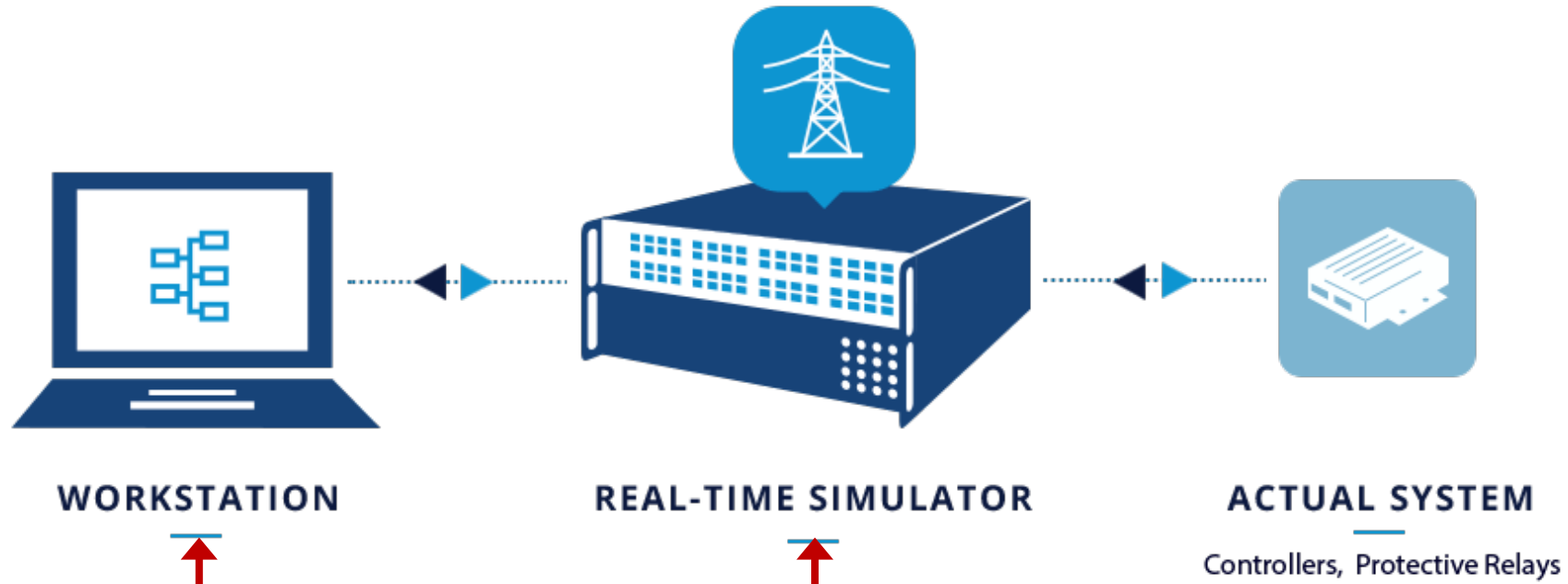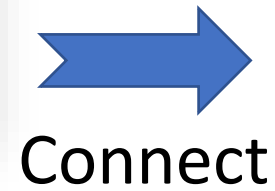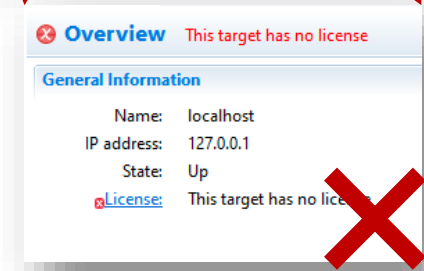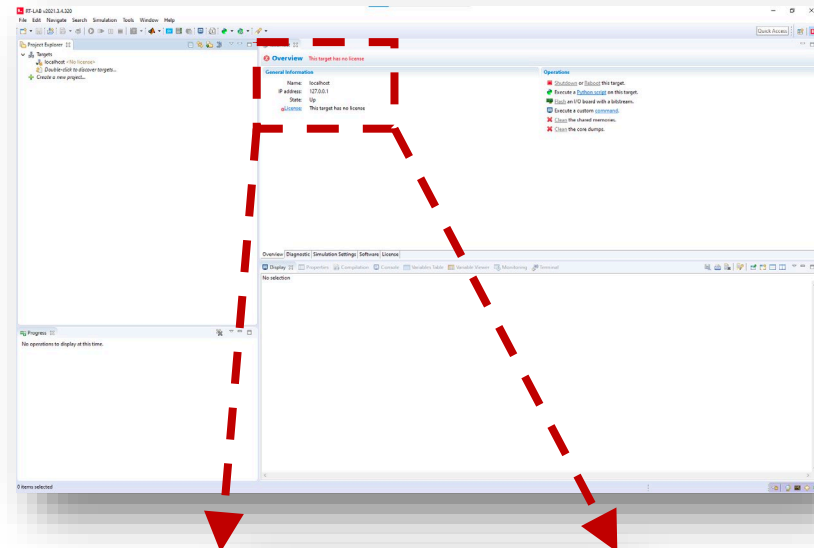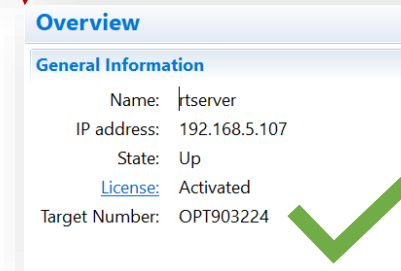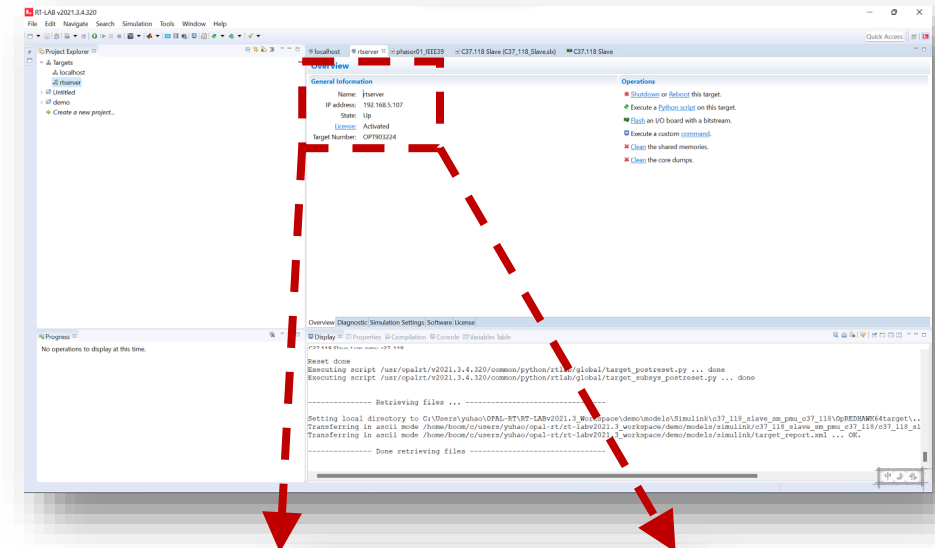- Configured the Opal-RT simulator with different connections for multi-tasking.
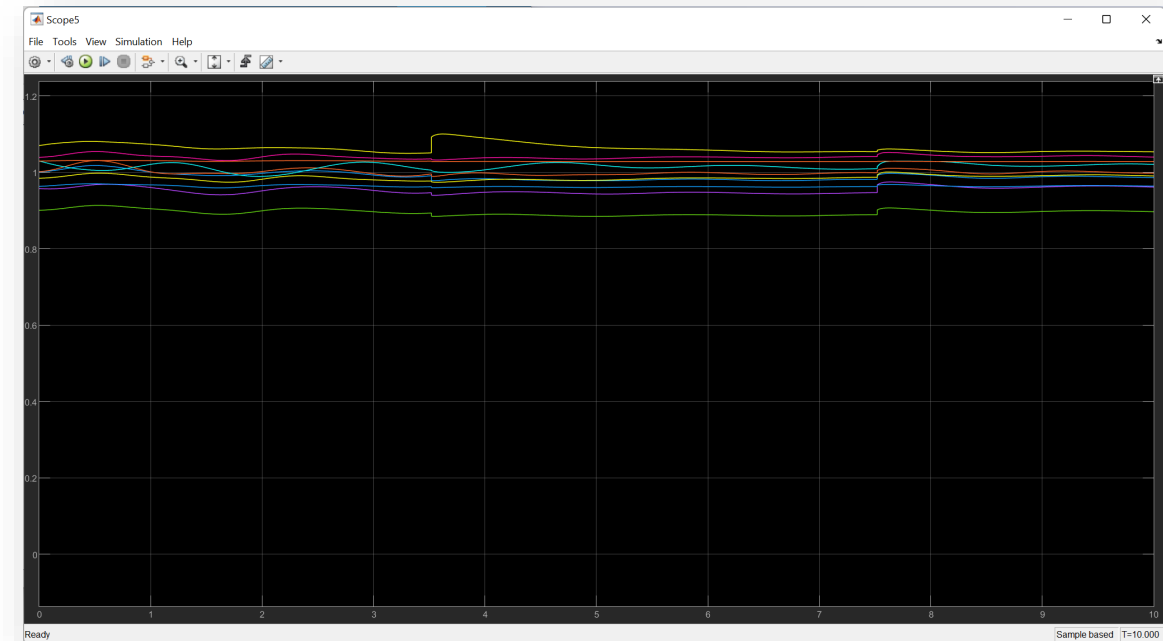
HIL Platform: Overview

