CERTS MicroGrid Symposium
Northern Power Systems
Update on Mad River MicroGrid and Related Activities




June 17, 2005

NORTHERN
POWER SYSTEMS
power without limits

MicroGrid Definition (NPS version)

A MicroGrid power system:

- Is a local scale power system using micro source generation scaled either by electrical or thermal output to the local system demand.
- Can serve a customer with multiple load locations, an industrial park, or a campus.
- Is designed to transfer seamlessly between connection with the local utility and isolated operation.
- Provides power reliability and power quality benefits not available from the conventional utility grid system.
- Incorporates communication/aggregation features to allow organization and control of the MicroGrid power system as a single entity.

MicroGrid Benefits

To Users or Customers:

- Economics
  - Potential spark spread savings
  - Thermal energy savings when CHP employed
  - Potential for economic dispatch of generation assets
- Power reliability & availability
  - Multiple generation assets
  - Isolation from local grid problems
- Power quality
  - Local voltage control
  - Voltage and current harmonic improvement

MicroGrid Benefits

To Utilities:

- Transmission and distribution support in constrained areas.
- Potential revenue from “premium power” product offered to customers.
- Potential revenue for thermal energy product in addition to electrical energy.
- Can behave as a single interruptible load.
- Can behave as a single dispatchable generation resource.

MicroGrid Benefits

To Society:

- Potential for more efficient overall fuel use than traditional generation.
- Potential for reduced emissions compared to centralized utility system.
- Ability to allow high penetration of renewable generation.
- Increased security of overall power delivery infrastructure.

Barriers to Widespread Deployment

Technical

- Limited availability of advanced DG options that compete economically with recip. engine generators.
- Lack of available power conversion systems with required advanced features needed to enable MicroGrid system operation.
- Need streamlined analysis tools for evaluating high penetration effects on distribution system.
- Need verified and recognized safety/protective relaying methods for both grid connected and isolated operation.

Barriers to Widespread Deployment

Economic & Regulatory

- Emerging DG technologies must achieve aggressive commercialization and cost goals
- Need interconnection standards that address MicroGrid systems (intentional islanding)
- Utility policies create barriers to market; should be partners
- No comprehensive method in place to monetize combined benefits to users, utilities, and to society

Northern's Roadmap

- Continue current DG commercial activity
  - On site generation with CHP, including critical load support
  - Power reliability enhancements
  - Fleet monitoring and dispatch of assets
- Develop key enabling technologies for advanced DG systems
  - Advanced power electronics
  - Fleet aggregation, monitoring and dispatch software
  - System modeling tools
- Demonstrate MicroGrid feasibility
  - Lab level 75kW MicroGrid system using power electronics based assets.
  - Build and test full scale, real world MicroGrid systems.

Mad River Park MicroGrid System

- Design, install, and test MicroGrid system at Northern's industrial park.
- System Description
  - 6 commercial and industrial facilities
  - 12 residences
  - Multiple generation assets
    - 280kW, 100kW generator sets
    - 30kW microturbine(s)
    - Photovoltaic array
  - MicroGrid isolation switch for islanded operation
  - Overall Energy Management system
- DOE funding support for design and commissioning phases of program

