Virtualizing Industrial Control Systems Testbeds for Cybersecurity Research

ACSAC ICSS 2016

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Overview

Problems:

- Industrial Control Systems are too big to fit in a lab
- ICS Cybersecurity researchers rely on small testbeds to collect data
- Small testbeds may not have all the data required for cybersecurity research

Accomplishments:

- Create a high fidelity virtual copy of a physical SCADA system
- Compare results between the physical and virtual testbeds during normal and attack conditions
- Scale up the virtual testbed to model a full-size ICS

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SCADA Components

Physical System
(sensors and actuators)

Wire bridge
Analog and
digital I/O

Programmable Logic Controller
(PLC)

Network /
SCADA Protocol

Human-Machine
Interface

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First Example
Gas Pipeline Testbed

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Physical System

Characteristics:

One inch diameter pipeline network

Four 90° pipe bends

Two T-joints.

Positive displacement pump connected to a 0.5 Hp 1Φ 120 Volts induction motor

Sensors:

Analog pressure sensor

Actuators:

Relay - Turn pump on and off

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Wire Bridge - Analog and Digital I/O

- Sends sensor signals to the controller
- Sends controller commands to the actuators
- Electrical communication between the controller and its physical interfaces

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PLC - Programmable Logic Controller

- Digital computer used on automation
- Input modules read data from sensors
- User program decides what to do based on the input data
- Output modules control actuators on the industrial plant

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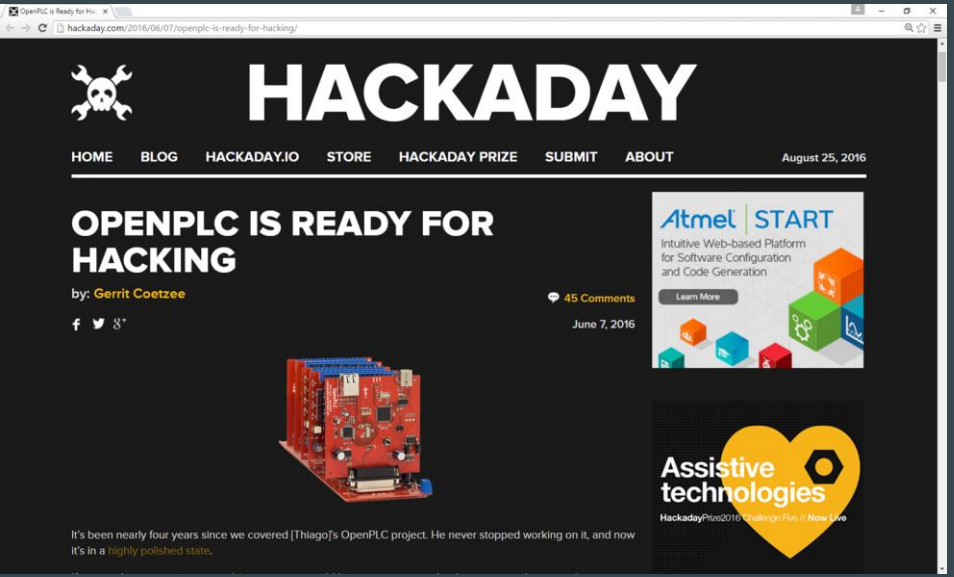
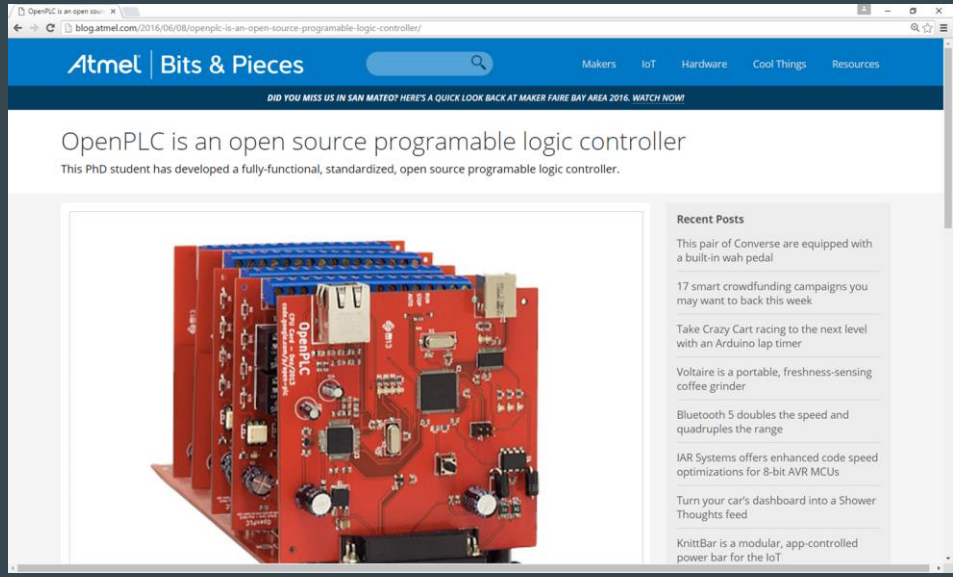
OpenPLC - An Open Source Industrial Controller

