St Paul Island Alaska Microgrid Development Project DE-OE0000731

DOE Microgrid Quarterly Review

April 28, 2016

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TDX Power

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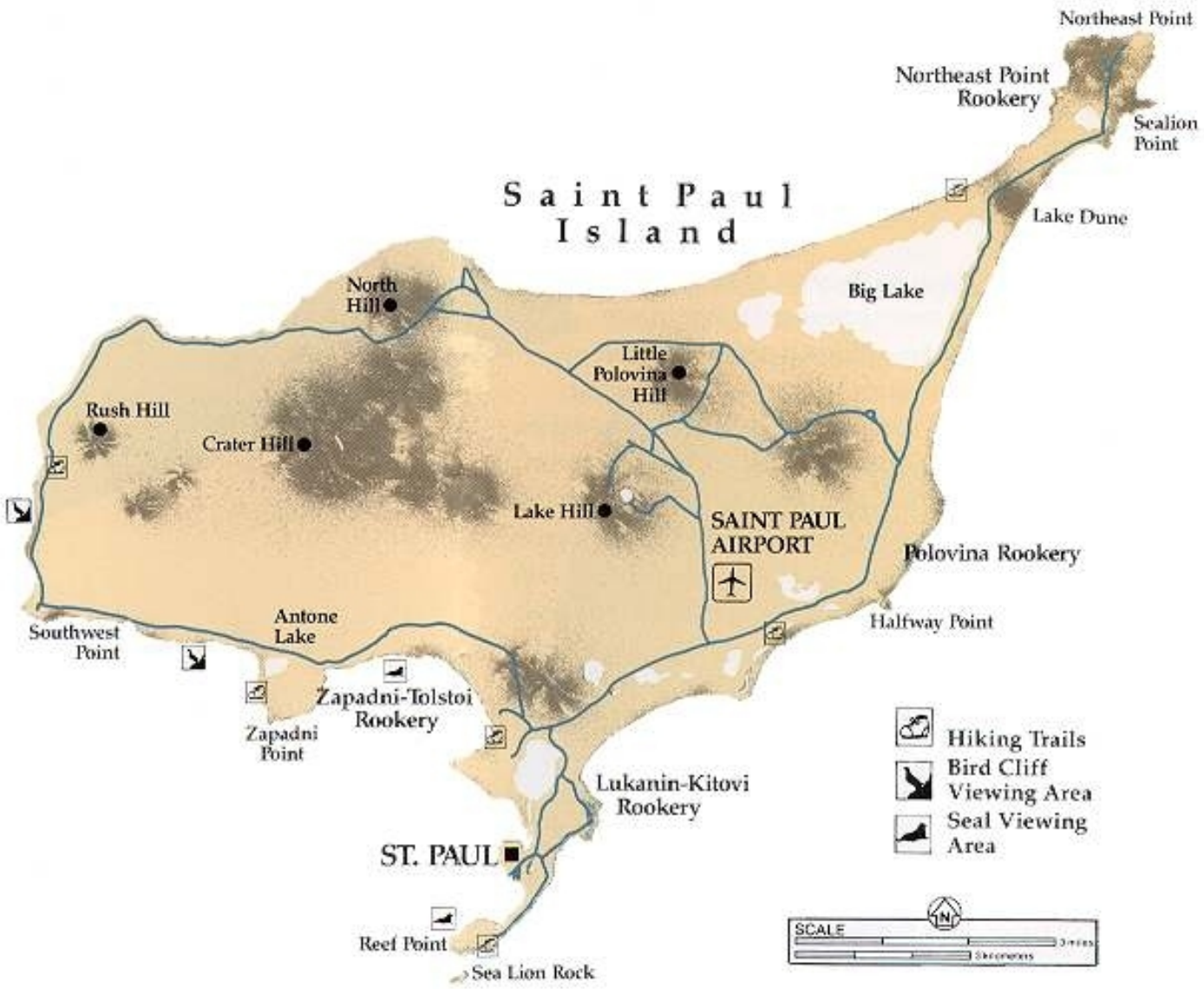
Schweitzer Engineering Laboratories, Inc. (SEL)

TDX Power

- Division of TDX Corporation
- Native to the island of St. Paul, Alaska
- TDX Power: Native owned Alaskan Utility Corporation
  - Four regulated municipals
  - Two commercial wind power projects
  - Village power test facility
  - Utility engineering and EPC services
    - Vermont-based: x-Northern Power Systems Engineers
      - Northern supplied the CERTS microgrid to AEP
      - Built customer microgrids in early 2000s

St Paul Island, AK

St Paul Island



St. Paul Island, Alaska

TDX Project Objectives

- Have Renewables provide 80% of all electrical and thermal heating requirements for the community of St. Paul
- Demonstrate integration of renewables as primary power sources
- Demonstrate the merits of Microgrids
- Develop and test a Microgrid Controller, with universal application
- Use Lessons Learned throughout Alaska and beyond

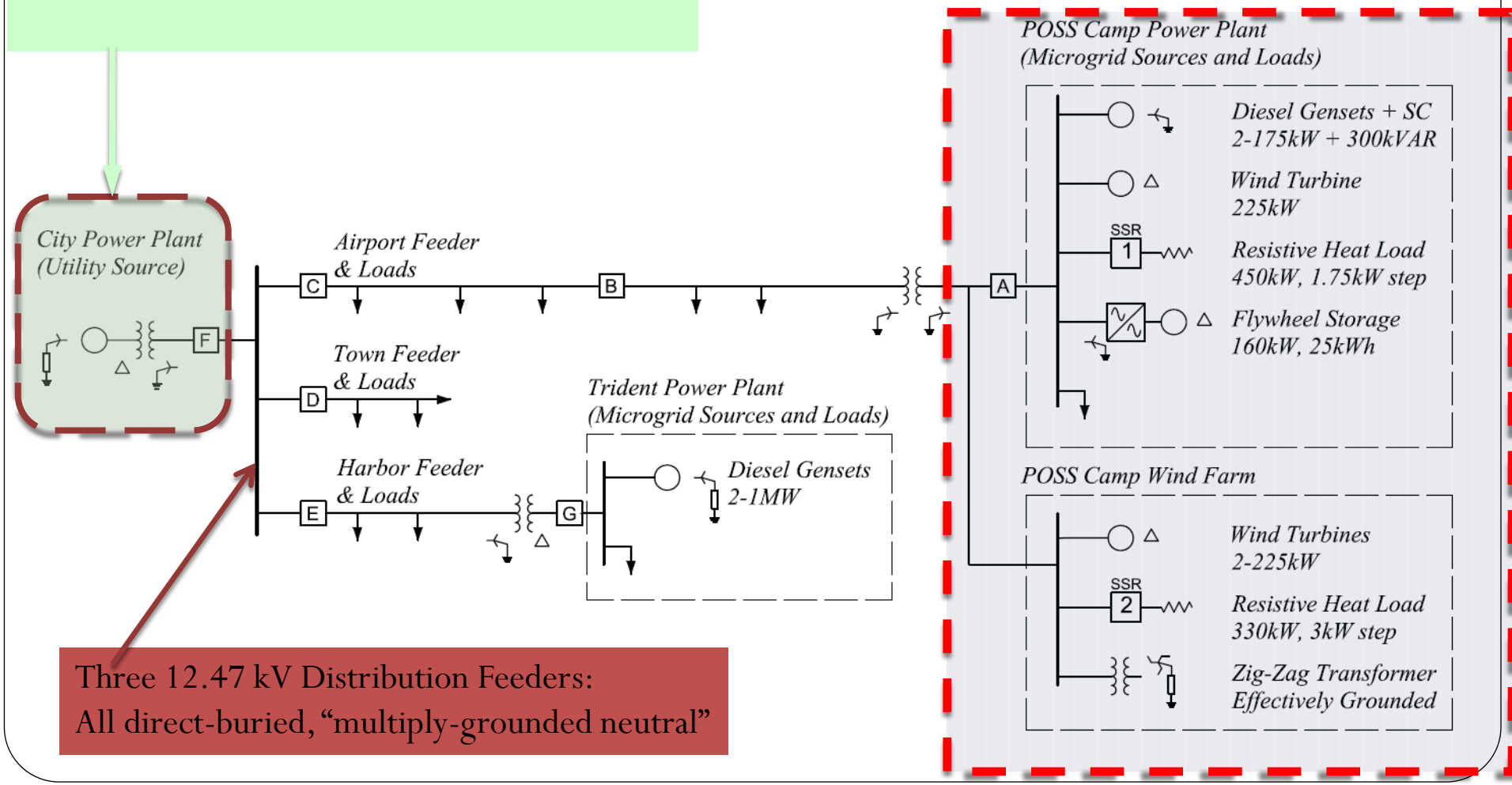
DOE
Project Performance Objectives

- Develop and test a Microgrid Controller, with universal application
- Reducing outage time of critical loads by >98% *at a cost comparable to non-integrated baseline solutions (i.e., UPS)*
- Reducing emissions by >20% with renewables
- Improving system energy efficiencies by >20% with renewables
- Enhance energy resiliency and increase robustness

Simplified System One-Line

- City Power Plant
  - 6 gensets; Rated 300 -1000 kW
  - Automated controls

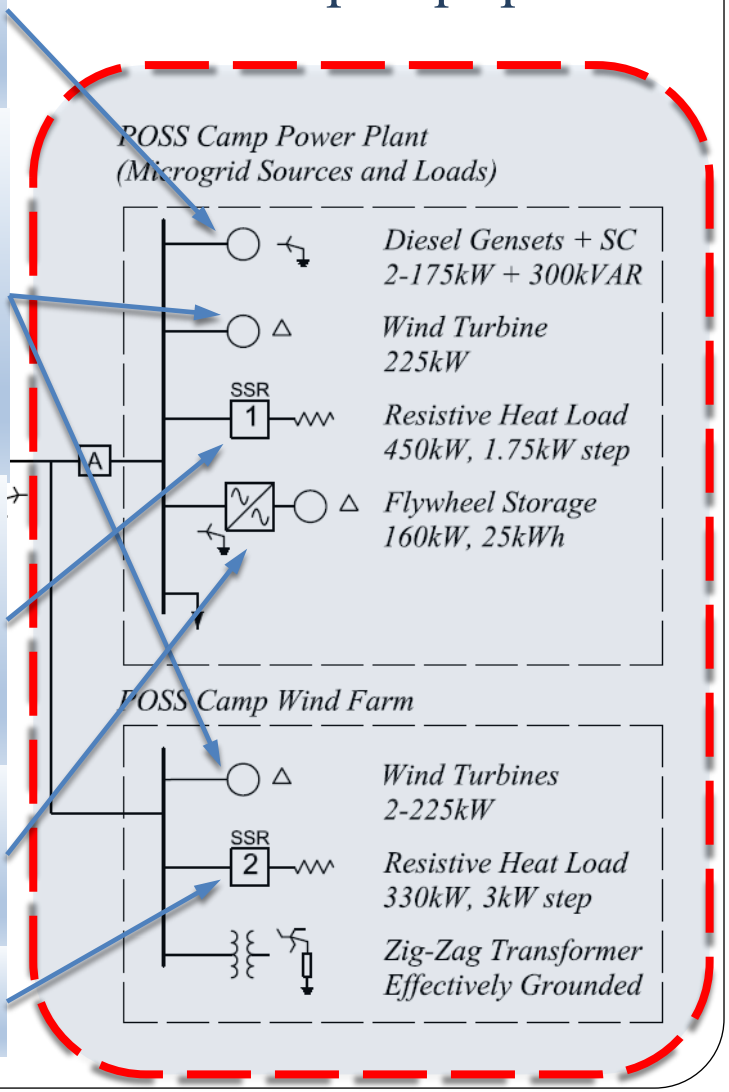
- POSS Power Plant



Three 12.47 kV Distribution Feeders:
All direct-buried, "multiply-grounded neutral"

Simplified System One-Line

- 2 – 160 kW Volvo diesel gensets with automated controls
- 3 – V27 Wind Turbines (1980 vintage)
  - Simple induction generator with thyristor soft start
  - Pitch Control
- Frequency controlled 450 kW secondary load
  - 1.75 kW step resolution, fast control
- Beacon Flywheel 160 kW with 25 kwh storage, and grid-tie PQ Inverter
- Dispatchable secondary 330 kW heat load

