WEBINAR

DE-RISKING MICROGRIDS WITH REAL-TIME SIMULATION AND HIL TESTING

RTDS Technologies

RTDS.COM

RTDS TECHNOLOGIES - THE COMPANY

- **Based in Winnipeg, Canada**
- **~75 employees**
- **World pioneer of real-time simulation and exclusive supplier of the RTDS Simulator**
- **Representatives in over 50 countries**
- **Hardware and software development, model development, customer support, sales and marketing, finance, product assembly and testing all under one roof**

HISTORY OF REAL-TIME SIMULATION

- **1986**

  RTDS development project begins

- **1989**

  World's 1st real-time digital HVDC simulation

- **1993**

  1st commercial installation

- **1994**

  RTDS Technologies Inc. created

WORLDWIDE USER BASE

WORLDWIDE USER BASE

SIEMENS

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

GE

ABB

UNSW
THE UNIVERSITY OF NEW SOUTH WALES

FLORIDA STATE UNIVERSITY
VIRES ARTES MORES
1851

SEL
SCHWEITZER ENGINEERING LABORATORIES

TU Delft

MANCHESTER
1824
The University of Manchester

APPLICATION AREAS

Distribution

- Microgrid testing.
- Renewables/DERs.
- Distribution automation.
- Inverter testing.

Smart Grid

- Wide Area P&C testing.
- PMU studies.
- Cyber security.

Power Electronics

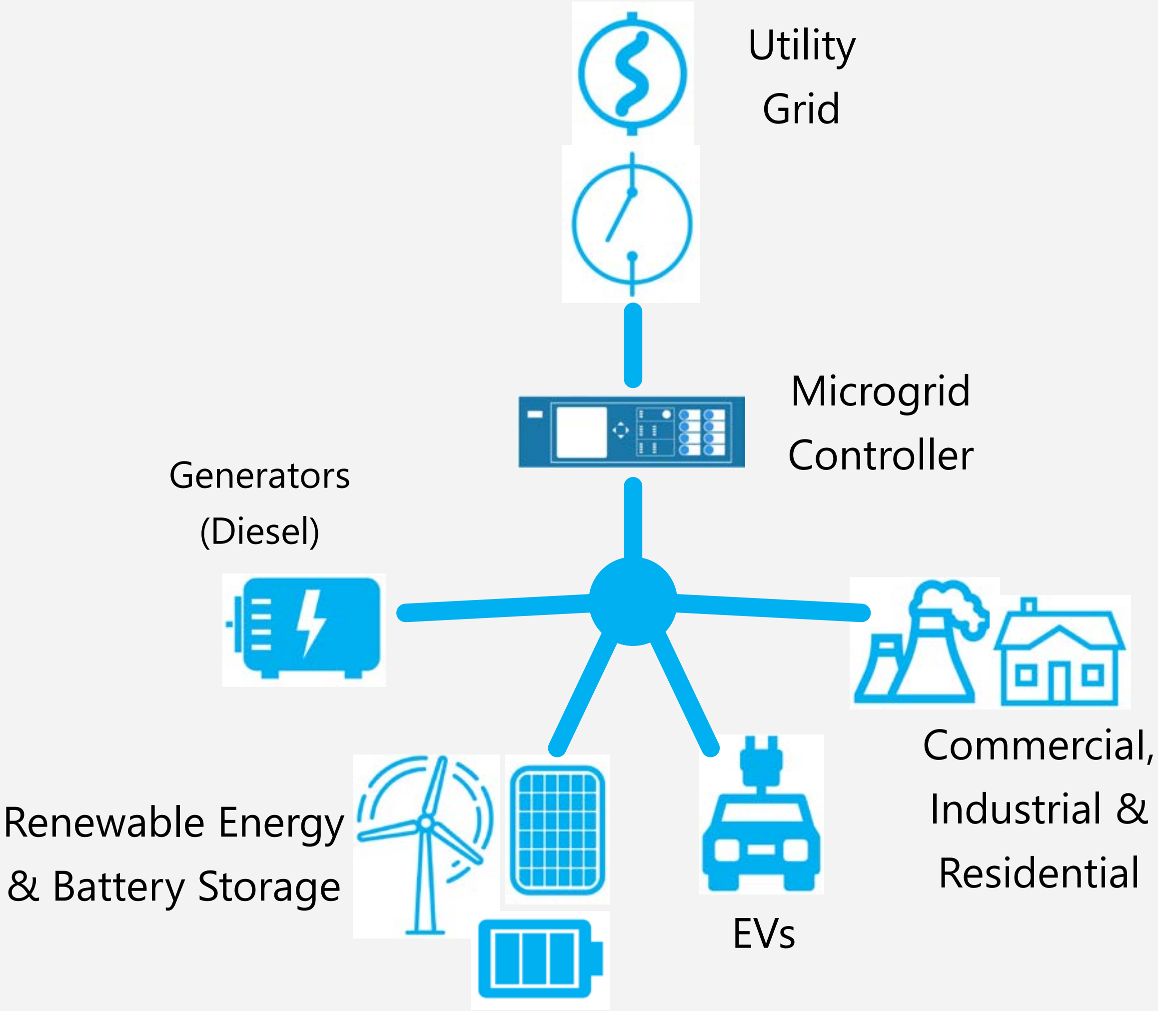
- HVDC and FACTS.
- Energy conversion.
- Drives.

Protection

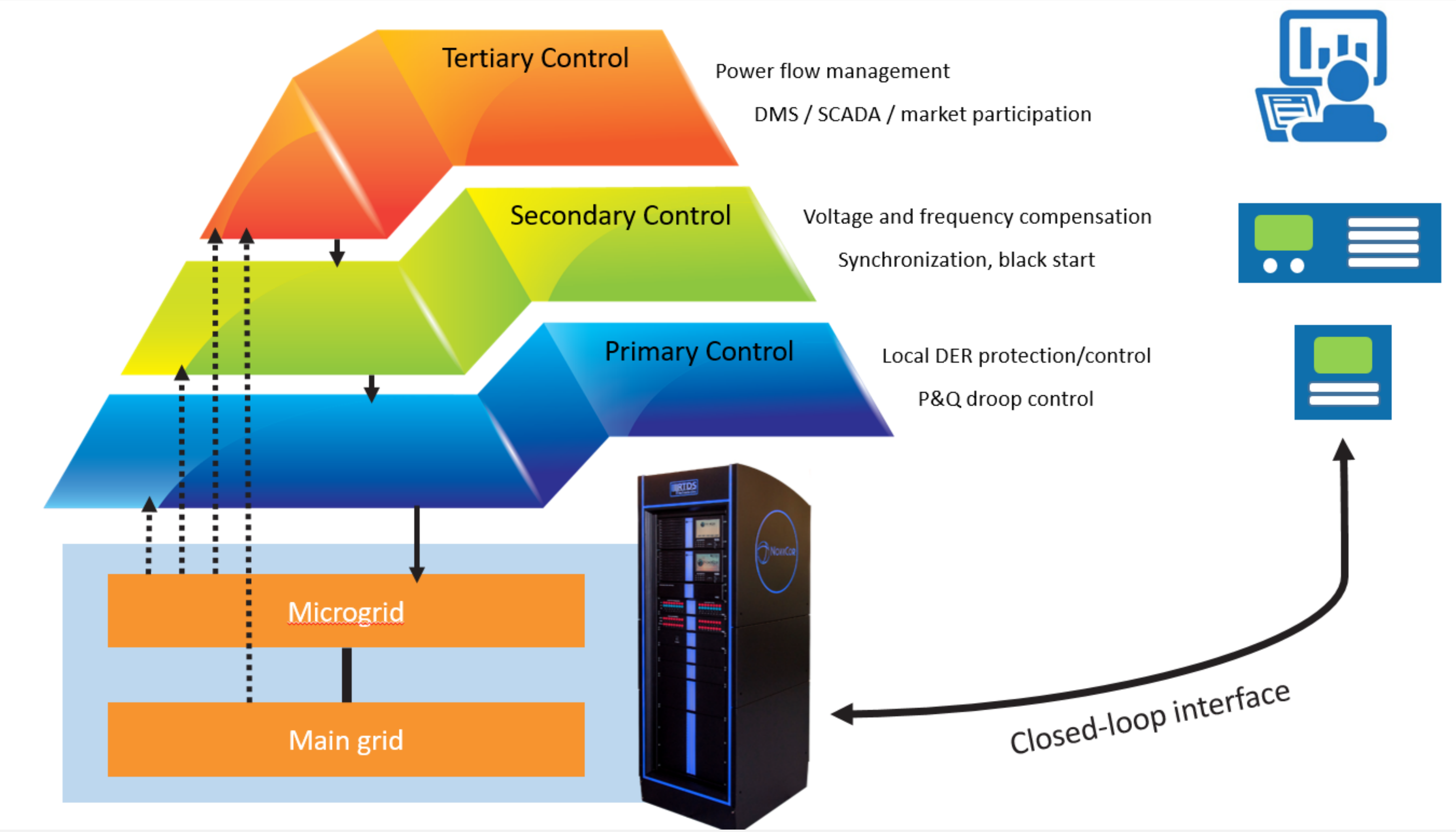
- Digital substations.
- Travelling wave testing.

MICROGRIDS: TECHNICAL CHALLENGES

- Coordination of multiple generation sources
- Generation sources involving renewable energy resources tend to be variable and intermittent
- Managing multiple loads with varying priorities
- Each individual asset (either generation or load) has it own set of local controls that must be designed and calibrated
- Coordination issues between local controls, secondary-level controls, and protection

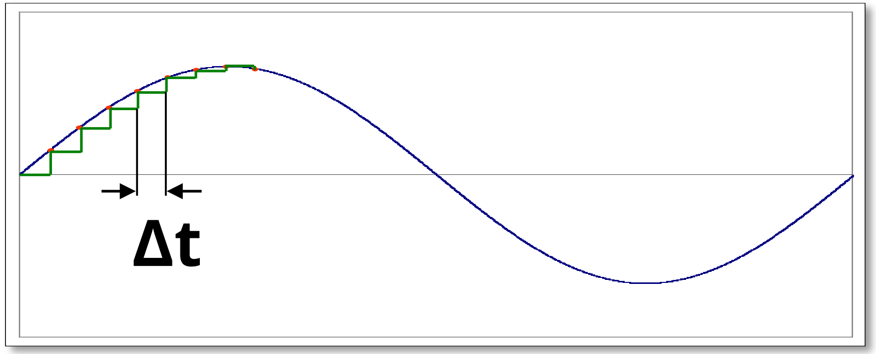


MICROGRIDS: TESTING OPPORTUNITIES



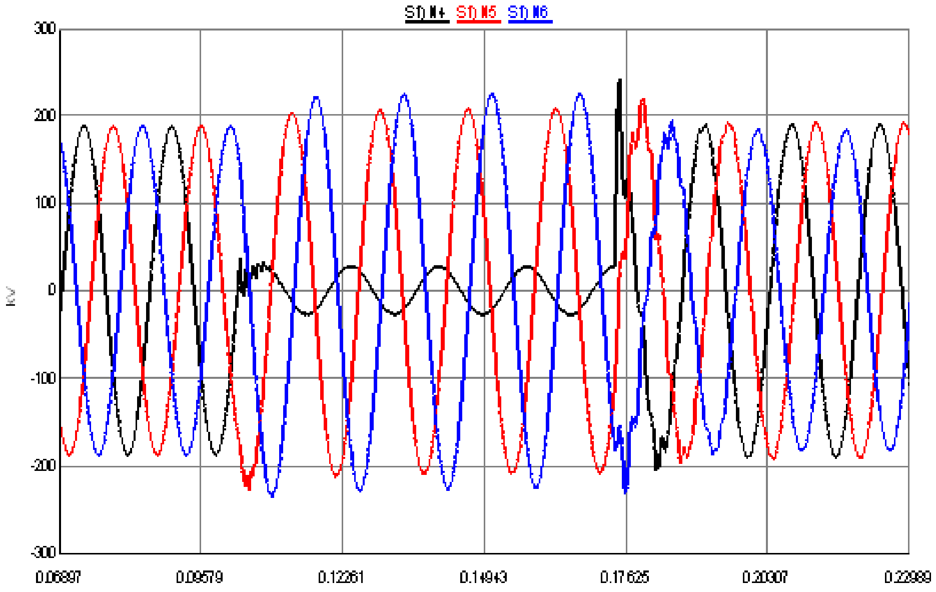
WHAT IS EMT SIMULATION?