WORKSTATION

REAL-TIME SIMULATOR

ACTUAL SYSTEM

Controllers, Protective Relays
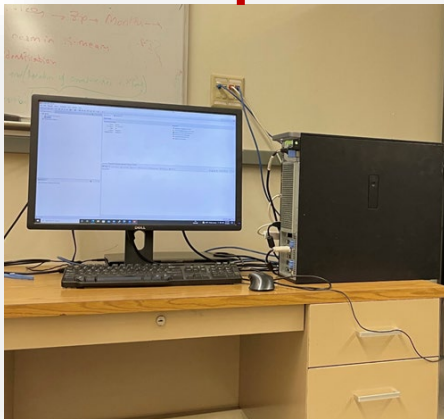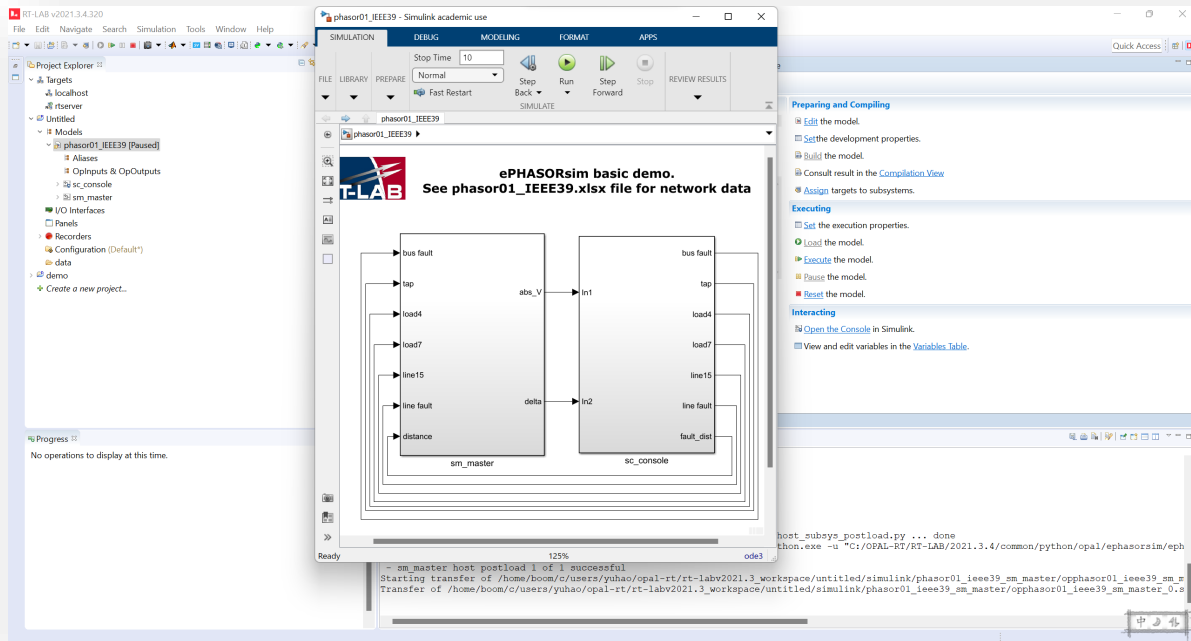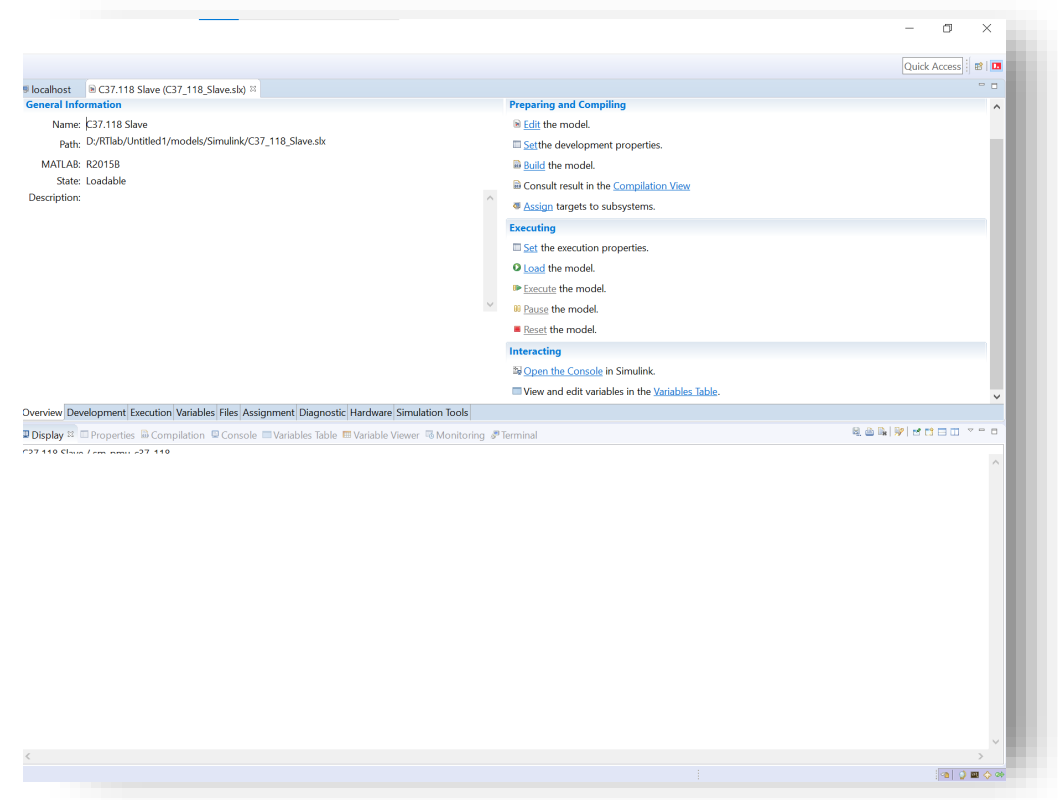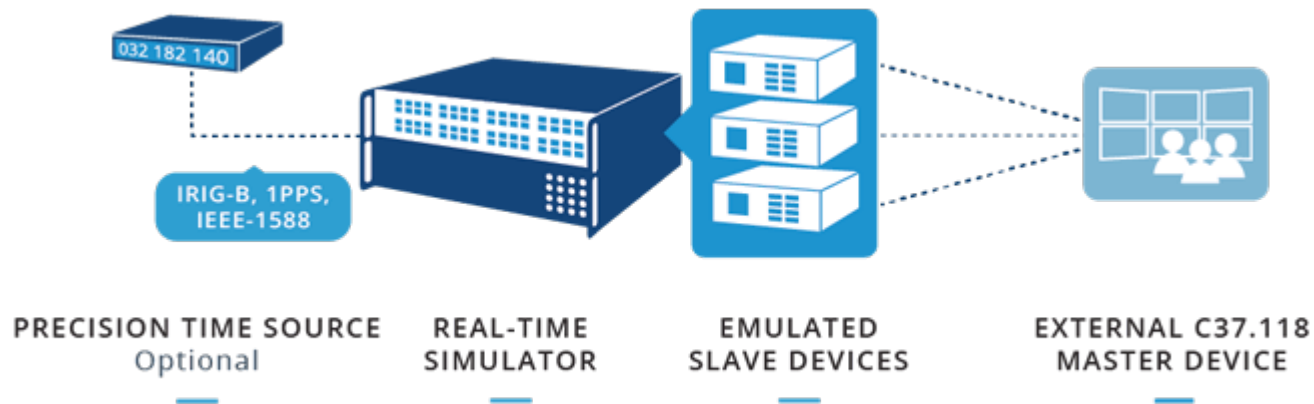
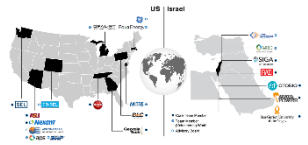# Software: Connection Set Up

