Real Time Digital Simulator Applications in Education and Research

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Outline

- UQ Renewable Energy Lab Introduction
- Renewable Energy Lab for Education
- Renewable Energy Lab for Research
- On-going Experiment

UQ Renewable Energy Laboratory

Network:

- RTDS (two racks and one NovaCor with two licenced cors)
- Eight Power Amplifiers
- Most commercial power system analysis tools (RSCAD, PSCAD and PSS/E)

Distributed Energy Resources:

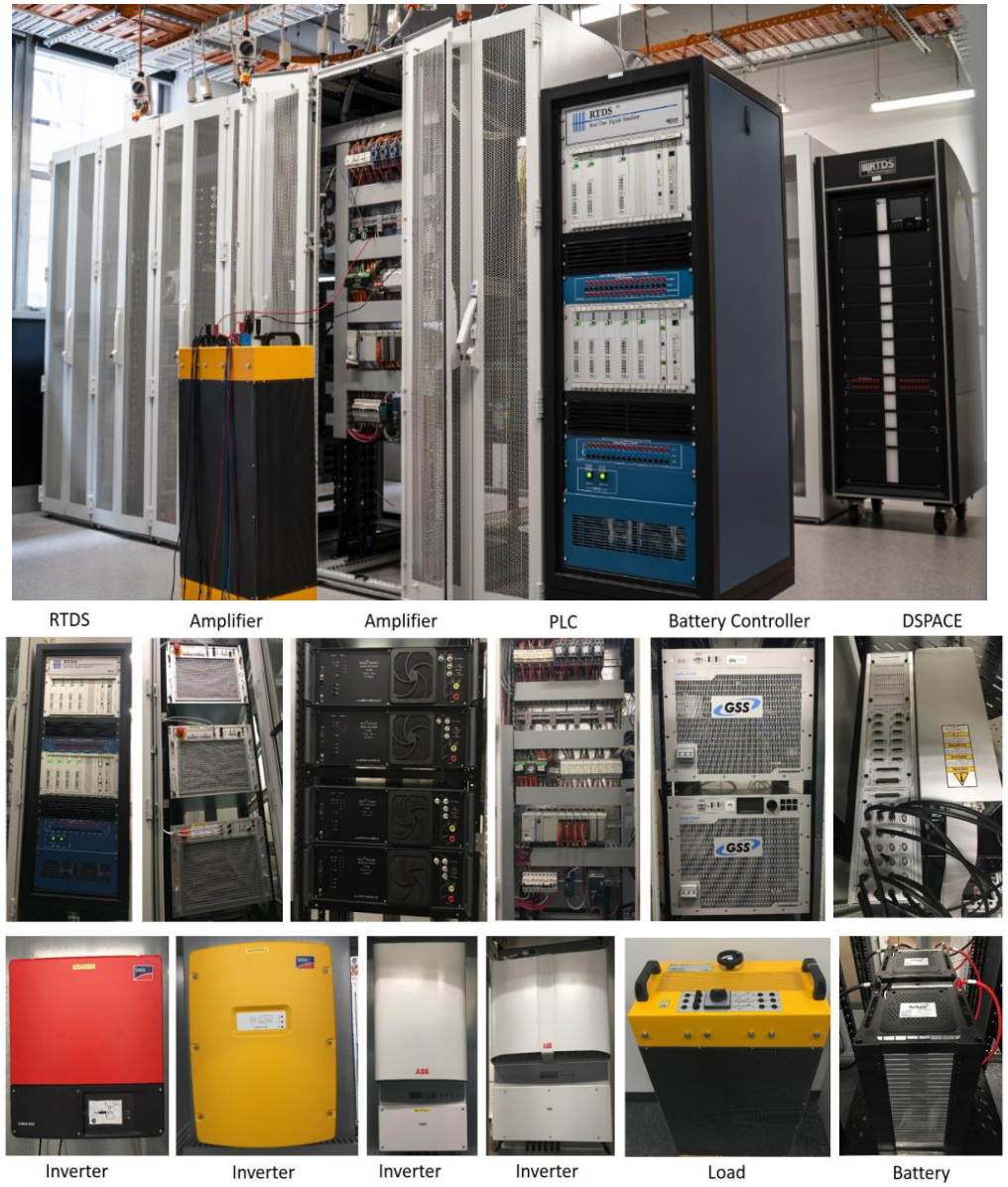
- Two Solar PV Emulators and 5 PV inverters
- Battery Storage and Battery Inverter, BMS, Battery Charge/Discharge Controller and Simulator (GSS)

Load:

- Electrical Load and Resistant Load, Air-conditioner, Fridge

Control and communication:

- Faster Controller dSPACE, two Siemens Relays
- Dedicated communication and control by PLC