Distributed Energy Systems

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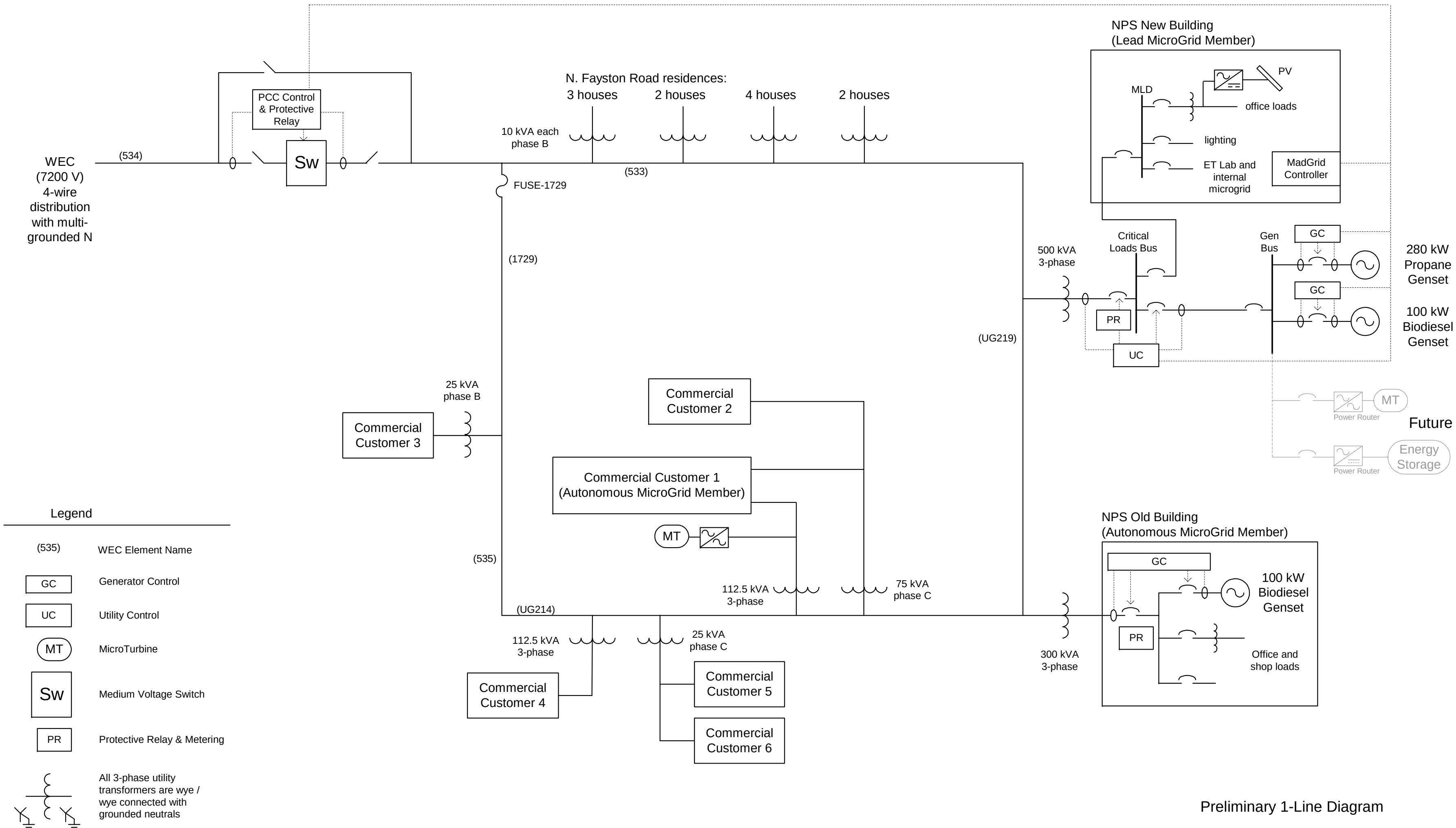
Mad River MicroGrid One-Line



Needs Addressed by Mad River MicroGrid Project

Identified need:

- Regulatory agencies and utilities lack experience base to deal with grid connected MicroGrid systems

Program objectives to address need:

- Work through regulatory and legal issues on an actual MicroGrid system, and develop framework for future projects
- Use real world project to demonstrate the operation, protection, and control of MicroGrid power systems.
- Increase overall understanding of the operation of MicroGrid systems to enable wider market adoption

Needs Addressed by Mad River MicroGrid Project

Identified need:

- Modeling and simulation methods available but little verification against real world MicroGrid systems

Program objectives to address need:

- Develop simulation methods for streamlining the design and approval process
- Model overall MicroGrid system and its effect on the distribution system
- Verify analysis tools and modeling methods using a fully functional MicroGrid system

Needs Addressed by Mad River MicroGrid Project

Identified need:

- Current interconnection standards don't address intentional islanding DER systems like MicroGrids

Program objectives to address need:

- Demonstrate safety/protective relaying control methods for both grid connected and isolated operation in cooperation with utility partner
- Align work with activities of IEEE1547 intentional islanding subgroup
- Provide power quality and availability benefits to the power customers within the Mad River MicroGrid

Technical Approach

- Partner with local utility to establish operating modes and practices, safe service protocols
- Model overall distribution circuit to predict effects of MicroGrid system
- Design and install automated isolation switch in 7.2KV utility feed to allow MicroGrid islanded operation
- Install and commission DER assets
  - Multiple conventional generator sets
  - Inverter based generation (PV, microturbines)
  - Provision for energy storage assets
  - Flexibility for changing/upgrading DER asset mix over time
- Demonstrate all defined interconnected and islanded operating modes
- Demonstrate and document system operation in full automated mode