http://www.openplcproject.com

Valuable research tool since entire source code is available online

OpenPLC - An Open Source Industrial Controller





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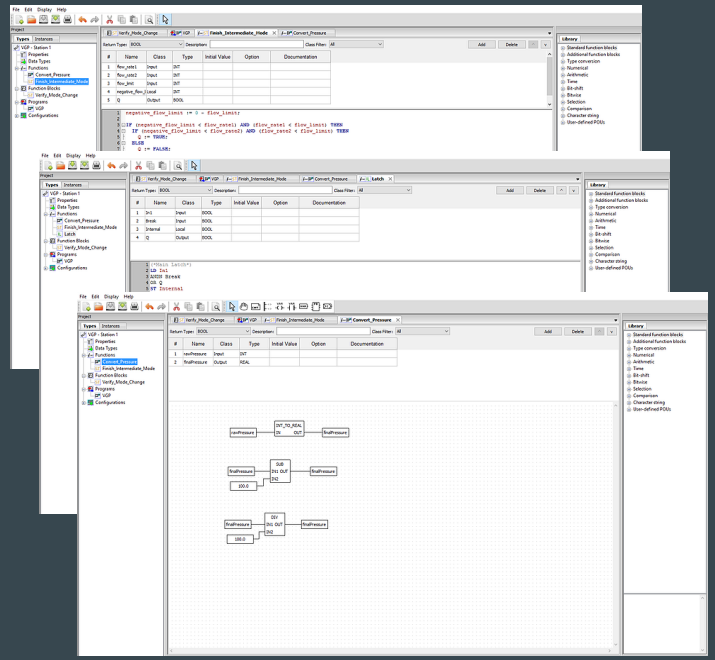
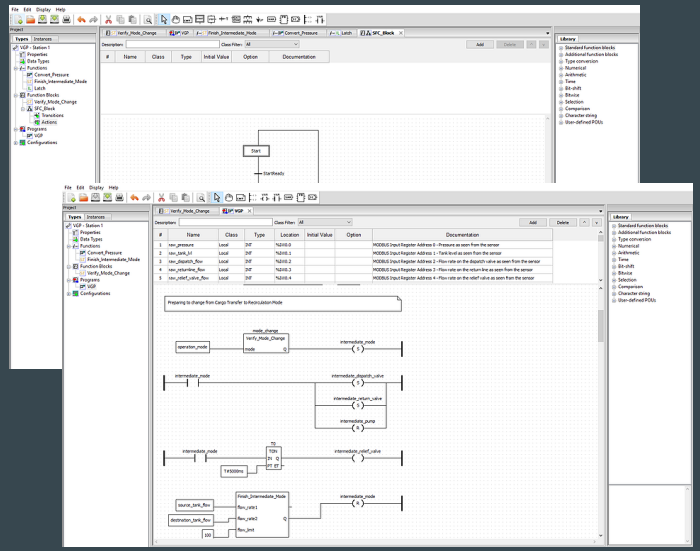
OpenPLC - An Open Source Industrial Controller





