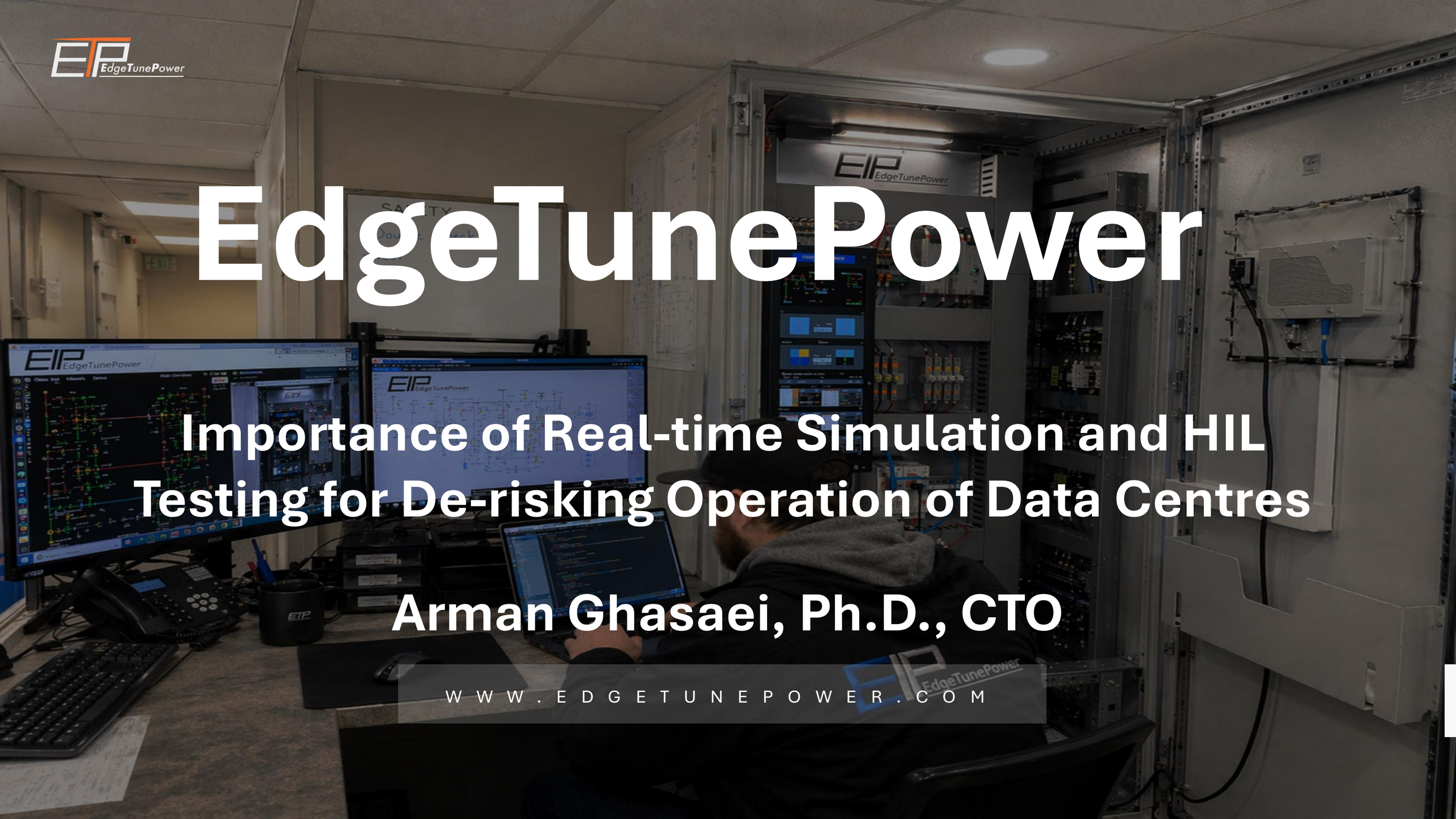

EdgeTunePower

Importance of Real-time Simulation and HIL Testing for De-risking Operation of Data Centres

Arman Ghasaei, Ph.D., CTO

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Agenda

- Problem statement
- What is HIL Testing
- Which devices can be tested for Data Centres with HIL Approach
- Results and Lessons Learned from a 20-MW Data Centre project

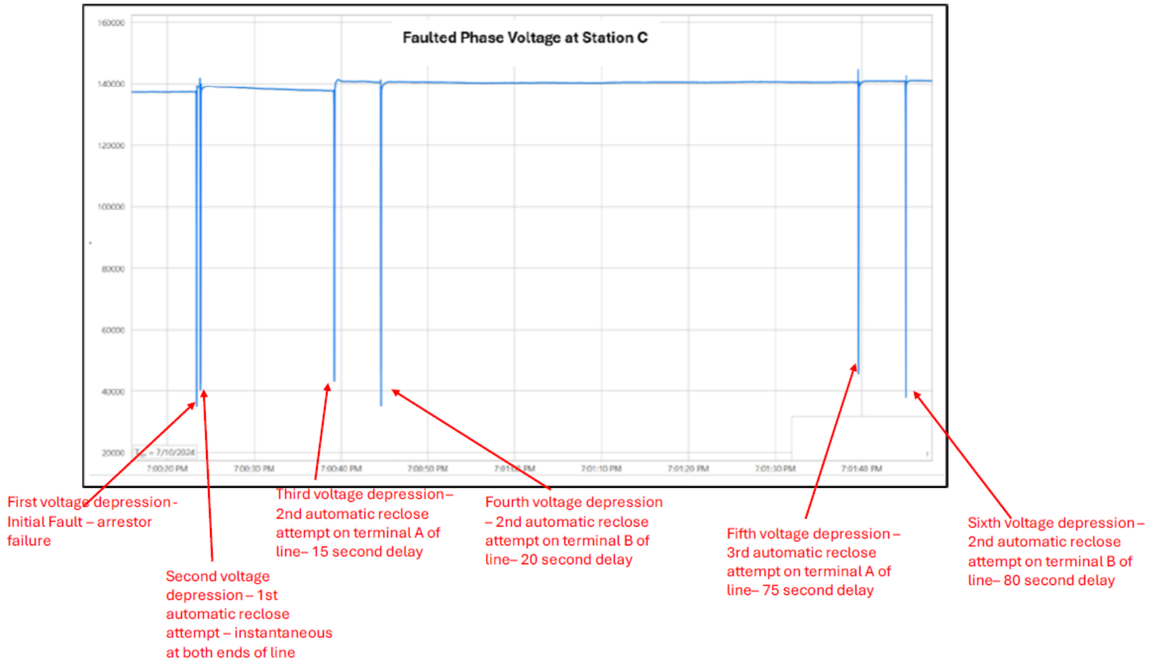
Problem Statement:

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Incident Review
Considering Simultaneous Voltage-Sensitive Load Reductions

- **Rising Risk** – Growing voltage-sensitive loads increase future reliability and reconnection challenges!

- 2024: Large Load Loss – 230-kV fault caused ~1,500 MW data center load drop, risking frequency/voltage swings.



- Reclosing Interaction – Reclose attempts triggered protection logic, keeping ~1,260 MW offline for hours!!!

Co-location of Data Centres with Power Plants.