Connect

- Installed the Rt-Lab and connected successfully to our Opal-RT simulator.
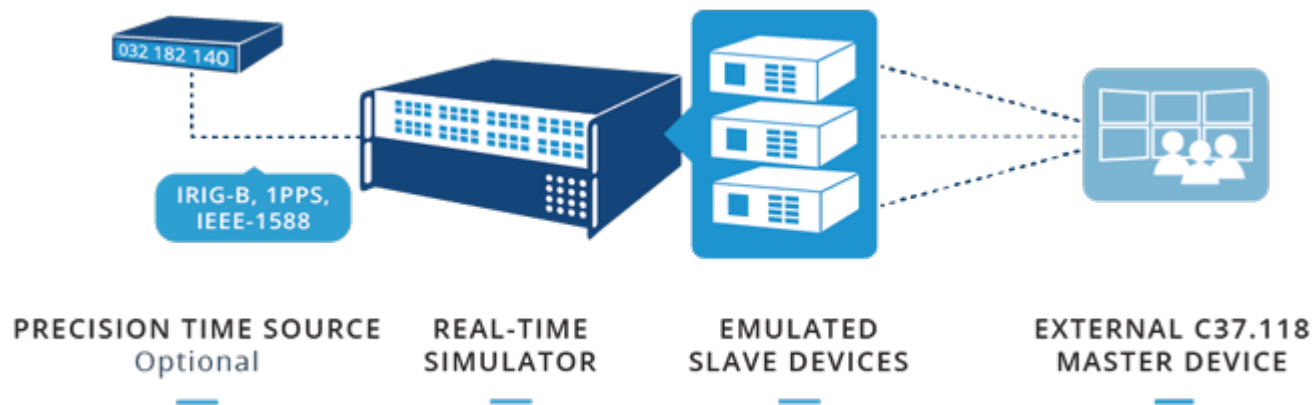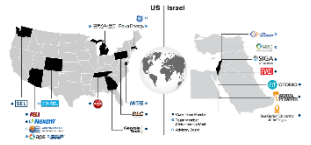
Software: IEEE 39-bus Simulation

- Configured the IEEE 39-bus test system and simulated fault events.