Supports all five IEC 61131-3 programming languages

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OpenPLC - An Open Source Industrial Controller

Compatible with Modbus/TCP SCADA

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OpenPLC - An Open Source Industrial Controller

Supported platforms

Raspberry Pi

UniPi

PiXtend

ESP8266

Arduino

Windows (soft-PLC)

Linux (soft-PLC)

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OpenPLC - Multiple platform support

Very easy to port to another platform

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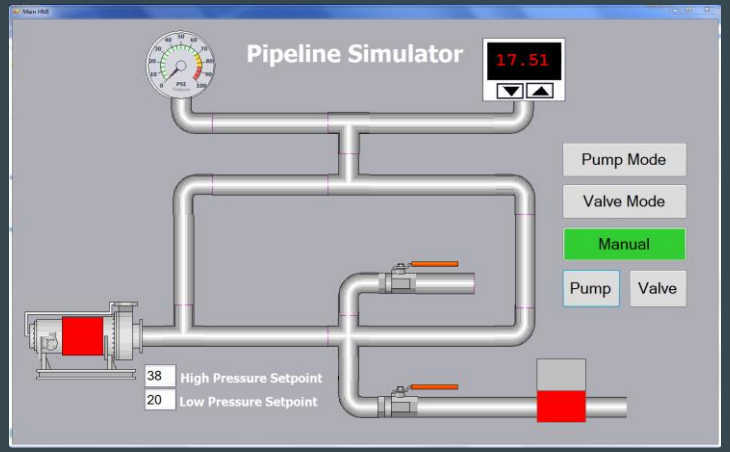
HMI - Human Machine Interface

- Built in C# using the EasyModbusTCP library
- Uses Modbus/TCP to communicate with the PLC
- Queries PLC for data every 100ms
- Display status on the screen



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Virtualizing the Gas Pipeline Testbed

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MATLAB
SIMULINK

Model with virtual
sensors and actuators

UDP Packets

OpenPLC
(on a Virtual Machine)