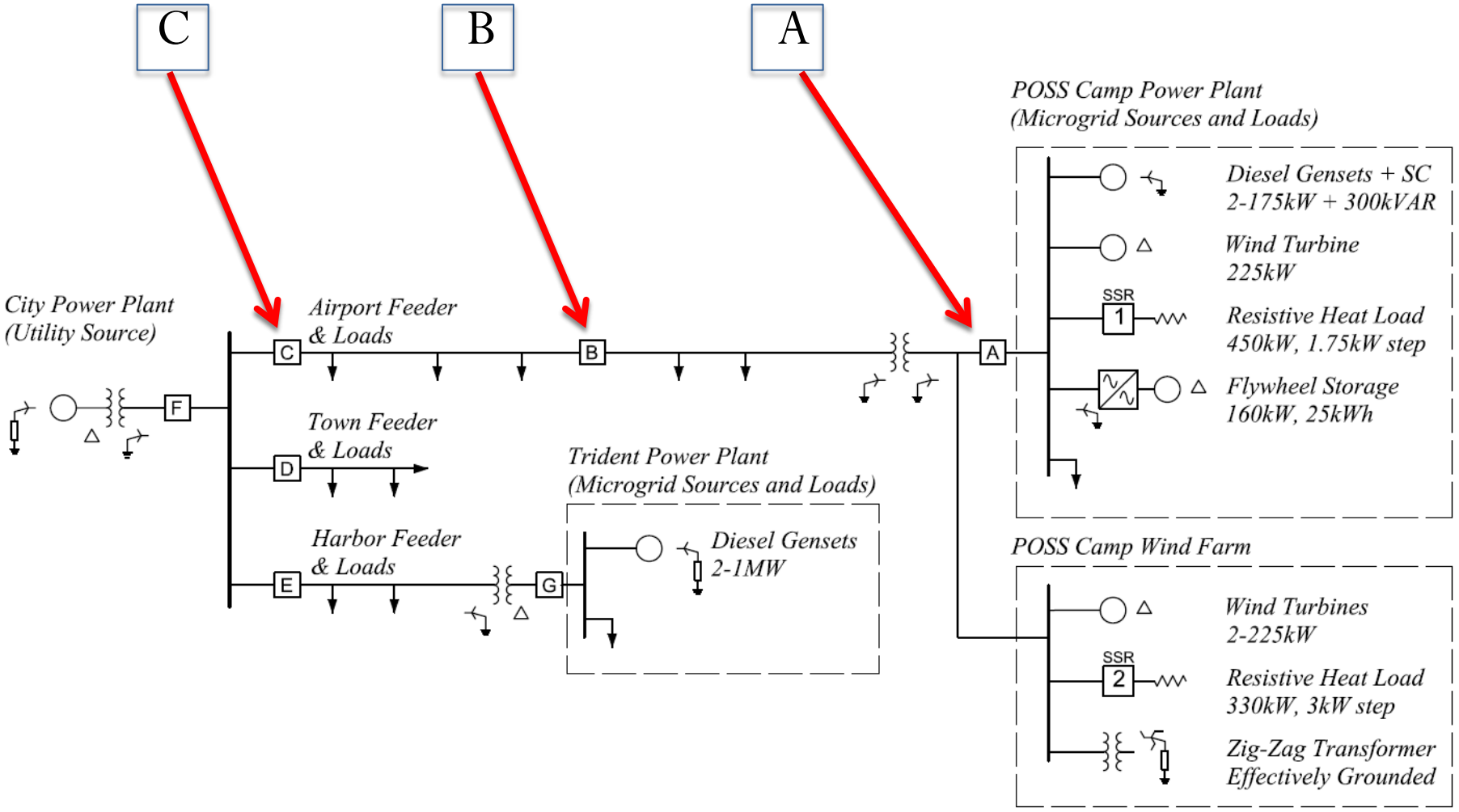


Electrical Loads

- High, Low and Normal city load cases (300kW to 1 MW)
- Critical Loads defined on each distribution circuit
- Non-Critical Loads defined and armed
  - Sheddable by MGC
    - Pre-armed within MGC based upon
      - Selected PCC
      - Operating Capacity inside potential microgrid
  - Repowered when microgrid stabilized after islanding
    - Generation ramped up to repower

MicroGrid Configurations

3 Cascaded MicroGrid PCC



Microgrid Configurations

- Airport Feeder: Three PCC Locations
  - A: POSS Camp islanded with one WT:
    - 2 turbines still connected to City
  - B: Partial feeder islanded with three wind turbines
  - C: Full feeder islanded with three wind turbines

- PCC Selection Process
  - Utility enabled (max) + operator enabled (min)
  - MGC assures minimum reserve to cover potential islanding event
    - Critical loads only: Load shedding armed
    - Wind turbine reserve: Wind turbine power minus 30 kW
      - Flywheel not assisting since it isn't grid forming
    - Diesels as required
  - MGC arms decouple triggers at PCC locations – SEL-451
    - Allows bigger Microgrid island if generation reserves allows

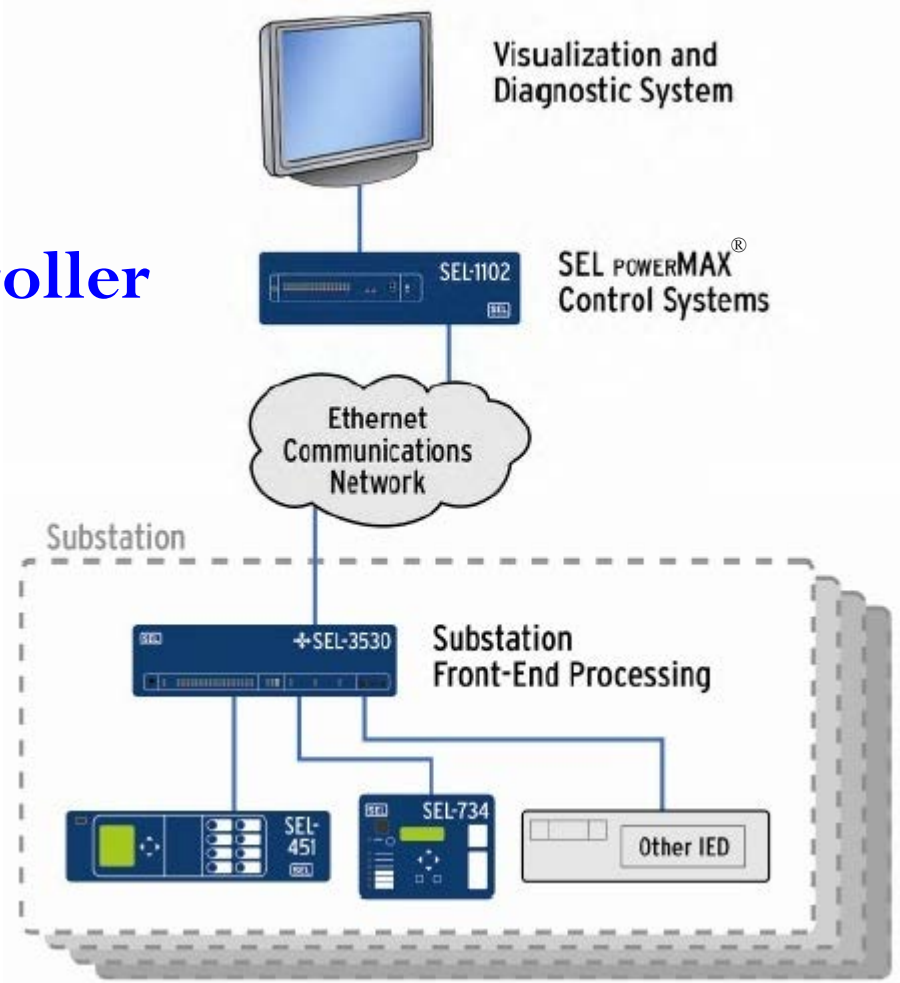
Airport Feeder Selection of PCC

Truth Table Approach

City Permissive	Operator Permissive	MGC PROCESS		PCC Breaker
Maximum	Minimum Sets Reserve	Verifies Reserve		
Breaker A	Breaker A	Breaker A		
Breaker B	**Breaker B**	**Breaker B**	Min	SELECTED
Breaker C	Breaker C	**Breaker C**	Max	Possible

SEL SmartGrid Technology

- PowerMAX Microgrid Controller
- SEL Fast, Smart Switches
  - 351
  - 451
  - 751



