UTILITY USE CASES FOR TESTING WITH HARDWARE IN THE LOOP

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2023 NORTH AMERICAN RTDS APPLICATIONS & TECHNOLOGY CONFERENCE

AGENDA

- Basics of Hardware in the Loop (HiL) Testing
  - Definitions
  - Power HiL vs Control HiL
- HiL capability at Duke Energy
- Why?
  - Projects
    - Regulator Controls
    - Microgrids
    - Urban Underground Automation
- What?
- Where?
- Urban Underground Automation Example

BASICS OF HARDWARE IN THE LOOP (HIL) TESTING

DEFINITIONS

- **Digital real-time simulator (DRTS):** A digital real-time simulator (DRTS) is an integral part of HIL test setups and simulates a model (rest-of-system, ROS), provides interfaces to exchange signals between the simulated subsystem and external hardware, and controls the test conditions at the terminals of the Equipment Under Test (EUT).
- **Low-power input/output interfaces:** Low power input/output (I/O) interfaces provide the means to interface signals that control power equipment or controls as part of HIL-based testing. Typically, analog I/O-signals are in the range of 0-10V
- **Power amplifier (PA):** Power amplifiers receive reference signals that reflect voltages and/or currents of simulated subsystems. The amplifier transforms the reference signals to voltages and/or currents at its power terminals to interact with the EUT.
- **Rest-of-system (ROS):** HIL tests require models to be simulated on the DRTS to close the loop between the simulated subsystem and EUT. Properties and requirements of models are specific to a HIL test. The rest-of-system (ROS) refers to the simulated subsystem that is executed on the DRTS and interfaced to the EUT.
- **Interface algorithm (IA):** Is a method of linking a DRTS simulated subsystem to a device under test.

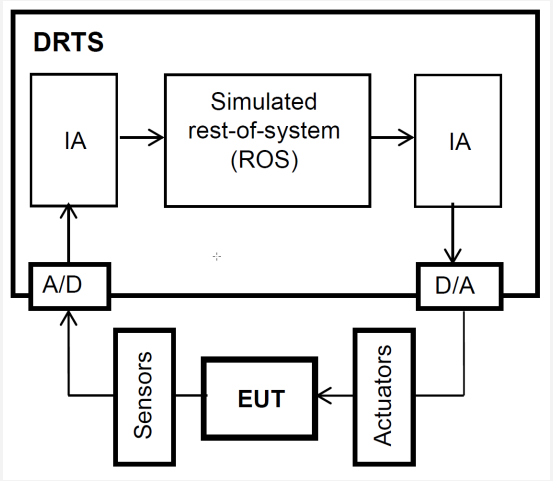
CONTROL HARDWARE IN THE LOOP (HIL) TESTING

CONTROL HIL

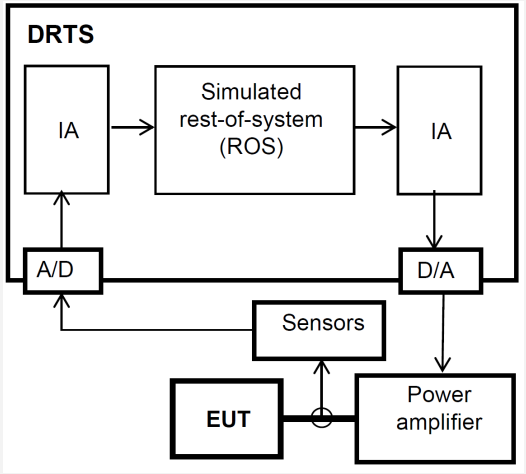
Hardware-in-the-loop or Hardware-in-Loop (HIL) simulation seamlessly integrates physical hardware and software models in a single closed-loop simulation.

- Control Hardware-in-the-loop (C-HIL) is where the RTS is interfacing low level and control signals to hardware, which is the ideal level of testing for our utility use cases
- Power Hardware-in-the-loop (P-HIL) is not a practical capability for the utility to develop or maintain, and is better suited for OEMs and Large Test Facilities.