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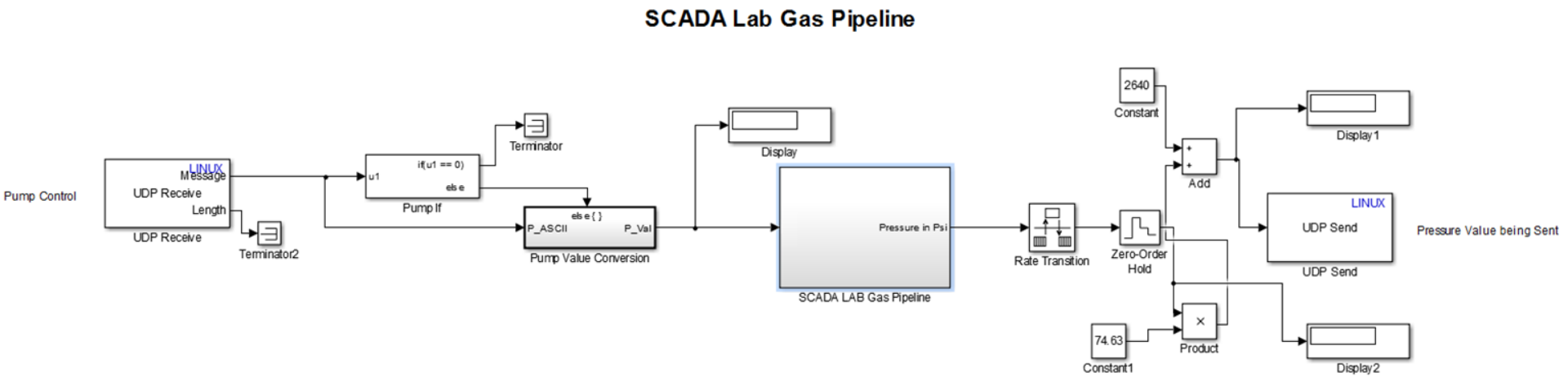
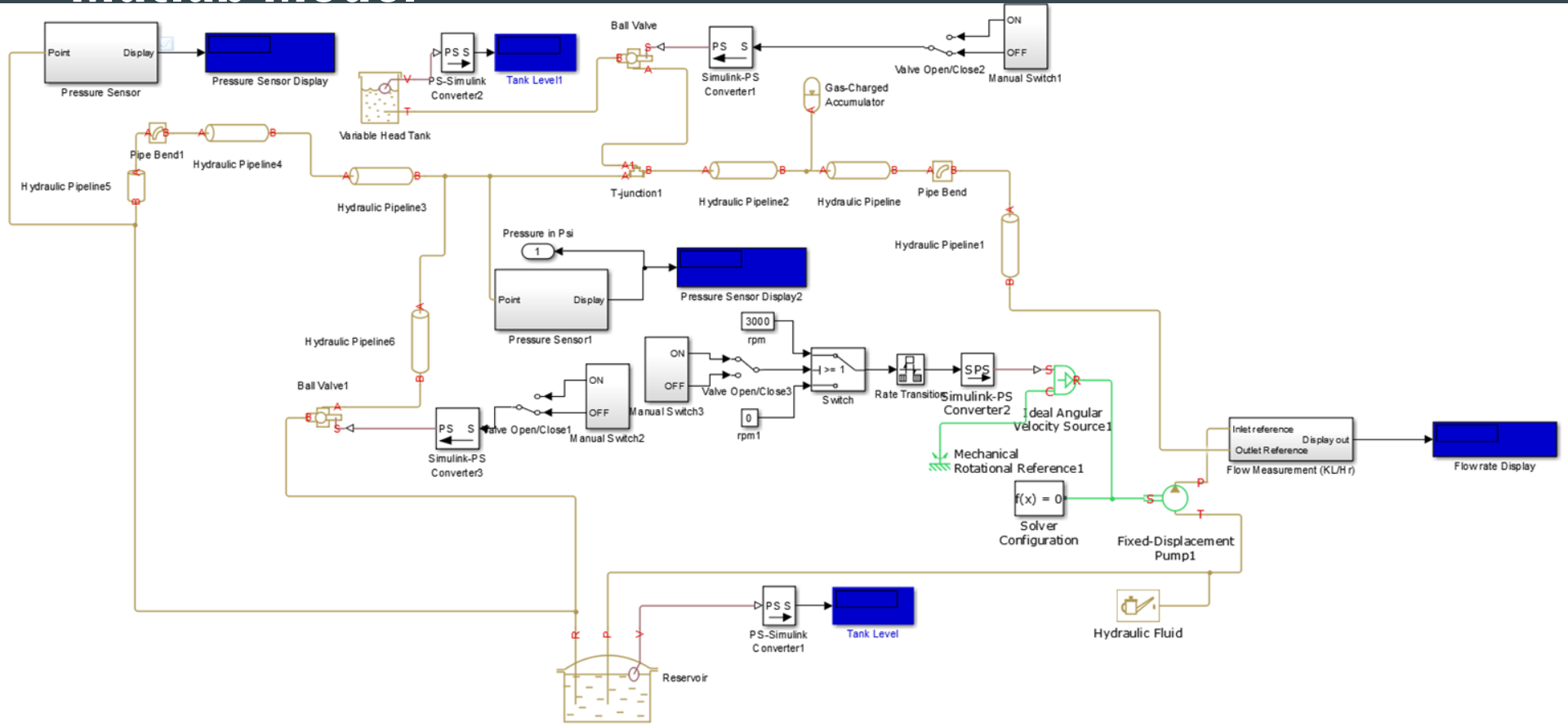
Matlab Model



Matlab Model



Other Examples Using the Same Approach

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Water Storage Tank Testbed

- Tower: 40cm height x 20cm diameter
- Total volume: 0.0126 m^3
- Constant flow rate pump to fill the tower
- One outlet valve for water distribuition