2004

SEL's MicroGrid Control System

Volt/VAR Optimization

Power Balancing

Contingency Based Load/Gen Shedding/Runback

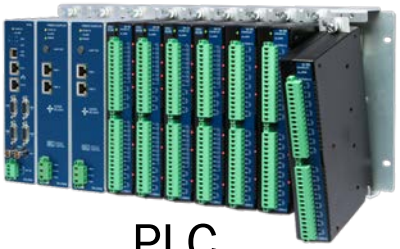
Decoupling and A25A

Visualization

Inertia Compensated Load Tracking

PowerMax Controller

Relays

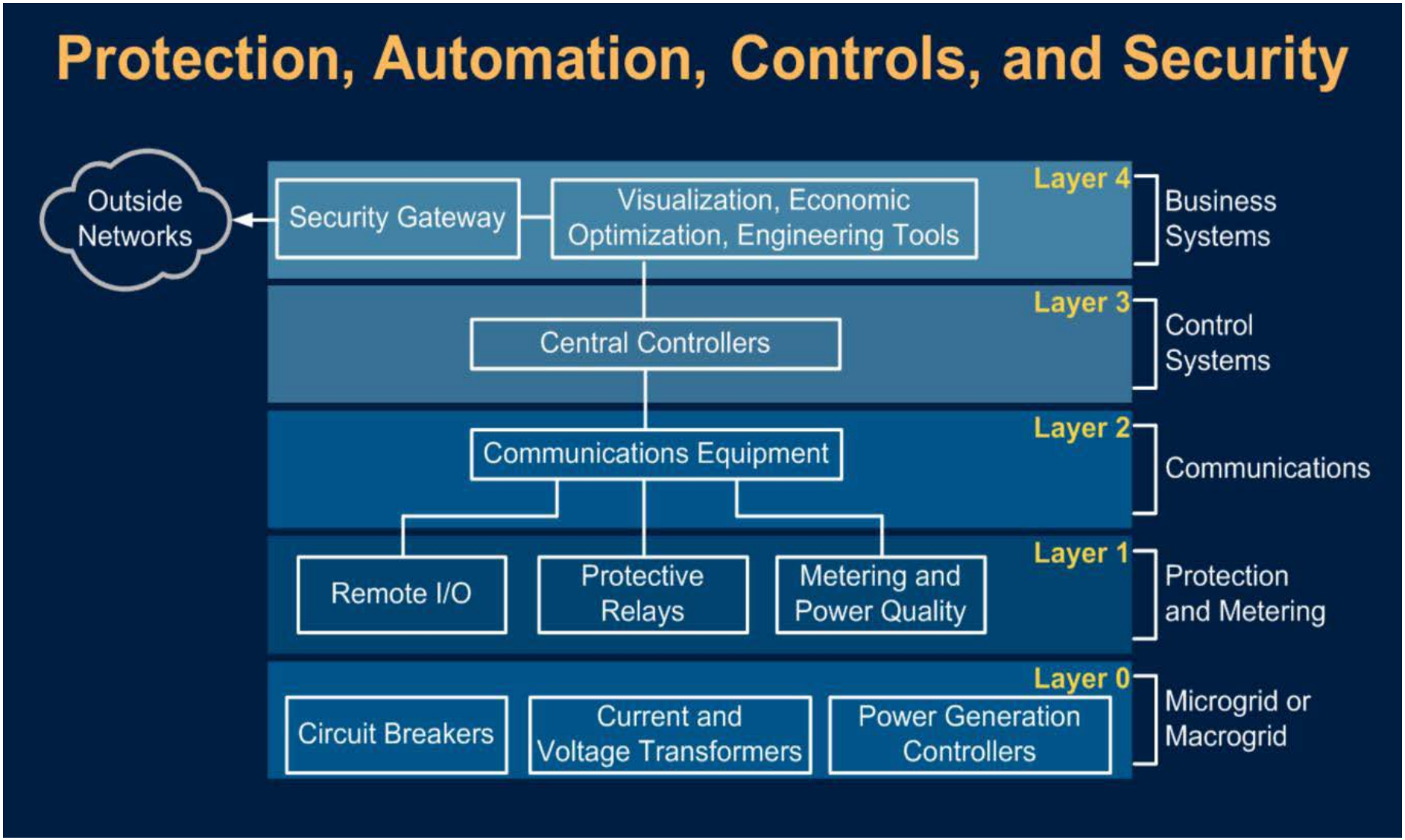


PLC

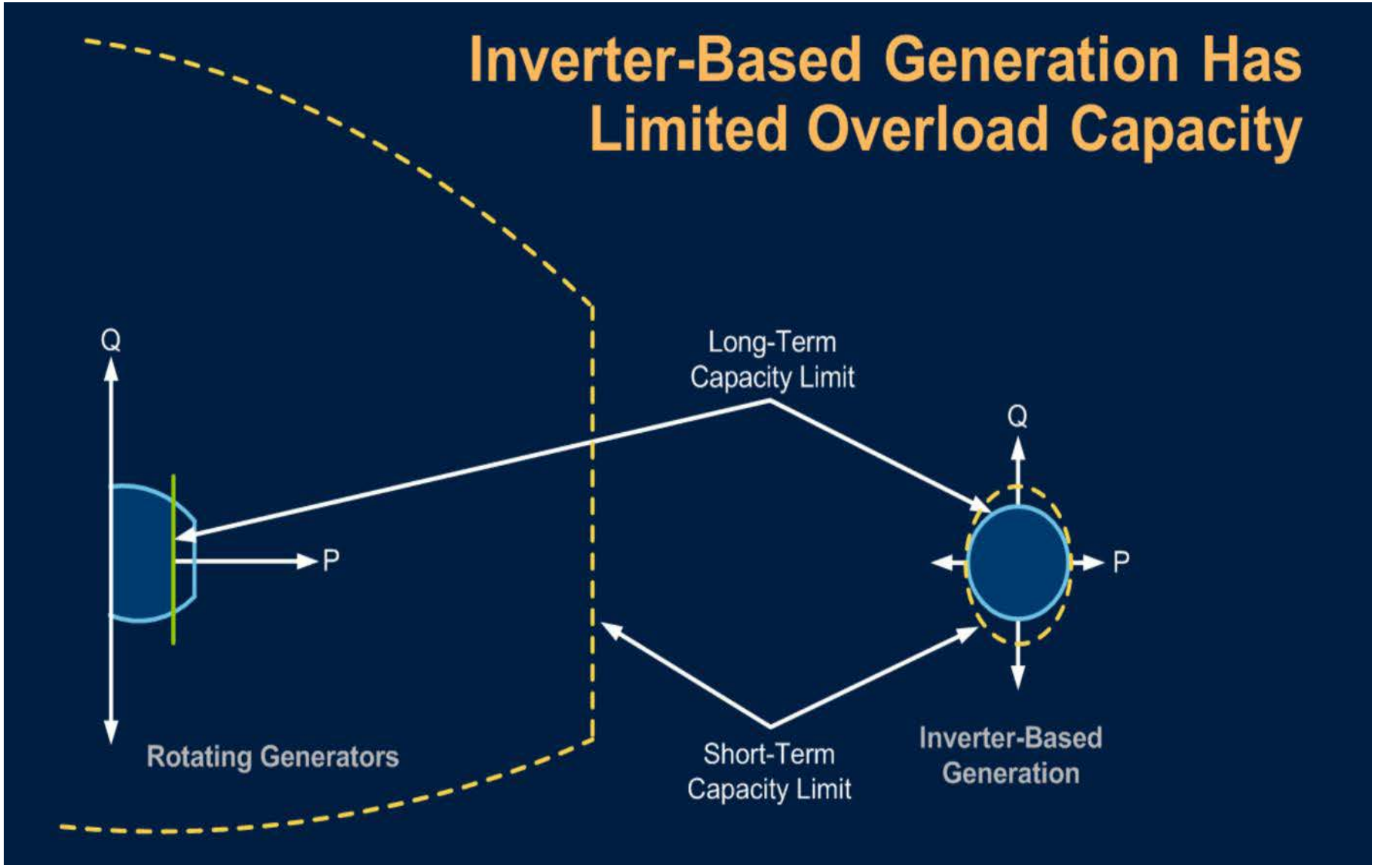
Remote IO

Ethernet & Security

SEL MicroGrid Control System



Renewable Issues



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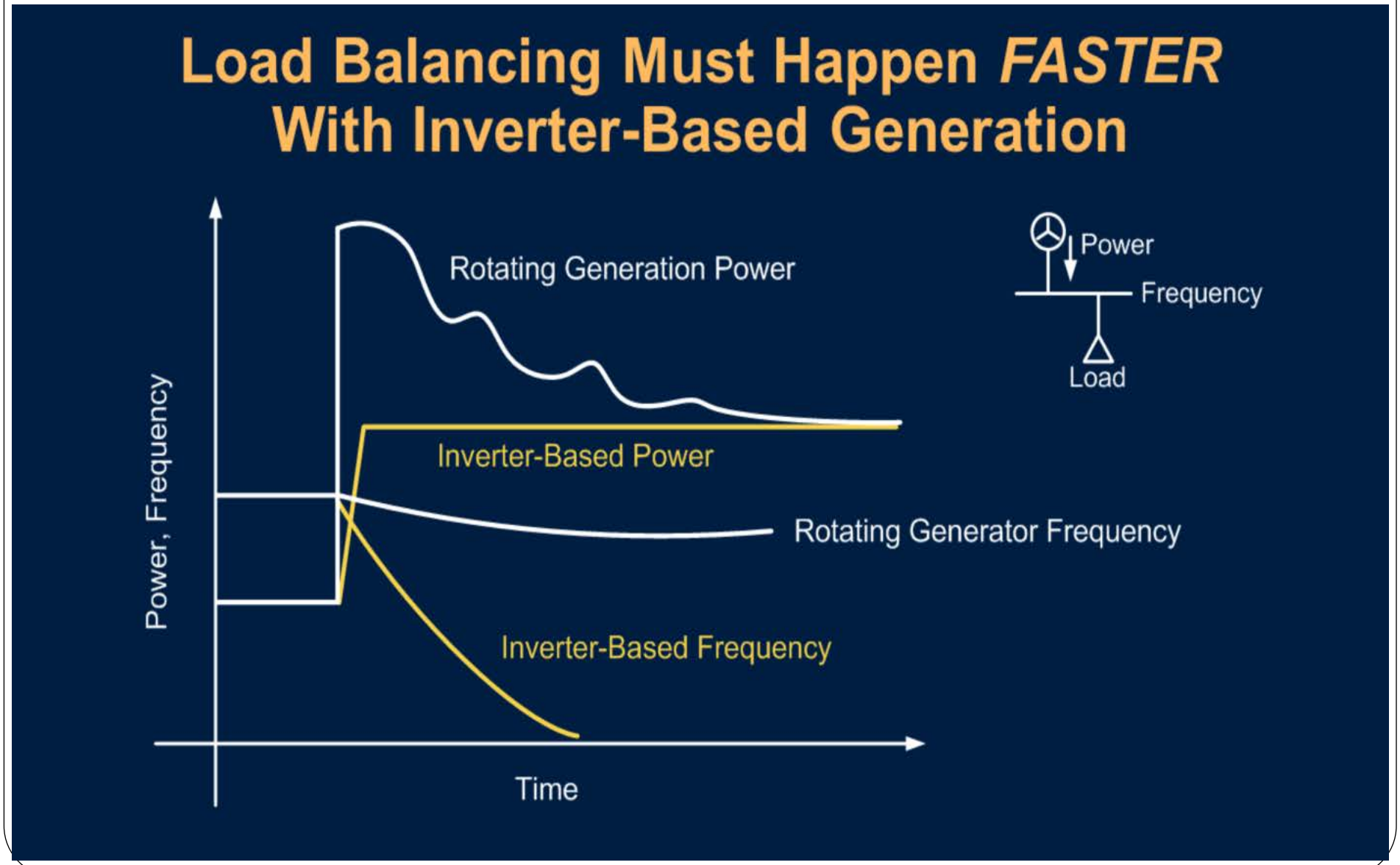
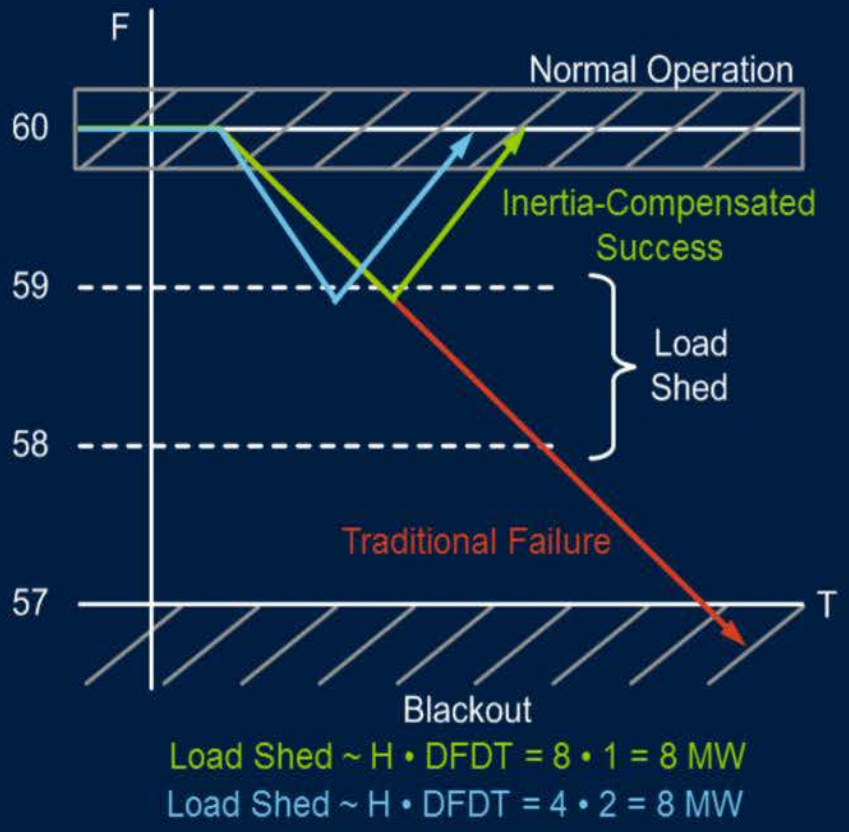


Embedded DSM Control

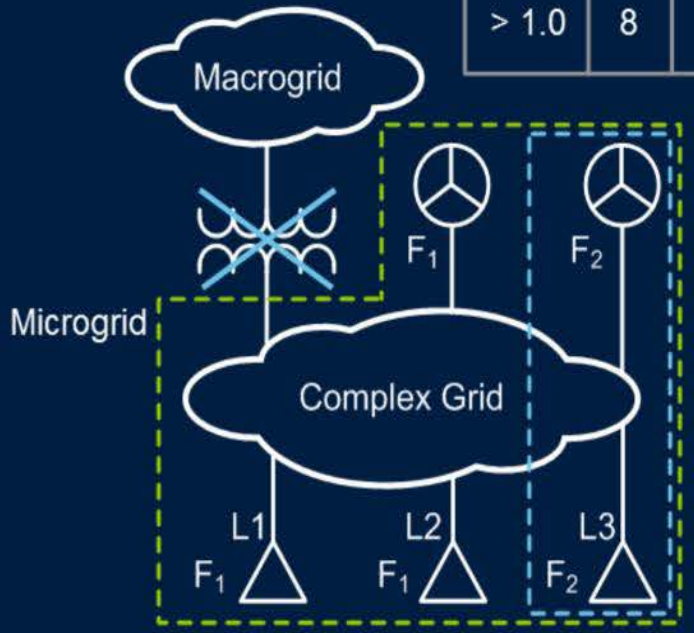
Inertia-Compensated Load Shedding

Do It Right!

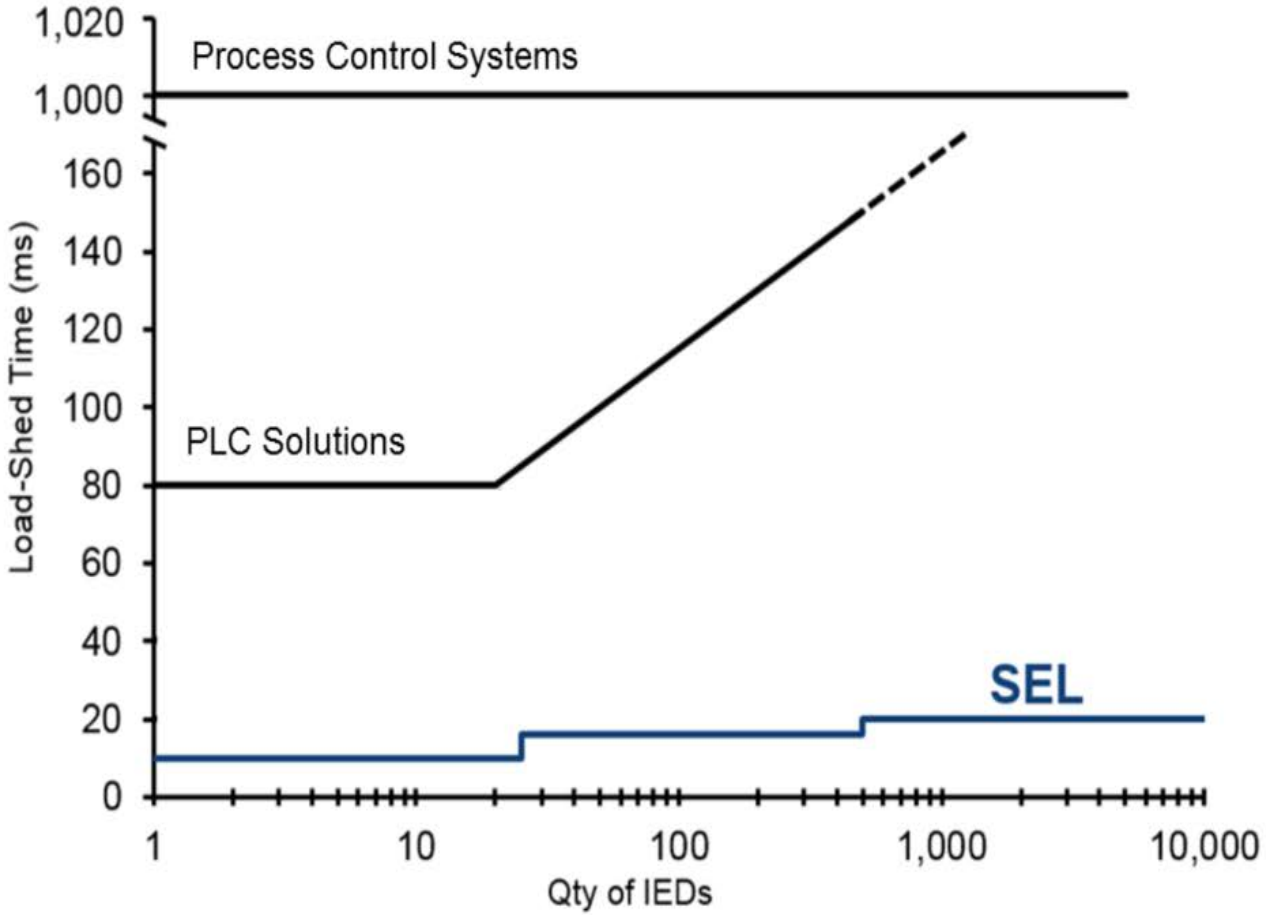


MW Load to Shed

DFDT \ F	59	58
< 0.5	2	4
0.5 to 1.0	4	8
> 1.0	8	12



SEL Controllers Take Action *FASTER*



SEL-451

Protection, Automation, and Bay Control System

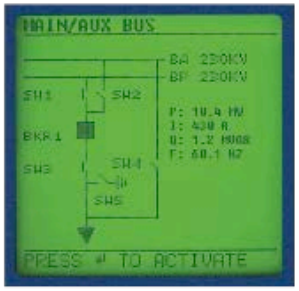
Reduce System Cost, Complexity, and Maintenance

SEL Synchrophasors

SEL IEC 61850

Shown with 5U chassis, expanded LEDs, operator buttons, and auxiliary trip/close buttons.