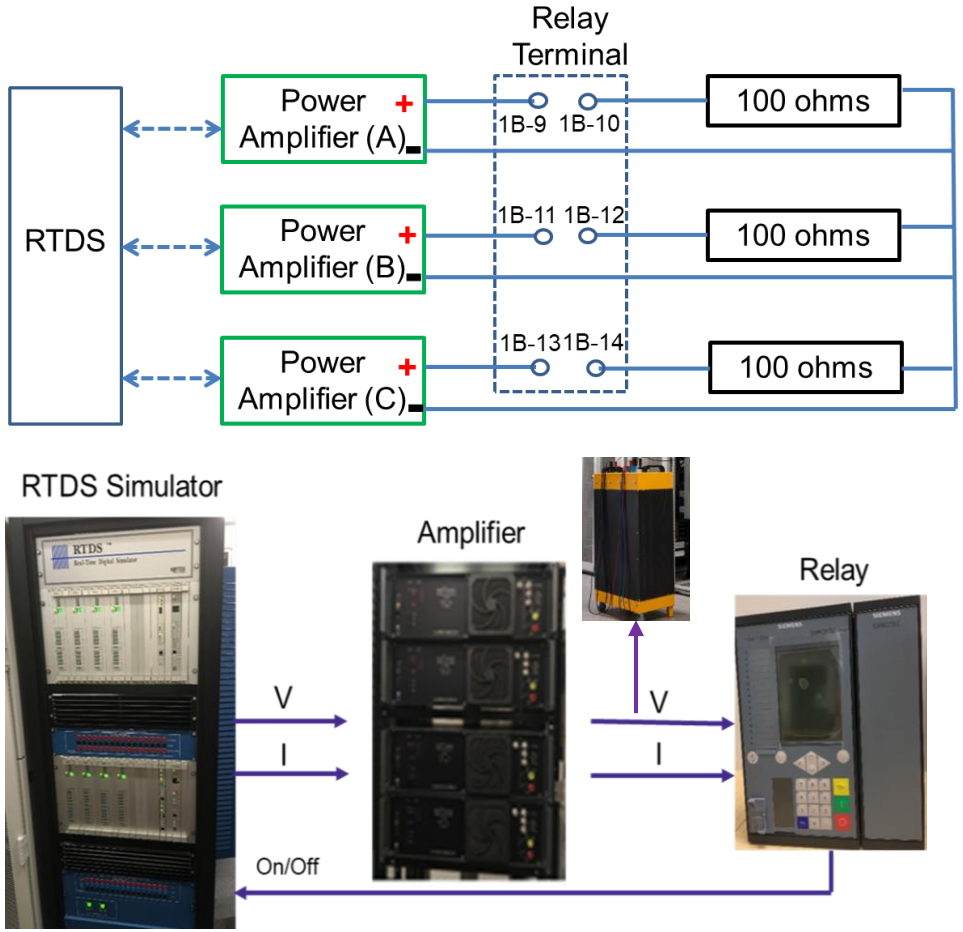


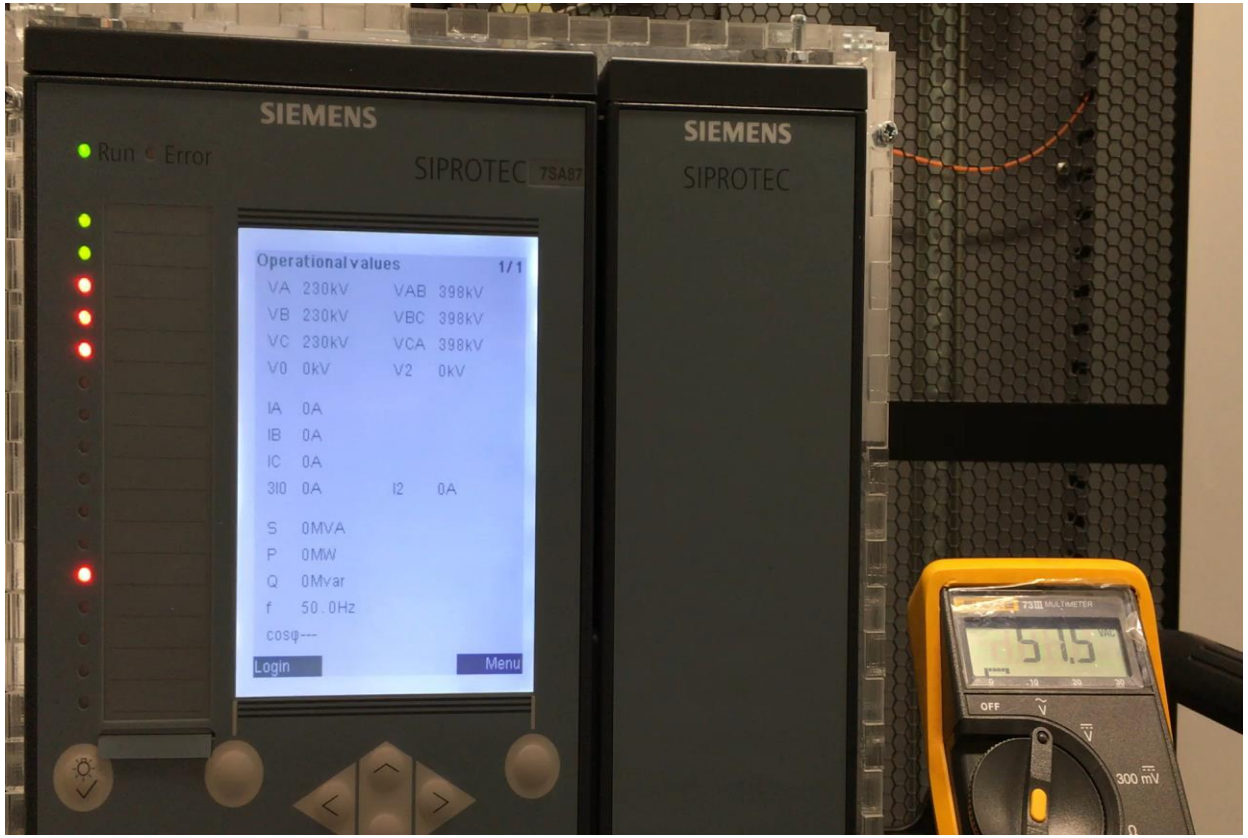
Renewable Energy Lab for Education

- Power system protection-relay test
- Power network modelling and simulation
- Hardware-in-the-Loop experiment