C-HIL

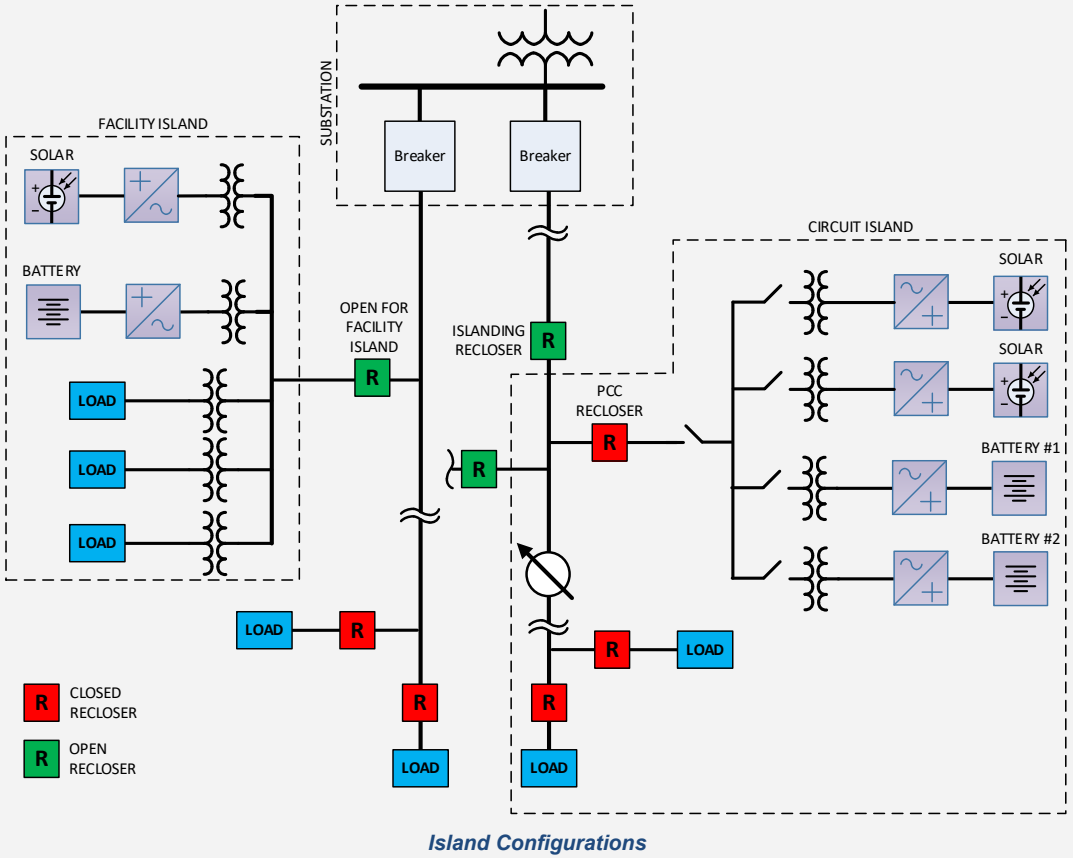


P-HIL



BASICS OF HARDWARE IN THE LOOP (HIL) TESTING

CONTROL HIL @ DUKE ENERGY



Island Configurations

WHY?

The increase of DER generation and Microgrids, prompted the evaluation of new tools

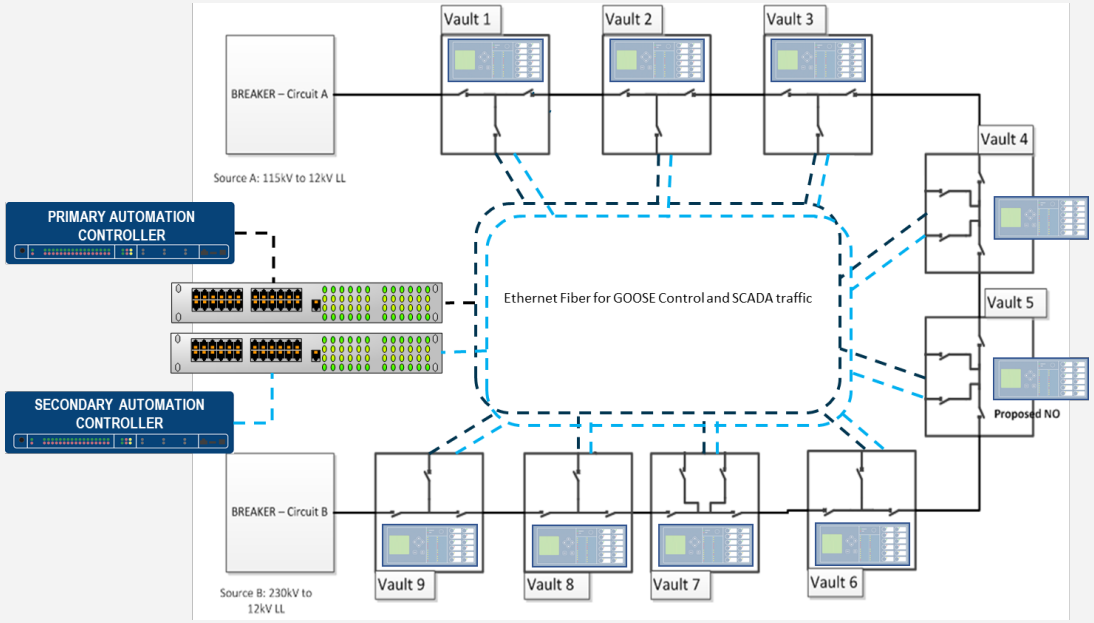
Analysis of Electro-Magnetic Transients (EMT)

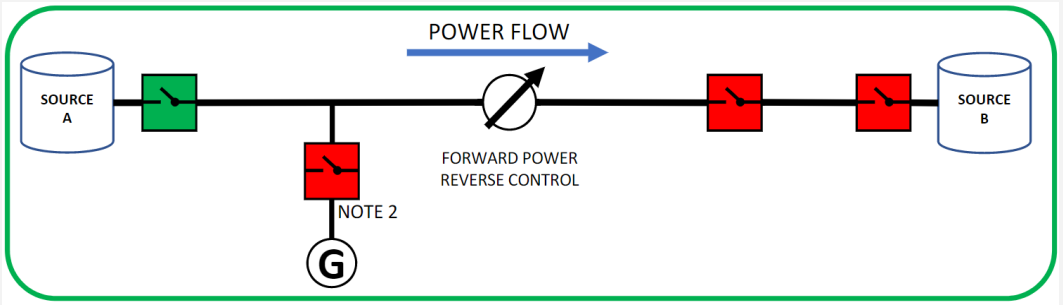
Microgrid are complex systems & controls that need to be evaluated as a system

Testing/validation of the system coordination, control, and protection to assist with system commissioning

BASICS OF HARDWARE IN THE LOOP (HIL) TESTING

CONTROL HIL @ DUKE ENERGY





WHY? – Continued

Other complex systems were identified that needed to be evaluated as a system

Underground High Speed FISR projects were complex

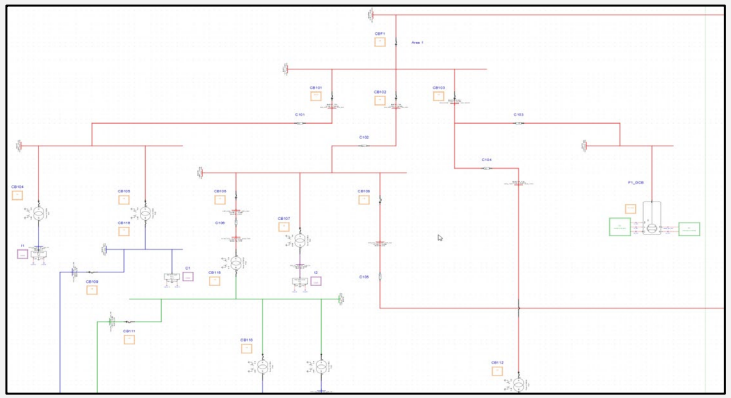
2-Way Power Flow on Distribution system challenging voltage regulation, need to test Auto-Deterministic Control Algorithms