Combine the control and protection of many substation devices into one fast, powerful, flexible, and economical system.



Dynamic one-line display.

Features and Benefits

Maximize the Capability of Substation Equipment

Fully load equipment by monitoring power, including thermal or rolling interval demand as well as peak demand on positive-, negative-, and zero-sequence current. Use the full capacity of the equipment while maintaining SEL quality protection.

Improve Operation With Built-In Real-Time Synchrophasor Measurements

Help system operators understand the network status with real-time visual displays of system phase angles and frequency. High-accuracy synchronized phasor measurements provide information and control to match frequency and phase angle for critical activities, such as switching, startup, and power transfer.

Provide Powerful Bay Control and High-Speed Breaker Protection

Complete two-breaker control and breaker failure protection complement the versatility of the SEL-451 Protection, Automation, and Bay Control System programmable logic to meet your bay control needs. Easily control motor-operated switches, capacitor banks, and field I/O from the front panel, or remotely.

Advanced Power System Monitoring

Provide advanced power quality monitoring of system disturbance information with voltage, sag, swell, and interruption (VSSI) monitoring.

Making Electric Power Safer, More Reliable, and More Economical®

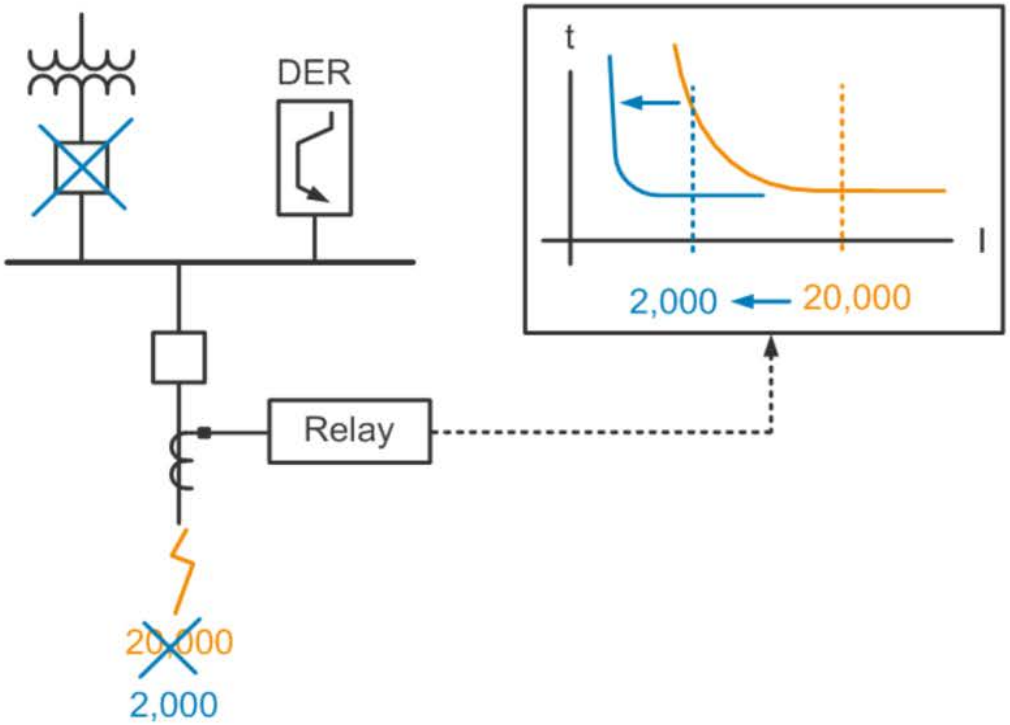
451 Relay Functions (general)

- Multi-function Protection
- Synchronization System
- Oscillography
- Sequence of Events Recordings
- Remote I/O and Metering
- Power Quality Monitoring
- Programmable Logic Controller
- Ultra High Speed Communications
- Continuous Self-Diagnostics
- Synchrophasors
- DC battery monitoring

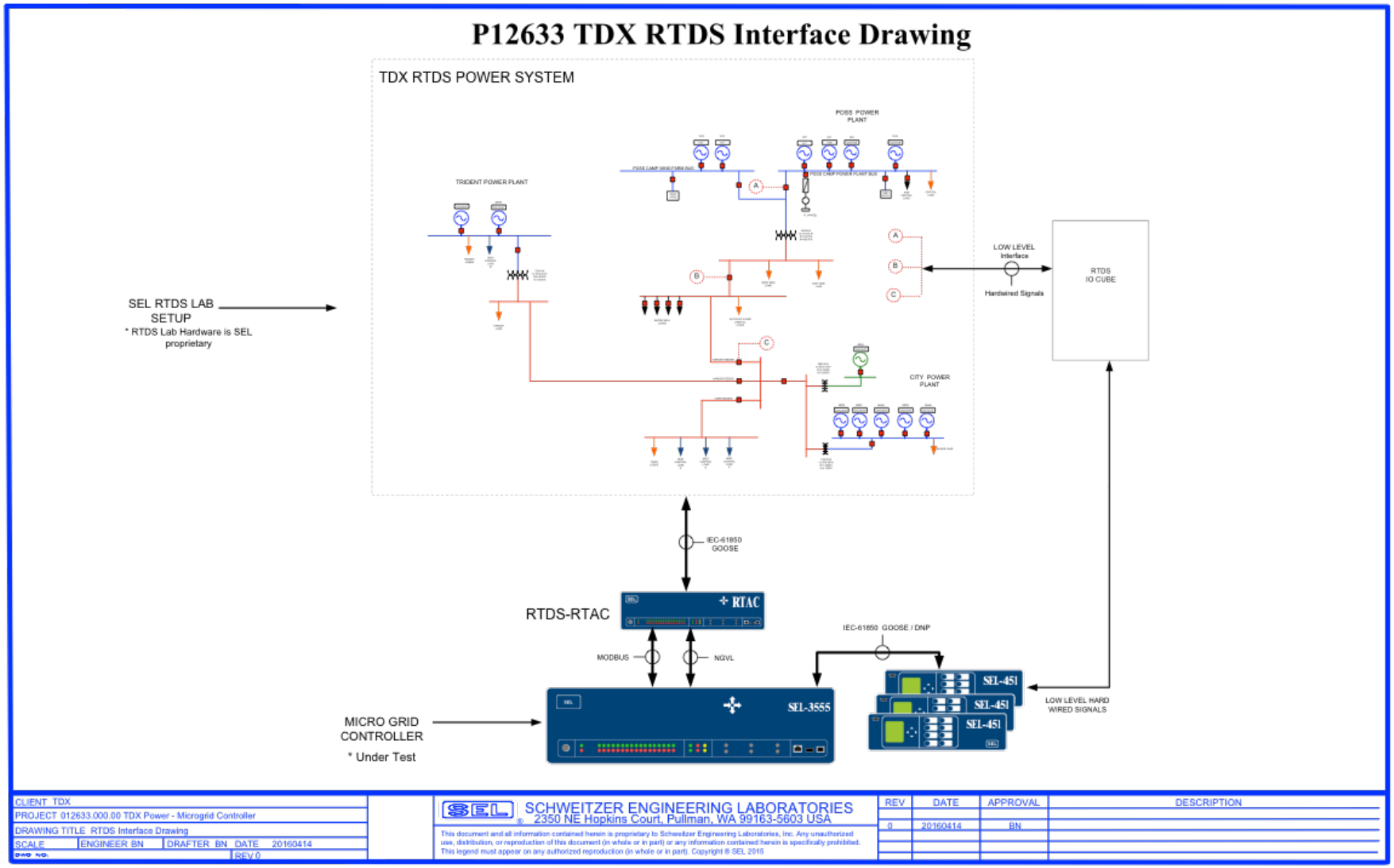
SEL Relays Protective Scheme

Protection Must *ADAPT* To Changing Fault Conditions

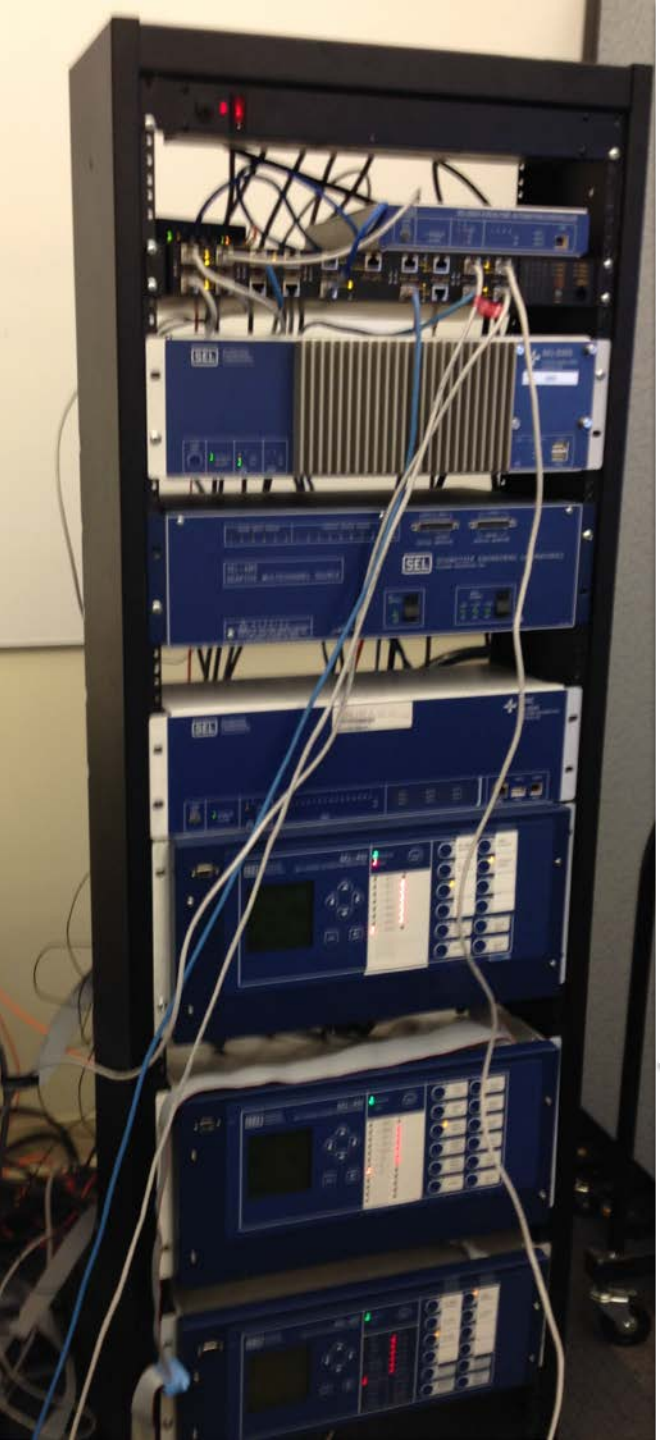
- Fault levels
- Grounding
- Directions
- Impedances