1. Relay Testing with Amplifier and RTDS

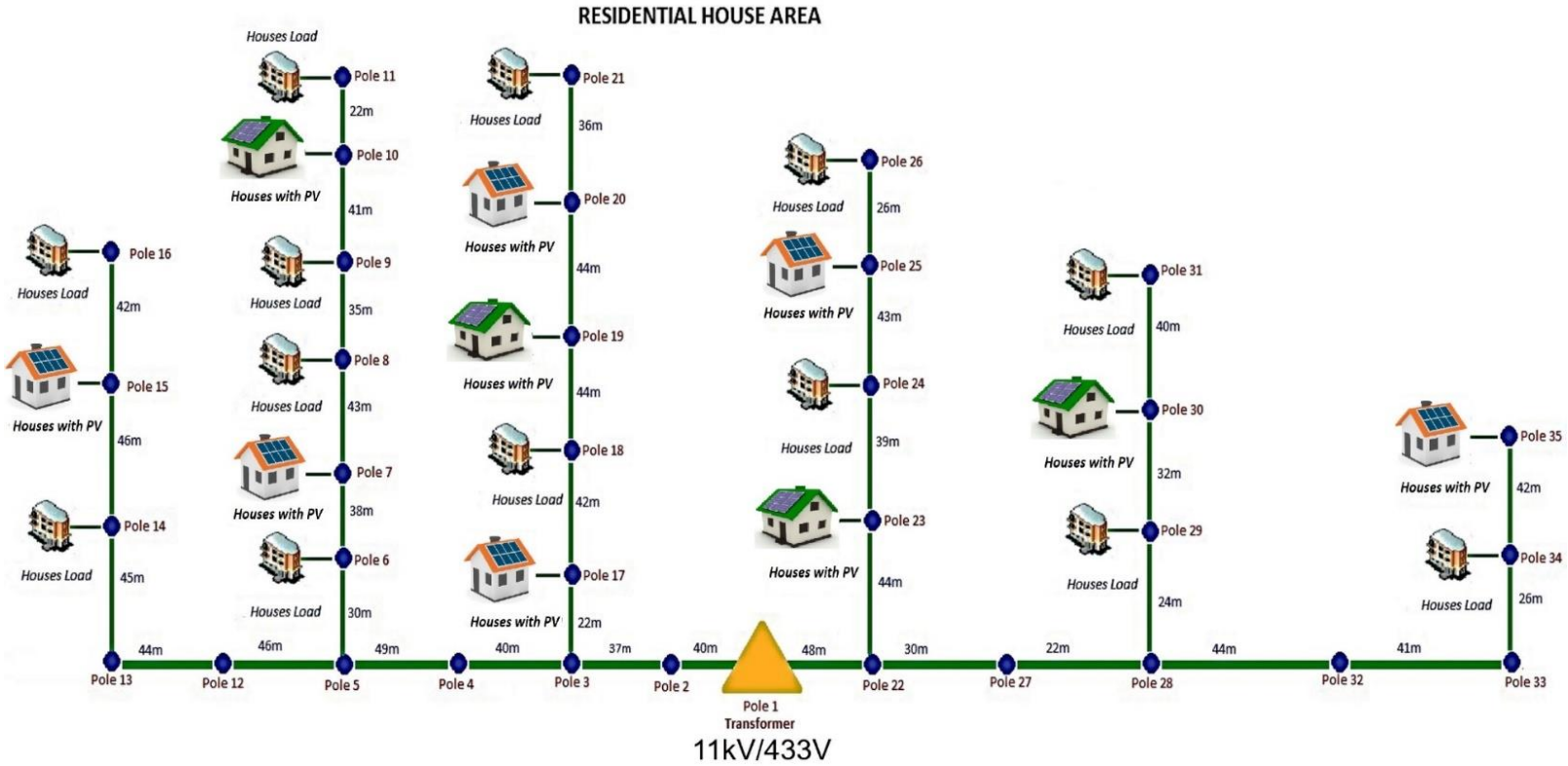
- Course: Power system protection (ELEC4302), ~35 students/semester
- Objective: Strengthen the understanding about the power system protection theory.
- Practical: Apply various events to test the existing and developed functionalities of the protection relay.
- Example: an under-voltage protection was programmed into the relay (40% voltage drop)





2. Distribution Network Modelling

- Course: Renewable energy integration (ELEC7313), ~35 students/semester
- Objective: Enhance the understanding of the renewable energy integration impact to the po networks.
- Practical: RSCAD-based modelling and hardware-in-the-loop test
- Example:
  - ✓ Three-phase 35-bus system
  - ✓ Operating at 11kV/433V supplies 102 houses
  - ✓ Transformer: 315kVA, Δ-Y

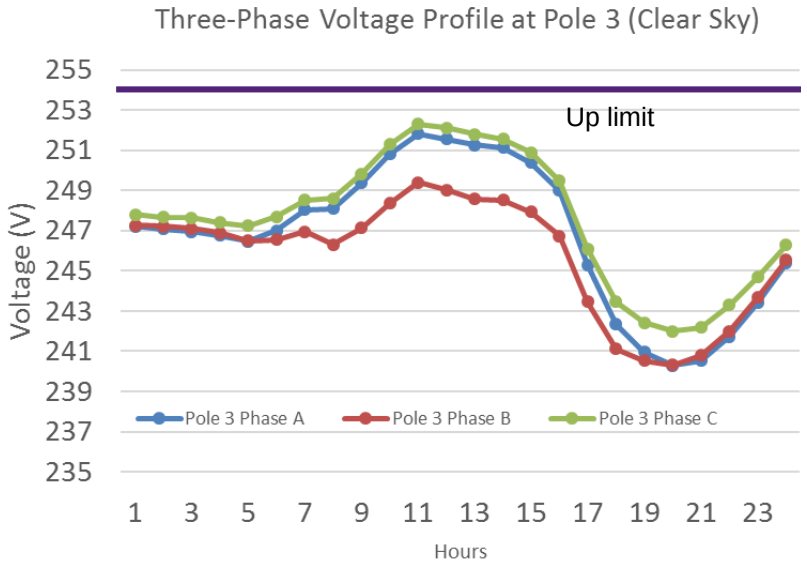


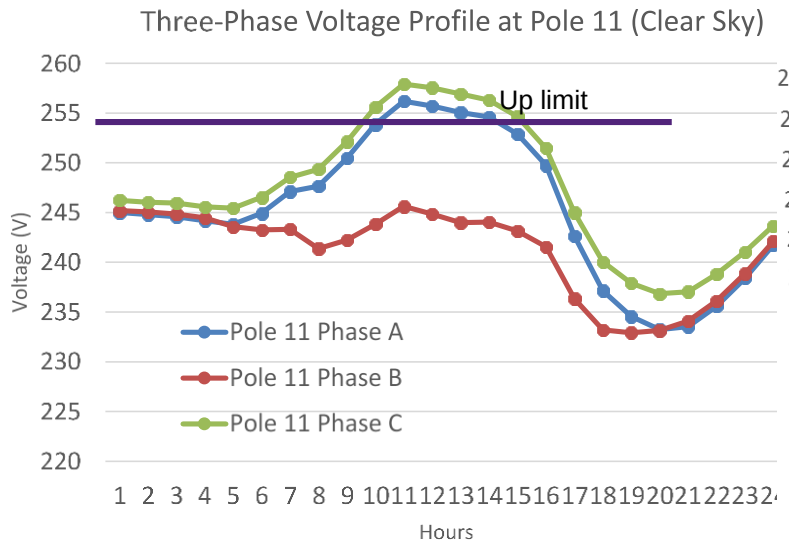
2. Unbalanced Distribution Network Modelling