Type of Simulation	Load Flow	Transient Stability Analysis (TSA)	Electromagnetic Transient (EMT)
Typical timestep	Single solution	~ 8 ms	~ 2 - 50 μs
Output	Magnitude and angle	Magnitude and angle	Instantaneous values
Frequency range	Nominal frequency	Nominal and off-nominal frequency	0 – 3 kHz (<15 kHz)



Dommel algorithm of nodal analysis used in RTDS, PSCAD, EMTP, etc.

ADVANTAGES OF EMT SIMULATION



- **Allows for a greater depth of analysis than phasor domain (RMS) representations such as load flow or transient stability analysis**

- **RMS models lack the ability to capture fast network dynamics during transient conditions and often provide optimistic results [1]**

- **Important for microgrids and other systems with many power electronic converters (more likely to predict control instability) [1]**

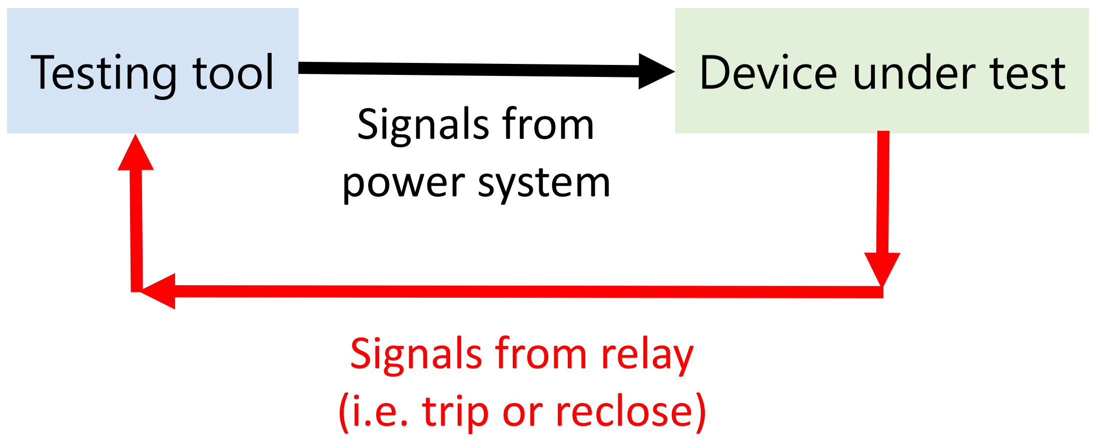
WHAT IS REAL TIME?

- Real time it takes for an event to occur = Simulation time of an event.
  - E.g. 3 cycle fault for 60Hz system = 0.05 seconds. RTDS simulates this fault in real time i.e. 0.05 seconds
  - Non-real-time simulations will simulate events faster or slower than real time depending on case complexity
- Values updated each timestep
  - All calculations and servicing I/O completed within a timestep.
  - Every timestep has same duration and is completed in real time
- Requires dedicated parallel processing hardware

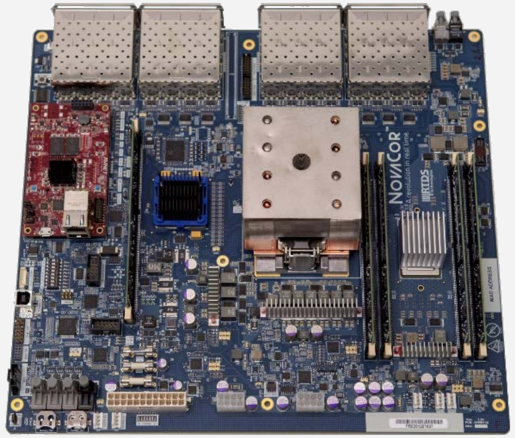
ADVANTAGES OF CLOSED-LOOP TESTING

Real time operation is what allows us to connect physical devices in a closed loop with the simulated environment

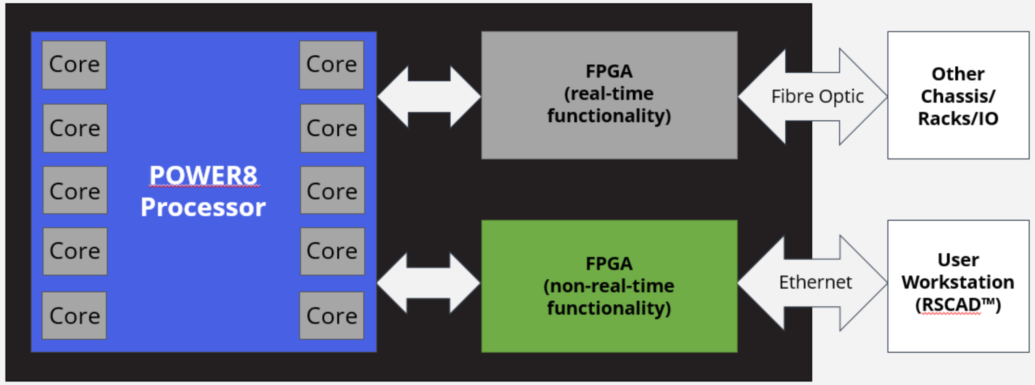
- **Test continues after the action of the protection/control device, showing dynamic response of the system**
- **Test multiple devices (and entire schemes) at once**
- **Much more detailed system representation than open-loop test systems provide (e.g. modelling power electronics)**
- **No need to bring equipment out of service**



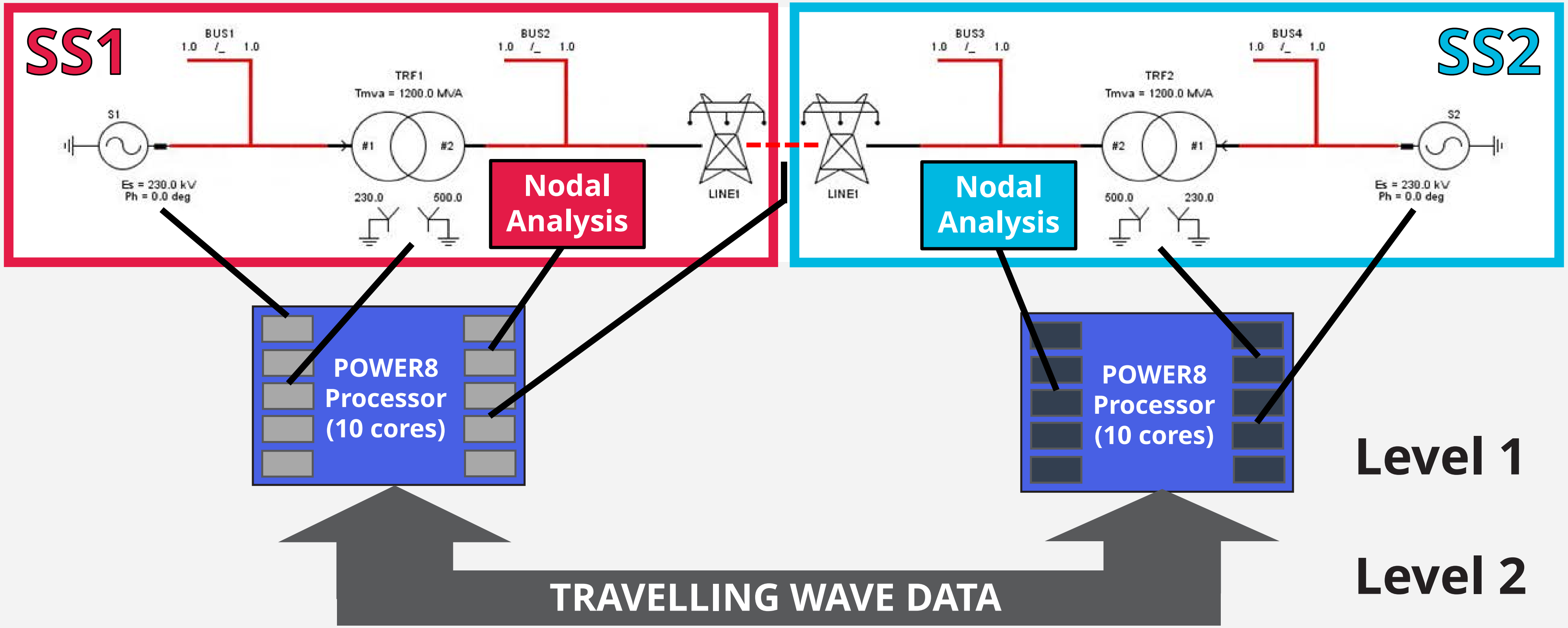
MAINTAINING REAL TIME: HARDWARE



- Parallel processing platform based on a IBM™'s POWER8® multicore processor
- Custom integrated, runs bare-metal (no OS)
- Modular design
- Main interface is through user-friendly software
- Ample I/O to connect physical devices



PARALLEL PROCESSING ON TWO LEVELS



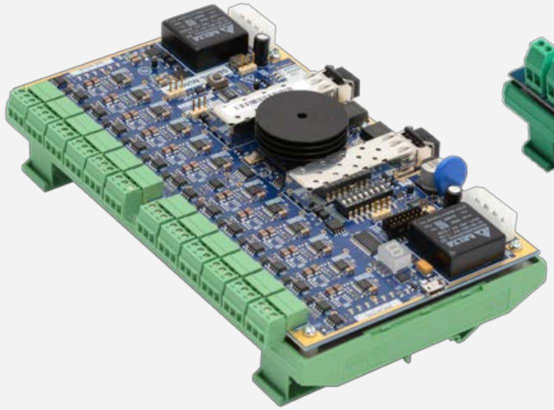
INTERFACING EXTERNAL EQUIPMENT: I/O

Modular digital and analogue I/O cards

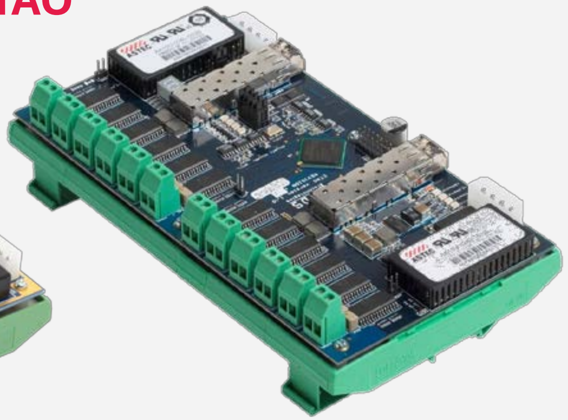
- 12 channel, isolated 16-bit analogue input/output cards

- 64 channel, isolated digital input/output cards

GTAI



GTAO



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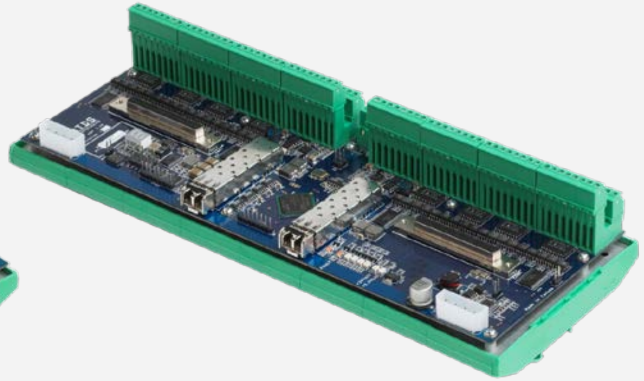


INTERFACING EXTERNAL EQUIPMENT: I/O

Network Interface Card

- Communication with external devices over Ethernet.
- Card has two “modules” and can have two network protocols operating simultaneously.