However, even in power plants:

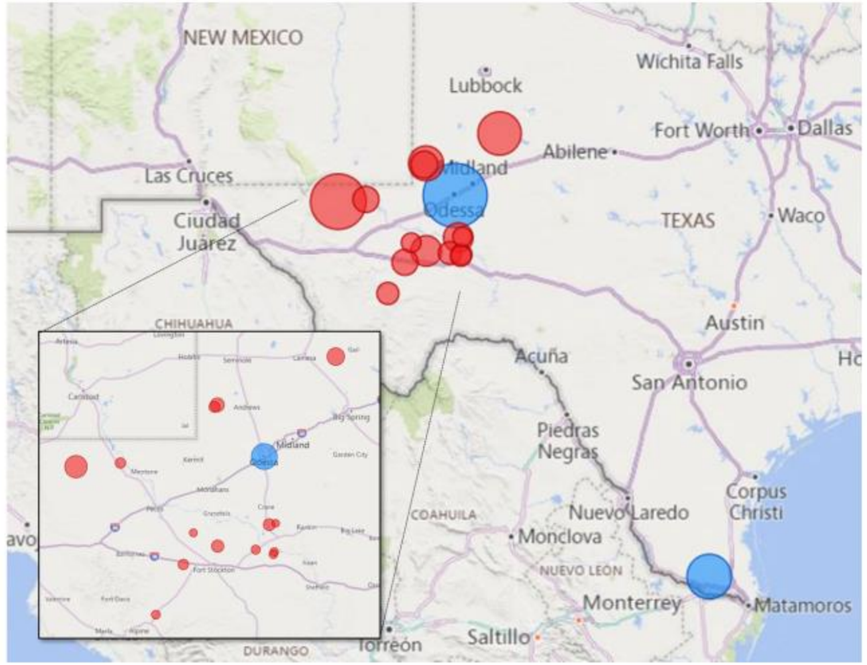
❌ Some IBR-dominated plants are not behaving reliably!

❌ Mal-operational **Physical** control systems, at IBR level and system level (PPC), during field operation

‼️ **Physical** control systems need to be tested in advance

‼️ Odessa Event 2021: **1.1 GW** solar-PV reduction after a S-L-G fault

‼️ Odessa Event 2022: : **1.7 GW** solar-PV reduction after a S-L-G fault



Root cause:

❌ Mal-operation of control systems (IBRs and PPC) despite offline simulations and modeling

ODESSA 2021	ODESSA 2022
PLL Loss of Synchronism: ***389 MW*** reduction.	**Inverter Instantaneous AC Overcurrent:** ***445 MW*** reduction.
Inverter AC Overvoltage: ***269 MW*** reduction	**Voltage Phase Jump:** ***385 MW*** reduction.
Momentary Cessation: ***153 MW*** reduction	**Inverter AC Overvoltage:** ***295 MW*** reduction.
Feeder AC Overvoltage: ***147 MW*** reduction	**Inverter DC Bus Unbalance:** ***198 MW*** reduction.
Inverter Underfrequency: ***48 MW*** reduction	**Slow Ramp After Low Voltage Ride Through (LVRT):** ***147 MW*** reduction.
Other/Unknown Causes: ***85 MW*** reduction	**Momentary Cessation:** ***131 MW*** reduction.
	Grid Over frequency: ***50 MW*** reduction.
Source: ERCOT	**Other/Unknown Causes:** ***59 MW*** reduction.

Root cause:

❌ Communication Latency!

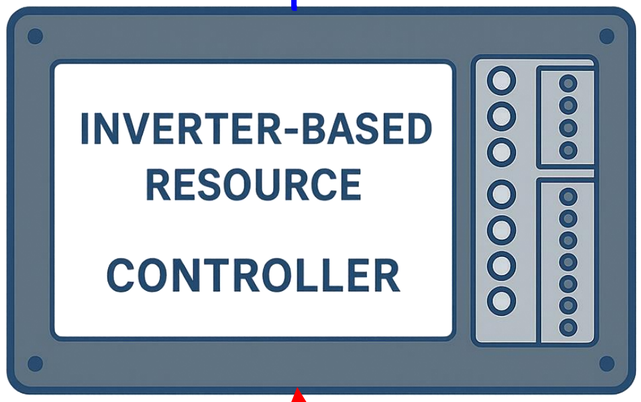
Protocol	Typical Latency
Goose (IEC 61850)	3 ms
Modbus RTU	20–100 ms
Modbus TCP	10–50 ms
DNP3 (Serial)	50–200 ms
DNP3 (Ethernet)	20–100 ms
MMS (IEC 61850)	10–100 ms

Source: SEL, IEEE

C-HIL for an IBR Controller

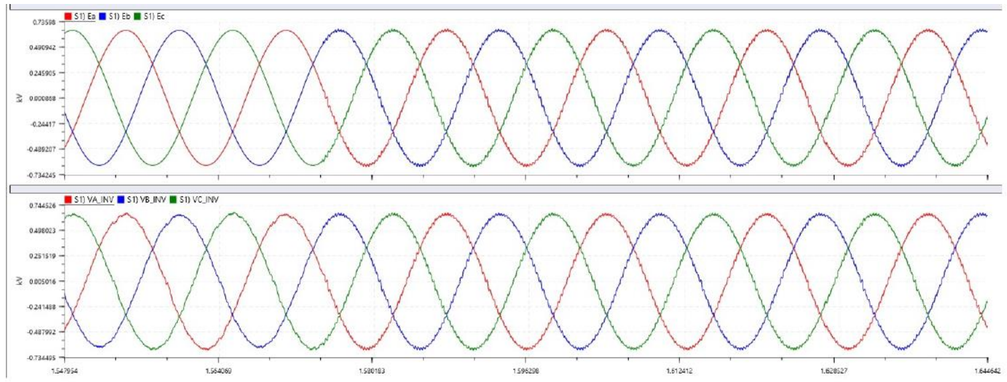
Real-time Digital Simulator

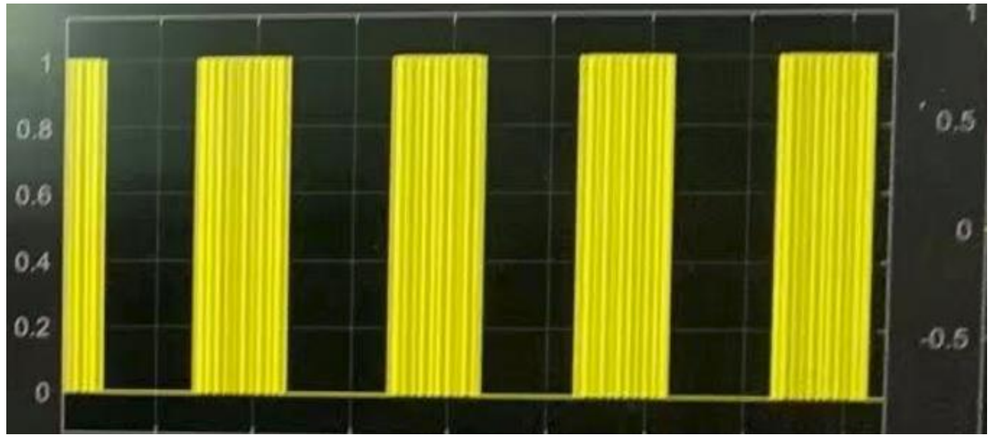
Analog
Voltage & Current
(+-10V)