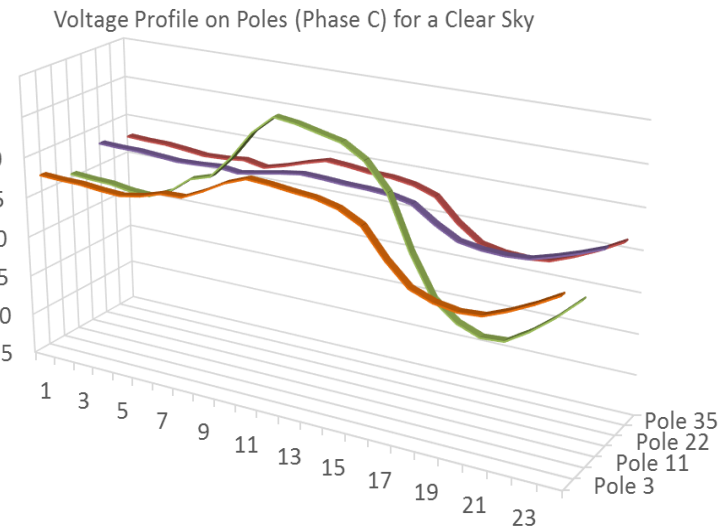
- ❖ Major components
- ✓ Single-phase house : dynamic PQ model with actual load data injection
- ✓ PV system: dynamic PQ model/current source with actual solar power data injection
- ❖ Power flow model validated with Open-DSS

Example scenario:

- ✓ 60% houses installed PV with 5kWp.
- ✓ More voltage unbalance during PV power injection time.
- ✓ Reverse power flow during the mid-day, some poles have voltage violation issues.