IEC 61850

GOOSE Messaging
IEC 61850-9-2LE, IEC 61869-9

SCADA

DNP3 and IEC 60870-5-104

Large data playback

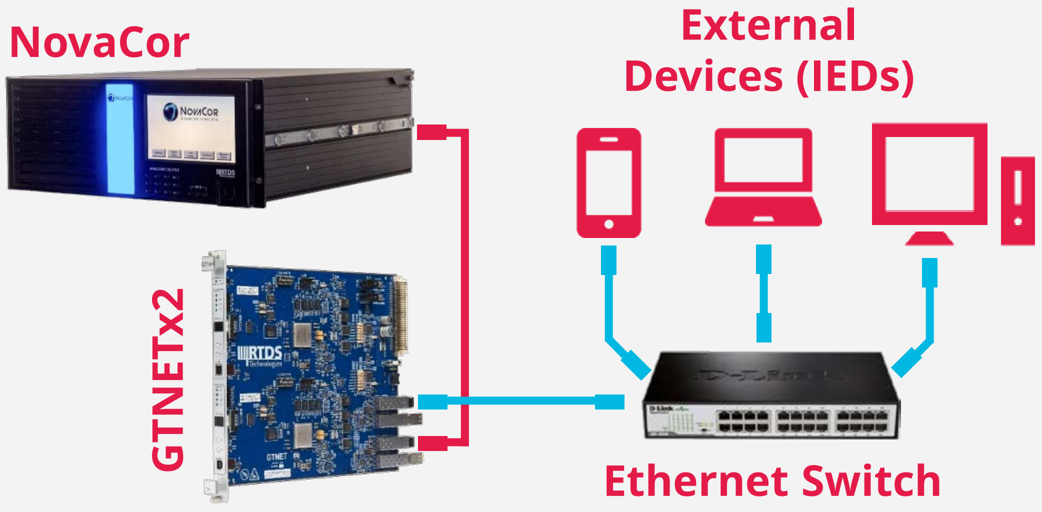
PMU

IEEE C37.118

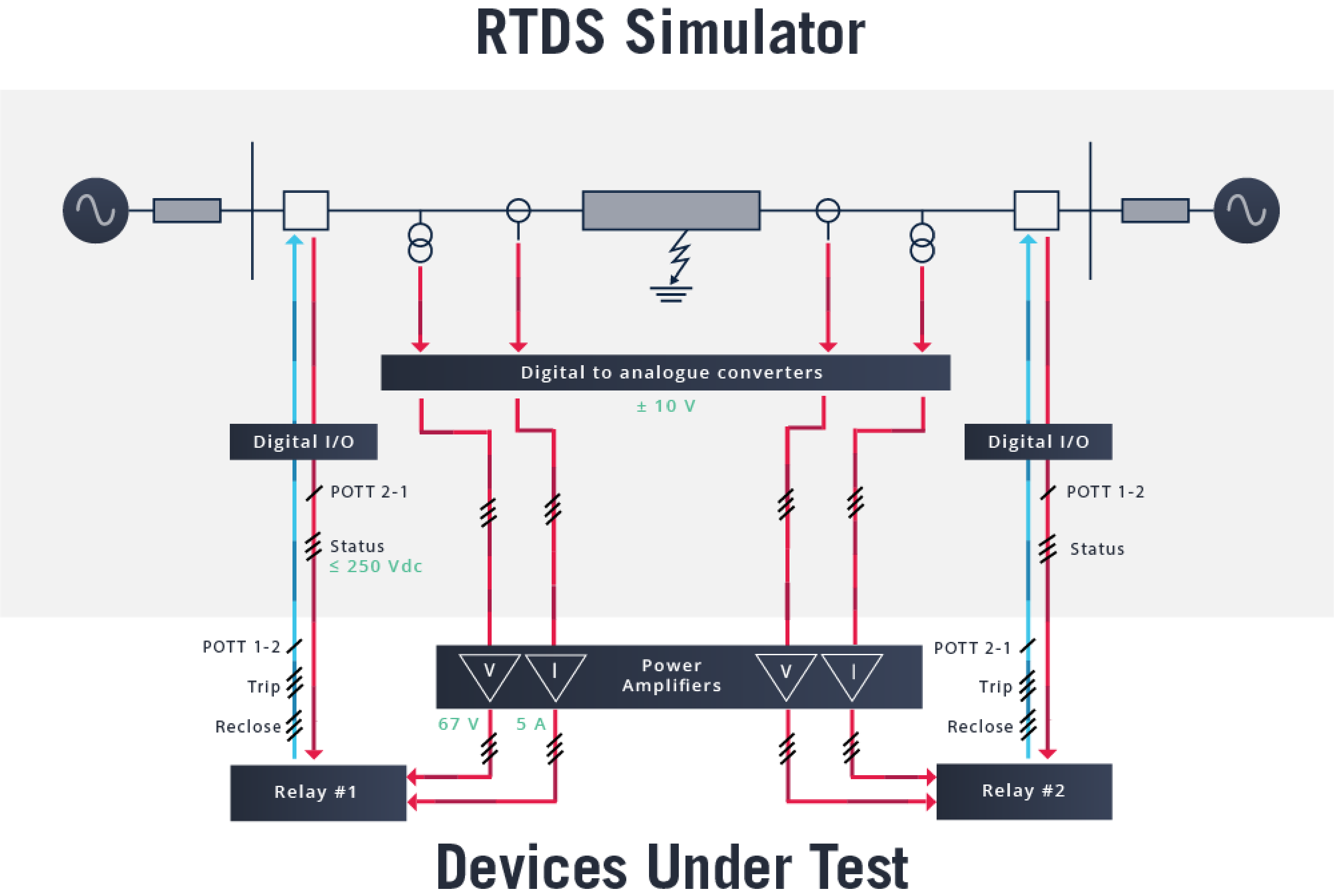
MODBUS

TCP, RTU over TCP, ASCII over TCP

Generic TCP/UDP Sockets

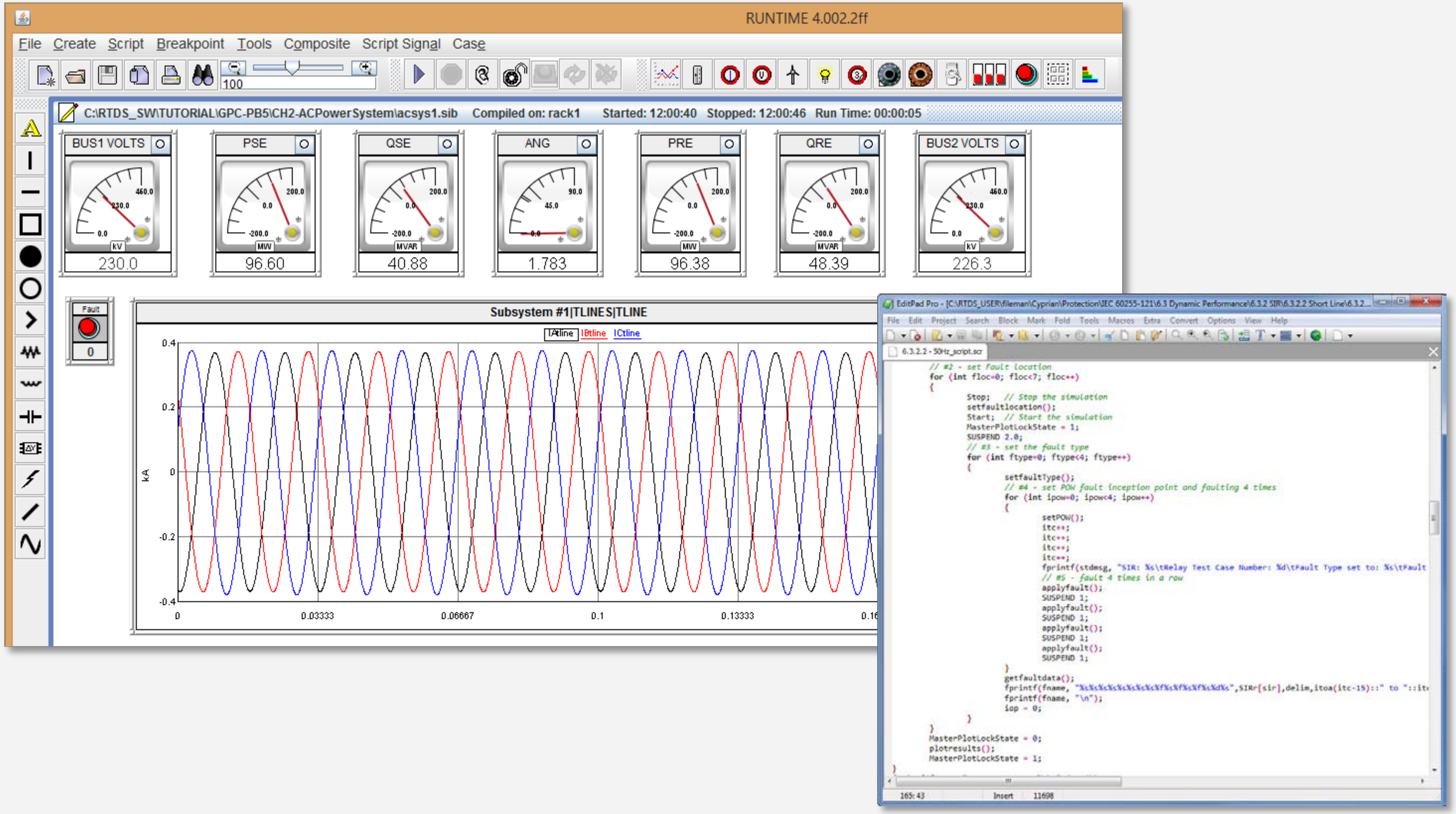


CLOSED-LOOP INTERFACE EXAMPLE



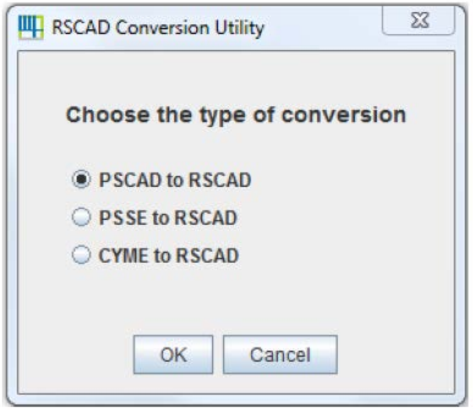
REAL-TIME SIMULATION SOFTWARE: RSCAD®

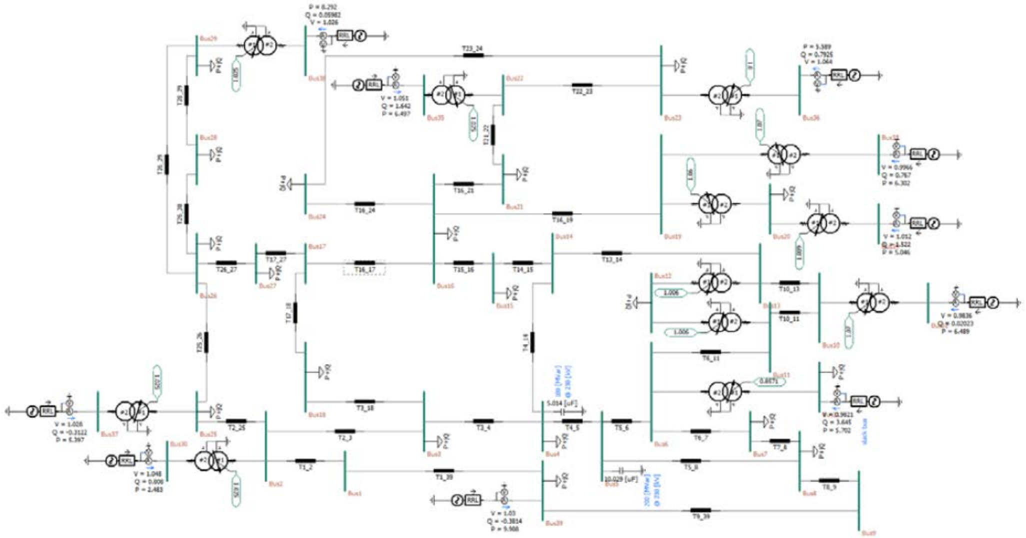
- **Real-time performance provides ability to operate the simulated power system interactively**
- **Simulator control**
- **Monitoring**
- **Data acquisition**
- **Scripting for automated batch mode testing**