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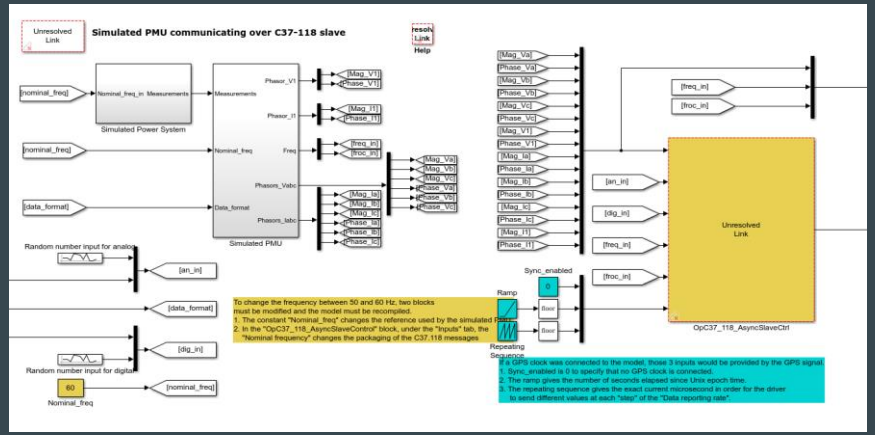
Power System

- 9 Bus Standard IEEE Power System
- 18 Simulated Relays with auto reclose
- Each relay can be controlled over Modbus
- 1 PMU Unit with C37-118 protocol support



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Virtual Gas Pipeline Testbed Fidelity Evaluation

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Performed Tests

- Real-time response
- Pressure rising curve
- Pressure discharge curve
- Man-in-the-middle attack

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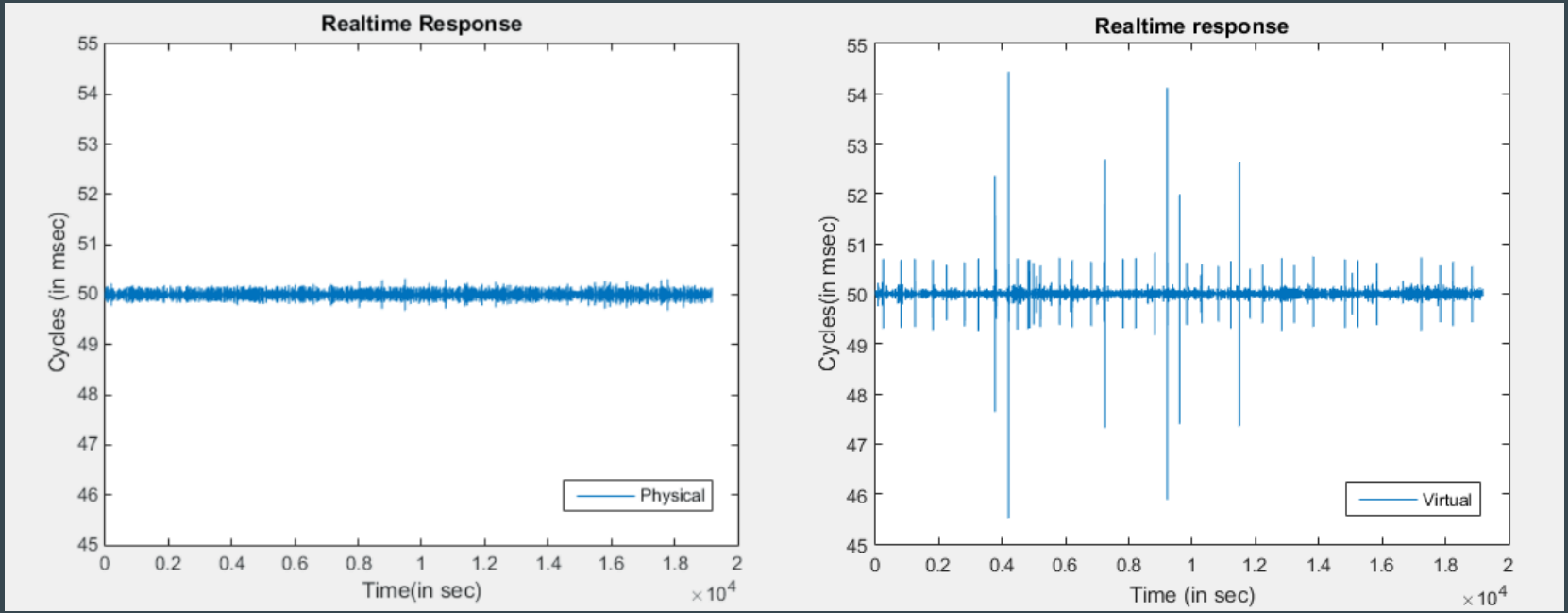
Real-Time response of the OpenPLC