Testing/validation of automation controls for various use cases

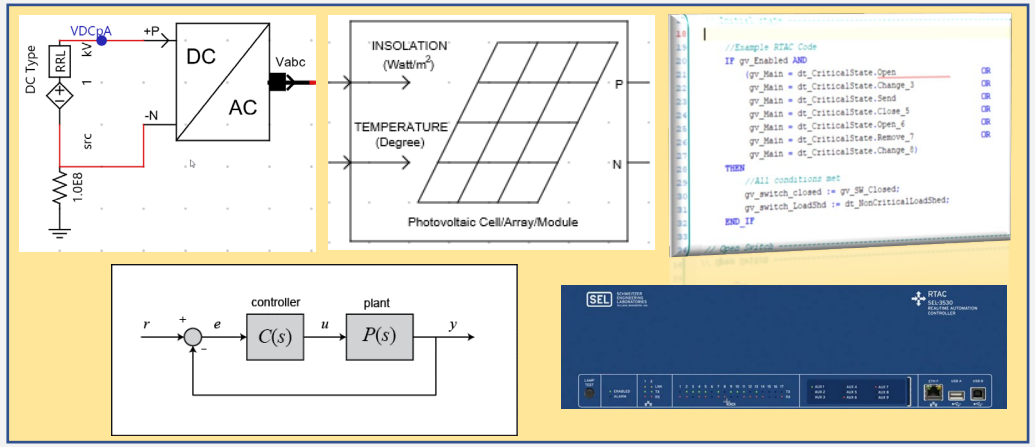
BASICS OF HARDWARE IN THE LOOP (HIL) TESTING

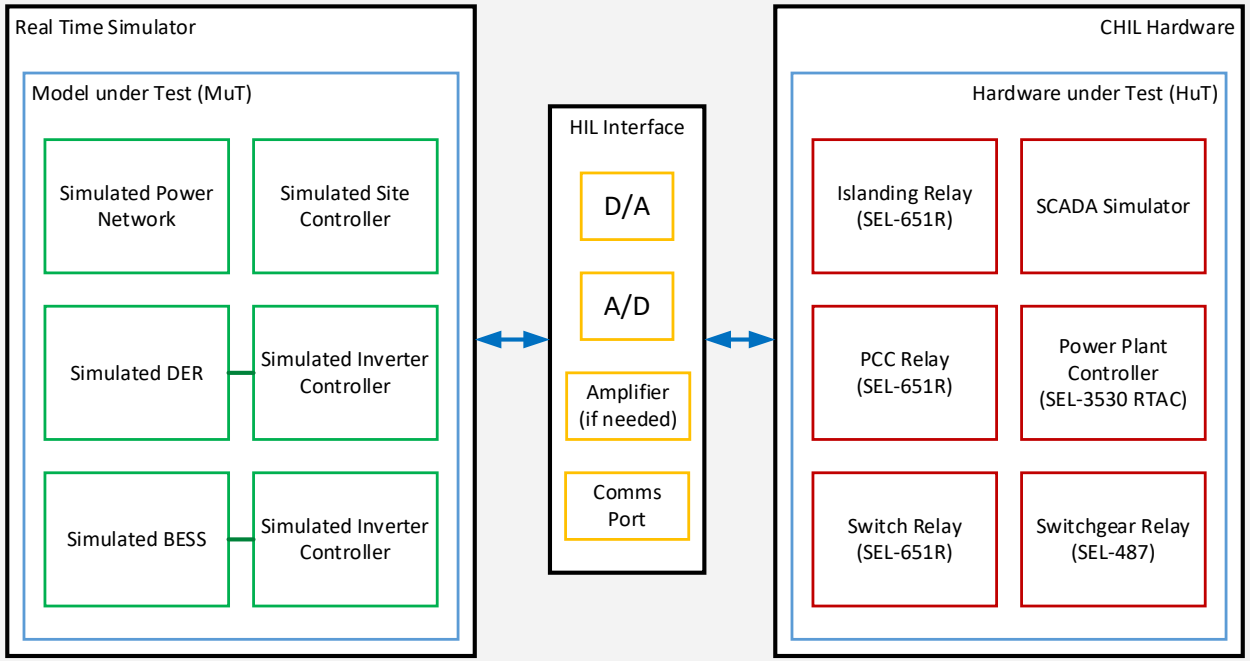
CONTROL HIL COMPONENTS

Simulated Power Network



Simulated Equipment



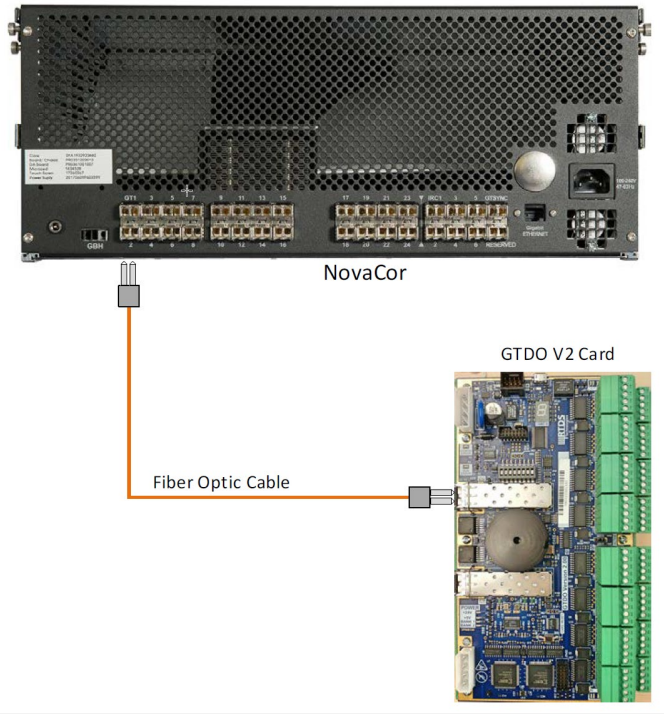