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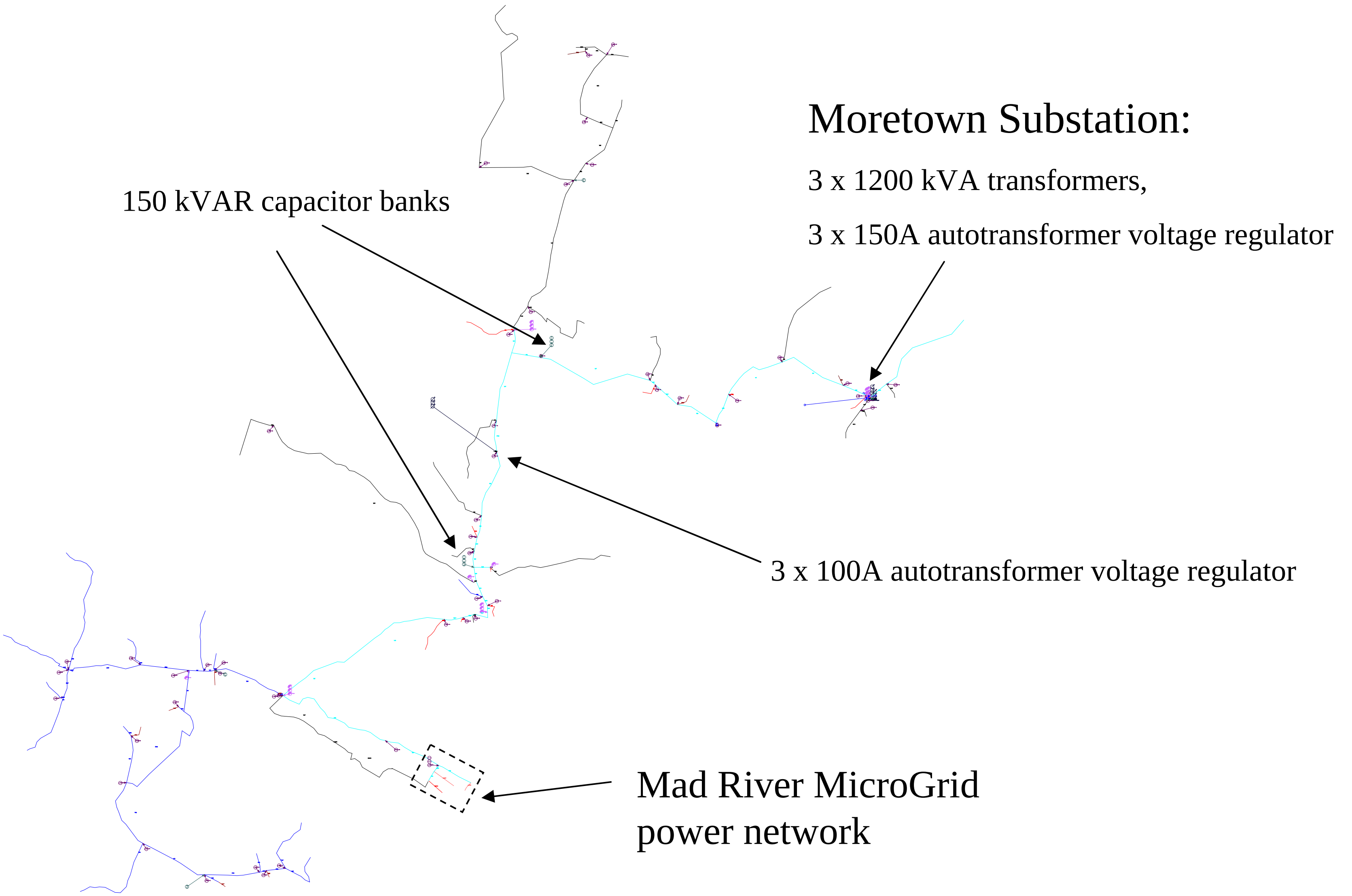