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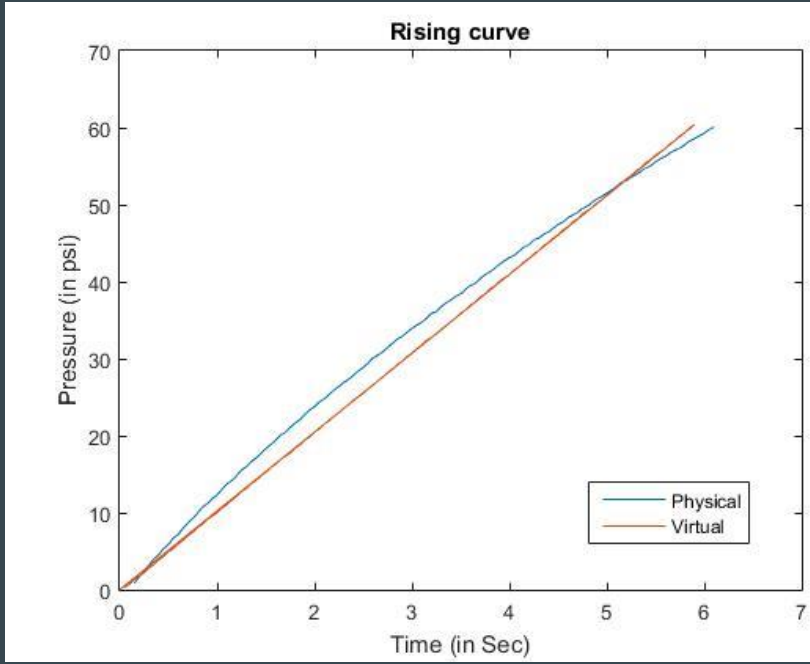
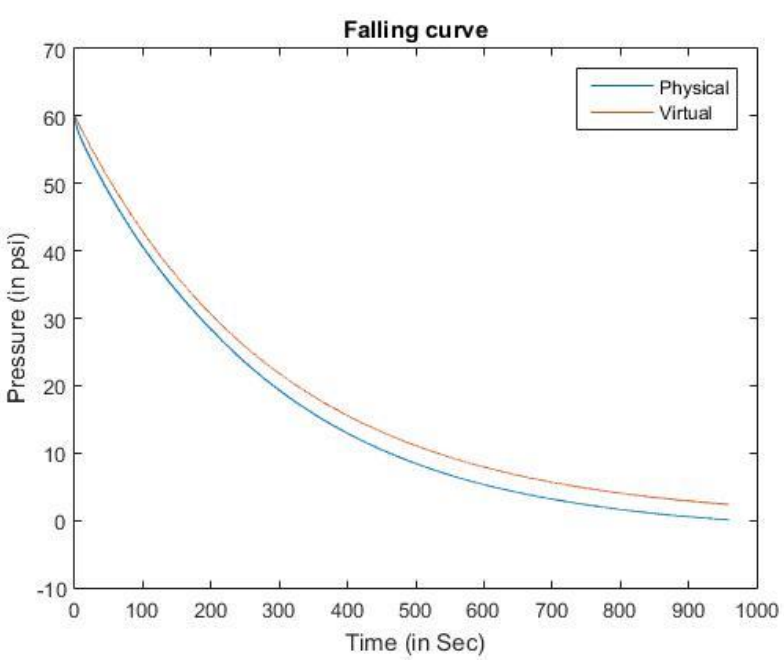
Comparison Results - Pressure Characteristics