Simplified C-HIL Configuration

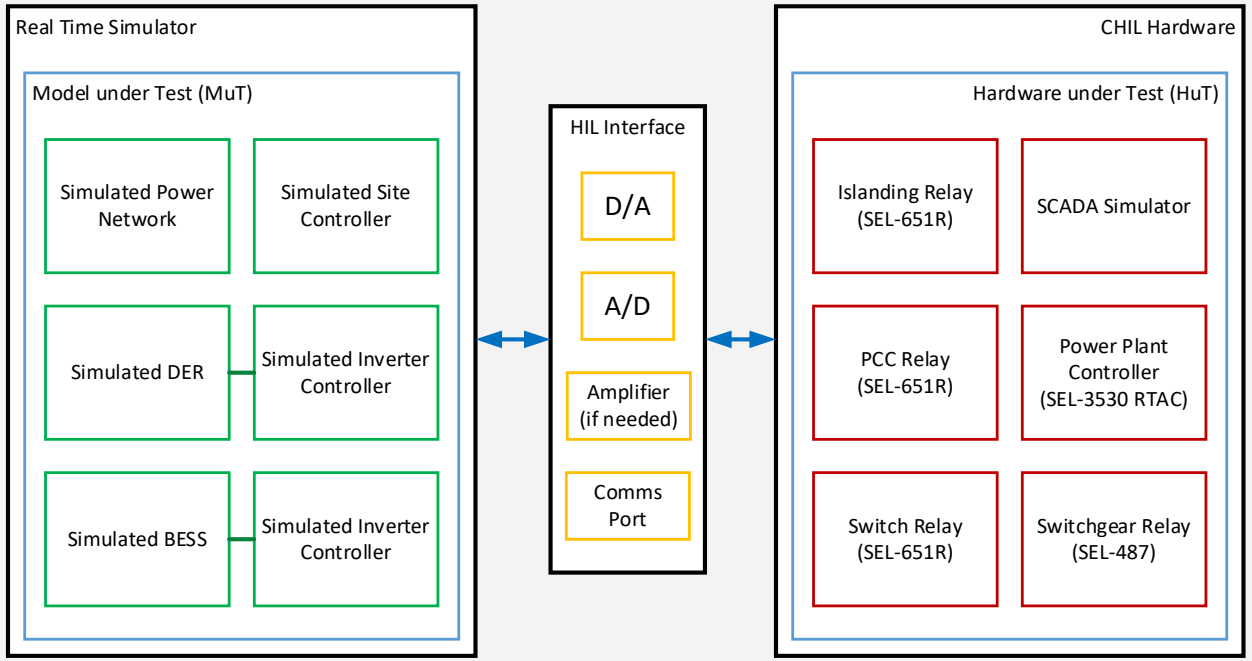
BASICS OF HARDWARE IN THE LOOP (HIL) TESTING

CONTROL HIL COMPONENTS

HiL Interface



Power Amplifier



Simplified C-HIL Configuration

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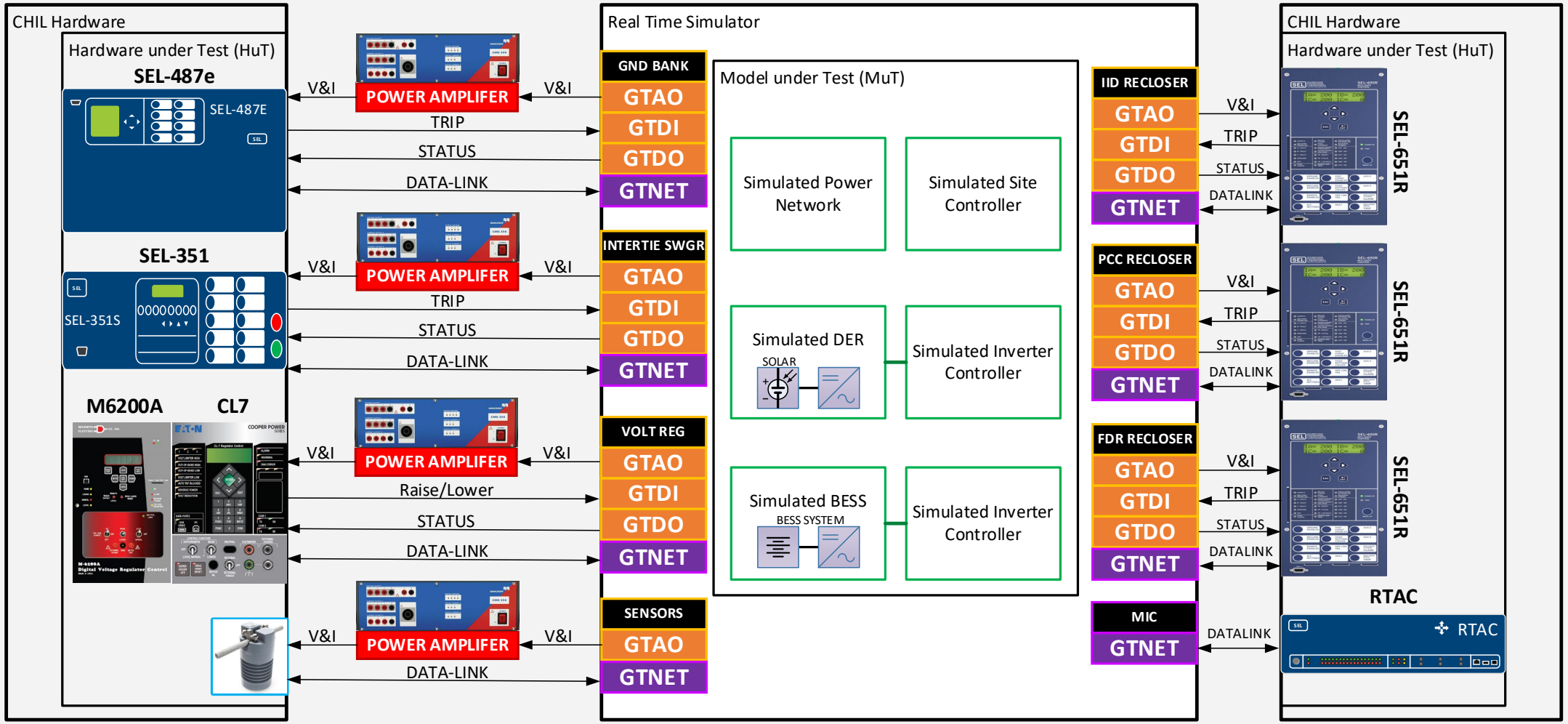
CONTROL HIL COMPONENTS