PRECISION TIME SOURCE
Optional

REAL-TIME
SIMULATOR

EMULATED
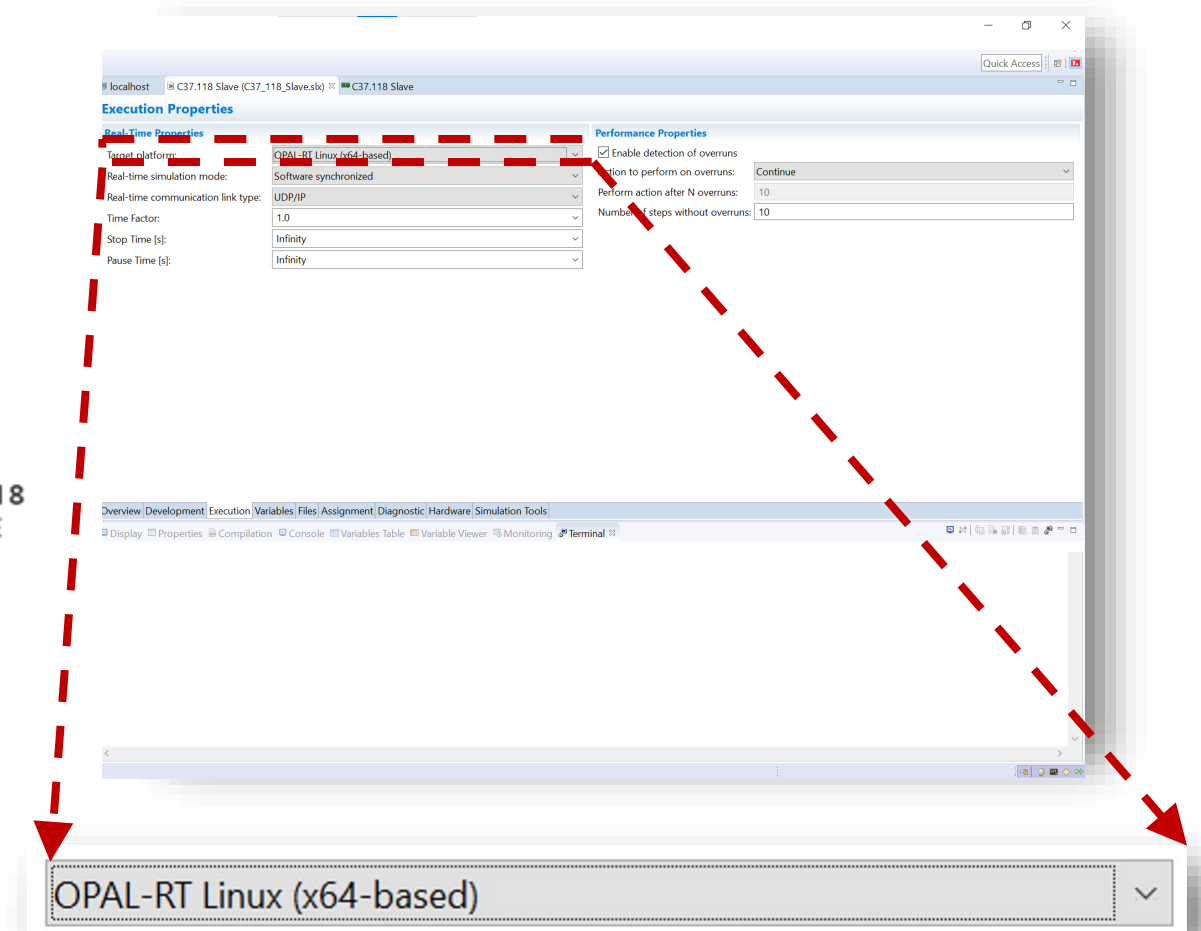SLAVE DEVICES

EXTERNAL C37.118
MASTER DEVICE

- Configured the C37.118 slave model and phasor output setting.

Software: C37.118 Slave Target Platform

PRECISION TIME SOURCE
Optional

REAL-TIME
SIMULATOR

EMULATED
SLAVE DEVICES

EXTERNAL C37.118
MASTER DEVICE

IRIG-B, 1PPS, IEEE-1588

032 182 140

- Configured the target platform.

OPAL-RT Linux (x64-based)