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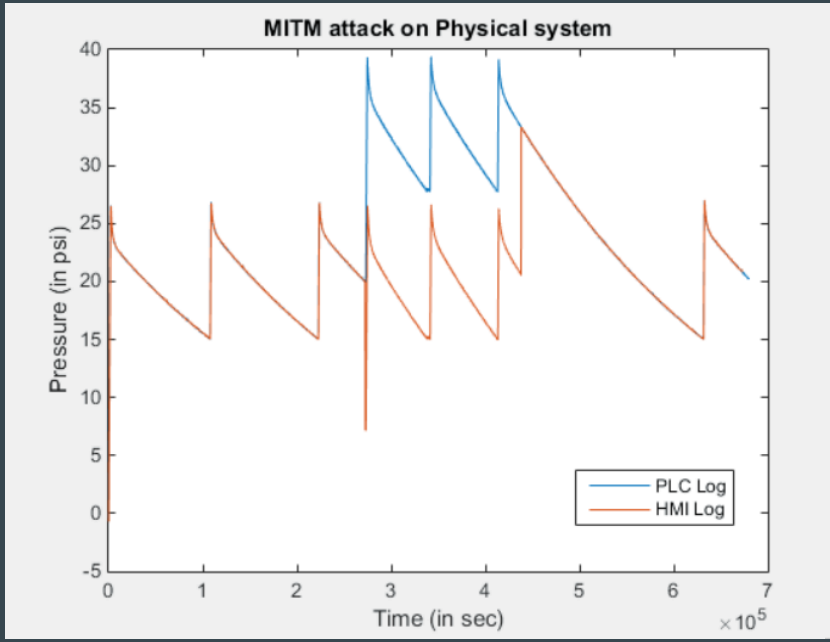
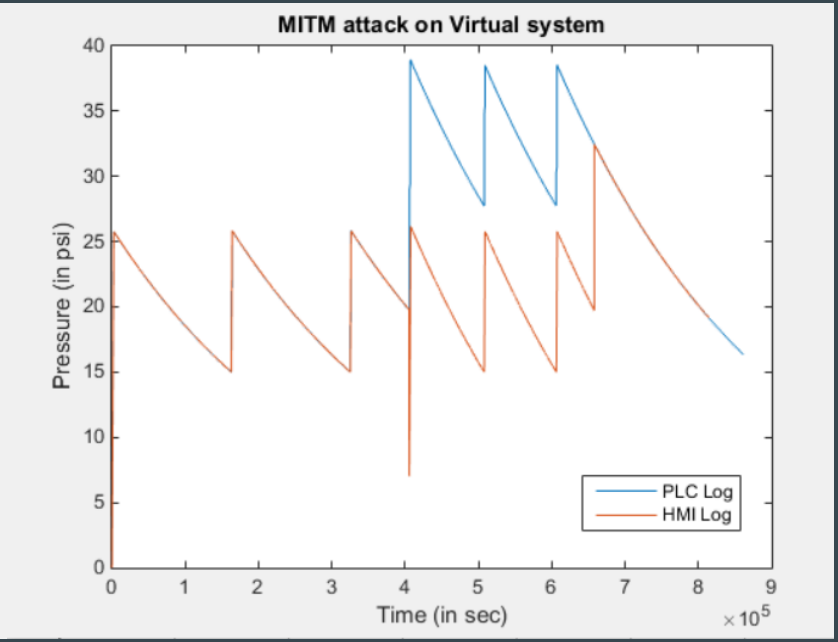
Comparison Results - Attacks (MiTM Injection)





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Expansion of the Virtual Gas Pipeline