BASICS OF HARDWARE IN THE LOOP (HIL) TESTING

CONTROL HIL @ DUKE ENERGY

- **What?: RTDS NovaCor HiL Simulator**
  - 7 Cores unlocked

Permanent Protection & Control Equipment

- Four (4) 651R2 Relays
- Two (2) 487E Relays
- One (1) 451 Relay
- Two (2) 787 Relays
- One (1) 751 Relay
- One (1) 3555 RTAC
- One (1) 3350 Blueframe RTAC
- One (1) CL7 Regulator Control
- One (1) M6200A Regulator Control

I/O Equipment

- 176 Analog Out Ch
- 12 Analog In Ch
- 192 Digital Input Ch
- 192 Digital Output Ch

Power Amplifier

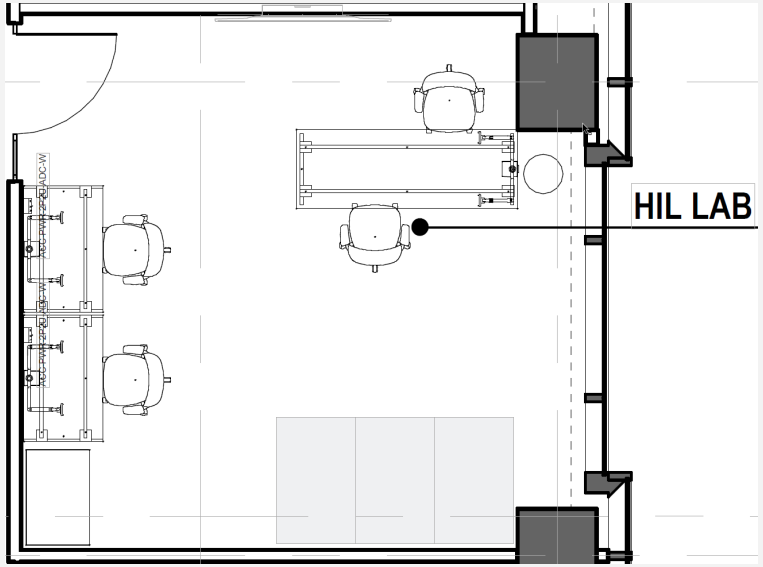
- 9 x 300V
- 18 x 64A

Equipment models/counts vary depending on applications being evaluated, additional equipment can be interfaced for specific project needs, ie: LVR, UUA-R

BASICS OF HARDWARE IN THE LOOP (HIL) TESTING

CONTROL HIL @ DUKE ENERGY

- **Where?:** Charlotte
- Currently located at the Emerging Technology Center (Mt. Holly, NC)
- Lab space under construction in new Duke Tower (Charlotte, NC)