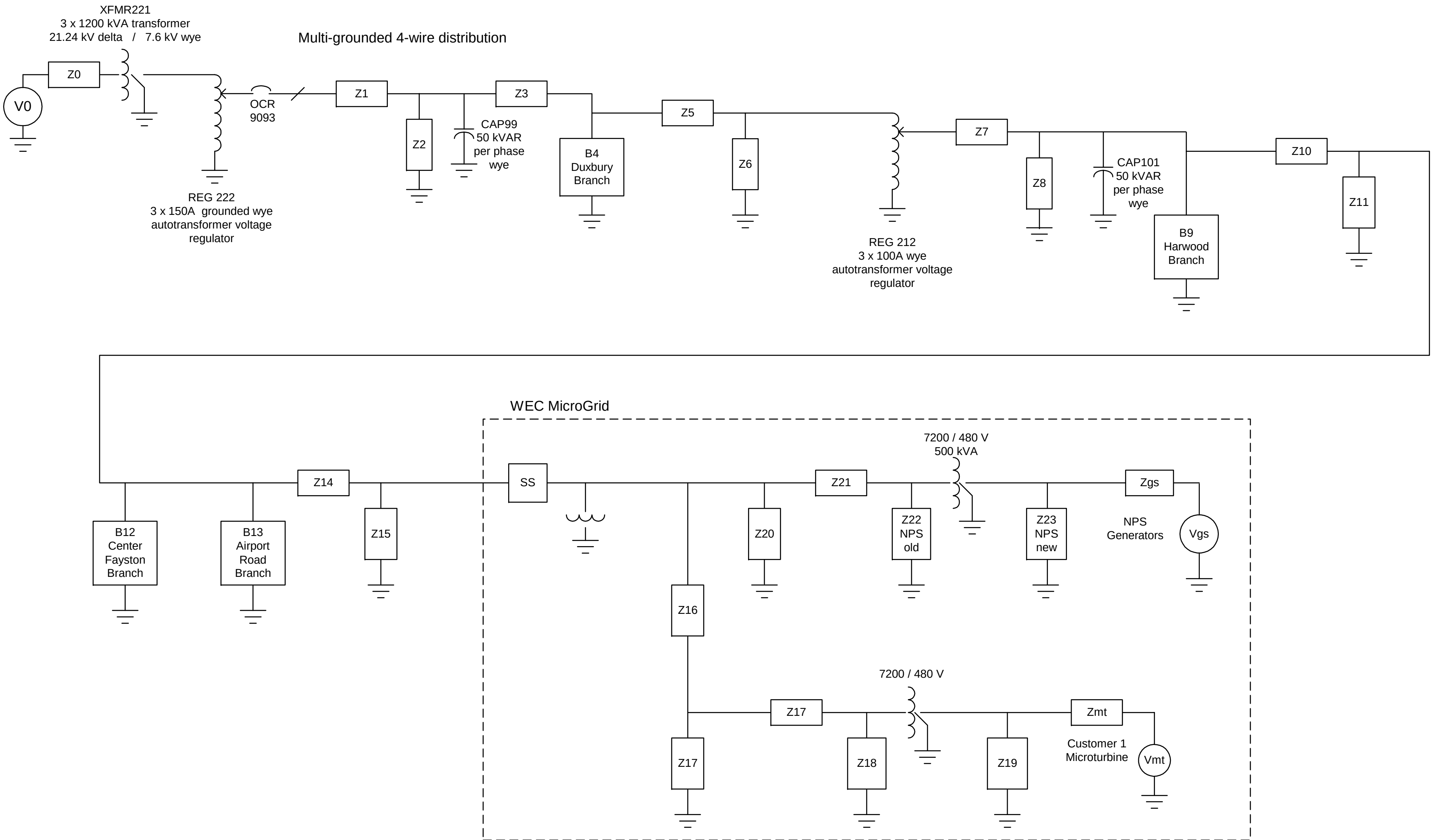
Mad River MicroGrid Modeling