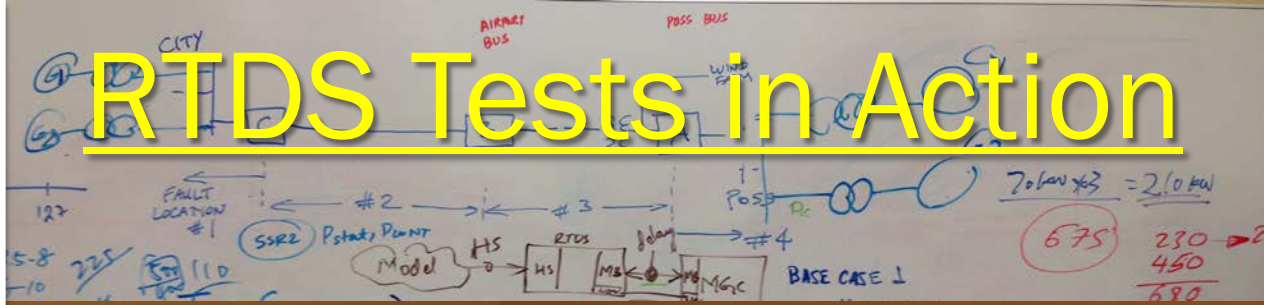


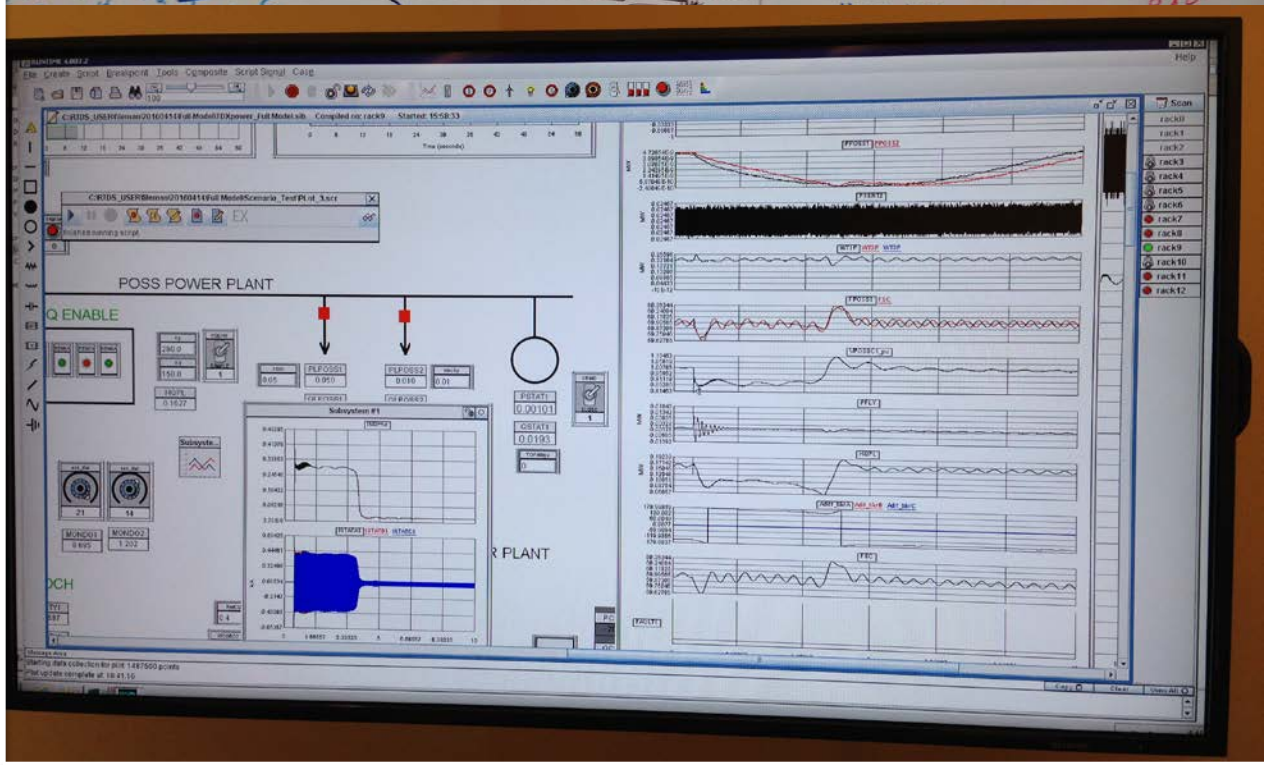
Hardware in the Loop Testing



RTDS Tests in Action

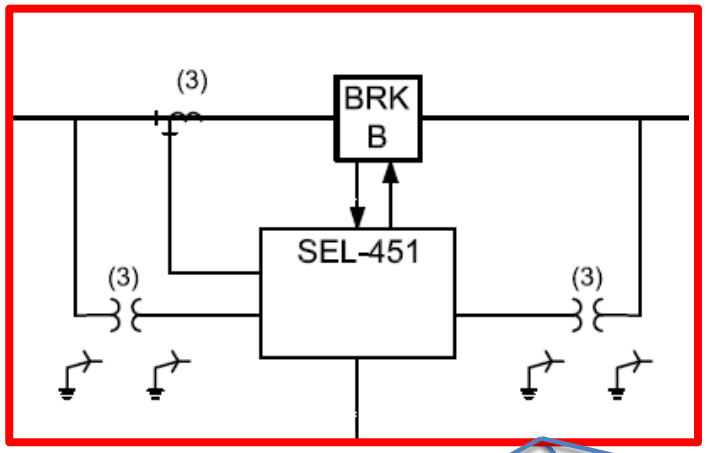


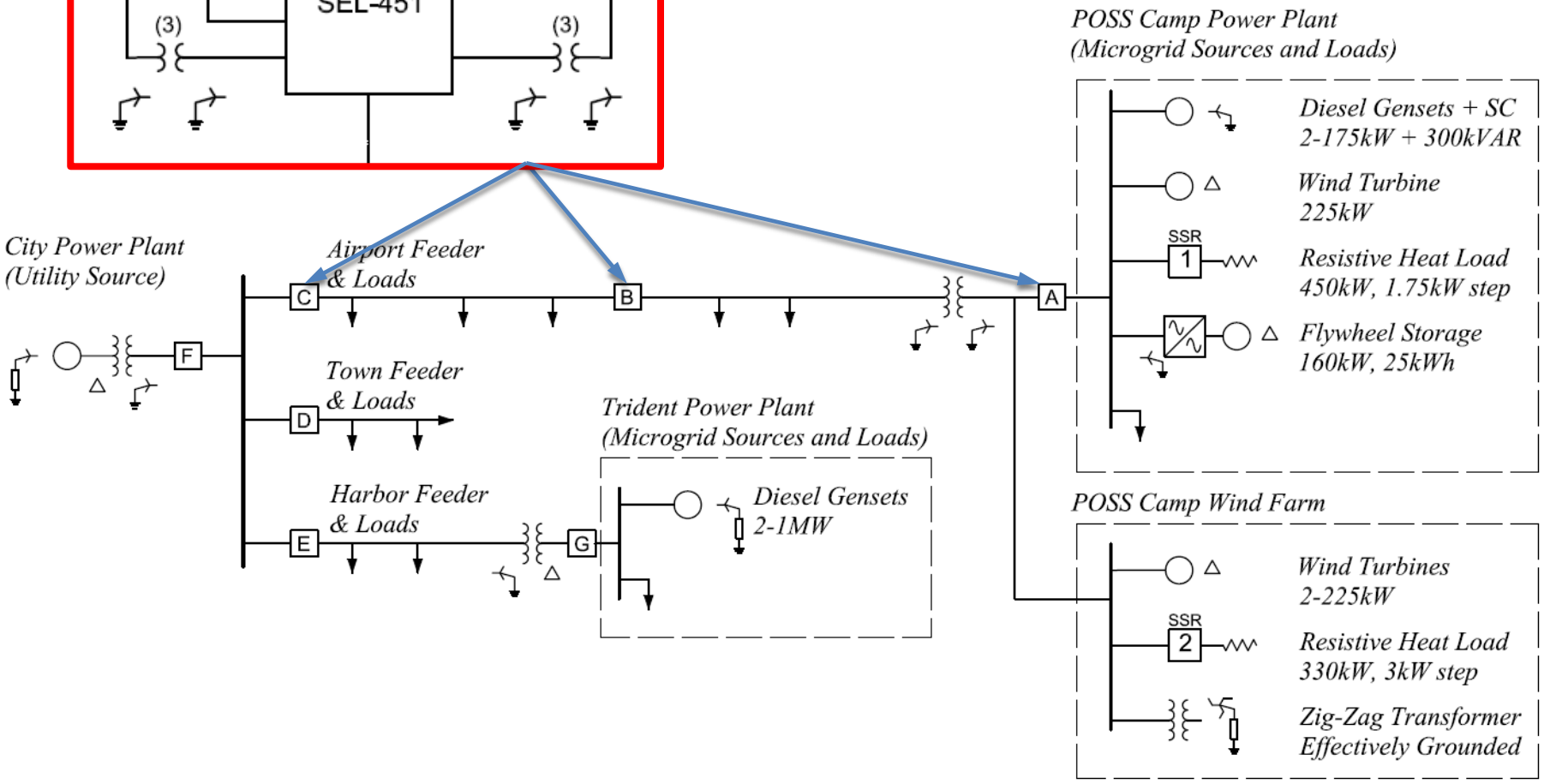




451 Relay Locations

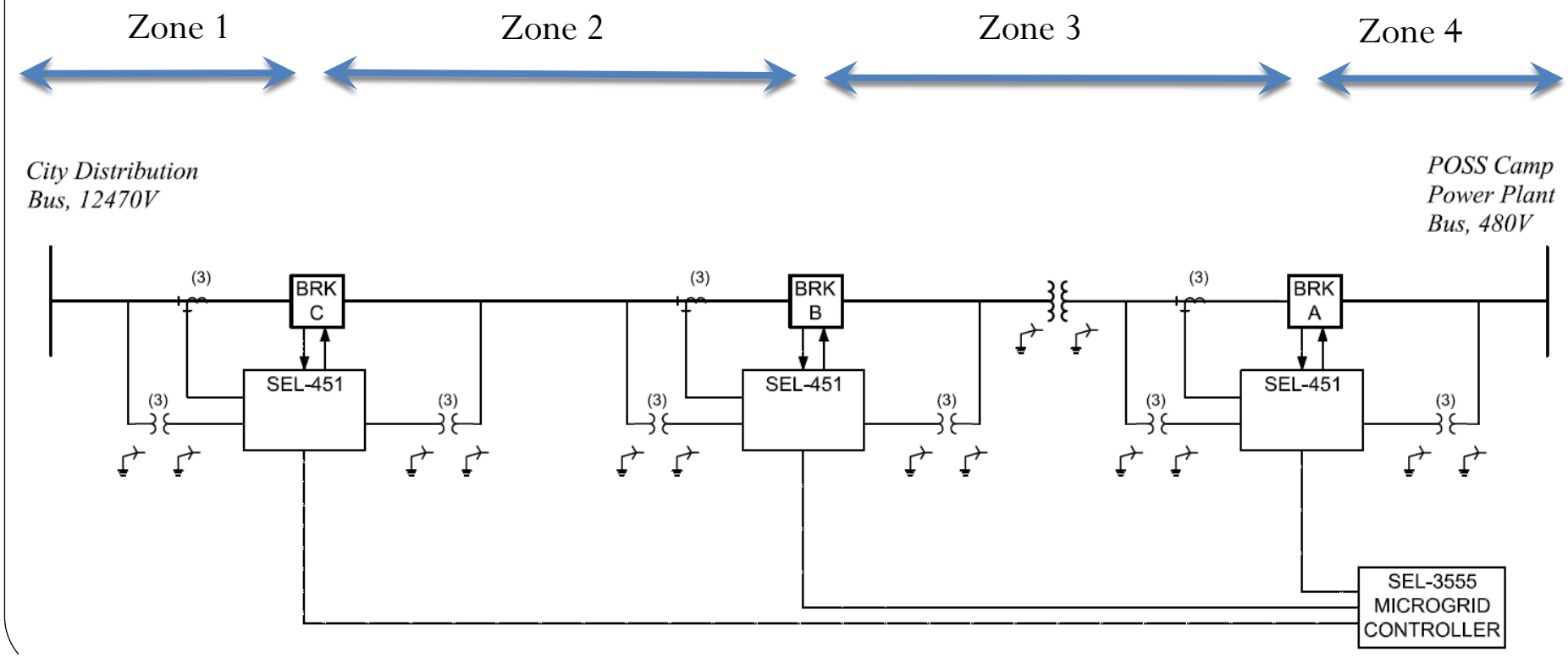
Microgrid Switch Equipment - 451 Relay at location A,B,C





451 Relay Config Overview

- Decouples to form Microgrid from failed grid, based on DOE criteria
- Clears faults when Microgrid faults
- Performs sync check & breaker close when grid recovers



SEL Process

- MGC Final Design Specification
  - MGC Coding Authorized
- Validation Testing
  - Component Performance Validation
  - Protection Modeling
  - Steady State and Dynamic Validation
- RTDS Cases (10 days)
  - Permissive Controls to Alarm PCC at A, B or C (9 Cases)
  - Wind Condition Verification (10 Cases)
  - Unintentional Opening of Breakers (19 Cases)
  - Decoupling Events with Faults (33 Cases)
  - Auto-Synchronization Events (6 Cases)
  - Genset and Wind Turbine Failure Events (5 Cases)
  - Faults and Specials, using measured wind profiles (22 Cases)