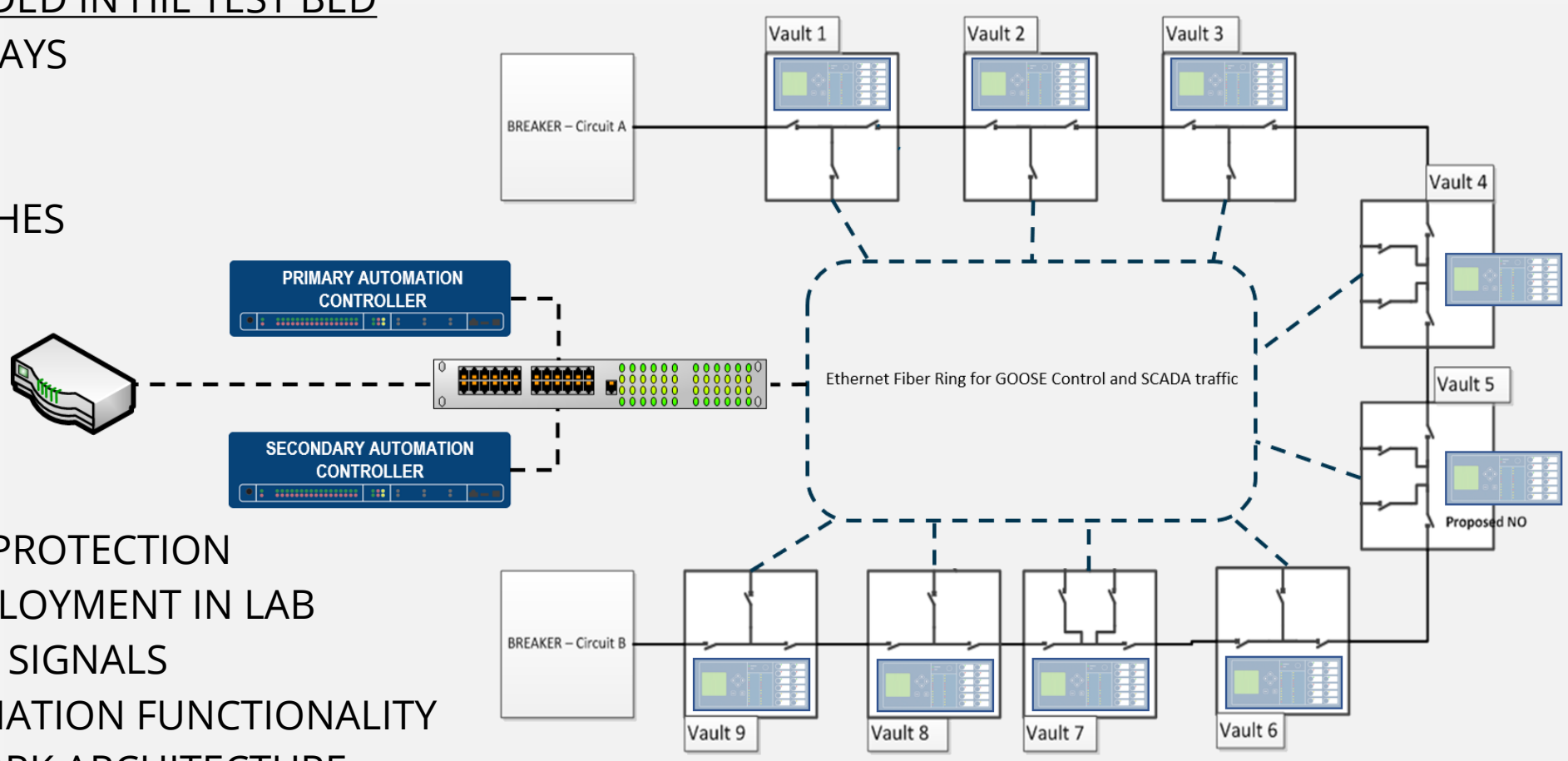


BASICS OF HARDWARE IN THE LOOP (HIL) TESTING

URBAN UNDERGROUND AUTOMATION EXAMPLE

EQUIPMENT INCLUDED IN HIL TEST BED

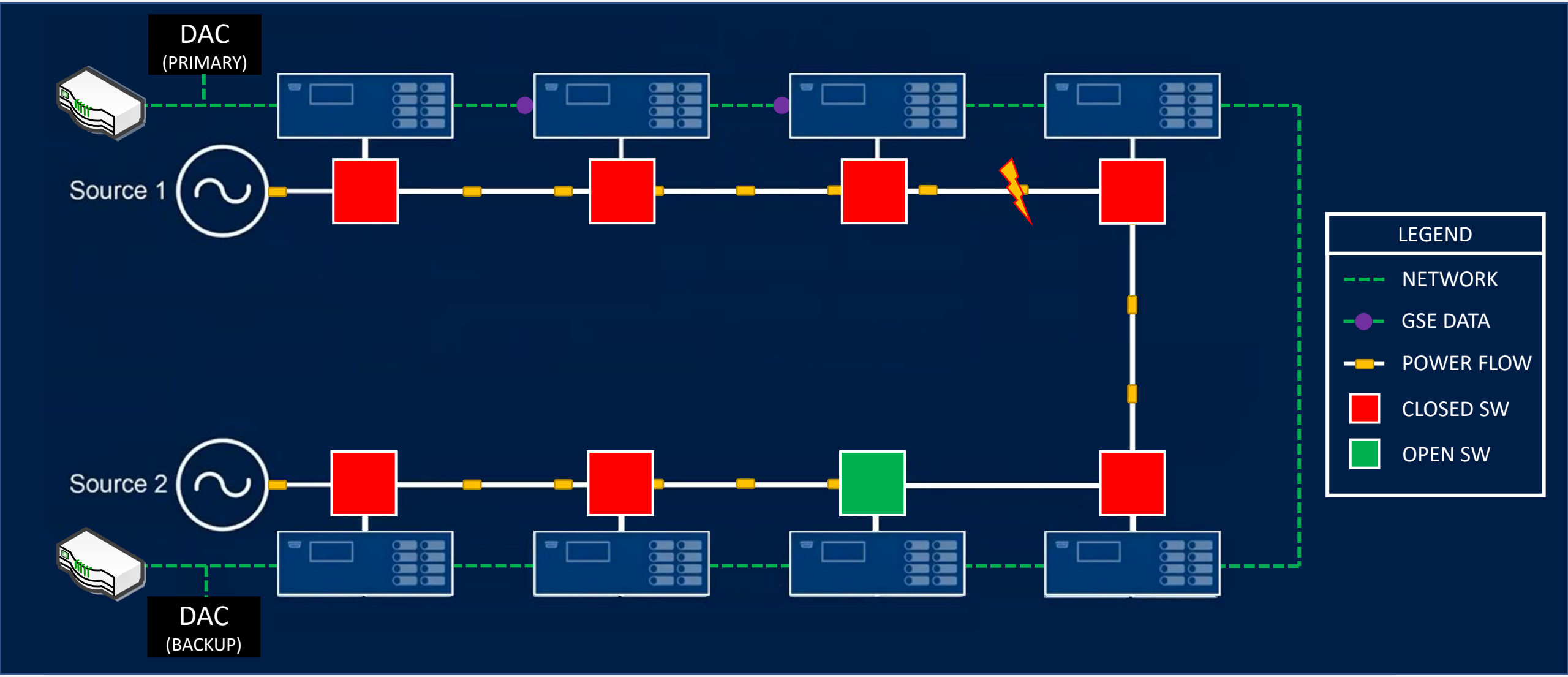
- SWITCHGEAR RELAYS
- AUTOMATION CONTROLLERS
- NETWORK SWITCHES



BENEFITS

- VALIDATE RELAY PROTECTION
- VERIFY FIELD DEPLOYMENT IN LAB
- VALIDATE GOOSE SIGNALS
- VALIDATE AUTOMATION FUNCTIONALITY
- VALIDATE NETWORK ARCHITECTURE