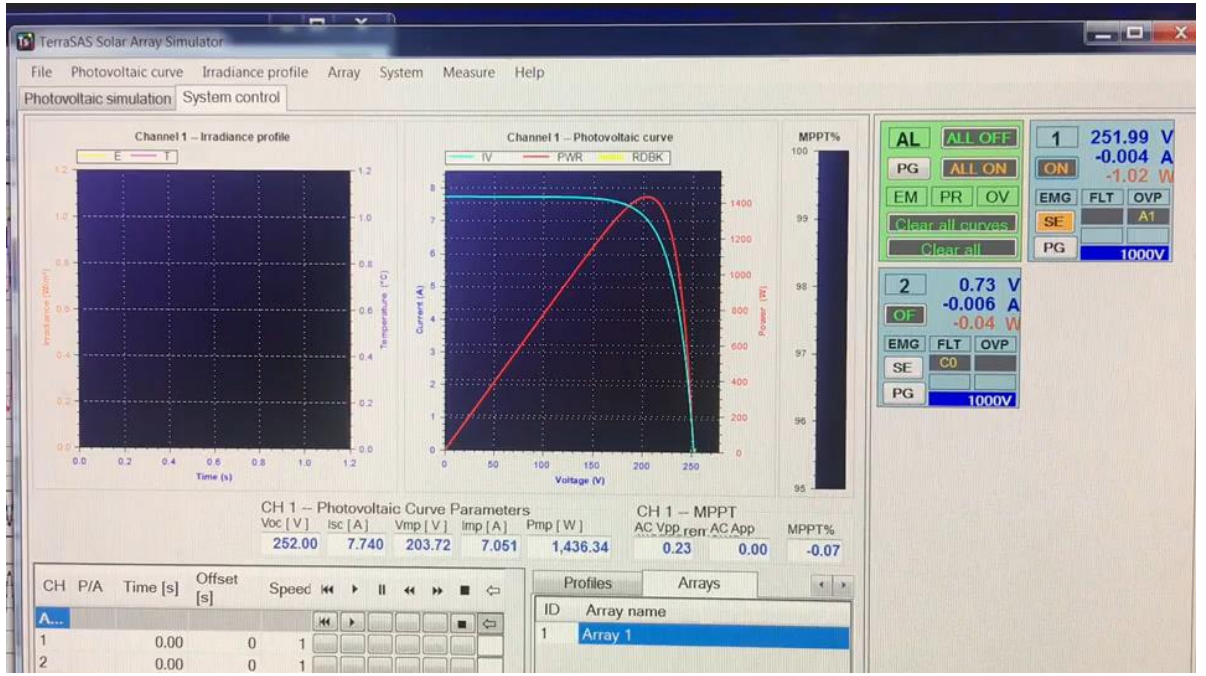


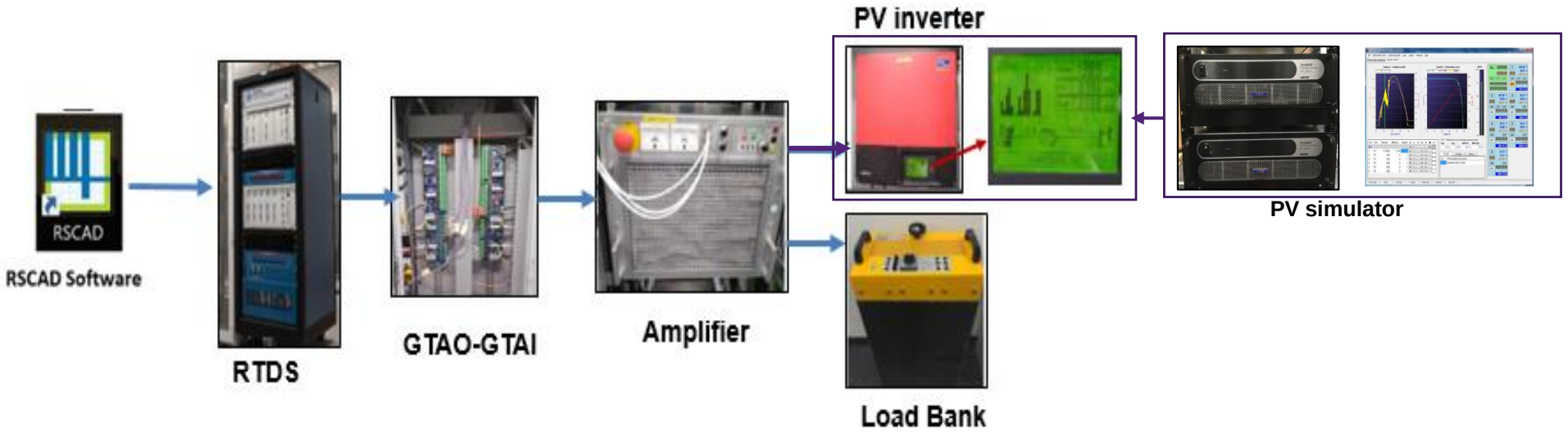




3. PV Inverter MPPT Test

- The power output of the PV simulator will be injected into the PV inverter.
- PV inverter MPPT boosts for around 2 minutes.
- Inverter DC side voltage and current become consistent after the power reaches the maximum power point (CT,PT installed).





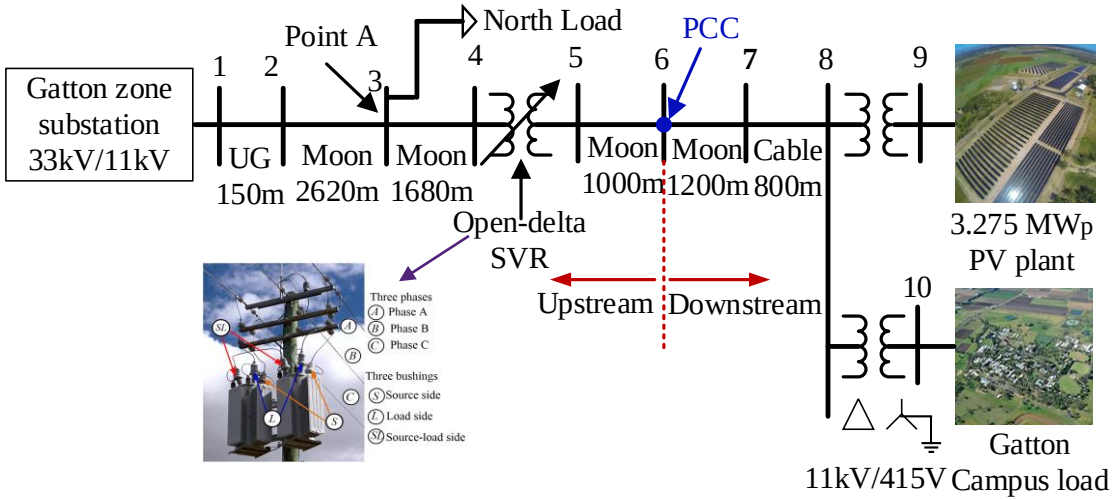
Renewable Energy Lab for Research

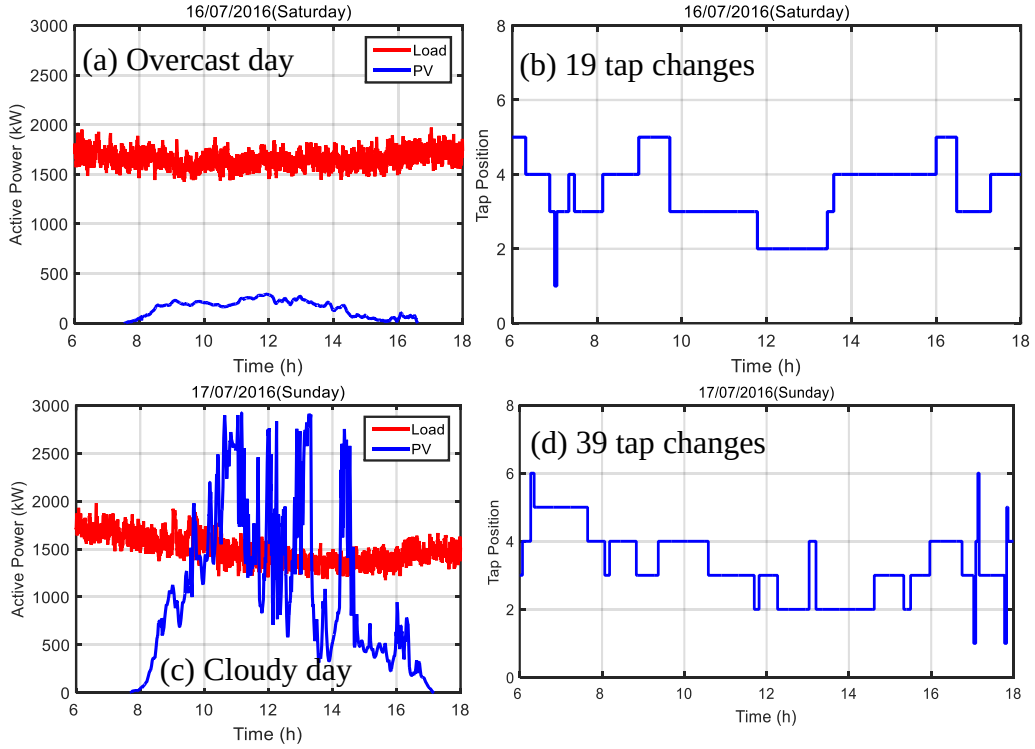
- Real-time voltage management validation
- Inverter-based device operating behaviours extraction
- Battery management demonstration

1. Coordinated Control for Voltage Regulation

- Studied System: Load 2.5MW to 3MW, PV Plant: 3.275MWp, BESS:760kWh
- Motivation: Excessive SVR tap operations, Battery overuse

  Voltage connection agreement [0.975 pu. to 1.01pu]
- Approach: short-term voltage sensitivity control + long-term voltage margin control
- Achievements:
  - Real-time control(every 5s)
  - Q priority (cost-effective)
  - Reduction of battery overuse
  - Non-interactive control with upstream SVRs