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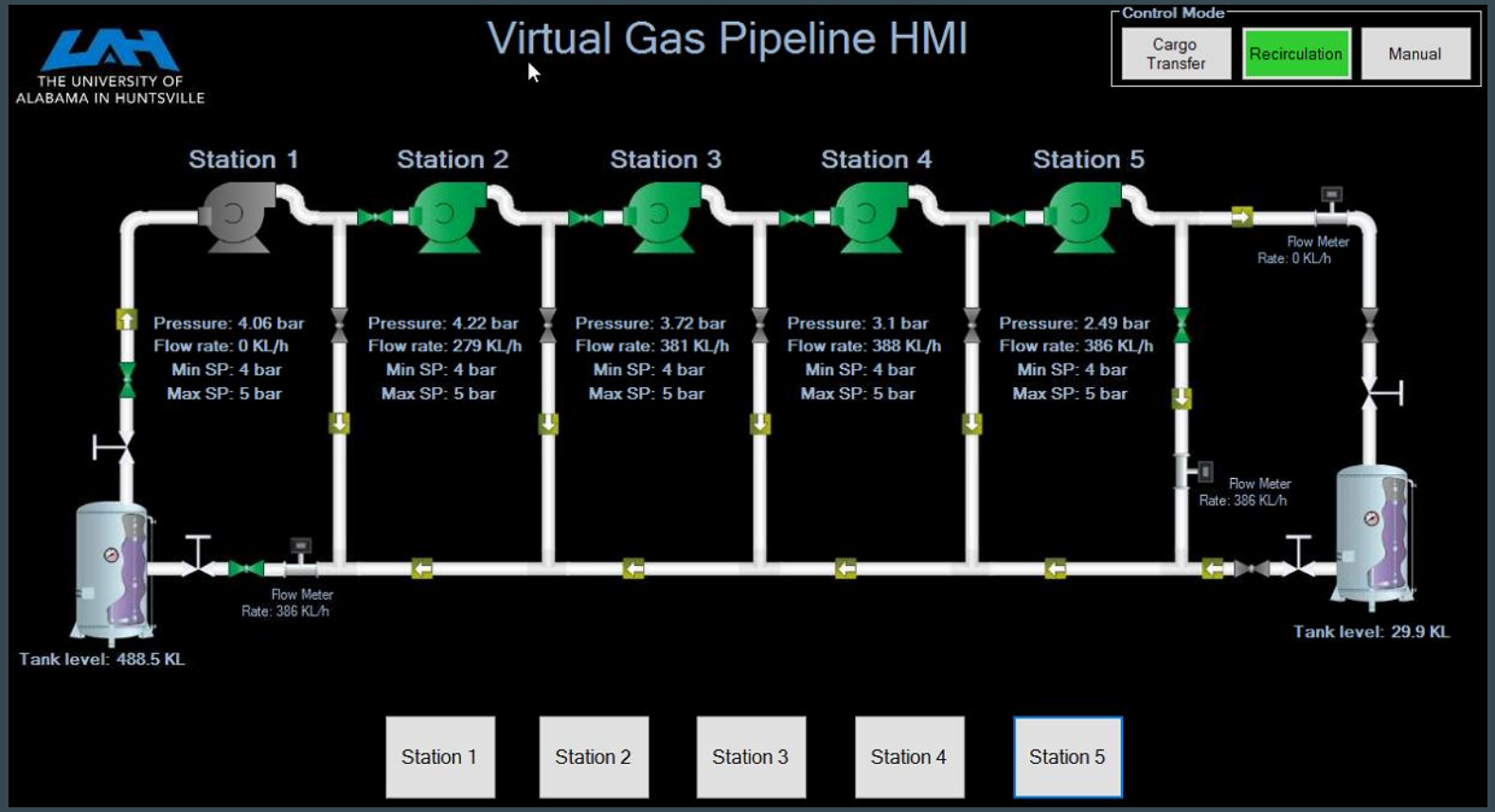
Virtual 15km Pipeline Testbed



Questions

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