FISR SCHEME TO BE TESTED



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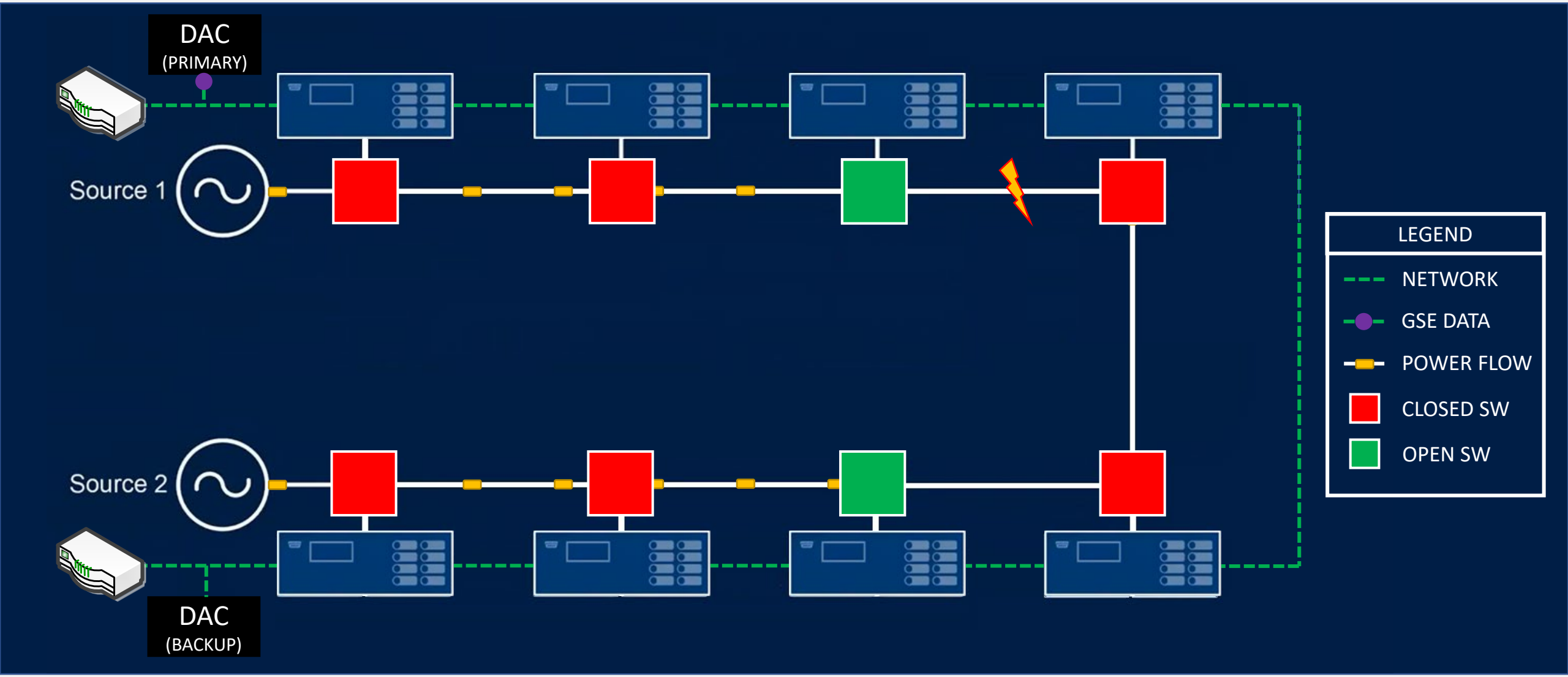

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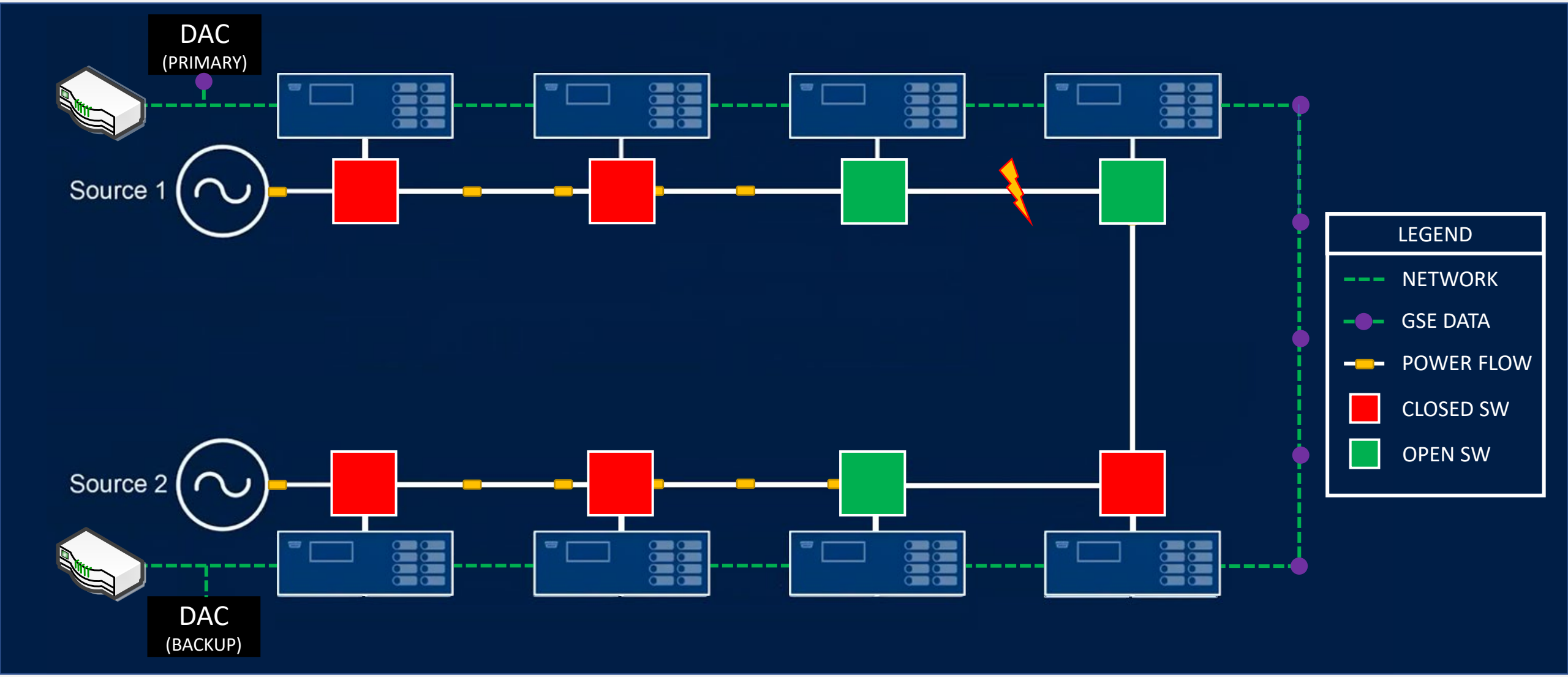