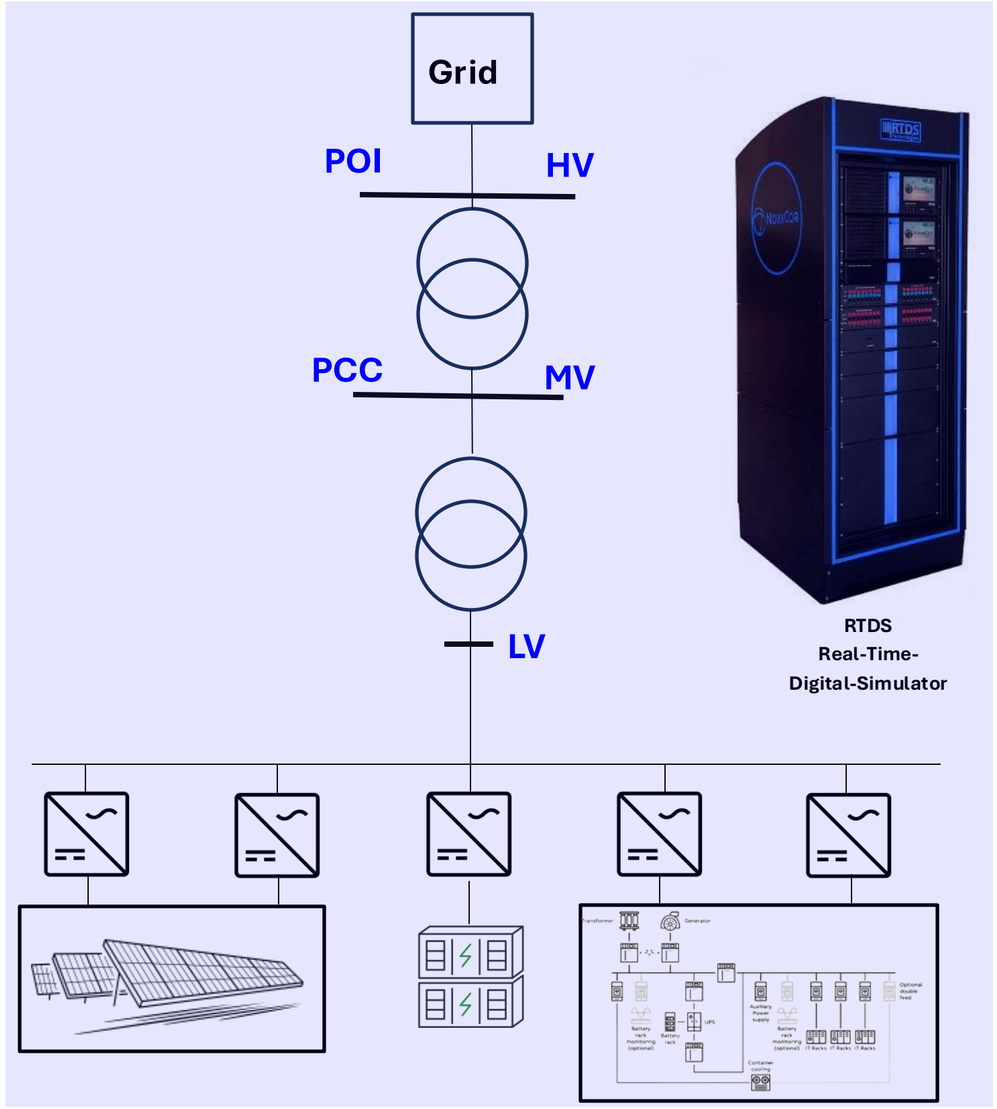
IBR Control System
(This is the OEM controller)

Digital
Firing Pulses
(+-24V)





Comprehensive HIL Structure



EMS+PMS+PPC

Communication
(IEC-61850, MODBUS, DNP3)

Network Card

Fiber Optic

Fiber Optic

Fiber Optic

IEEE C.37.118
Synchrophasor

Communication
(IEC-61850)

Protection & Meters

Analog IOs

Voltage & Current
(HV, MV, LV)

MODBUS
DNP3

Firing Pulses

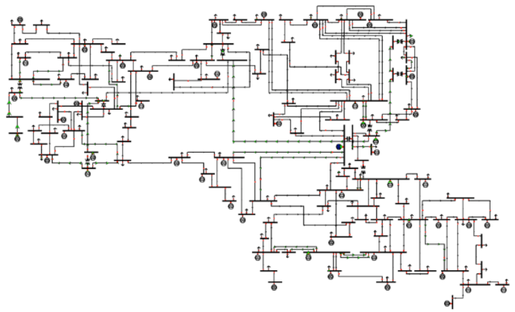
Digital IOs

Communication
(IEC-61850)

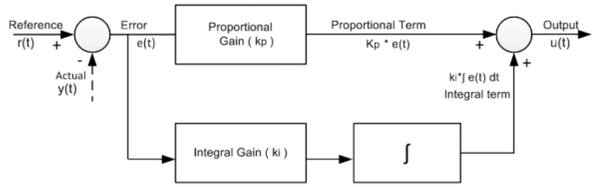
PCS Controller

Importance of HIL

Power System/ Data Centre Model



Control/Protection System



Offline:

PSCAD PSS®E DSATools™ Dynamic Security Assessment Software

Power System Data →

Simulation Freezes!

← P&C Command

MATLAB SIMULINK

Realtime (HIL):

Power System Data →

Everything is Real-time!