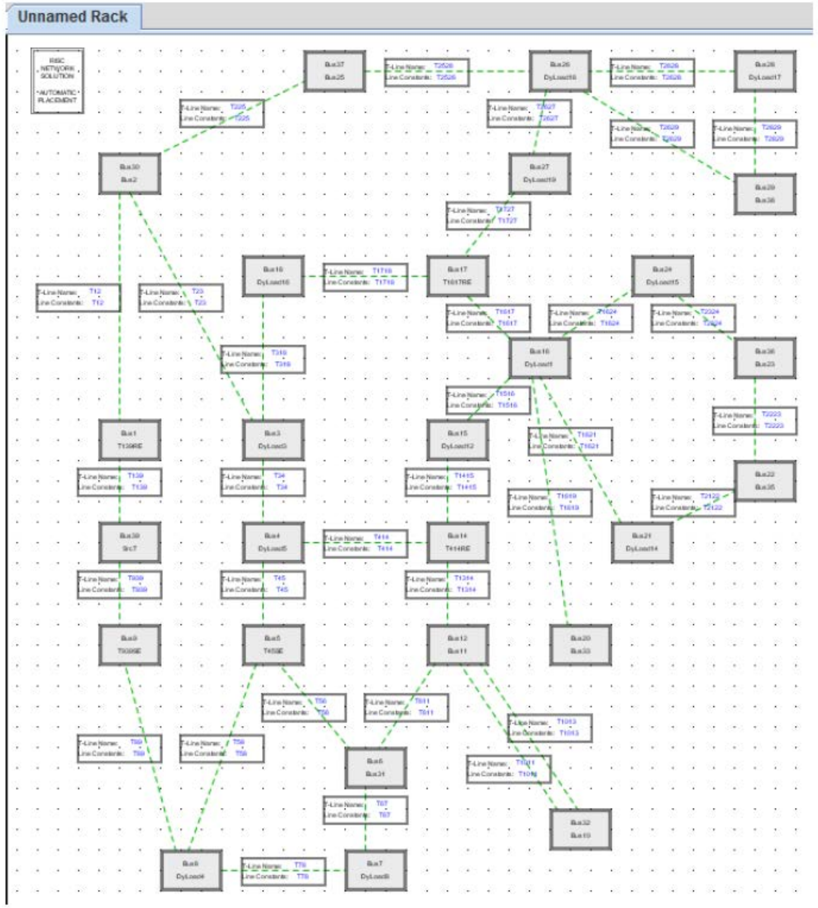


CONVERSION PROGRAMS

- **PSCAD**
- **PSSE**
- **CYME**
- **MATLAB/Simulink controls**

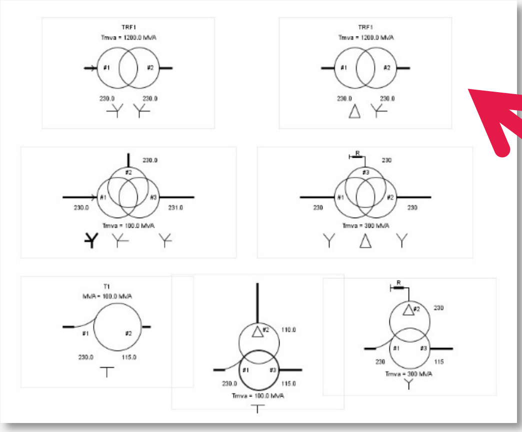






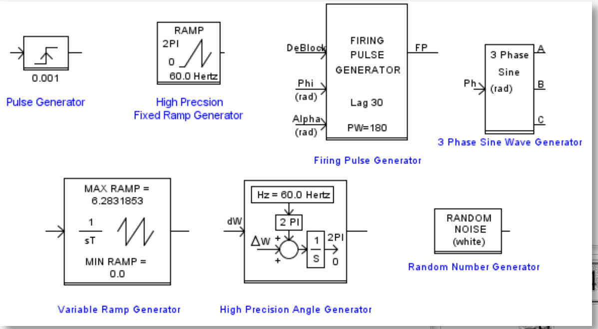
COMPONENT LIBRARIES

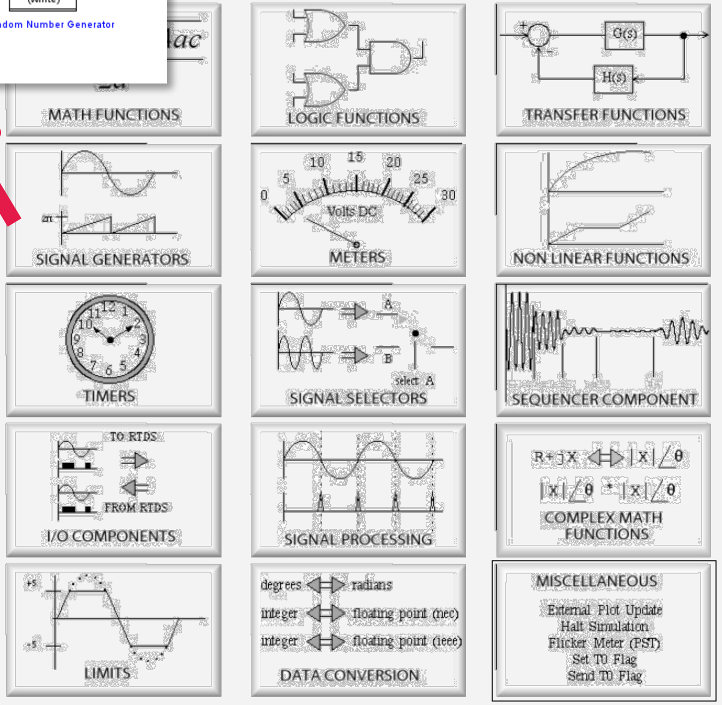
- **Large established library, plus CBuilder module for creating custom, user-written components**



Transformer Models

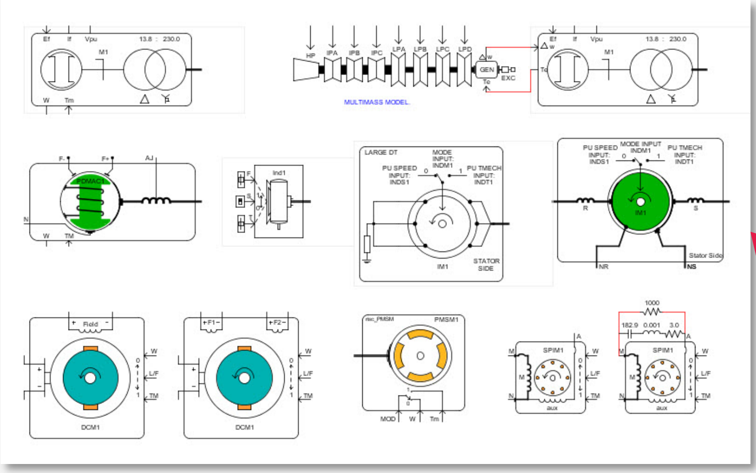
Fault and Breaker Models





Valve Group and SVC Models

RLC Components

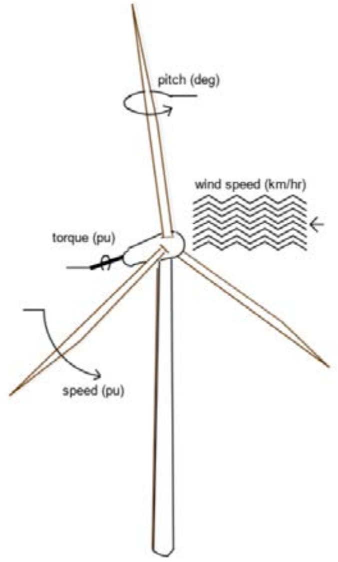


Machine Models

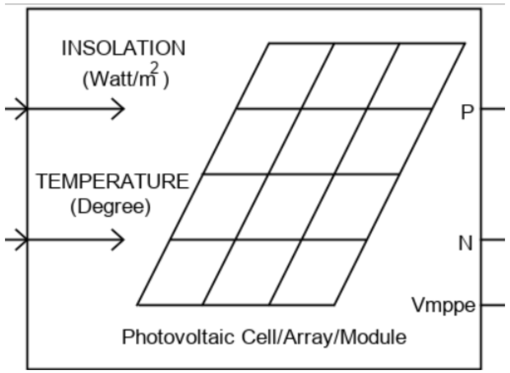
Transmission Line and Cable Models

MICROGRID MODELLING

- **Wind energy**
  - **Turbine model with active input for wind speed, pitch control, power coeffients**
  - **Example cases provided in RSCAD for**
    - Type II – direct connect induction machine via transformer
    - Type III – double fed induction machine (DFIG)
    - Type IV – full converter permanent magnet synchronous machine



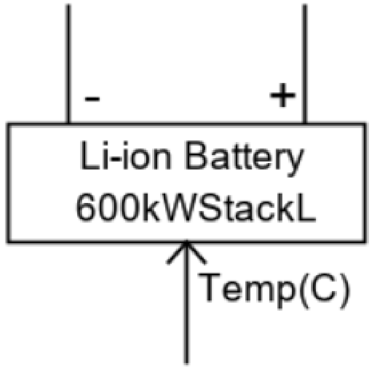
- **Solar PV**
  - **Array model with active input for insolation, temperature**
  - **Partial shading effect**
  - **Maximum power point tracking**

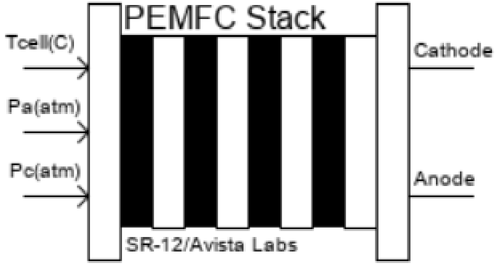


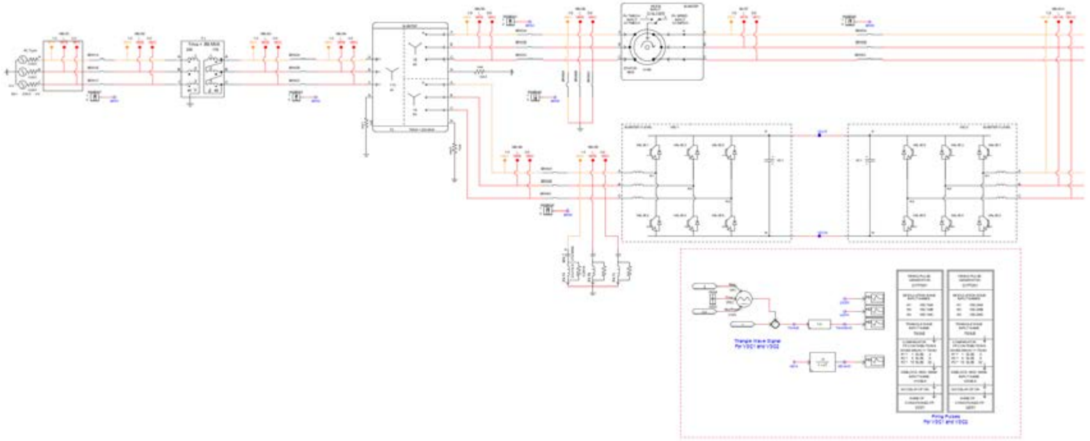
- **Aggregate wind/solar farm models using linear scaling**