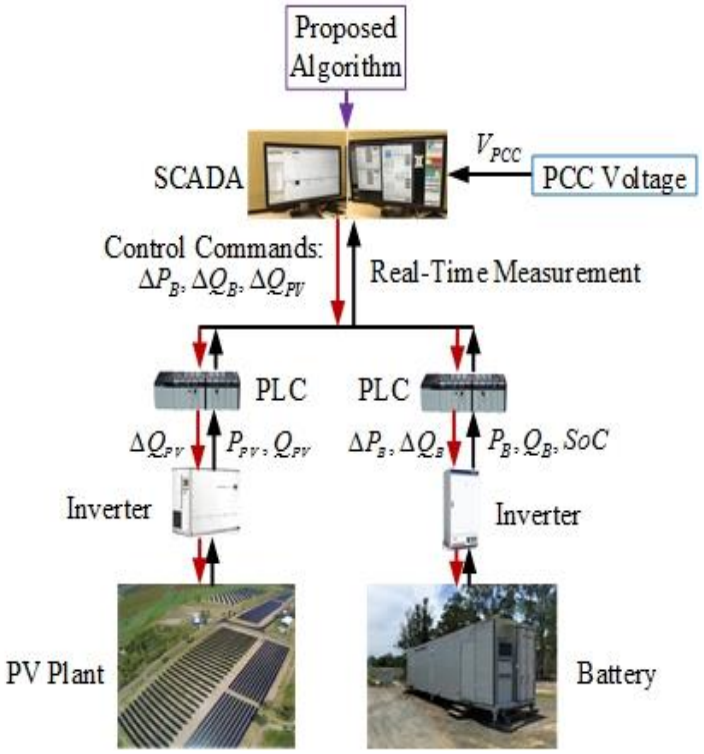


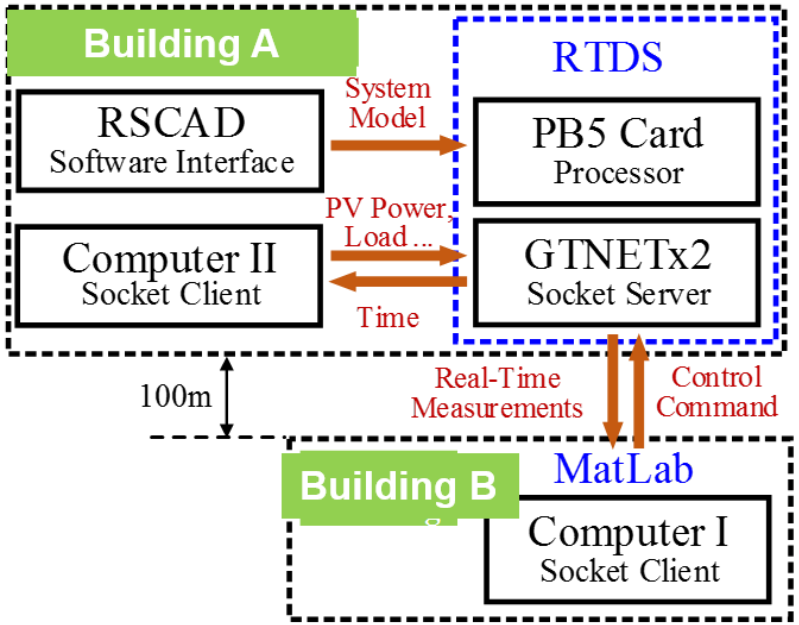


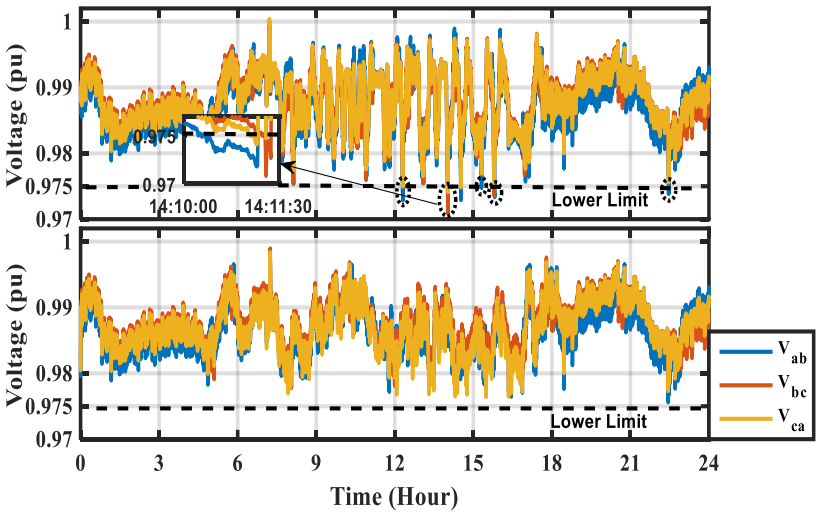
L. Wang, F. Bai, R. Yan, T. K. Saha, "Real-Time Coordinated Voltage Control of PV Inverters and Energy Storage for Weak Networks with High PV Penetration", ***IEEE Trans. on Power Systems***, 2018, Vol.33, issue:3, pp:3383-3395.

1. Coordinated Control Algorithm Validation with RTDS

- ❖ To model the real application scenarios, the actual system (Building-A) and the control centre (Building-B) are location in different places.
- ✓ A bidirectional communication link is created between RTDS and MatLab through GTNETX2.
- ✓ Computer II for network : Update the load, voltage and PV generation in RTDS at every 1s.
- ✓ Computer I for control centre: Send the generated control commands by Matlab control algorithm to RTDS.