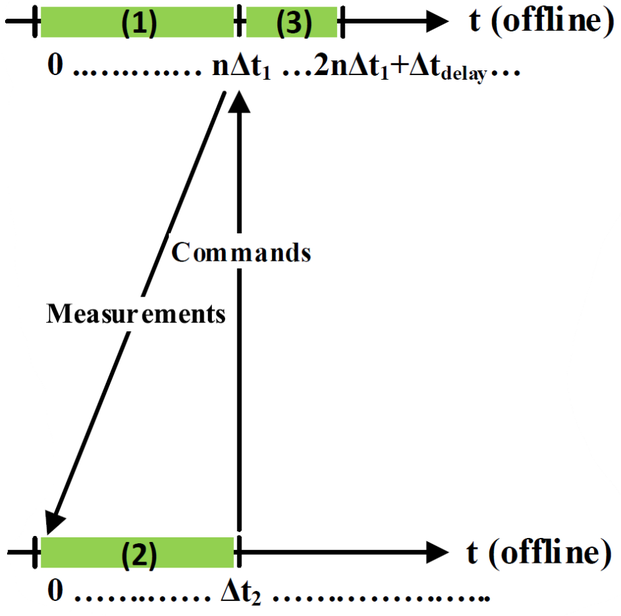
← P&C Command

Difference with Conventional Simulation

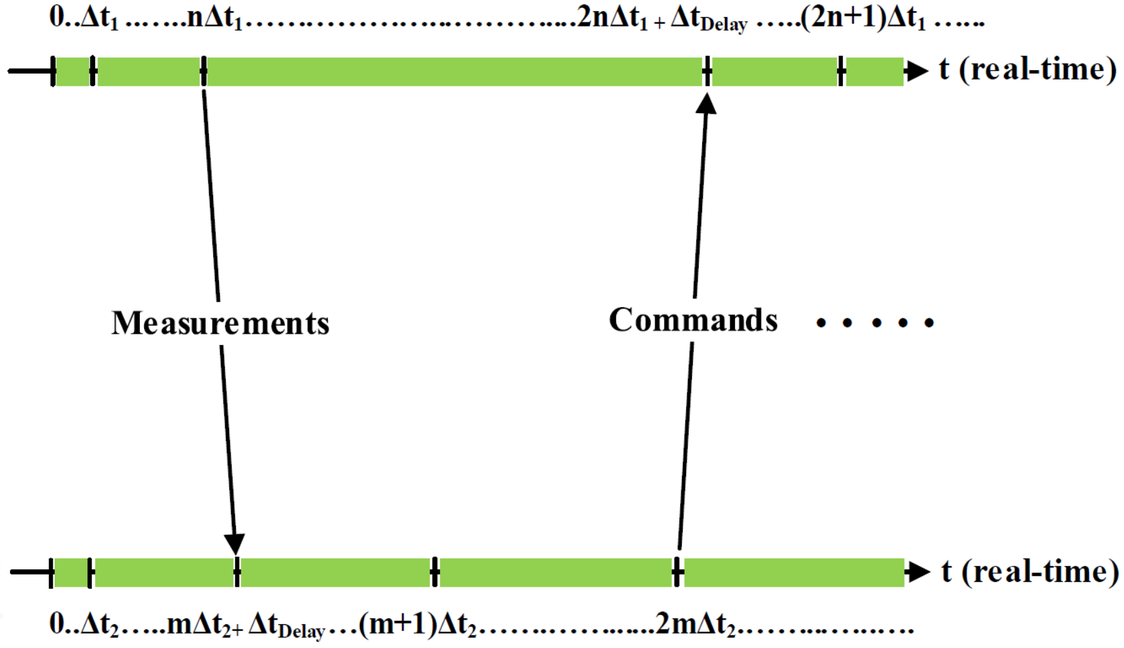
PSCAD PSS®E

DSATools™

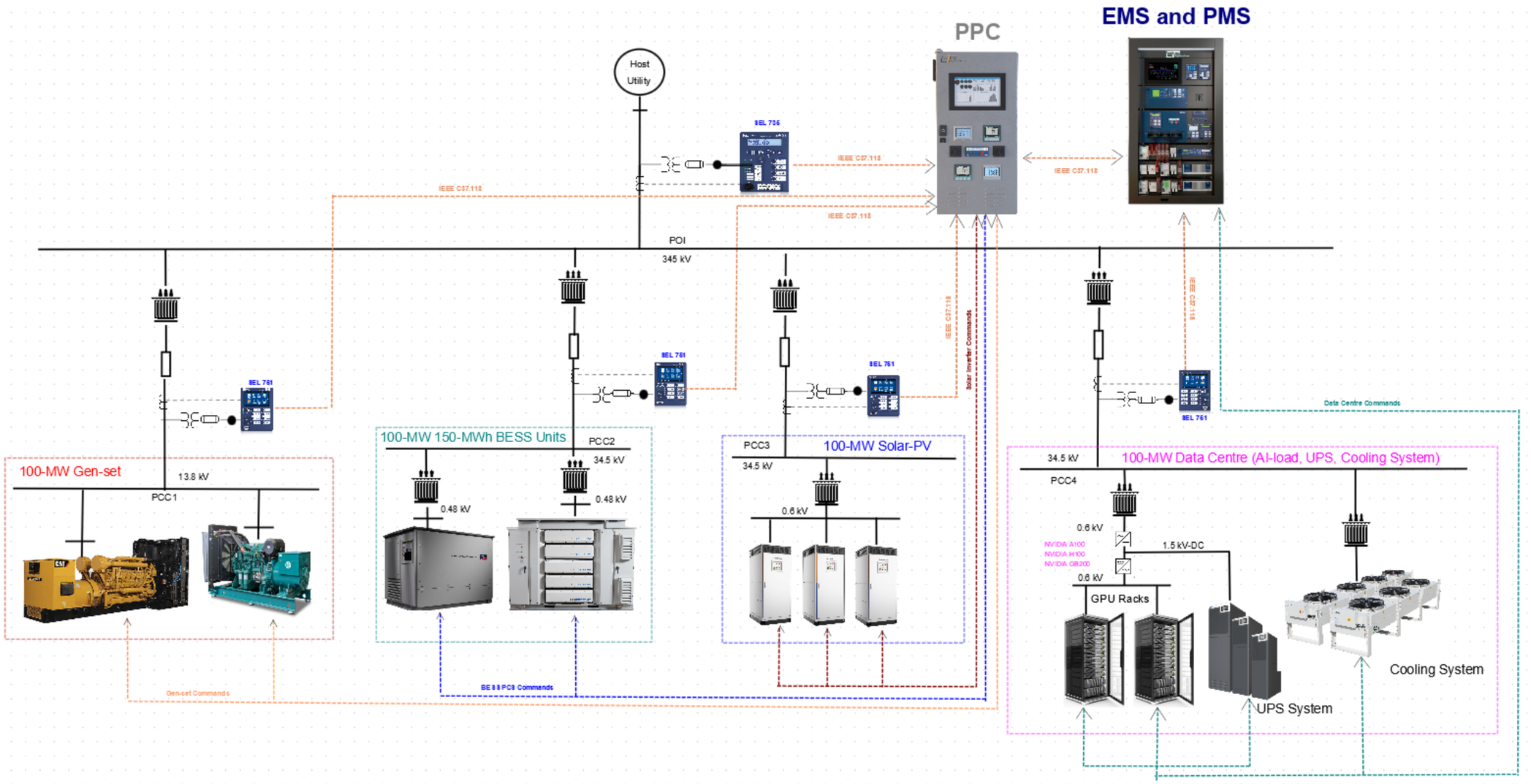
Dynamic Security Assessment Software



MATLAB SIMULINK



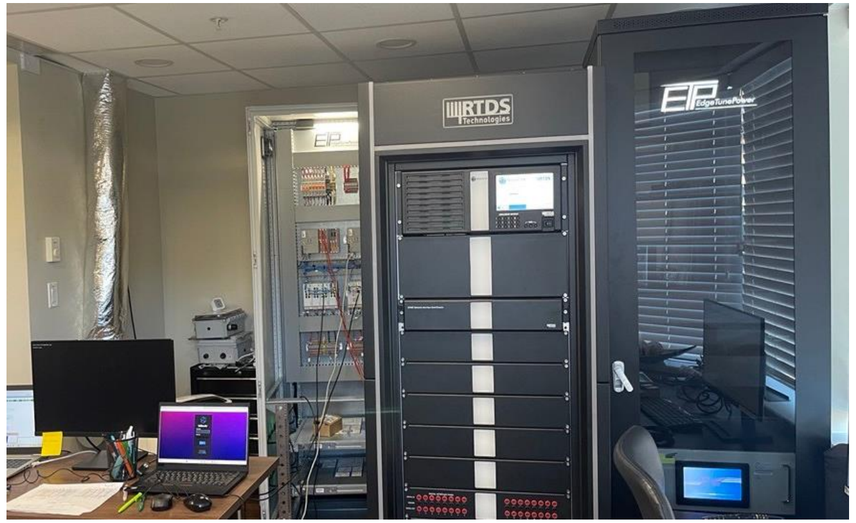
Data Center Test-bed and AI load Simulator