MICROGRID MODELLING

- **Energy storage**
  - **PEM fuel stack model**
  - **Battery energy storage systems**
    - Lithium ion battery model
    - Input for temperature
  - **Flywheel sample case**
    - **Wheel modelled via added mass to PMSM rotor**
    - **Average model case also available**
  - **Pumped hydro sample case**
    - **Variable-speed DFIM system**
    - **Average model case also available**

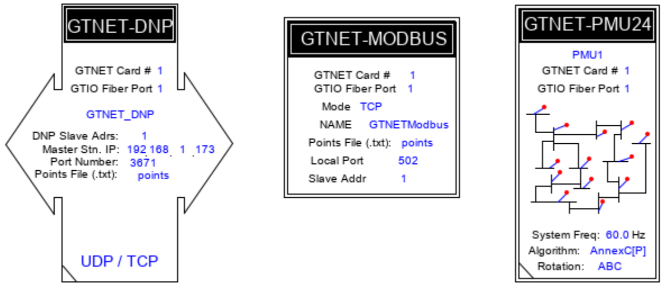


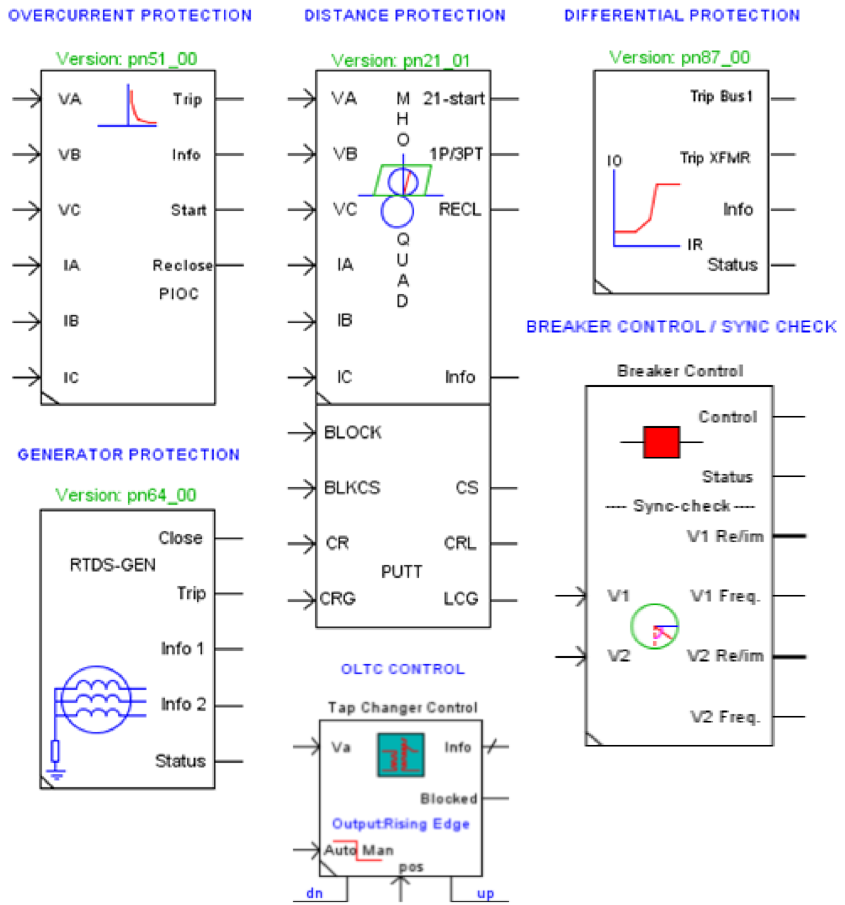




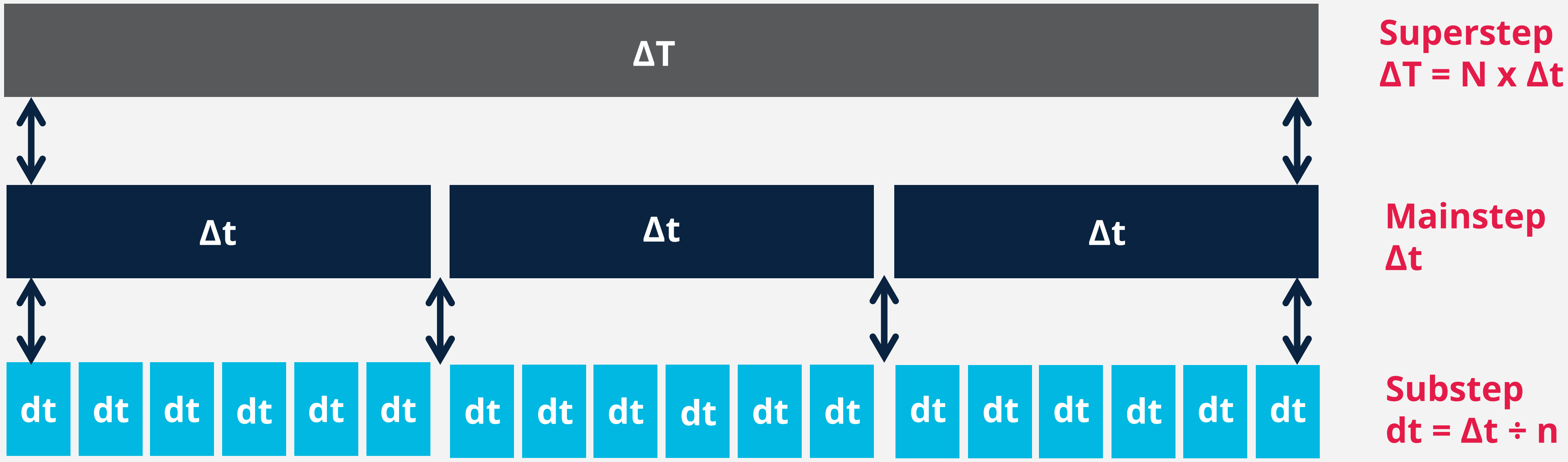
MICROGRID MODELLING

- Protection & automation modelling library
  - Various generic relay models
  - Breaker control / sync check
  - Software PMU models
  - Smart grid protocols
    - MODBUS
    - DNP3/IEC 60870-5-104: communicate with multiple masters in real time
    - IEC 61850 GOOSE / Sampled Values
    - Synchrophasor data



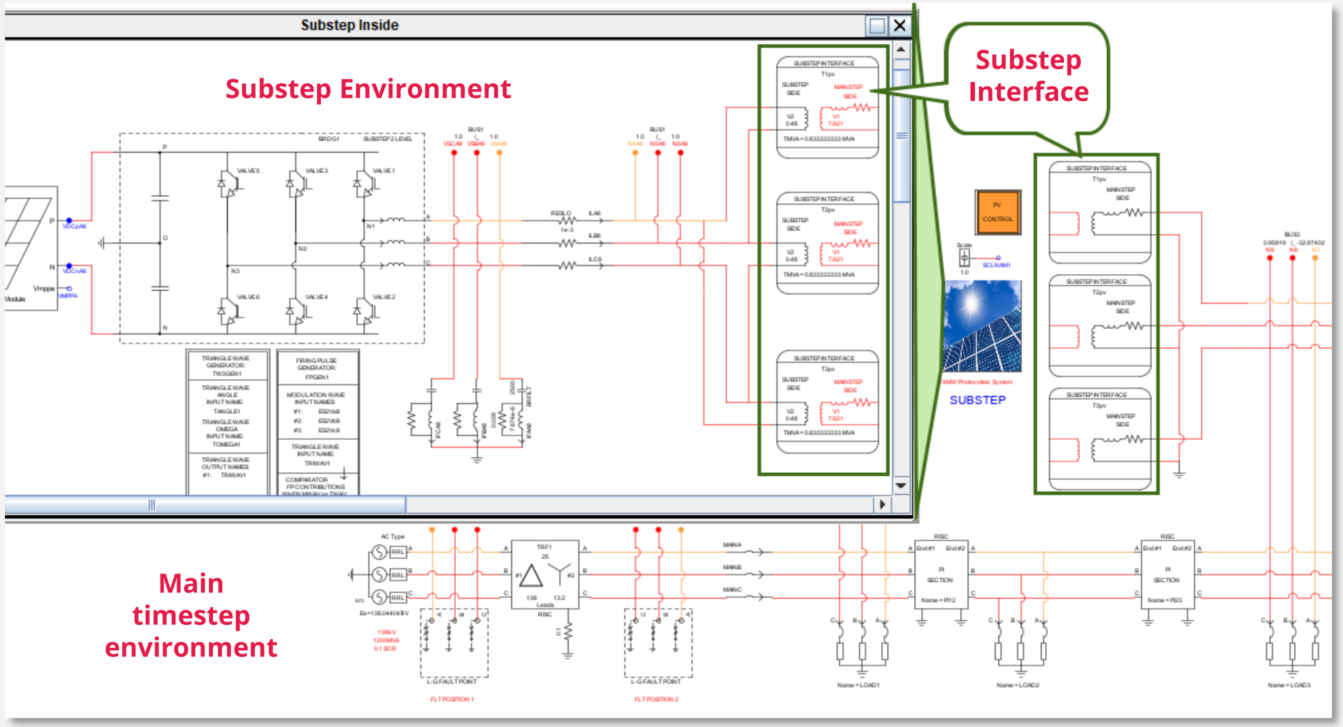


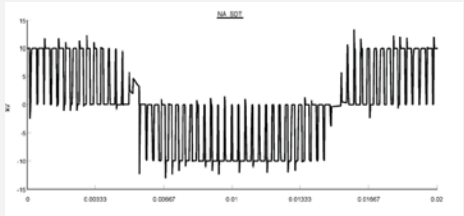
MULTI-RATE SIMULATION



SUBSTEP ENVIRONMENT: POWER ELECTRONICS MODELLING

- Runs on a dedicated core
- Sub-microsecond timesteps possible
- Can use substep, main timestep, control components
- Resistive switching for several popular converter topologies
- Individual switching elements available
- Full I/O capability

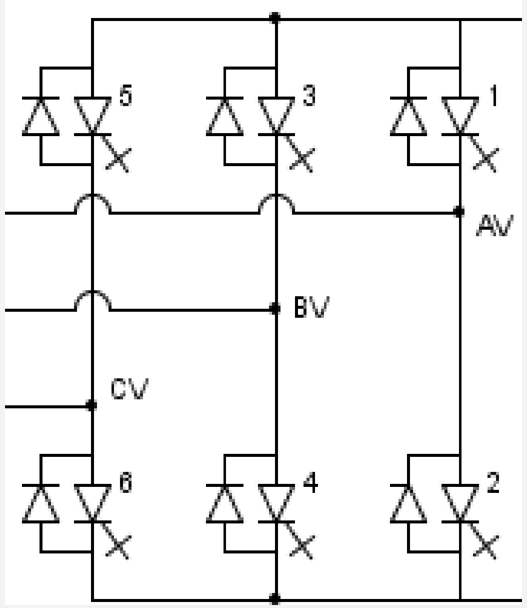




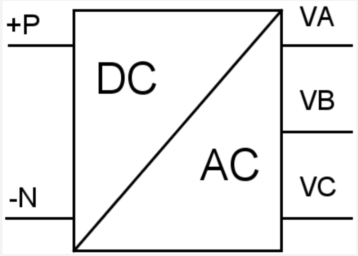
MICROGRID MODELLING

Average models vs. fully-switched power electronic models for converters:

Multiple flexible options with varying levels of detail and hardware requirements