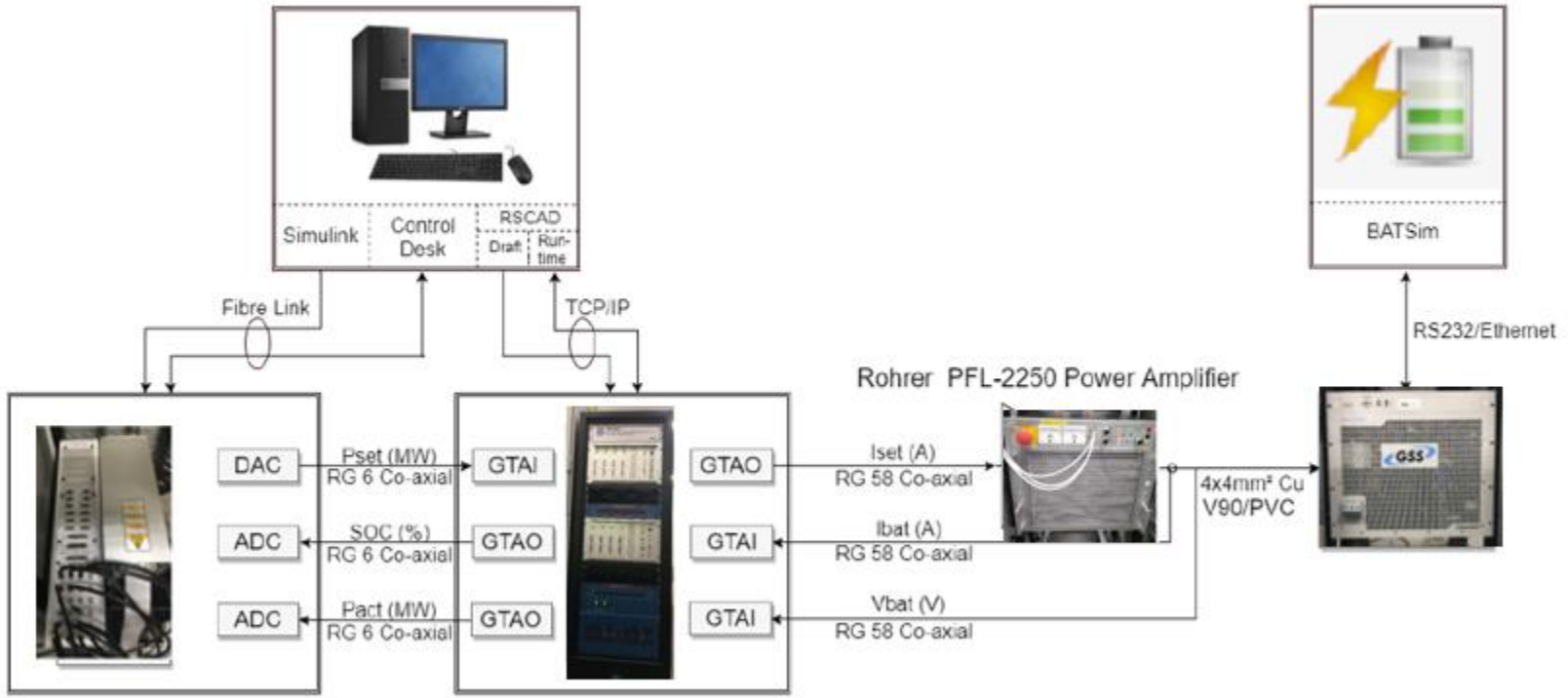






3. Hardware for Battery Management

- ❖ dSPACE conjunction with Matlab to test control prototype in real time (50μs time step).
- ✓ dSPACE: Monitoring status receiver and control comments sending
- ✓ Matlab/Simulink: Battery control algorithm, dSPACE -BATSim interface
- ✓ RSCAD: Network, GTAO, GTAI
- ✓ Battery： Battery simulator (BATSim)/Kokam Battery

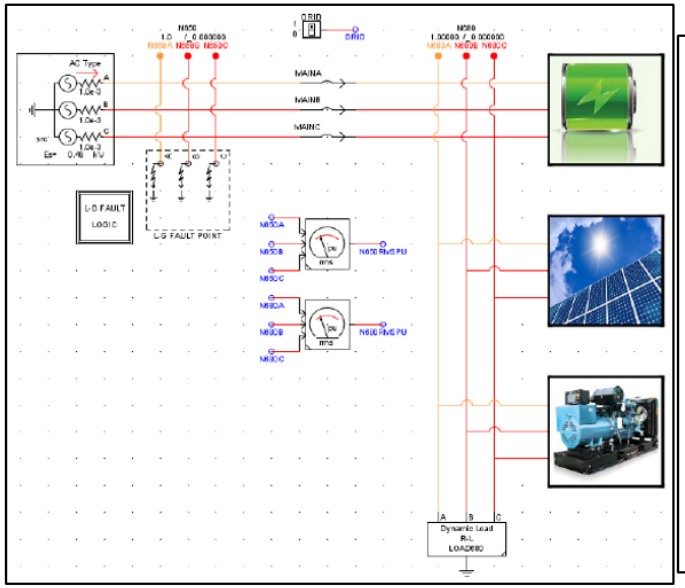


3. Battery Management Applications

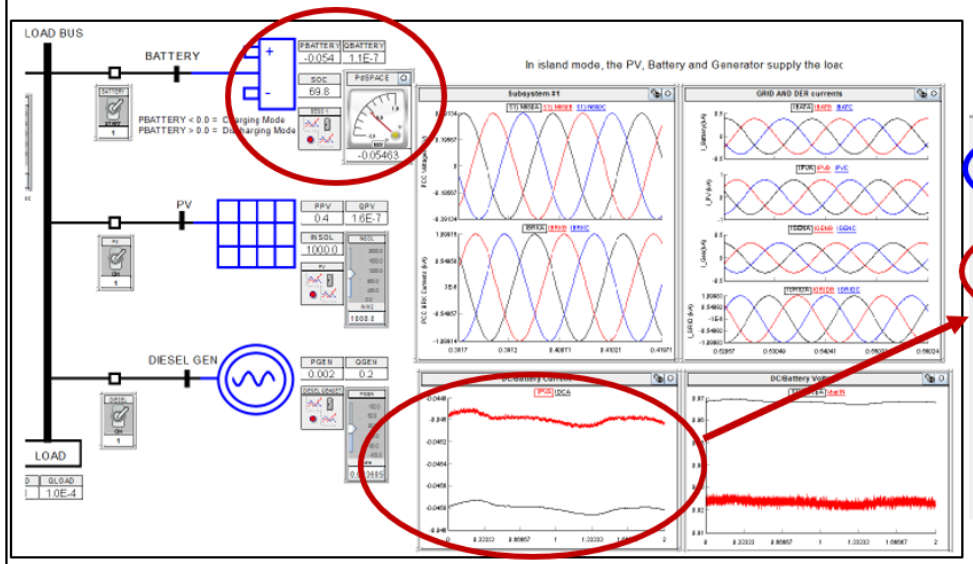
- The system performance successfully demonstrated a realistic scenario of a grid connected BESS under the control of a dSPACE model.
- Scenario: Battery charging mode