Software: C37.118 Slave I/O Interface
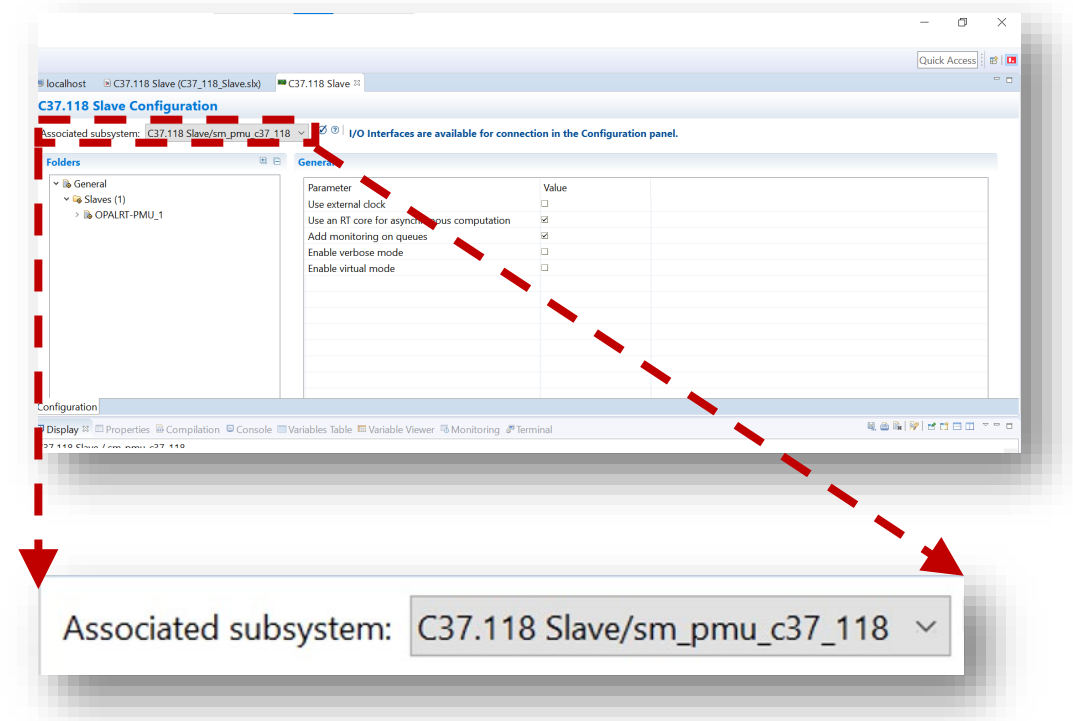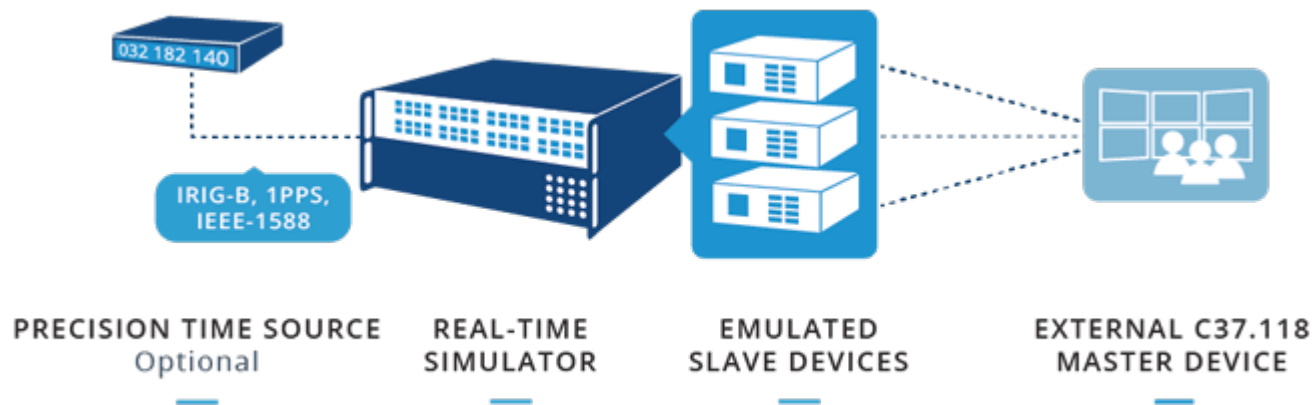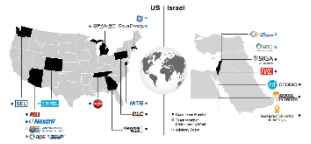
- Connected C37.118 Slave model to a subsystem.