Digital Twin

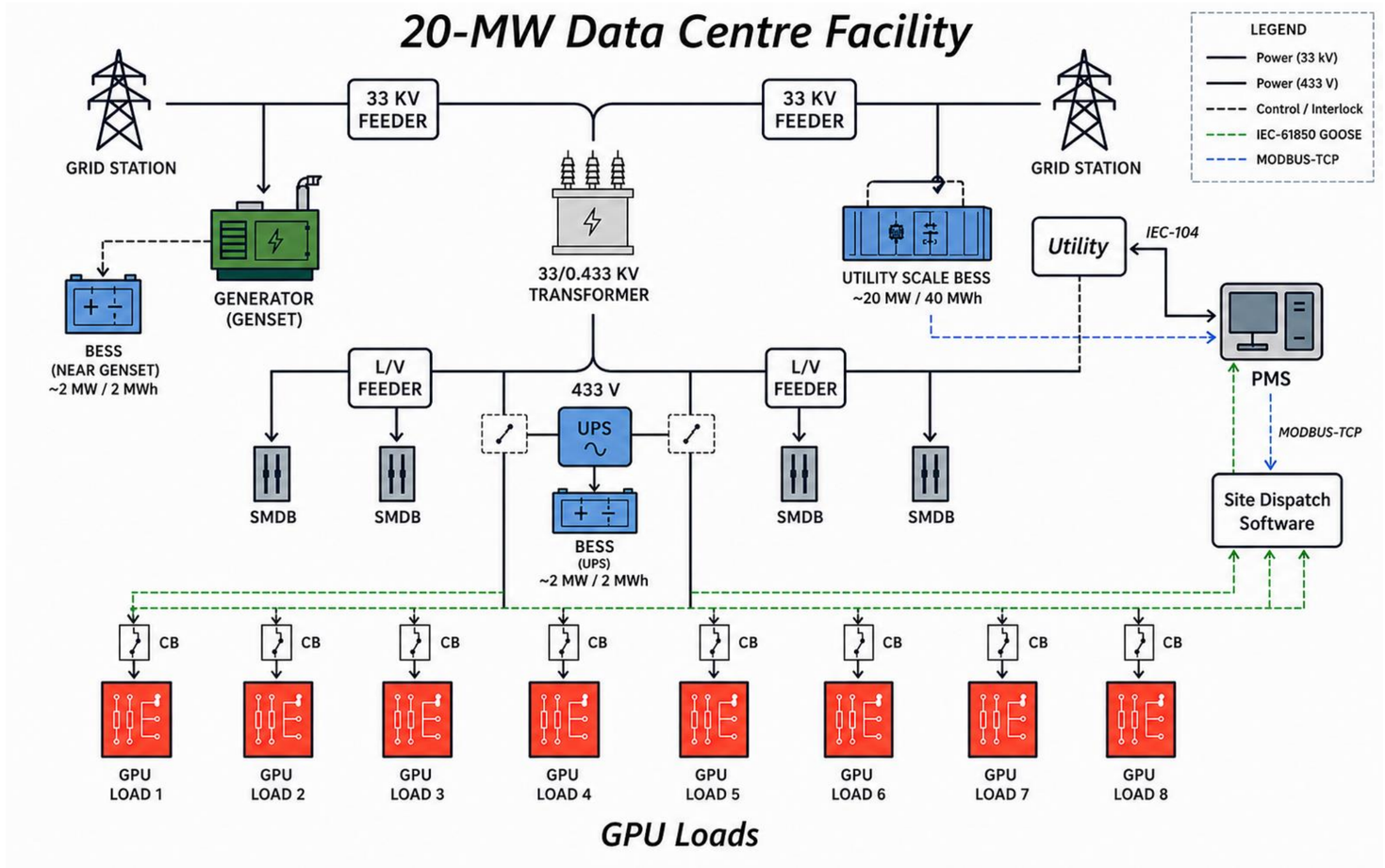
De-Risk Commissioning and HIL Testing

- PCS, IBR Control Systems
- PPC, PMS, EMS via IEEE C37, MODBUS, DNP3, and IEC 61850
- Test and Validate controllers, protection, and communication

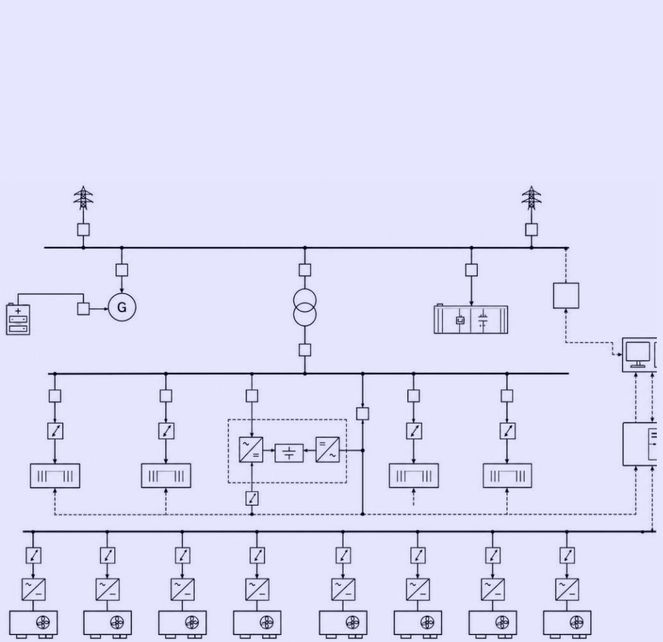


Data Centre Facility

Link	Protocol
UTILITY ↔ PMS (ETP)	IEC-104
PMS (ETP) ↔ Site Dispatch Software Between GPUs	Modbus-TCP
Site Dispatch Software ↔ GPU Systems	Ethernet (Modbus-TCP)
PMS (ETP) ↔ CBs Connecting GPUs	IEC-61850 (GSE)

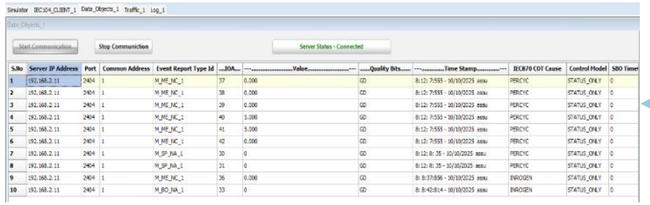


HIL Testing of Dema Data Centre Facility



RTDS
Real-Time-
Digital-Simulator

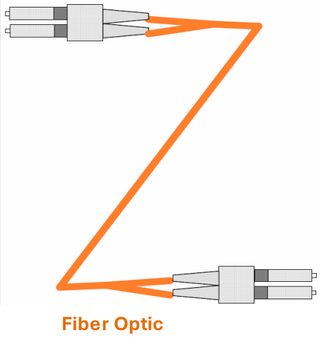
IEC-104 Emulator for Utility



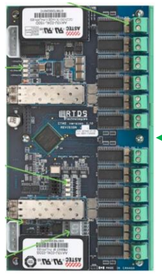
Fiber Optic

Network Card

MODBUS TCP

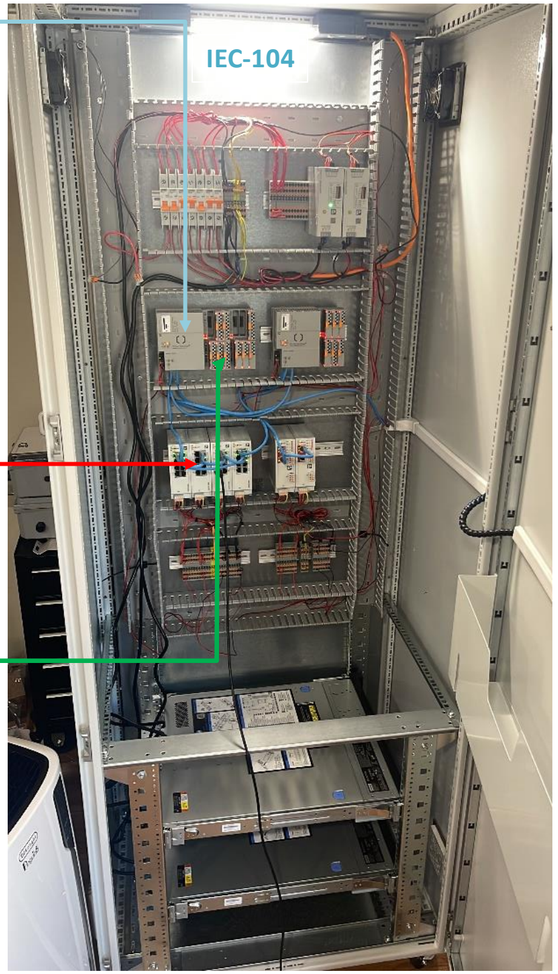


Fiber Optic



Digital IOs

Digital Load Shedding
Commands



Finding Issues with PCS Controller!