✓ Battery setting: $P = 0.05MW$

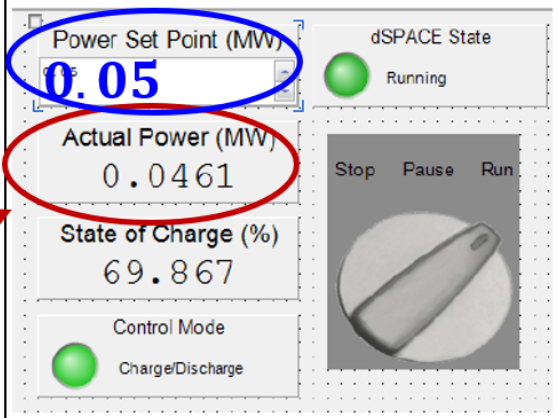
✓ Battery response:$P = 0.0461MW, \mathrm{SOC} = 69.867\%$, PBATTERY<0==charging mode



Microgrid in RSCAD for network



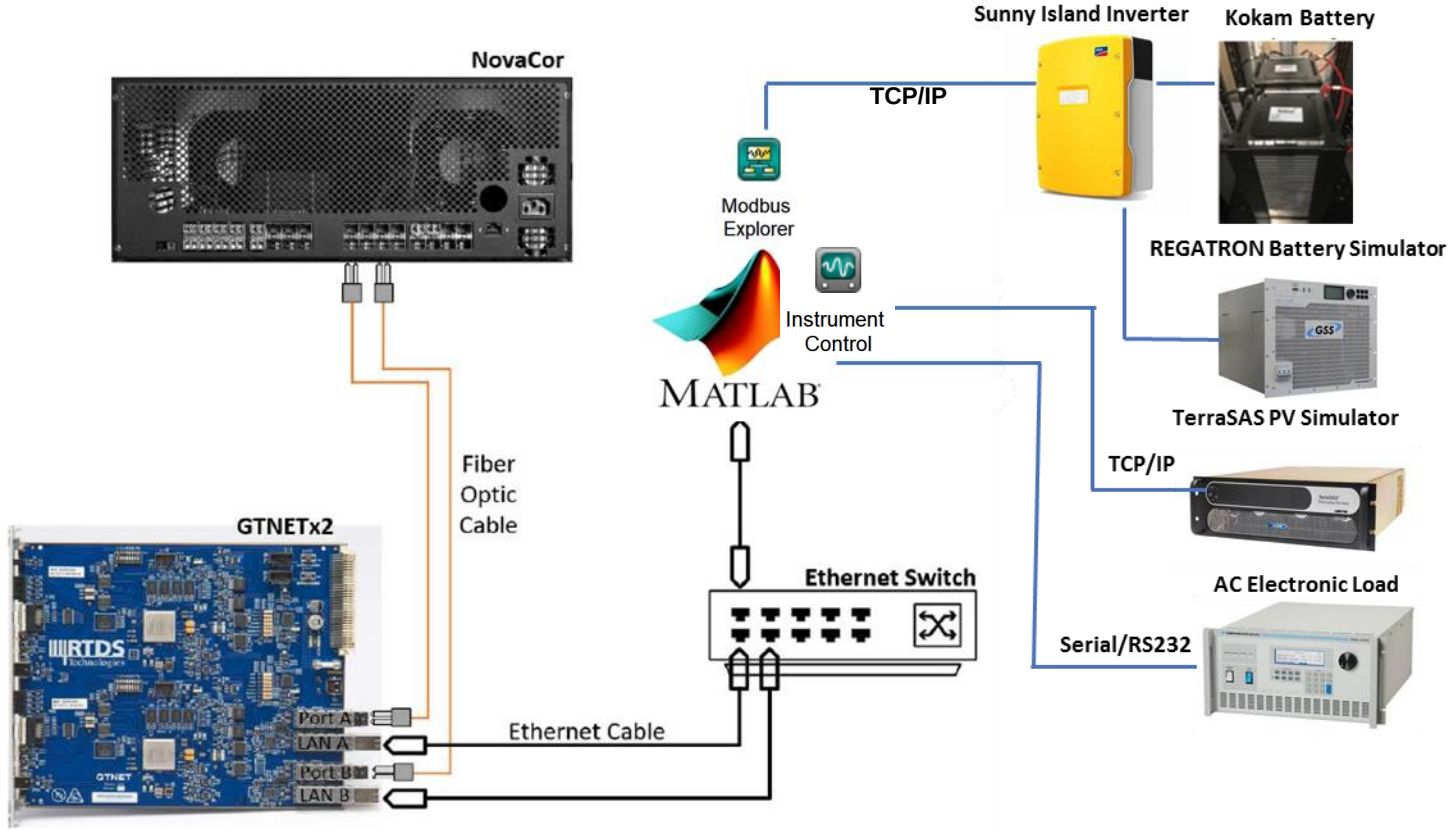
RSCAD Running



dSPACE Experiment Layout

4. Centralized Control Platform Design

- ❖ Centralized Control Platform Design for monitoring status receiver and control comments sending
- ✓ PV simulator, Battery inverter:TCP/IP
- ✓ Matlab/Simulink: Control algorithm, dSPACE -BATSim interface
- ✓ RSCAD: Network, GTAO, GTAI, GTNETX2
- ✓ Battery： Battery simulator (BATSim)/Kokam Battery



On-going RTDS-based Experiment

- Centralized control of all controllable devices with RTDS through Matlab interface.
- Battery storage control system testing with Lithium-ion battery, BMS and battery inverter.
- South Australia model development and validation
- PMU testing
- …

Thank you!

Thanks for the strong support from RTDS Team!