Output Model

Software: C37.118 Slave Connection Parameters

PRECISION TIME SOURCE
Optional

REAL-TIME
SIMULATOR

EMULATED
SLAVE DEVICES

EXTERNAL C37.118
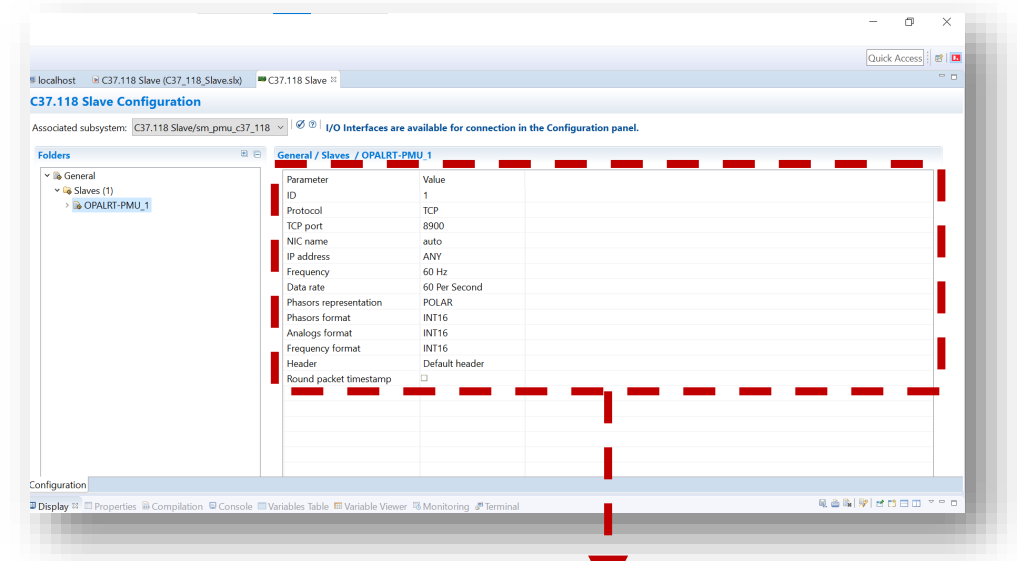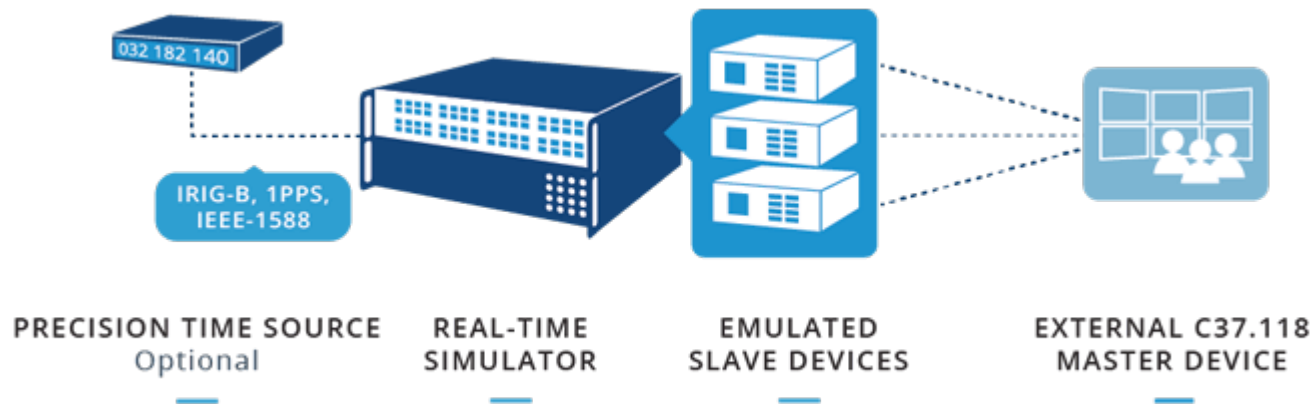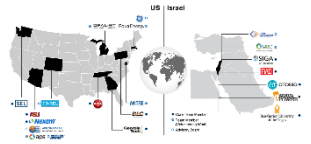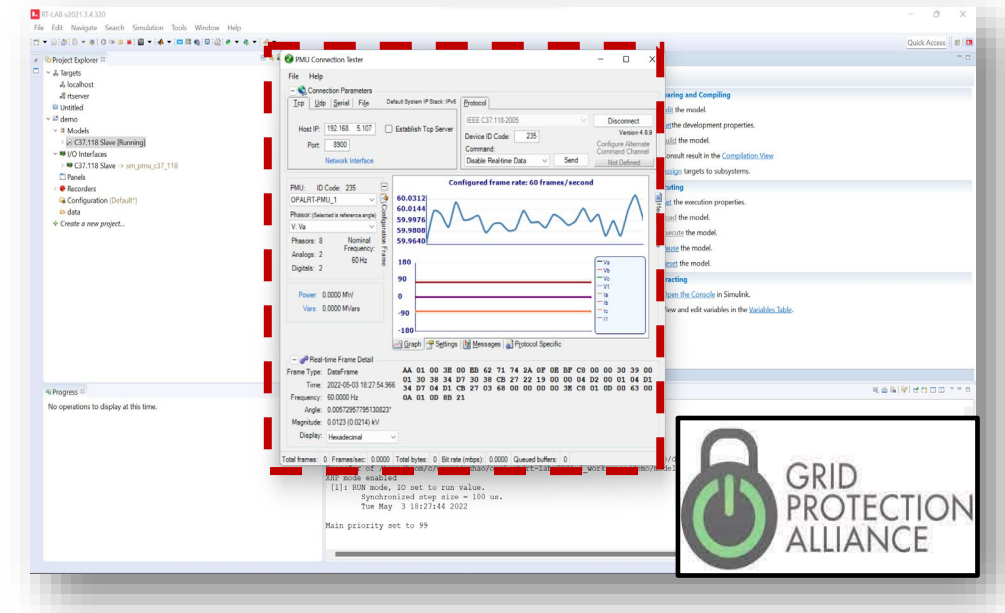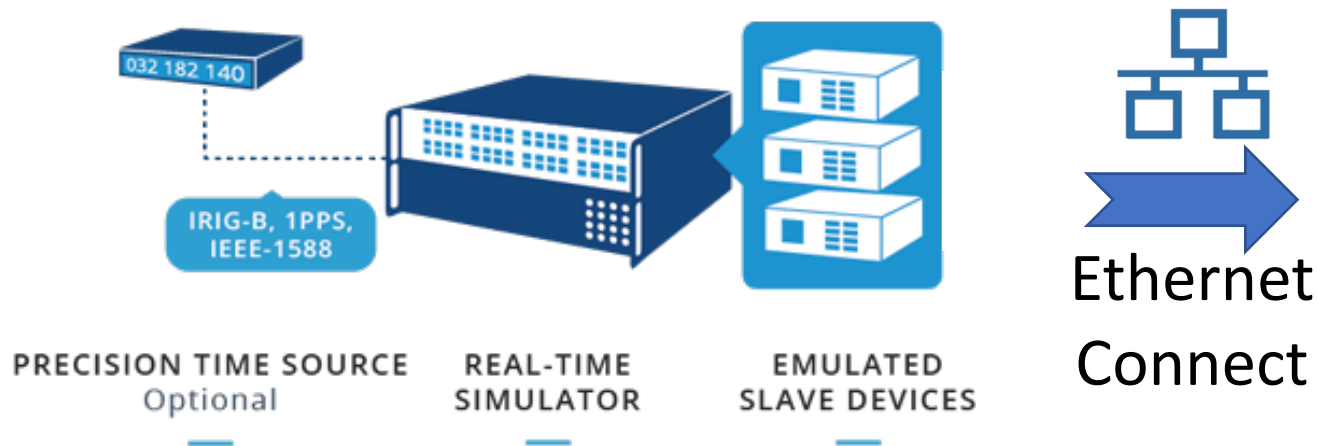MASTER DEVICE

- Configured the C37.118 slave model connection parameters
    - Protocol
    - Port Number
    - IP Address

Parameter	Value
ID	1
Protocol	TCP
TCP port	8900
NIC name	auto
IP address	ANY
Frequency	60 Hz
Data rate	60 Per Second
Phasors representation	POLAR
Phasors format	INT16
Analogs format	INT16
Frequency format	INT16
Header	Default header
Round packet timestamp	☐

PRECISION TIME SOURCE
Optional

REAL-TIME SIMULATOR

EMULATED SLAVE DEVICES

Ethernet Connect

- Connected successfully to the Grid Protection Alliance (GPA) commercial software: PMU Connection Tester.