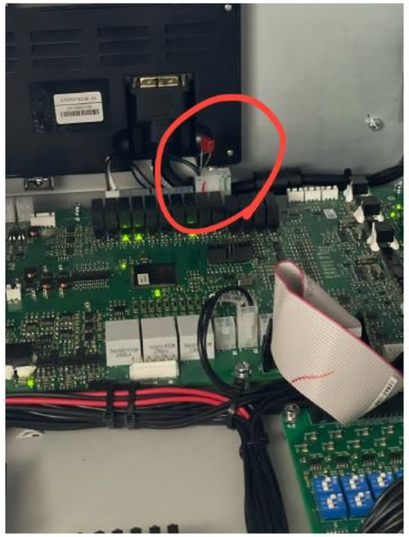


Figure 17. Installation of the film capacitor inside the [redacted]

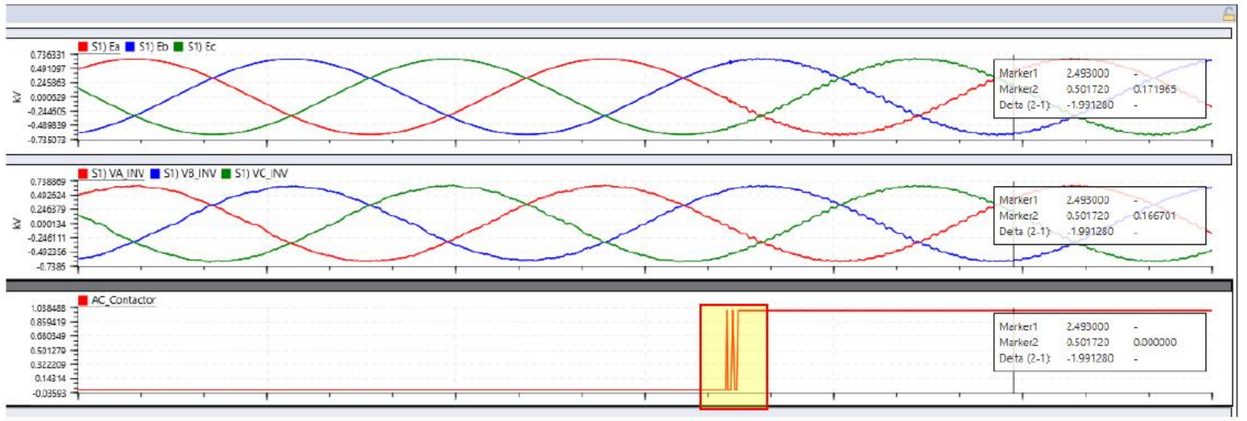
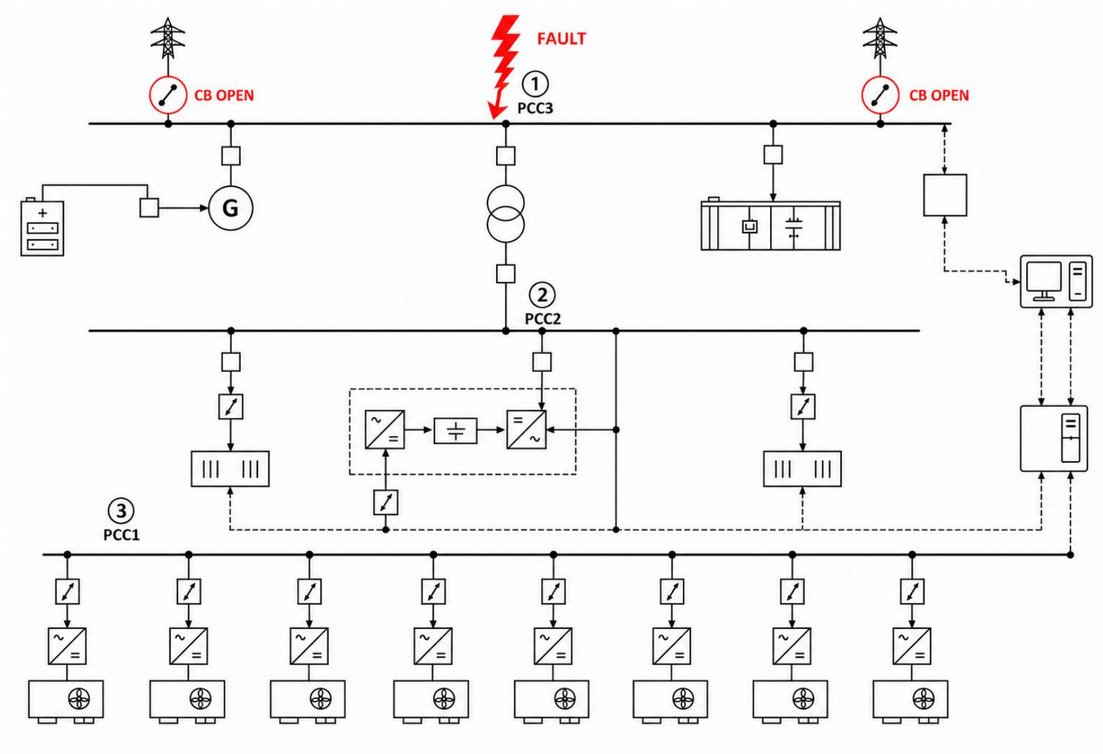
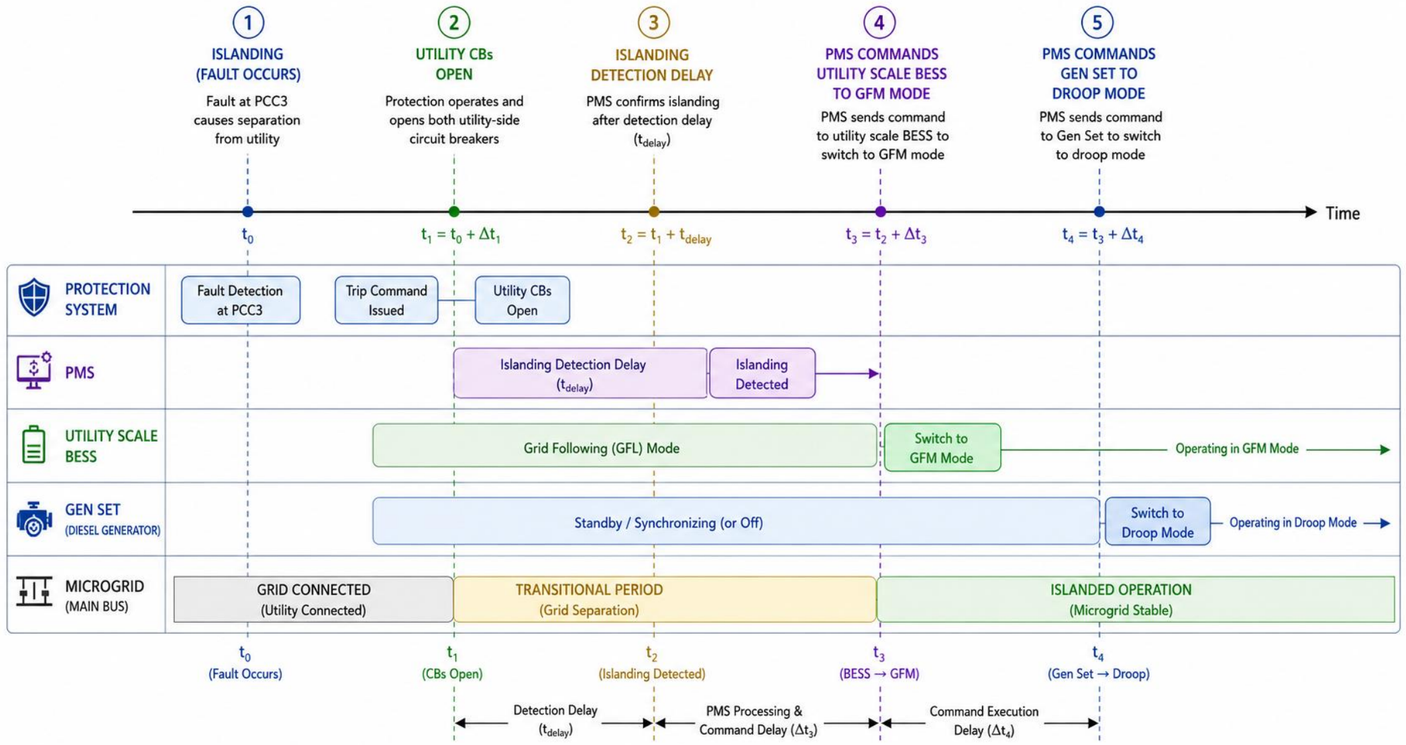