Decoupling Event at 'C' Wind Only

Test Case 31a

Initial Conditions

City Gen #1- 930 kW

Microgrid Generators

3 Wind Turbines on line

- Wind 14 m/s

POSS Diesel off

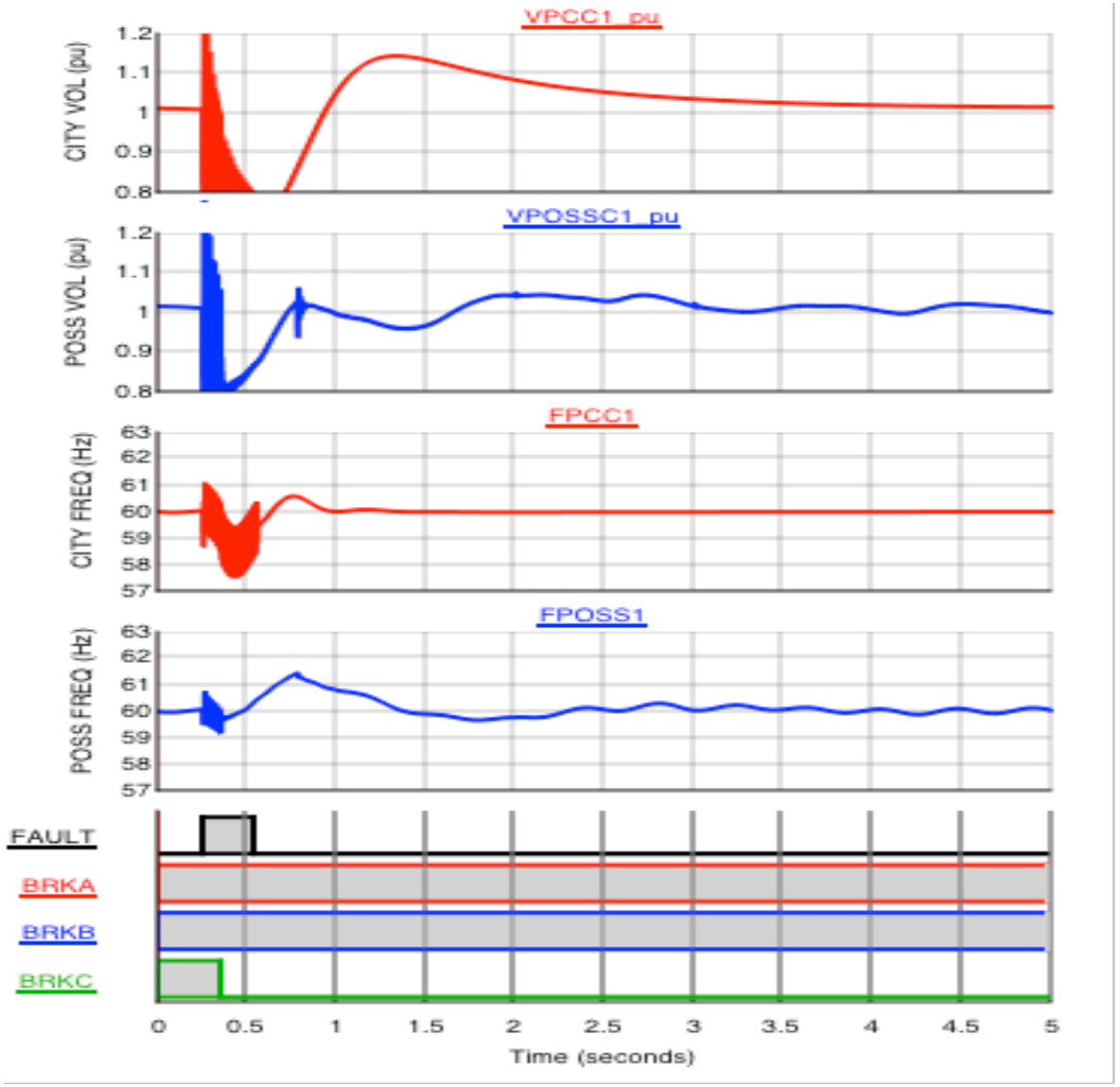
High Load Case

Action

Fault on City Distribution Breaker

- Single Phase Short to Ground

- 300 ms



Decouple at 'C' Power Flow Wind Only

Test Case 31a

Initial Conditions

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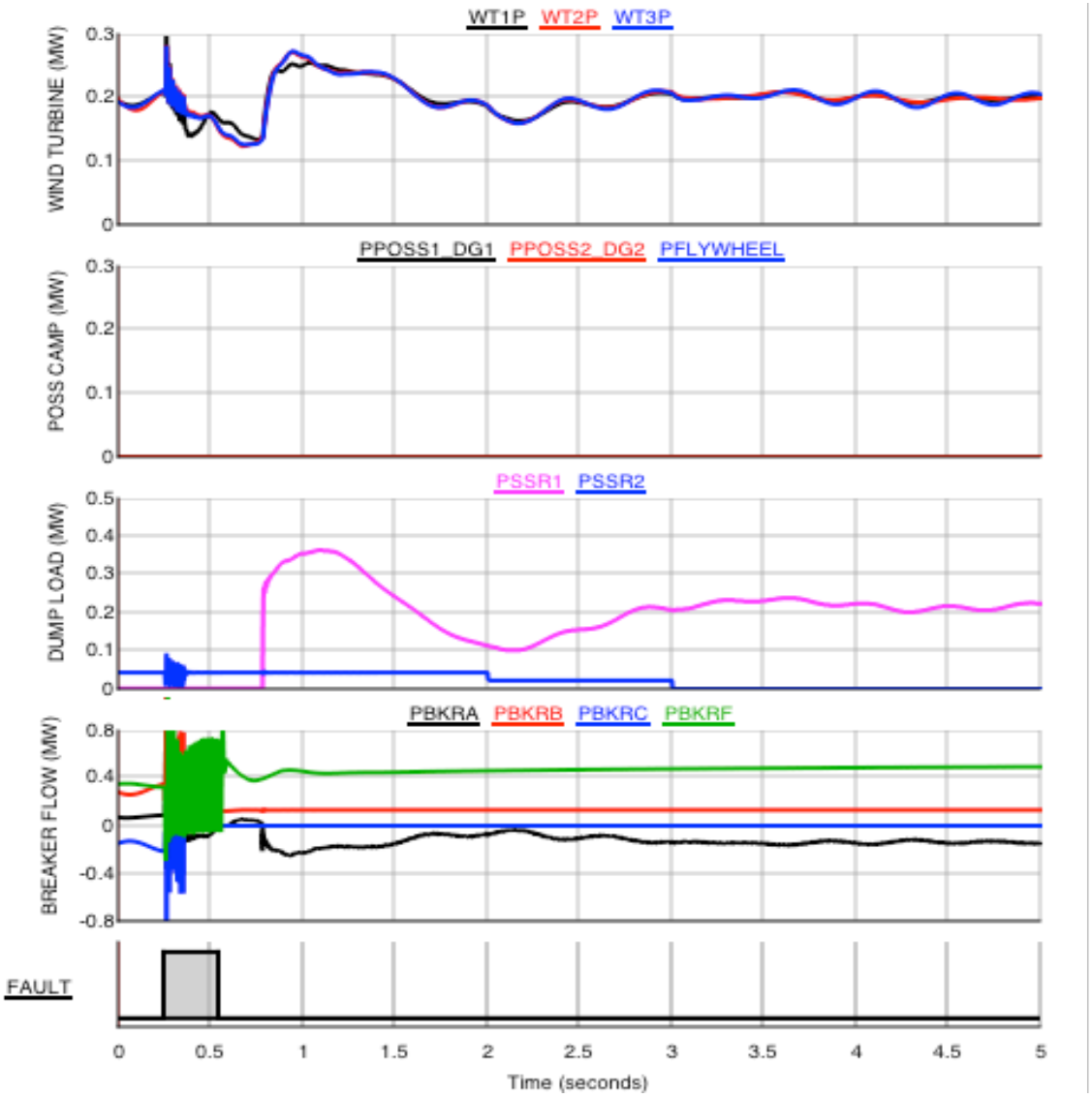
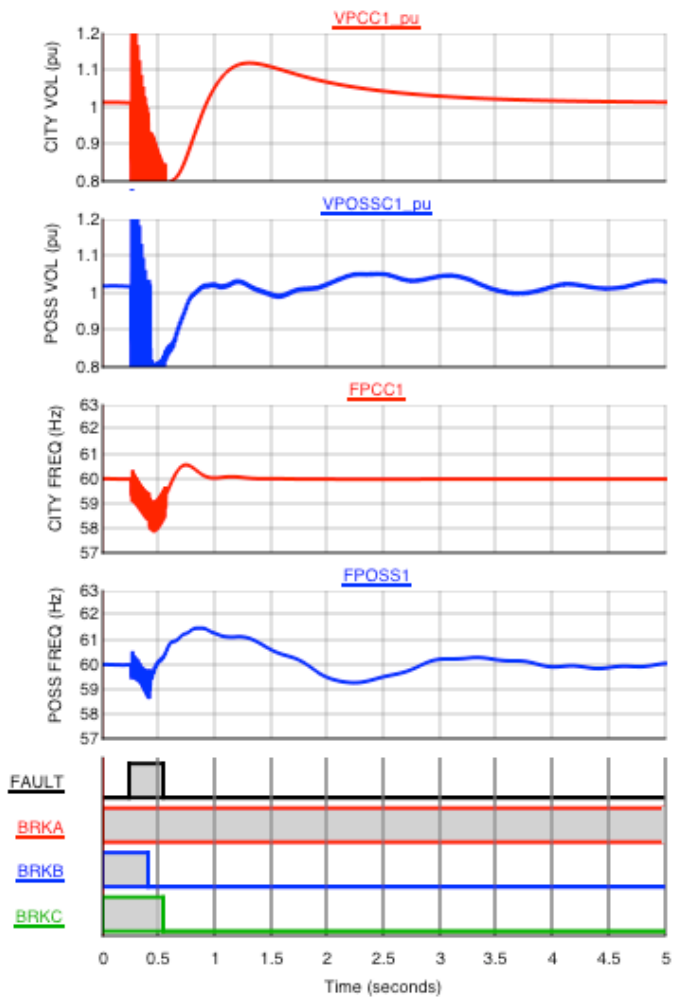


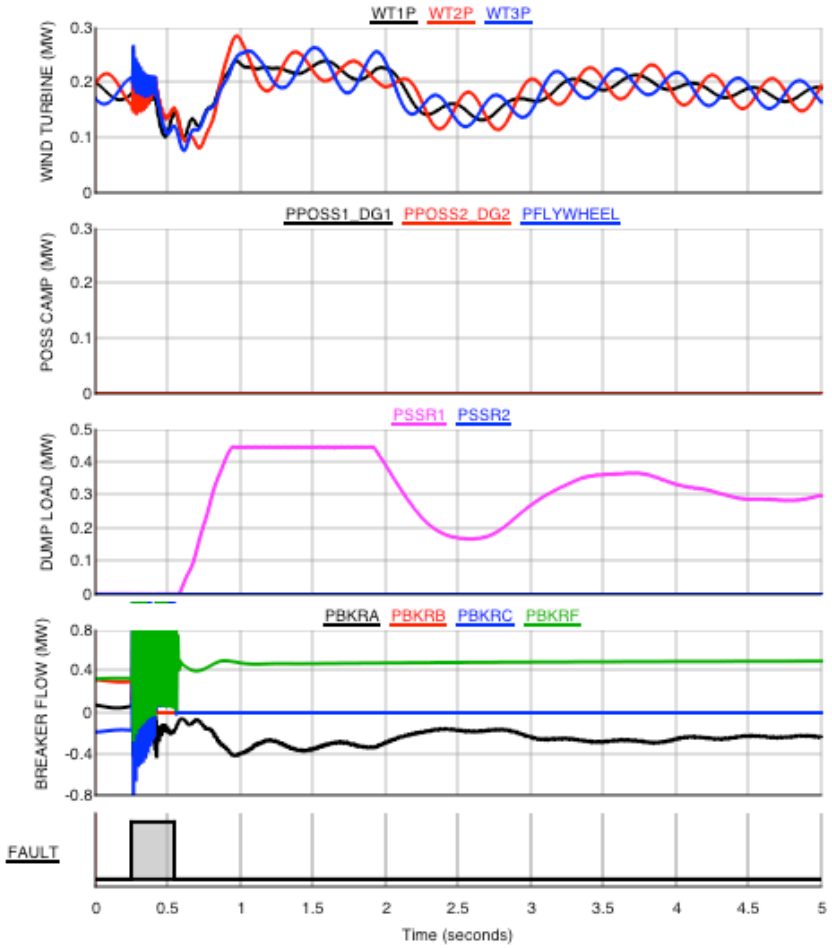
Decoupling at 'B'