Software: C37.118 Slave to PMU Connection Tester
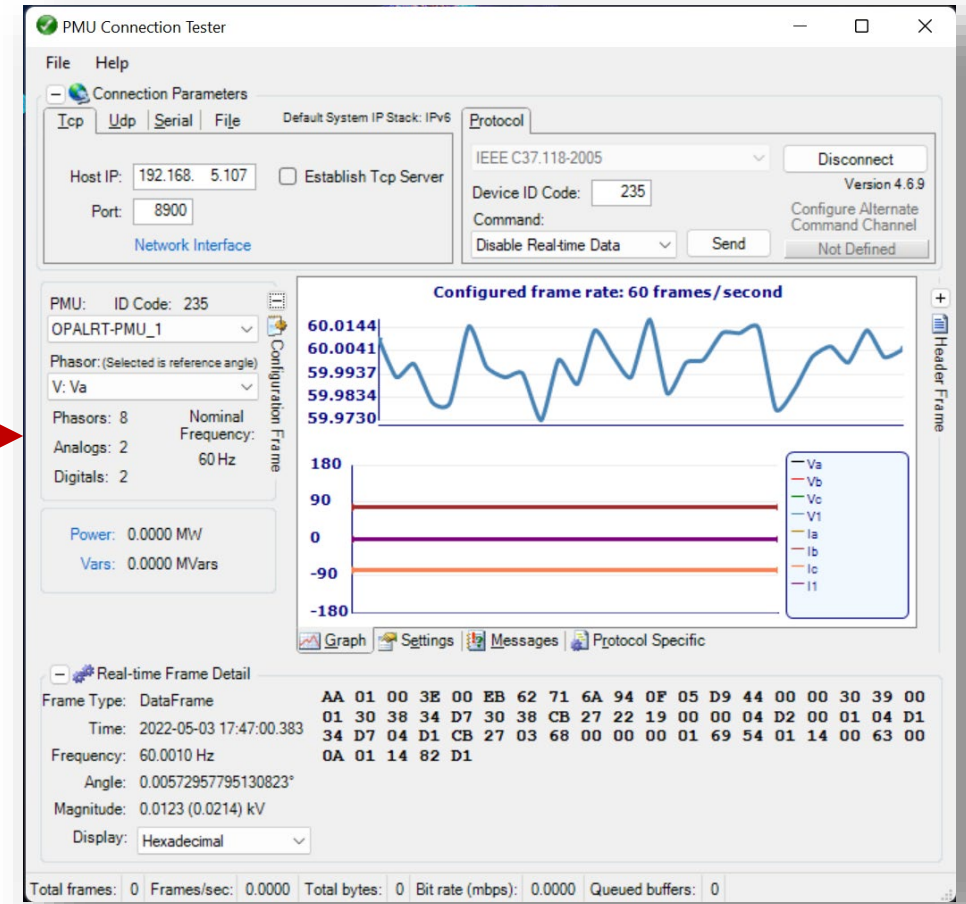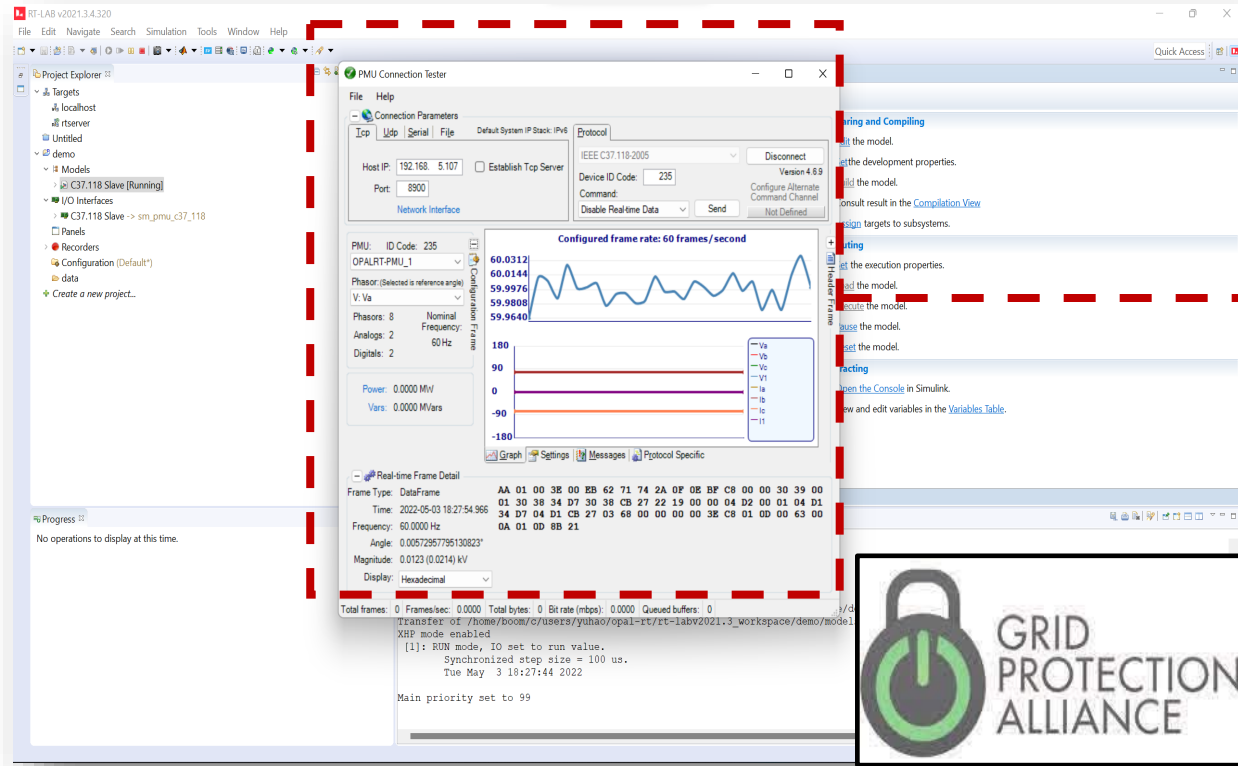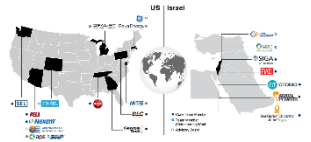
- **PMU Connection Tester can detect PMU - Phasor**