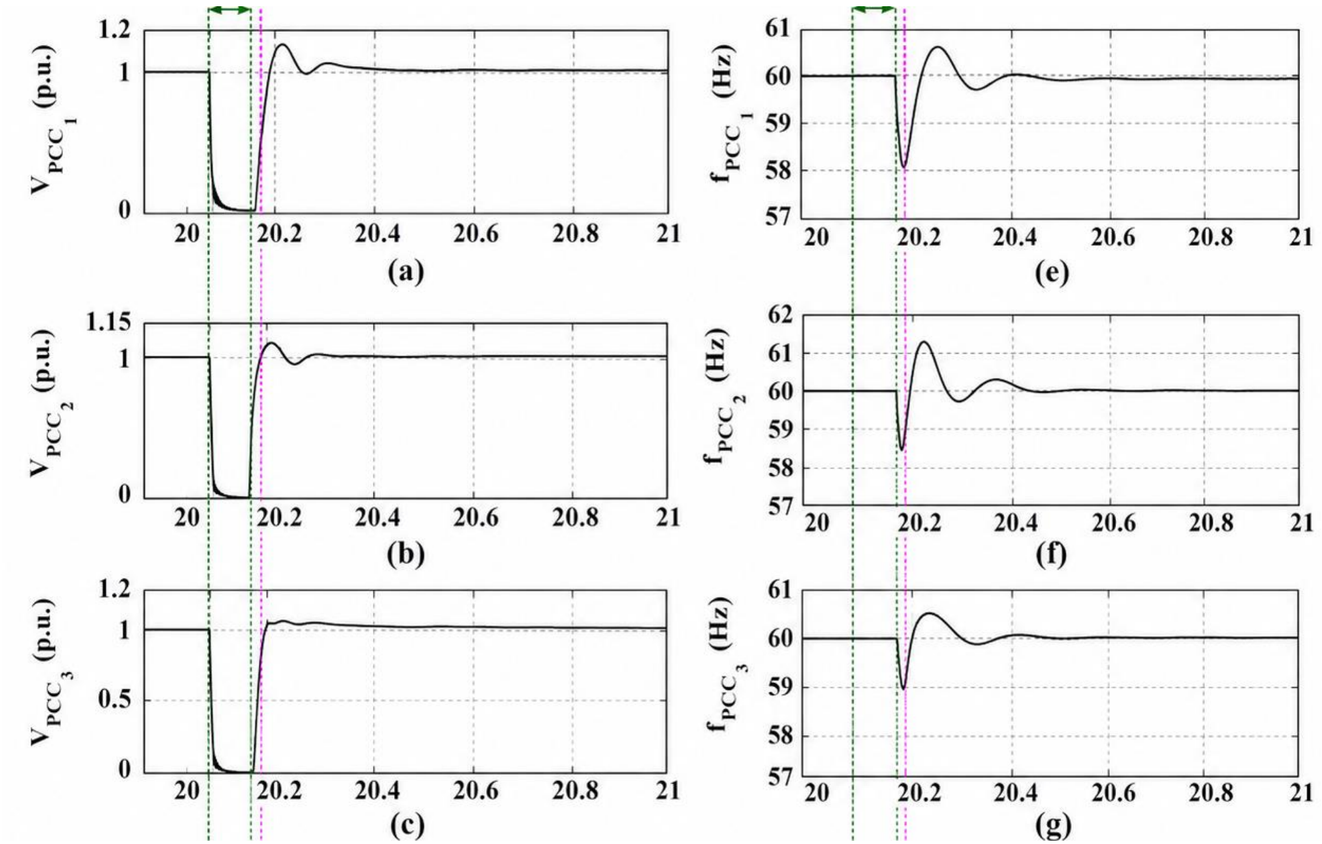
Figure 18. Jittering is observed in the status of the CB breaker