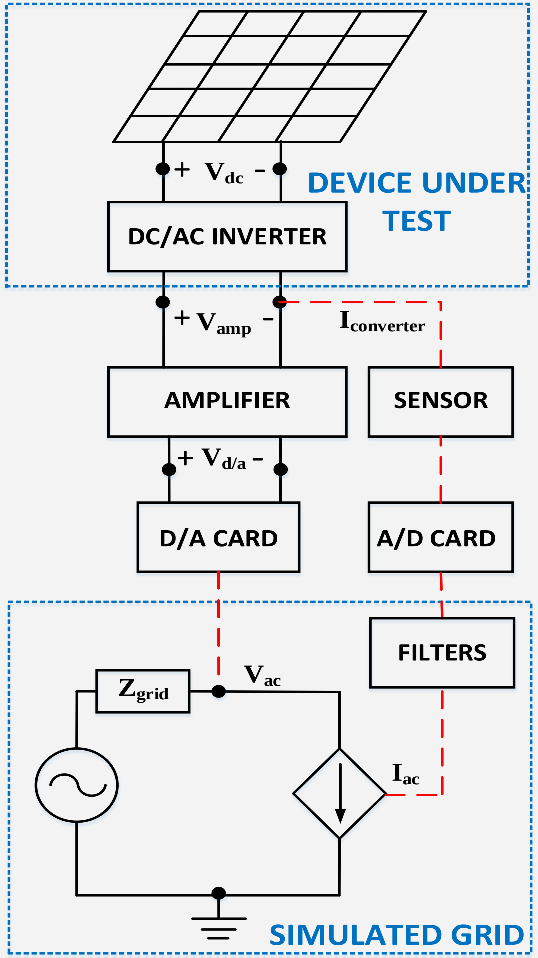
- Consider the switching topology and switching characteristics of the converter
- Allows for low level testing of the controllers and underlying algorithms used to generate the individual switching pulses for the converter



- Replaces detailed models with controlled voltage and current sources
- Modulation waveforms from the same current controller can be used to strategically control the sources such as to reproduce an averaged version of the high frequency switching transients

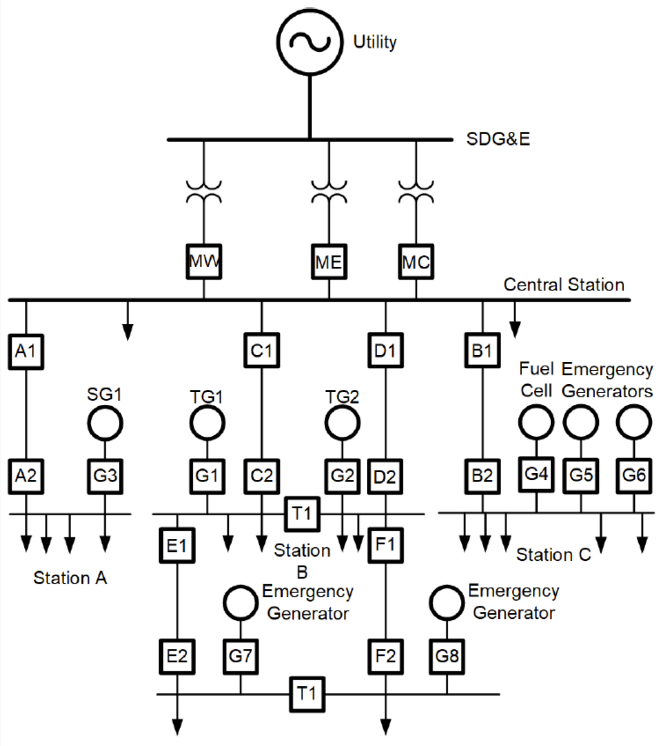
POWER HARDWARE IN THE LOOP (PHIL)

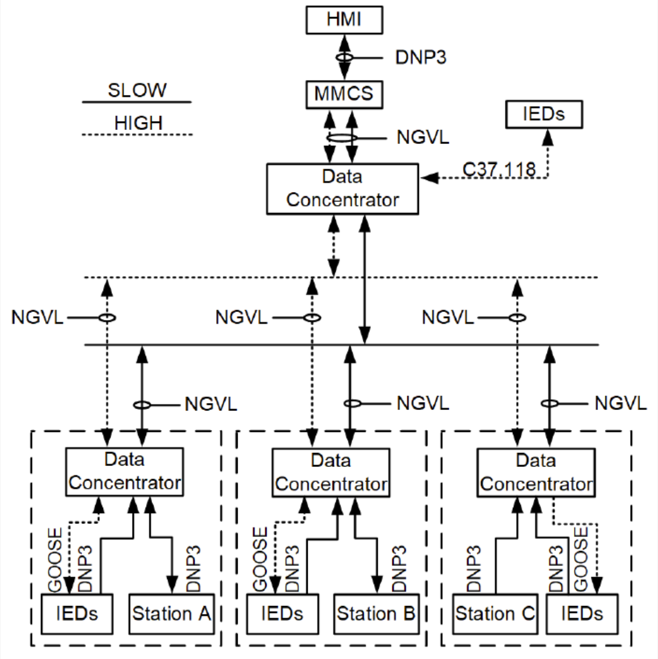
- **Simulated environment exchanges power with renewable energy hardware, motors, batteries, loads, etc.**



CASE STUDY: UC SAN DIEGO MICROGRID

- **Microgrid control and protection scheme including synchrophasors in the wake of the Southwest blackout**

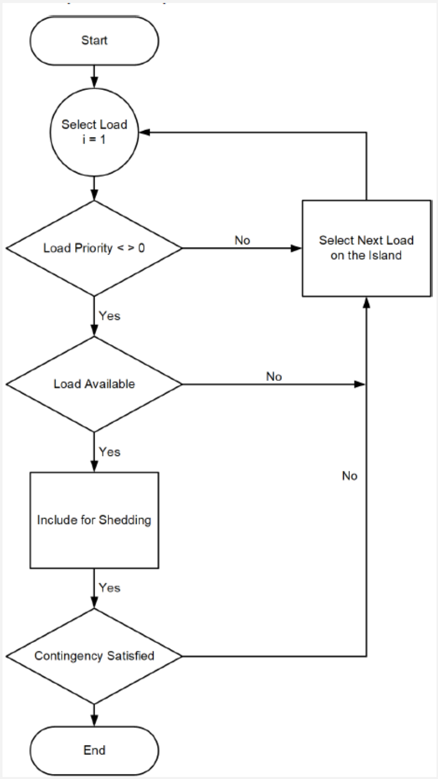


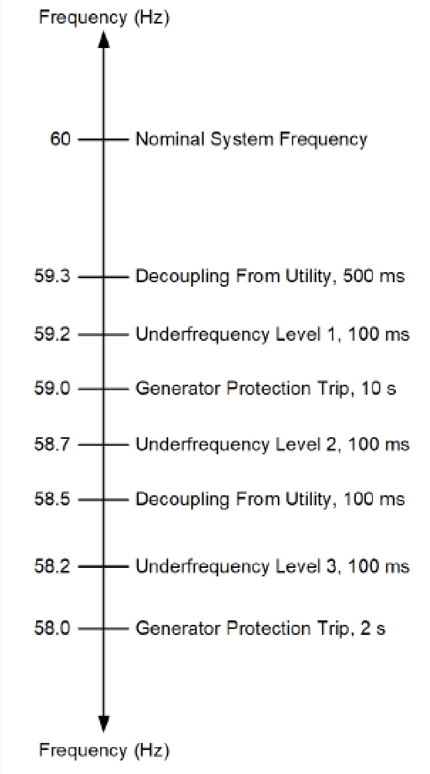


Source: [3]

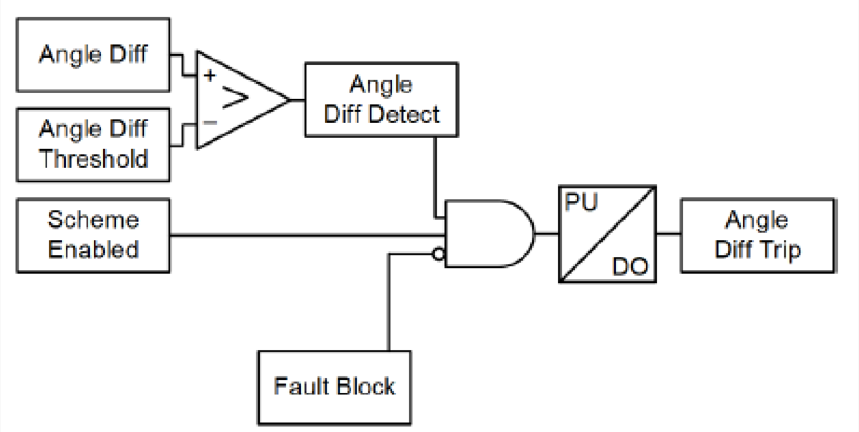
CASE STUDY: UC SAN DIEGO MICROGRID

Contingency and Frequency Based Load Shedding





Local and Wide Area Islanding Detection and Decoupling



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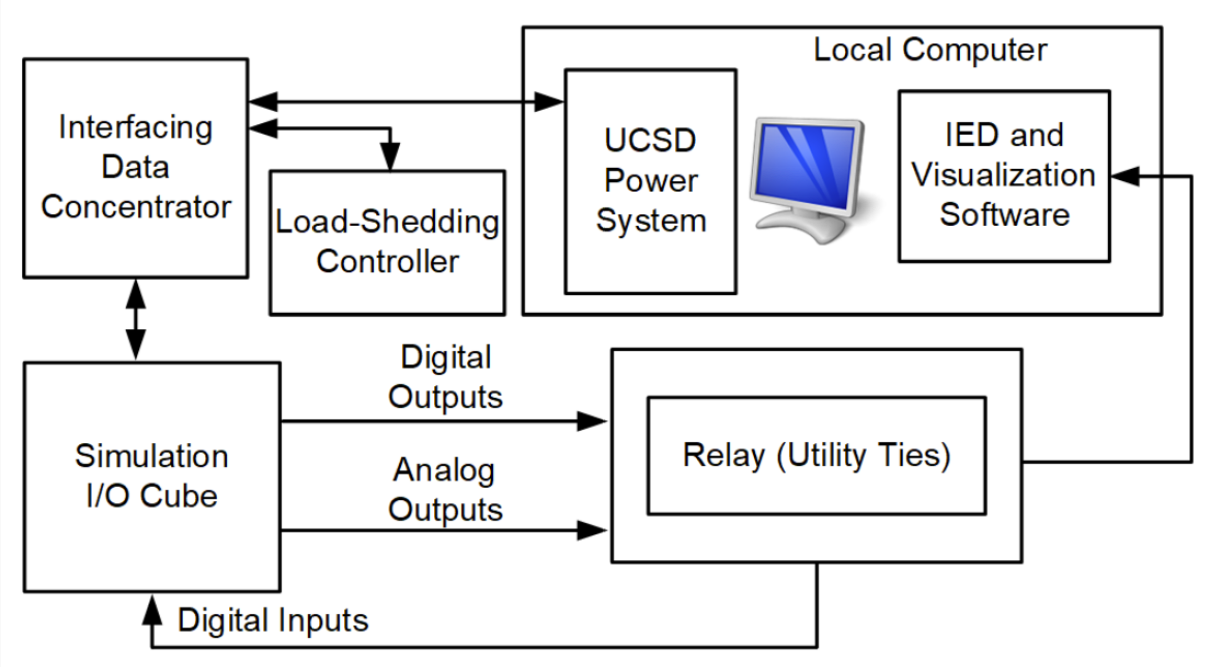
CASE STUDY: UC SAN DIEGO MICROGRID