3 Wind Turbines near rated power: High Loads: City Gen #2 only

Test Case 30b

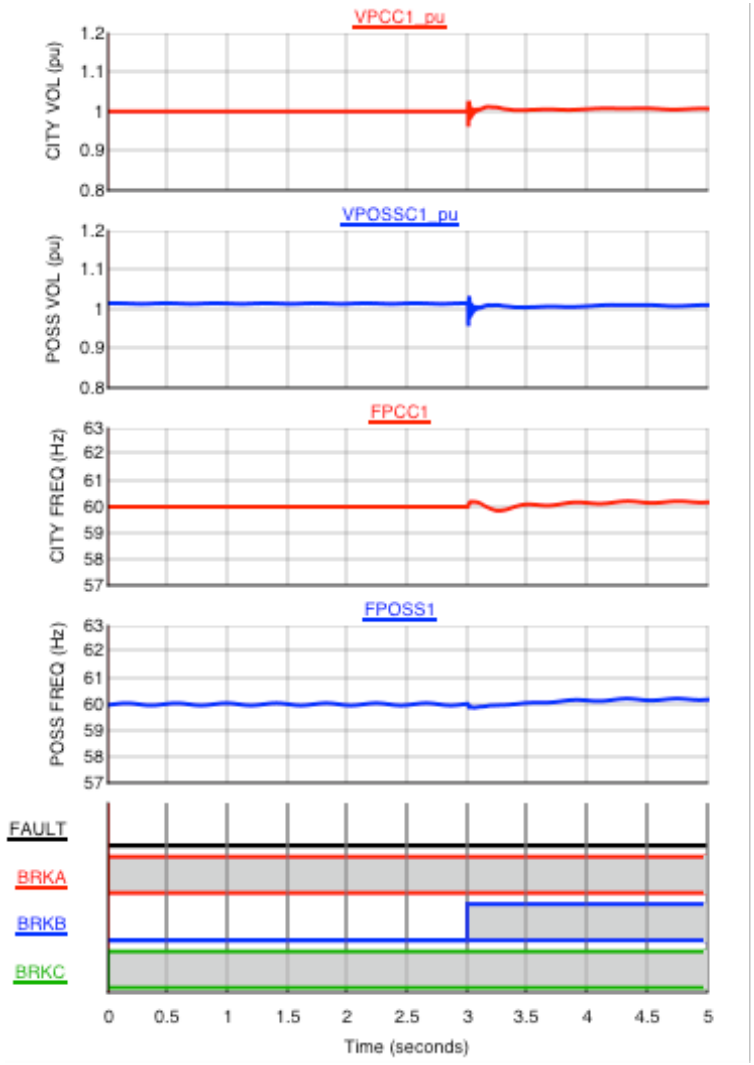
Fault in Zone 2: Decouple at 'B':



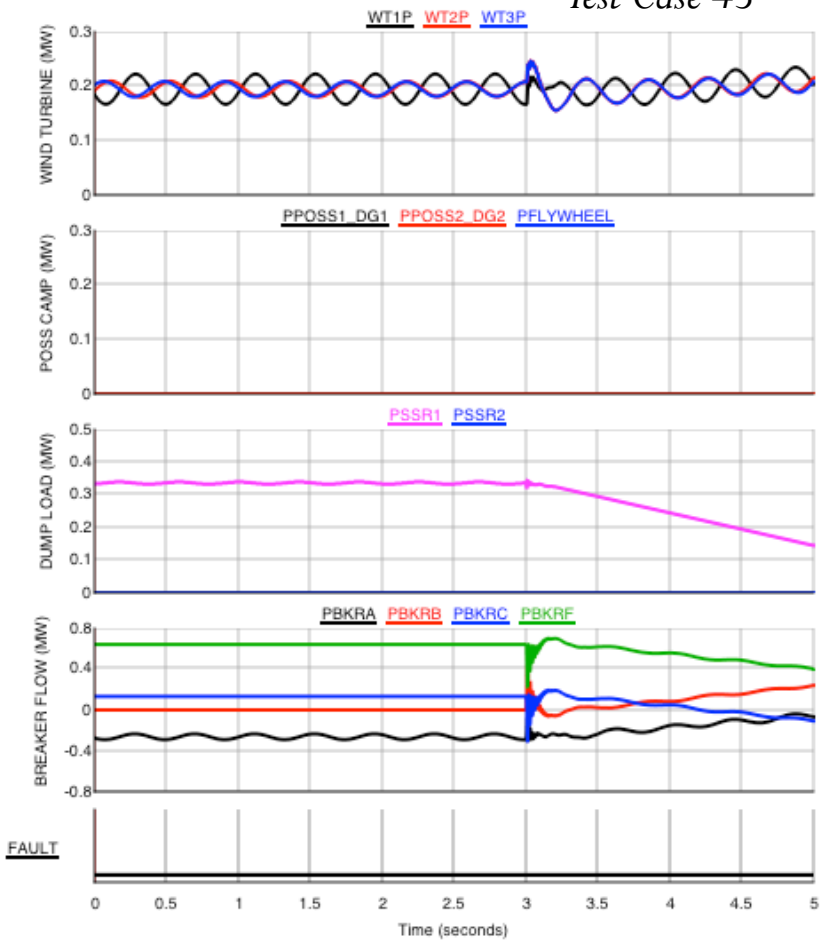


ReSyn at ‘B’

3 Wind Turbines near rated power: POSS generators off: City Gen #1: High Loads



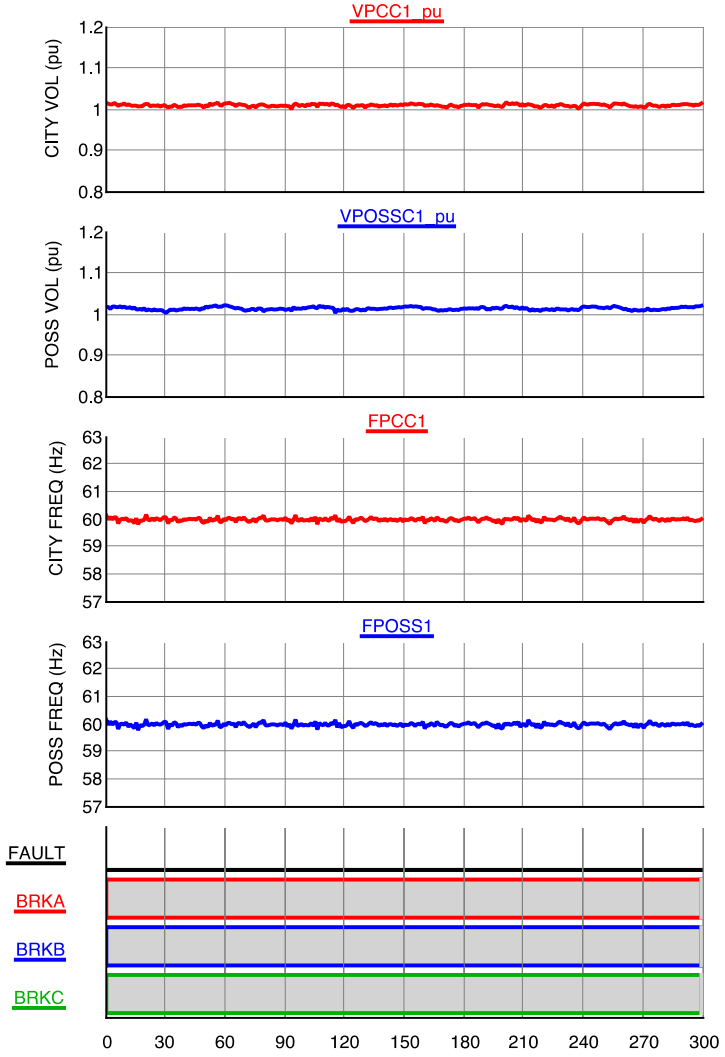
Test Case 45

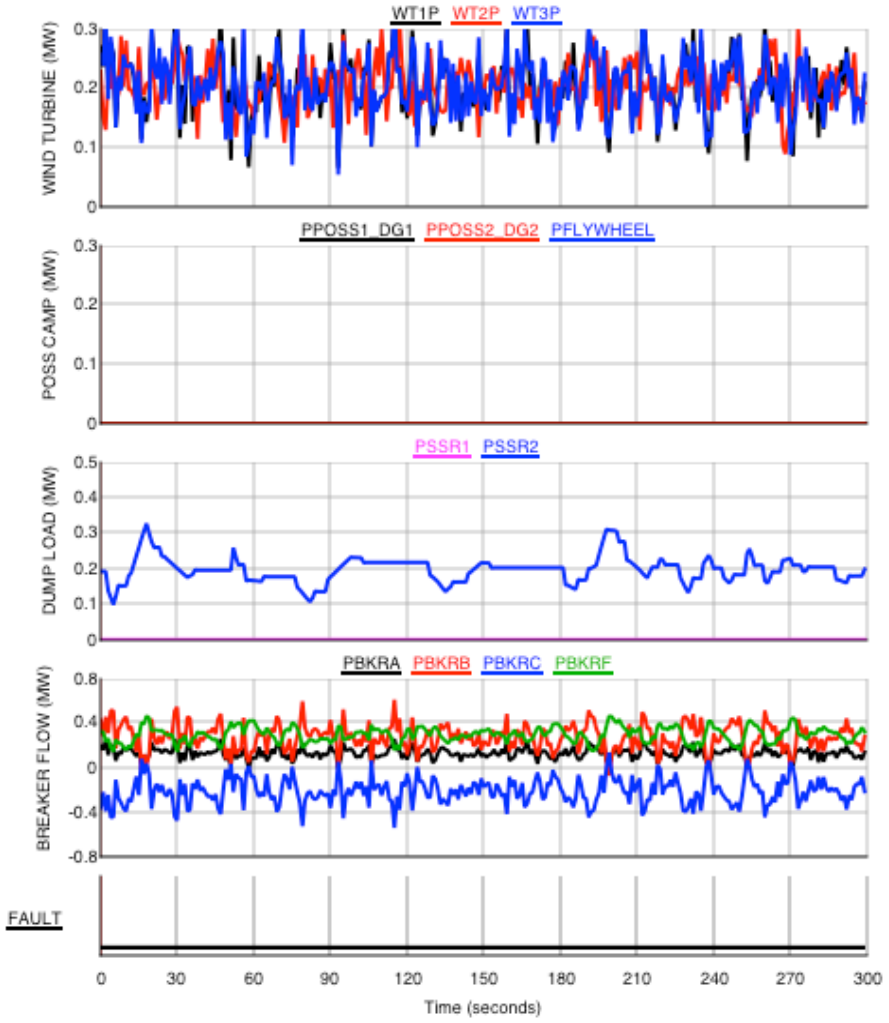


Stable Connected Operation

5 minute period

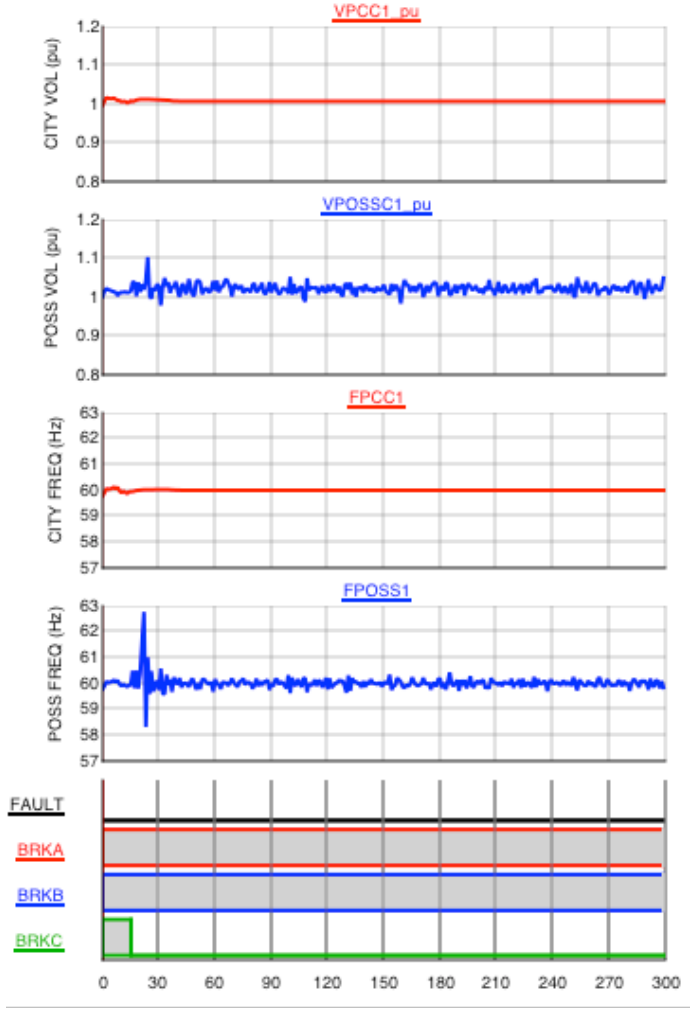
Three Wind Turbines near rated power: Normal Loads: City Gen #1