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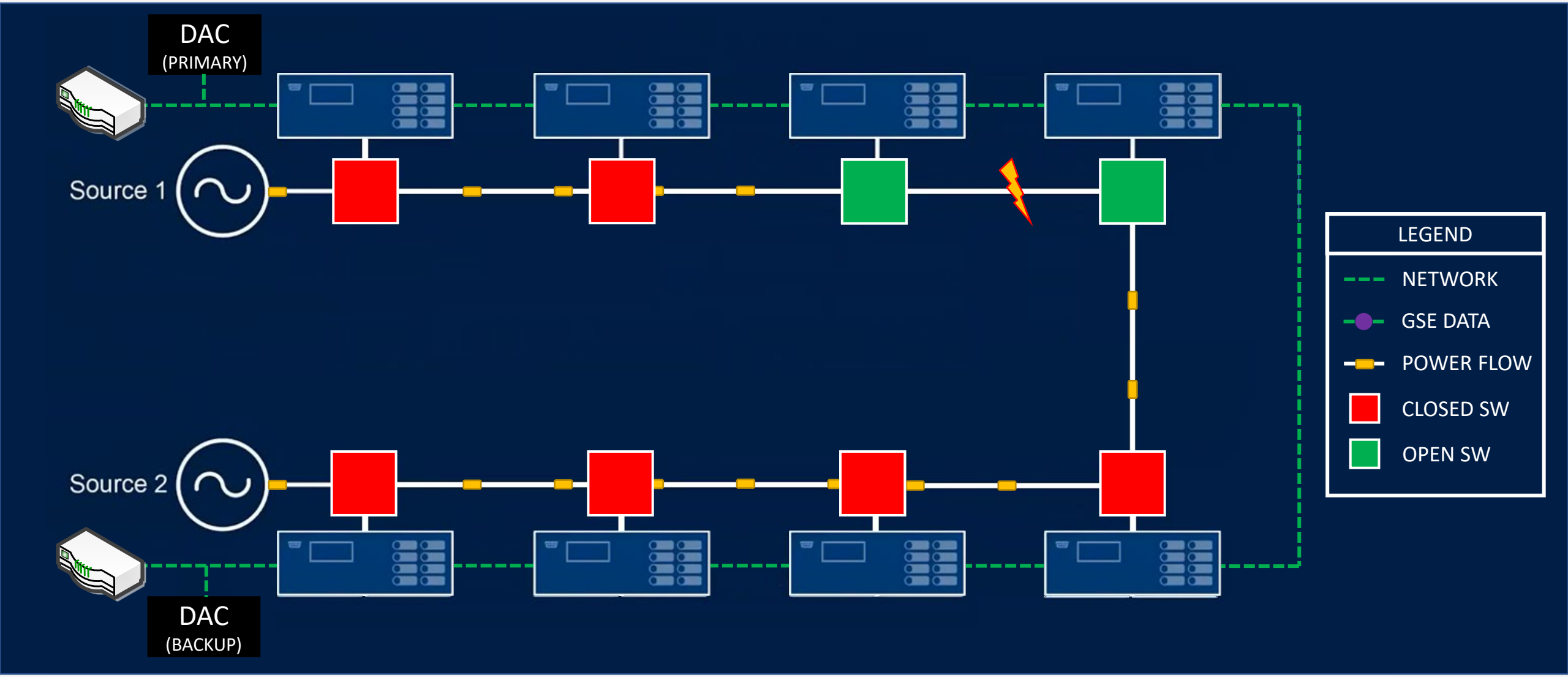

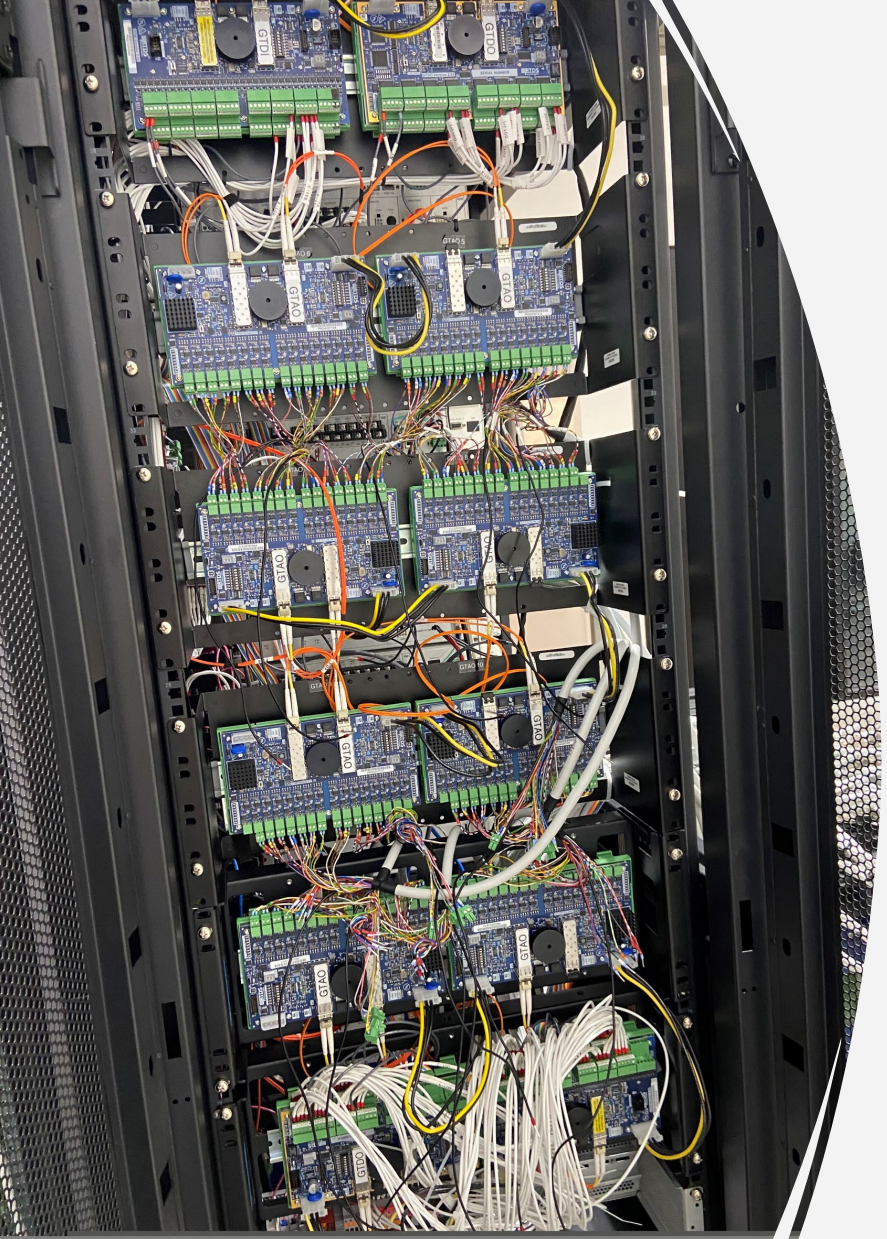

QUESTIONS?