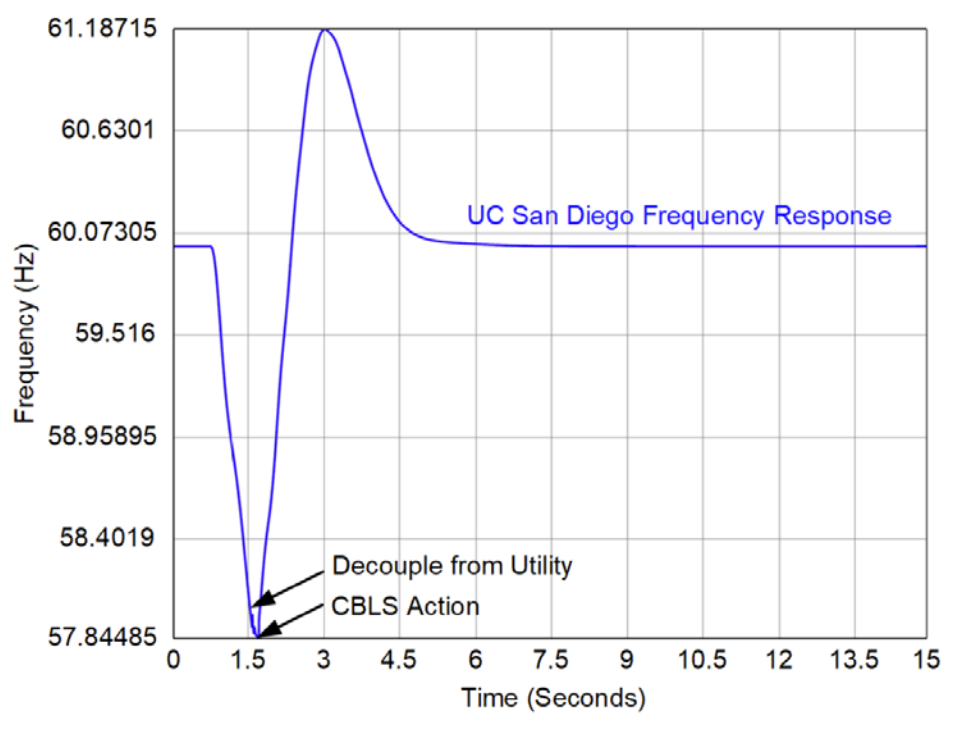


SEL performs Factory Acceptance Testing of protection and control systems with the RTDS® Simulator prior to delivery

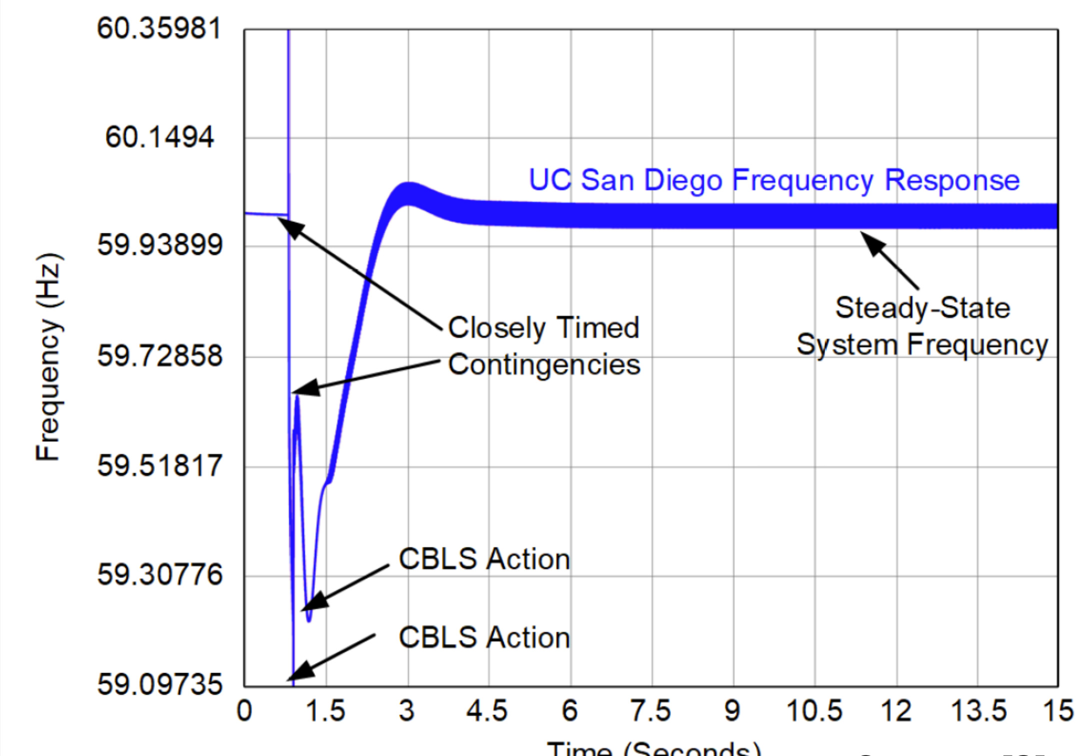
Source: [3,4]

CASE STUDY: UC SAN DIEGO MICROGRID

Validating IDDS and CBLS (decay rate 2.5 Hz/s) (5.35 MW shed)



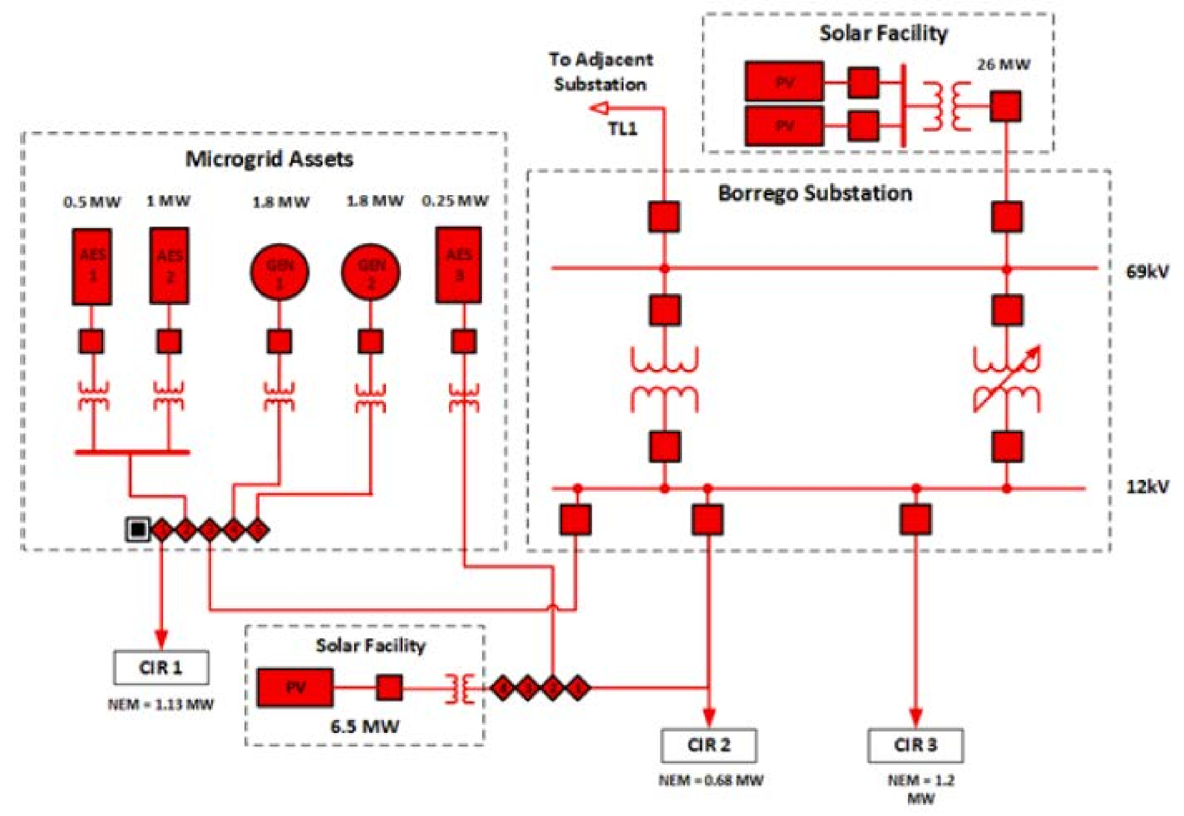
Three-phase fault on utility tie plus loss of generation (contingency chain reaction)



Source: [3]

CASE STUDY: BORREGO SPRINGS MICROGRID

San Diego Gas & Electric



Operation for planned and unplanned outages (with blackstart)

Successful transition to 3 different islanding configurations

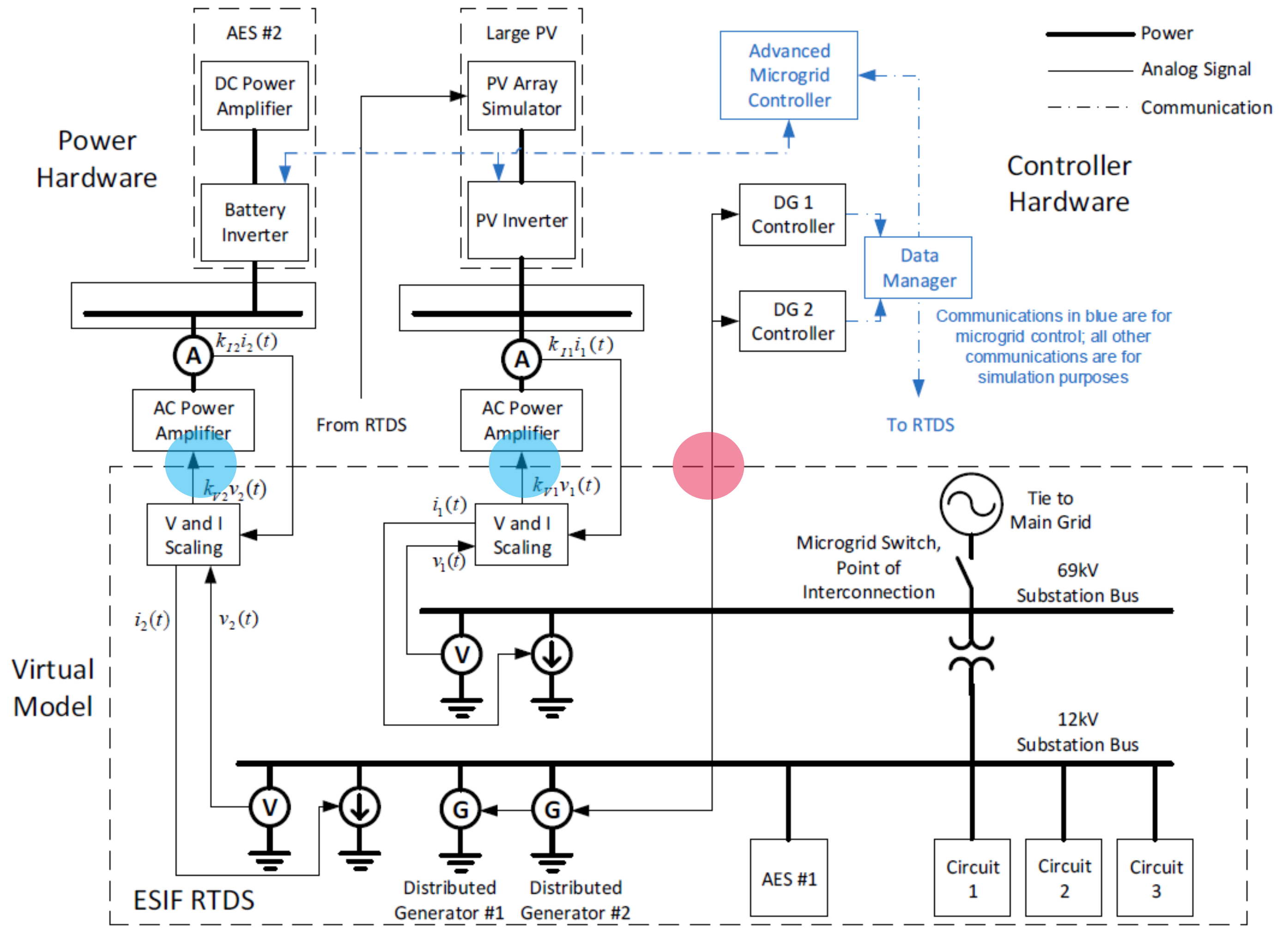
Manage up to 100% renewable energy supplying community load