System performance subsequent to accidental islanding





System performance subsequent to accidental islanding



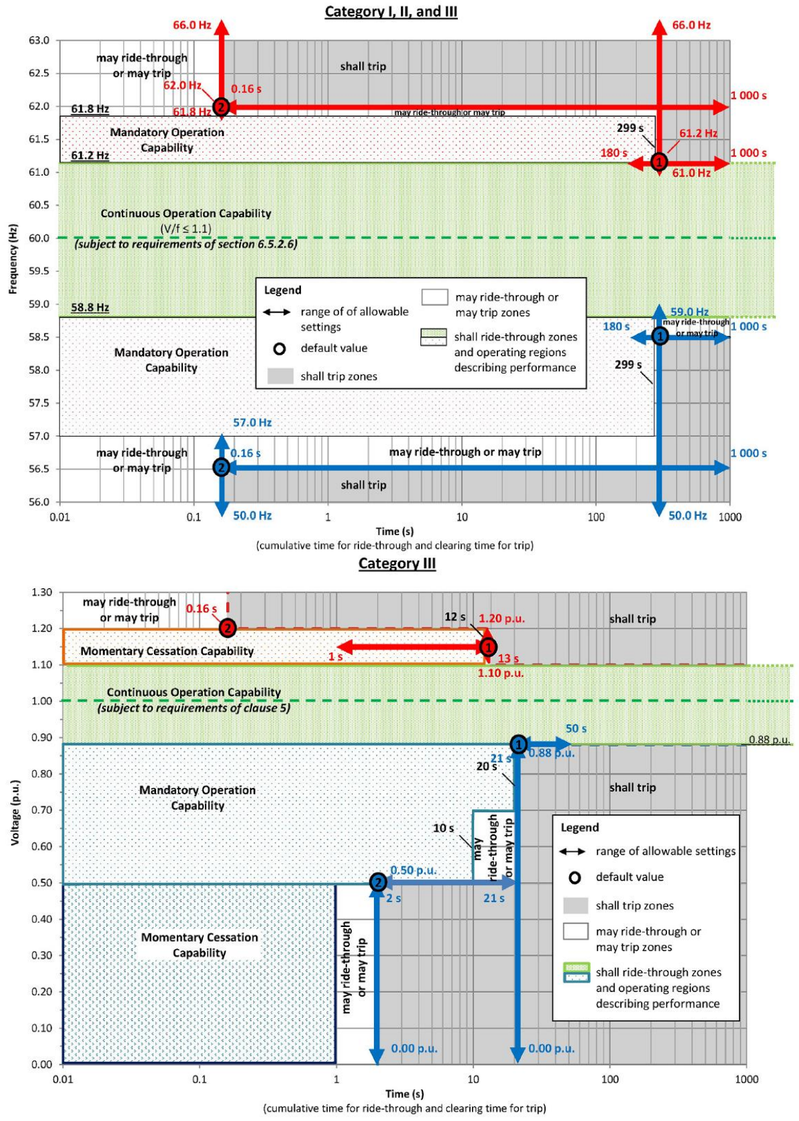
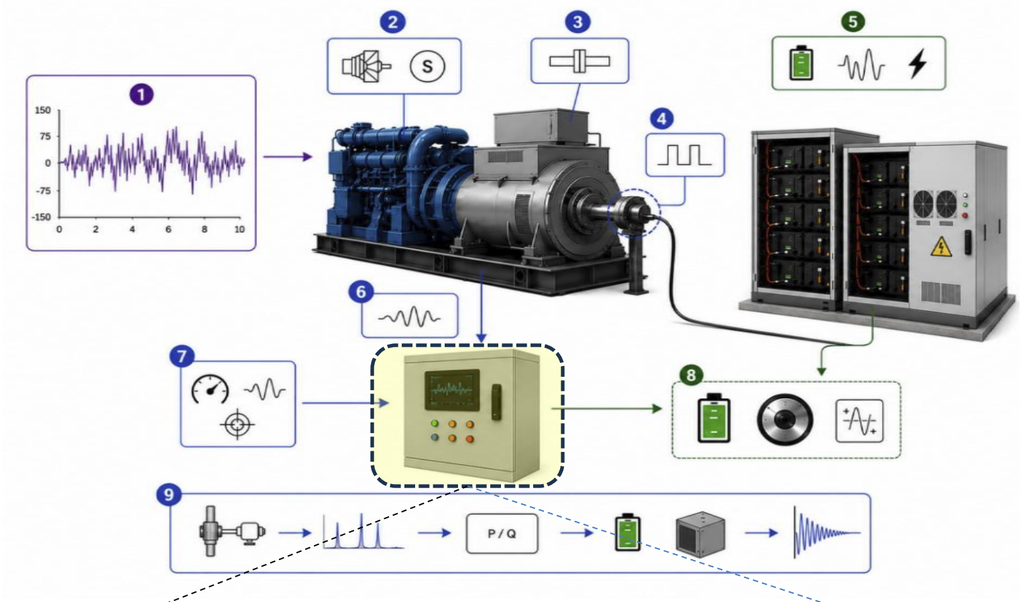


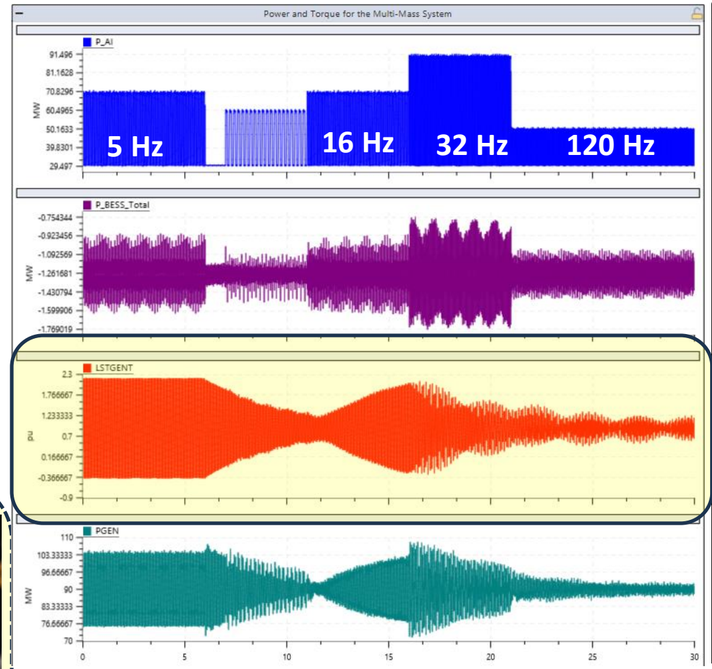
Figure H.9—DER response to abnormal voltages and voltage ride-through requirements for DER of abnormal operating performance Category III

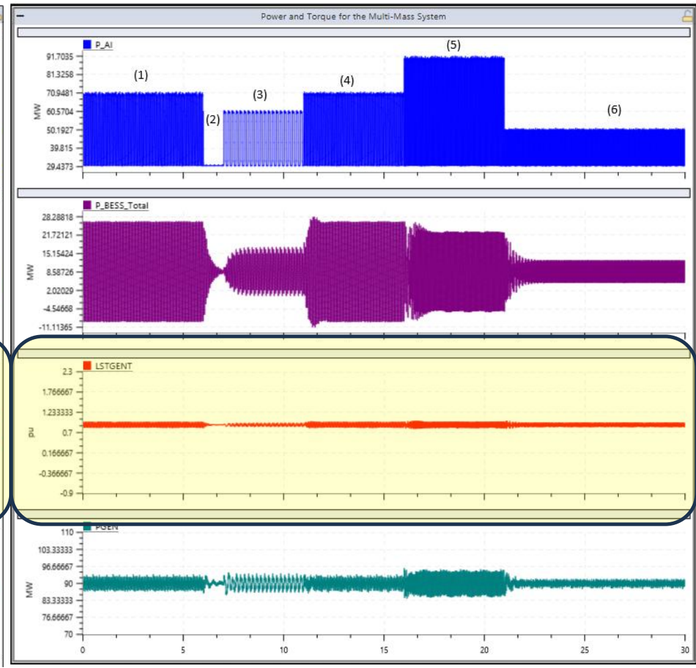
Novel Solution for SSTI Damping

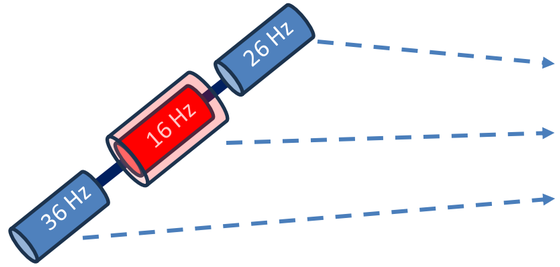


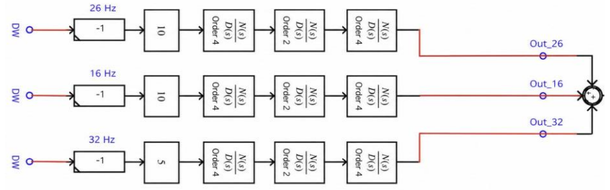
Advantages

- No Communication Latency
- Targeted Shaft Frequencies
- Only ~20% of the generator size for BESS









THANK YOU

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