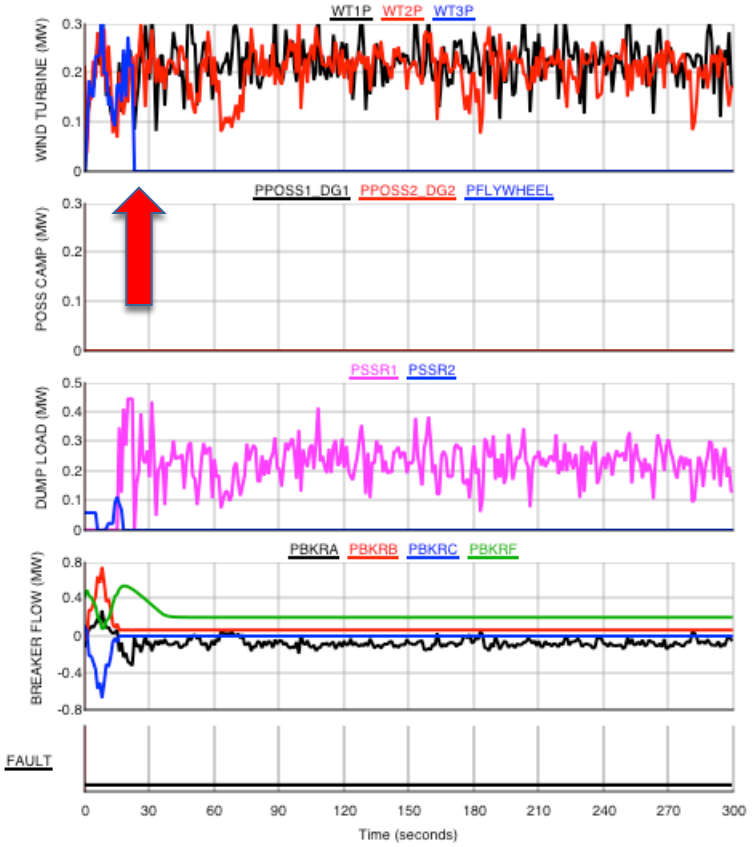


Stable Decoupled Operation

3 Wind Turbines near rated power: Normal Load: City Gen #1
Decouple at C : Microgrid Wind Only on 2 Wind Turbines



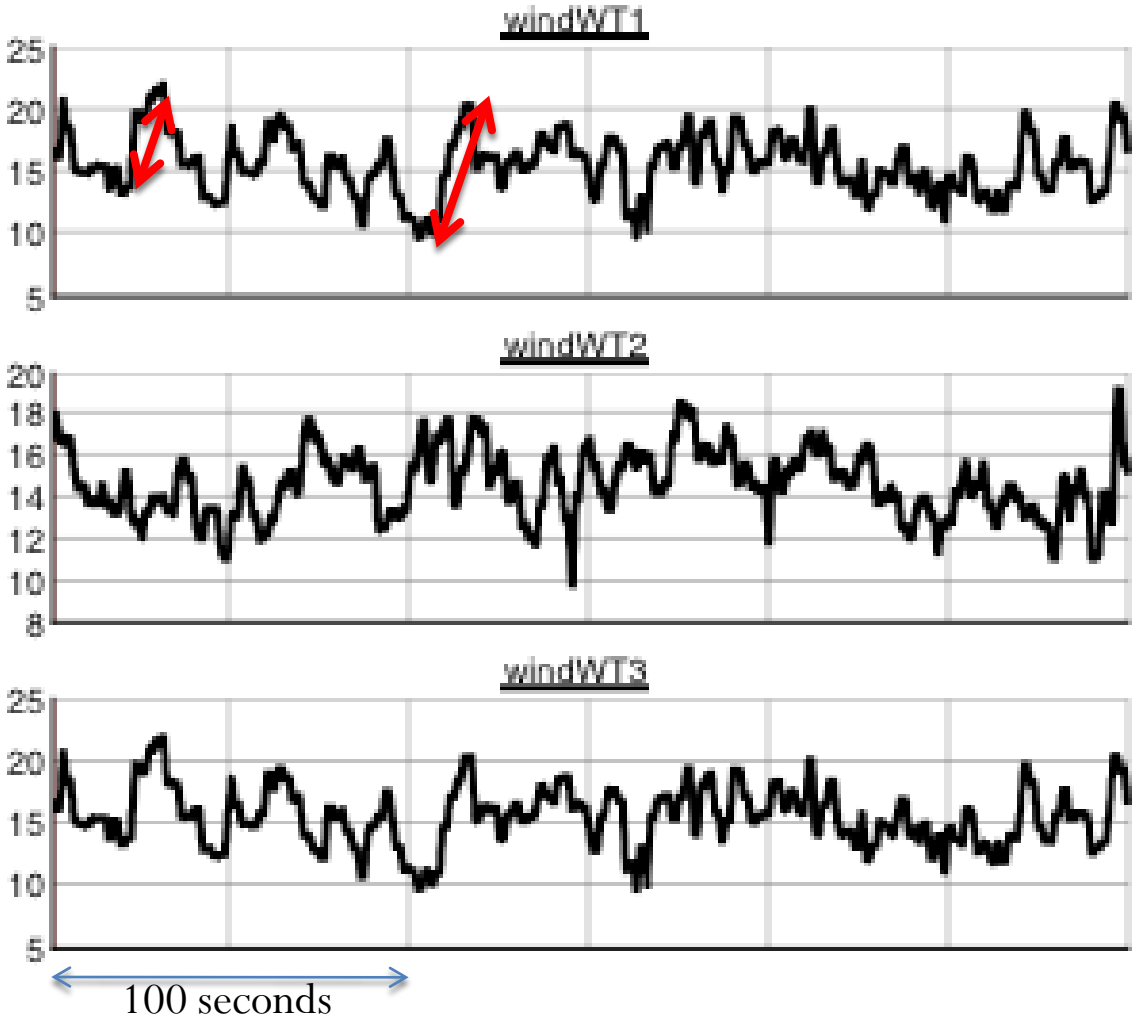
WT#3 Trips off on Over Frequency
62.6 Hz for 300 ms



Gusty Wind Conditions

Wind Gusts in Sample
-14 to 24 m/s
-10 to 20 m/s

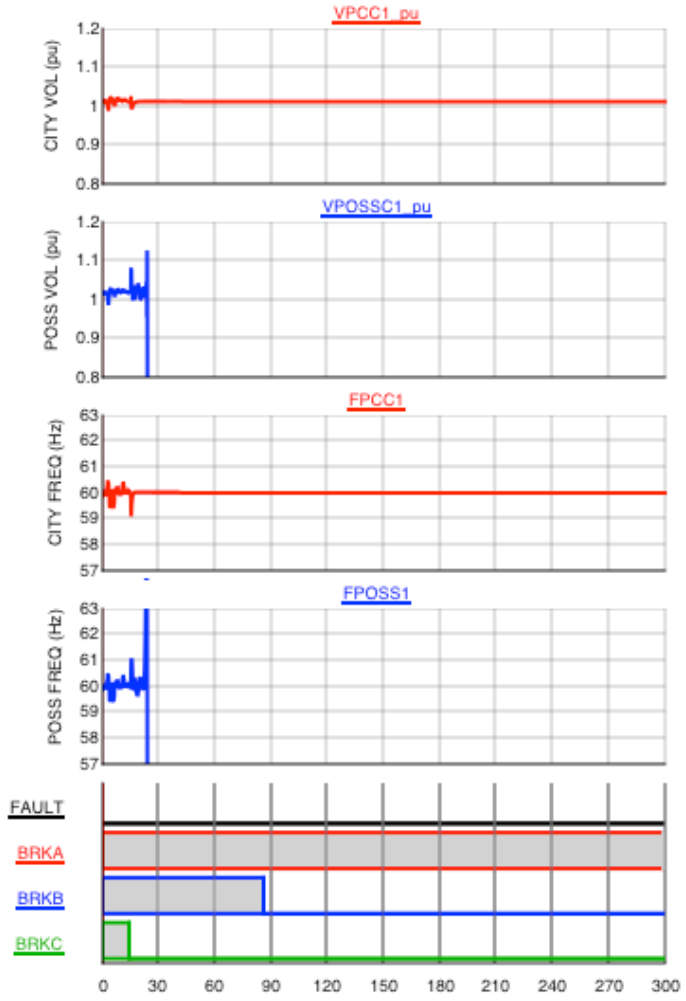
Wind Turbine Power Change
-180 kw/turbine
-540 kw for wind farm
- Model includes pitch controls

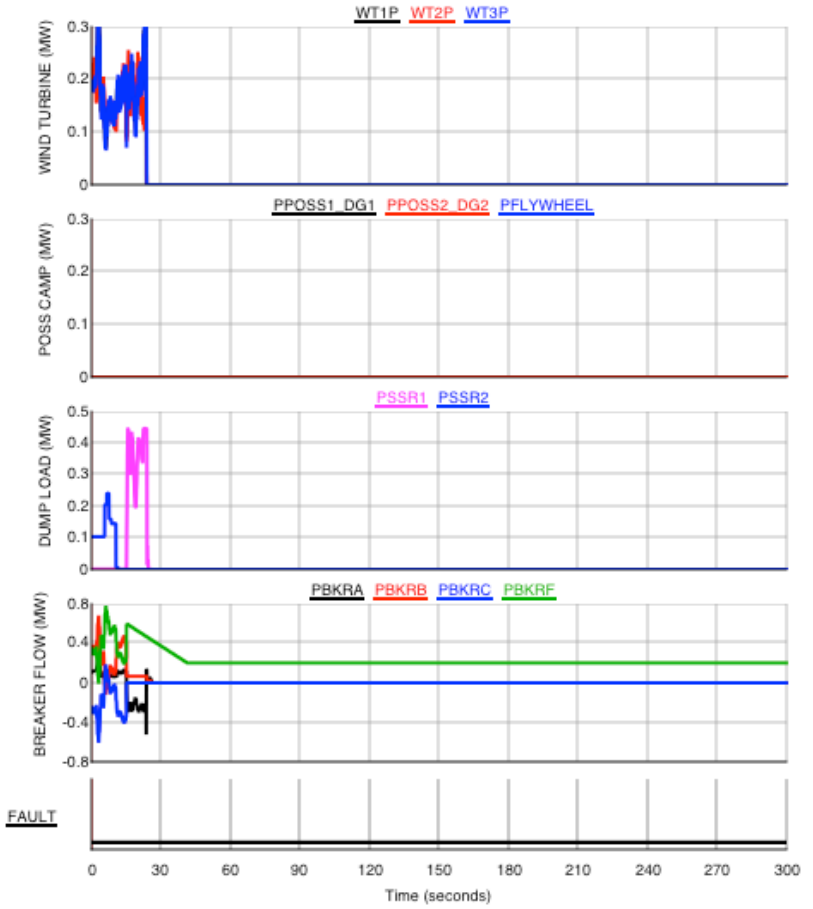


Same Case

Relax WT Freq protection to 62.6 for 800 ms

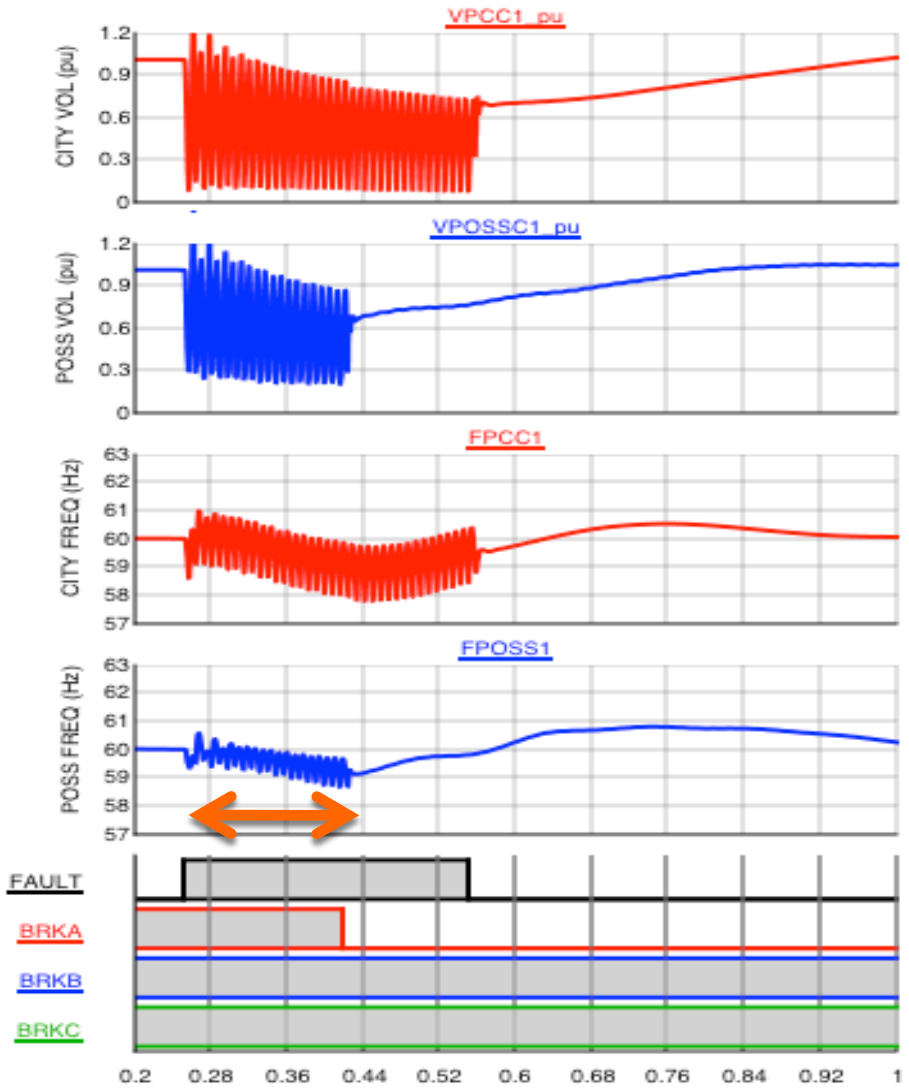
More Power from Wind so more frequency excursion and Microgrid crashes





Decoupling Breaker Response

Fault: Single Phase Fault on City Buss for 300 ms



City

Microgrid

Breaker response is 160 ms

RTDS-HIL Conclusions

- Model fidelity critical:
  - Line capacitance model effects results
- Component characteristics critical:
  - Synchronous machine exciter models have big effects
  - Wind turbine pitch regulation and synchronization transients
  - Flywheels model is demanding
- Comms speed critical to stability controls
- RTDS provides
  - MGC validation with real time inputs
  - Allows fine tuning of all assets
  - Allows exploration of stability corners

Next Step Field Testing
St. Paul Island