Serve critical loads

Source: [5]

CASE STUDY: BORREGO SPRINGS MICROGRID

SDG&E testbed at NREL test facility



PHIL

CHIL

Source: [5]

CASE STUDY: BORREGO SPRINGS MICROGRID

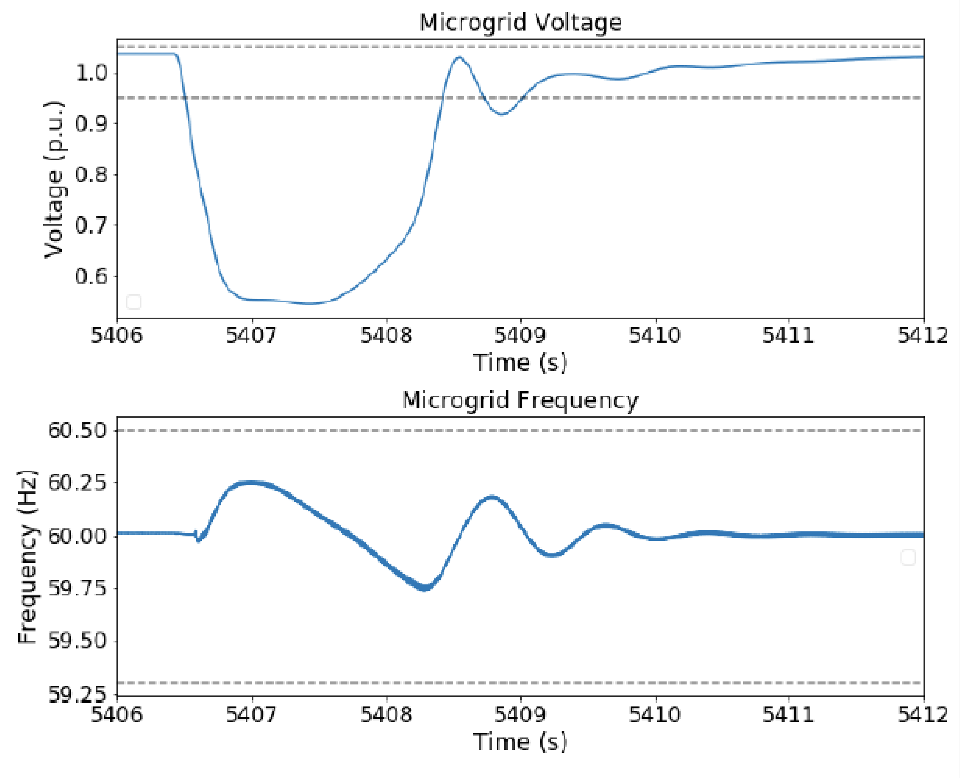
Metrics for performance evaluation:
- **Survivability of critical loads**
- **Cost of operation**
- **Environmental performance**

Table 17: Mapping Scenarios to Functional Requirements

Scenario Description	C1	C2	C3	C4	C5	C6
	Disconnection	Resynchronization and Reconnection	Steady-State	Protection	Dispatch	Enhanced Resilience
A. Operating While Connected to the Utility					X	
B. Separating from the Utility	X			X		
C. Operating While Separated from the Utility			X	X	X	X
D. Connecting to the Utility		X				

Source: [5]

Test results for unplanned islanding after grid undervoltage



Thank you!

References

[1] B. Badrzadeh, Z. Emin, February 2020. The need for enhanced power system modelling techniques and simulation tools. CIGRE ELECTRA No. 308.

[2] M. Davies, October 2019. Preparing for the Future Power System – Now. Presentation, RTDS Technologies Australian UGM.

[3] Dillot, John; Upreti, Ashish; Nayak, Bharath; Ravikumar, Krishnanjan Gubba, 2018. Microgrid Control System Protects University Campus From Grid Blackouts. 45th Annual Western Protective Relay Conference.

[4] Schweitzer Engineering Laboratories, Inc, 2016. UC San Diego Optimizes Microgrid System With SEL POWERMAX® and Protection Relays.

[5] Katmale, Hilal; Clark, Sean; Abcede, Laurence; Bialek, Thomas, 2018. Borrego Springs: California's First Renewable Energy Based Community Microgrid. California Energy Commission. Publication Number: CEC-500-2019-013.

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A revolution in real time.

the new world standard for

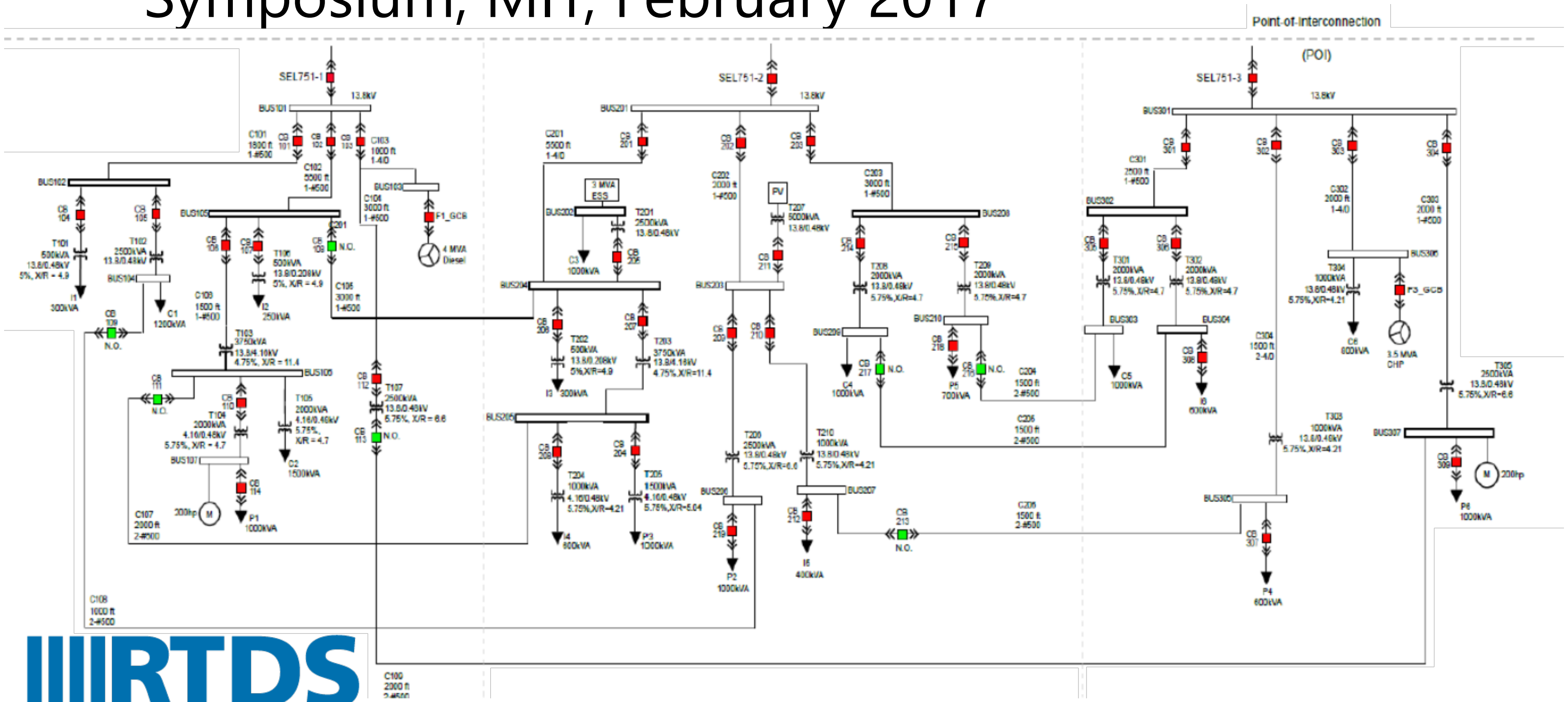
REAL TIME DIGITAL SIMULATION

RTDS Technologies

HIL Demo: Microgrid Controller

HIL Demo: Microgrid Controller

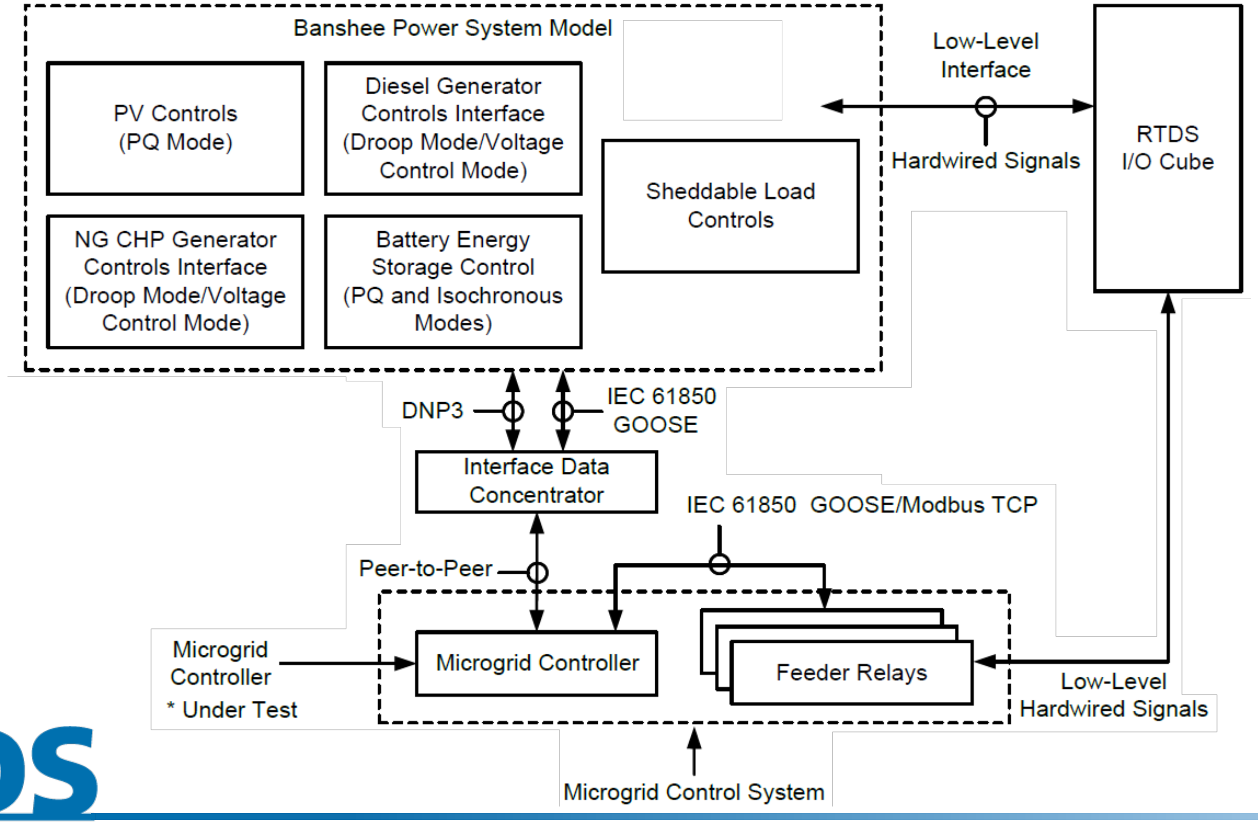
Example: Banshee Microgrid, Microgrid and DER Controller Symposium, MIT, February 2017



- Industrial facility with 3 utility radial feeders
- 47 Circuit breakers
- Load range 5-14 MW
- 18 Aggregated loads
- 4 MVA Diesel Gen.
- 3.5 MVA CHP
- 3 MW PV
- 2.5 MW BESS

Microgrid Applications using RTDS [4]

Example: Banshee Microgrid (Microgrid and DER Controller Symposium, MIT, February 2017)



- Interface between RTDS and Microgrid Controler (SEL RTAC) using DNP3 & GSE protocols

Questions