Software: C37.118 Slave to Synchrophasor Based Machine Learning
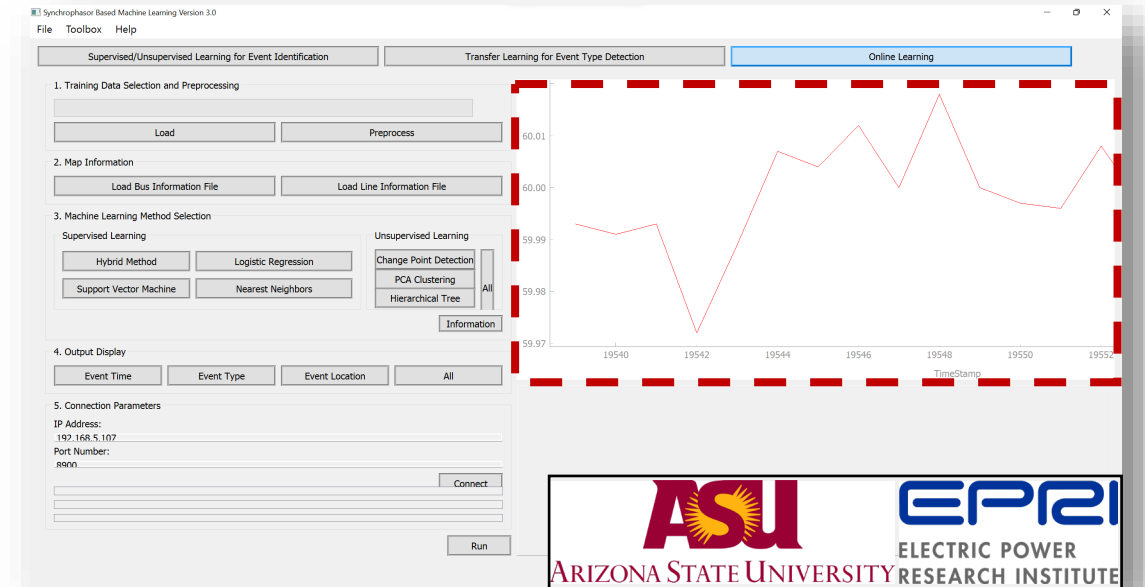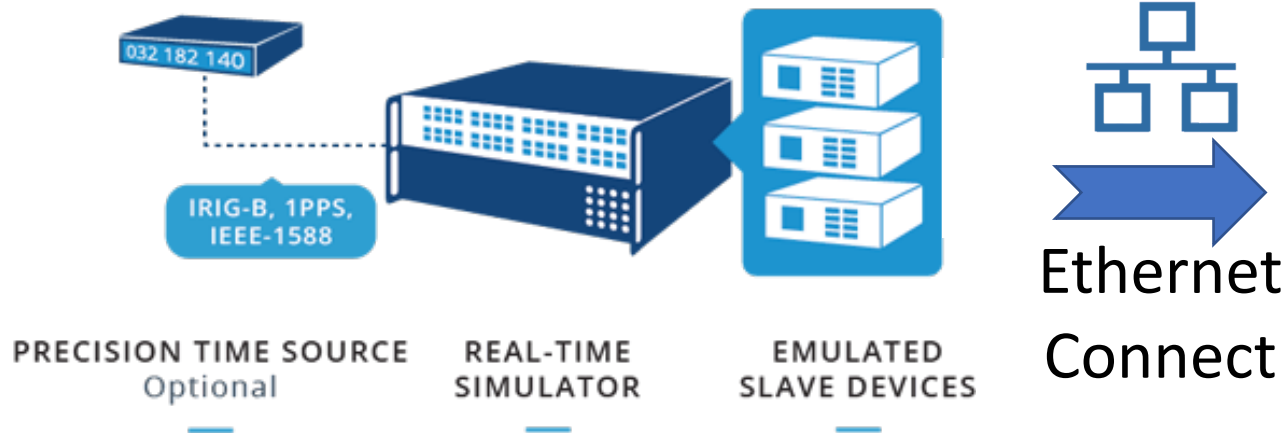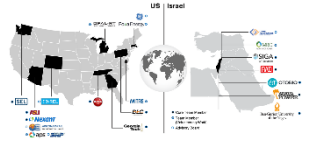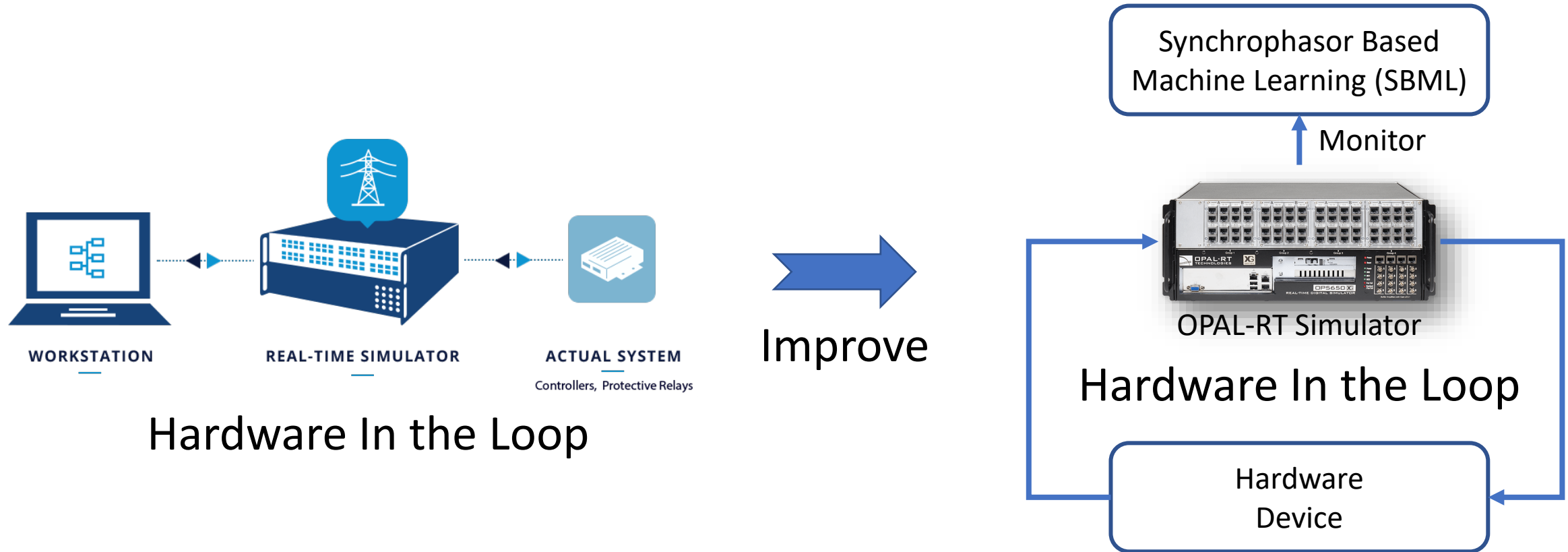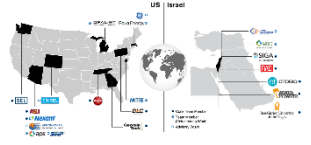

- Connected successfully to our Synchrophasor Based Machine Learning (SBML) software for future fault detection.

Software: Connection

Ethernet

Connect

IP Address

Port Number

Improve

Synchrophasor Based
Machine Learning (SBML)

Monitor

OPAL-RT Simulator

Hardware In the Loop

Hardware
Device

WORKSTATION

REAL-TIME SIMULATOR

ACTUAL SYSTEM
Controllers, Protective Relays

Hardware In the Loop

- Connect SBML software to monitor the HIL system when simulating cyber attacks.
- Support event differentiation and localization to the fault event and may provide more applications in the future.

Conclusion:

- Setup the HIL platform and software connection

- Simulate IEEE 39-Bus model and C37.118 Slave model

Future Works:

- Implement more devices in the HIL platform

- Simulate some events (such as Ground fault) in the HIL platform