- Developed overall distribution system model using PSCAD
  - Substation
  - Distribution lines and loads
  - Utility voltage regulators
  - MicroGrid isolation switch
  - MicroGrid assets & controllers
- Simulated system response under multiple operating modes
  - Baseline mode – match MicroGrid output to critical load needs
  - 0kW mode – control MicroGrid to net zero power flow at PCC
  - Export mode – command generators to full rated output
- Simulated operation in normal and fault conditions
  - Load flow in all modes of operation
  - Single and three phase fault response
  - Loss of load response

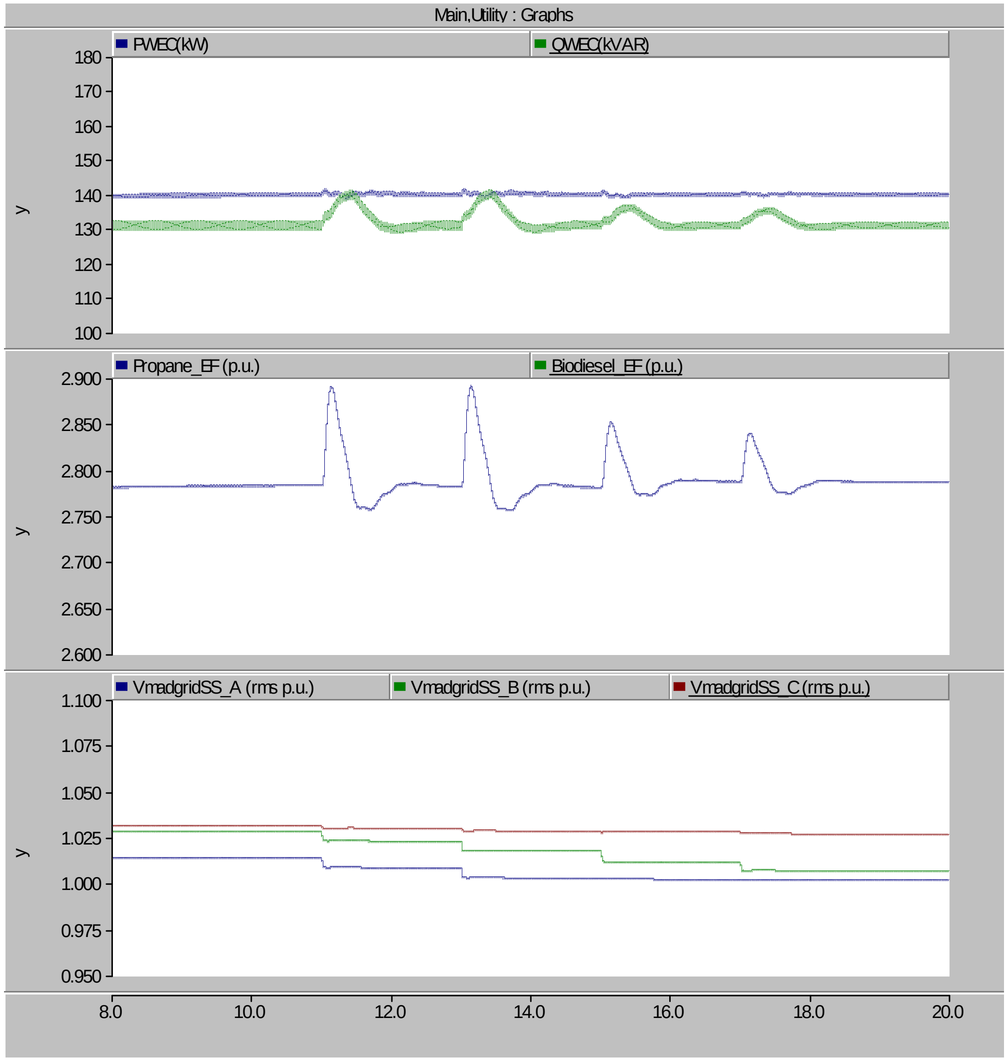
Distribution System - Moretown Circuit



Simplified Distribution Circuit Model



Power Export Mode – System Response

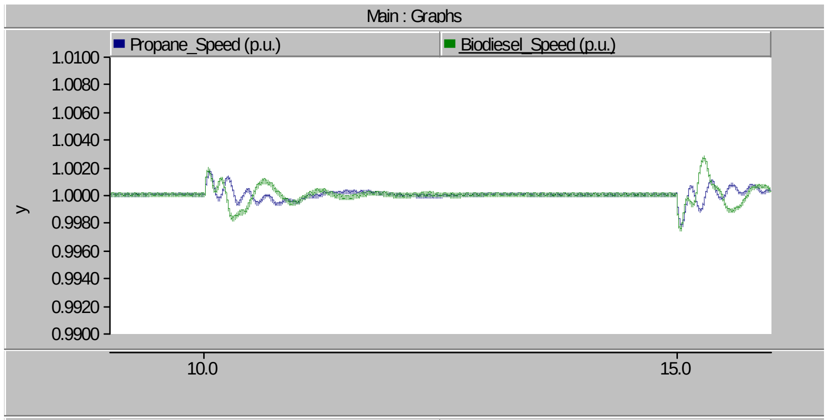


Real & reactive power at PCC

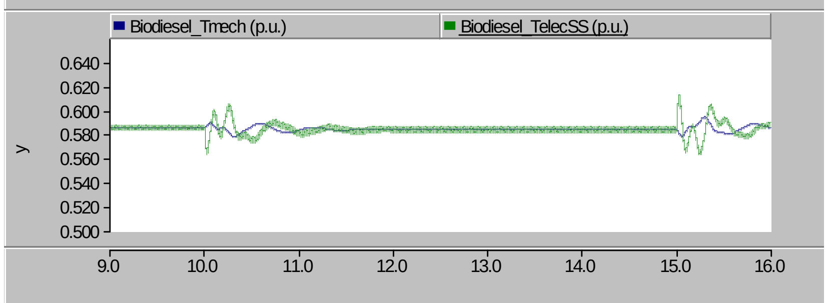
Gen. field reg. P.u. voltage

VREG2 p.u. voltage setting

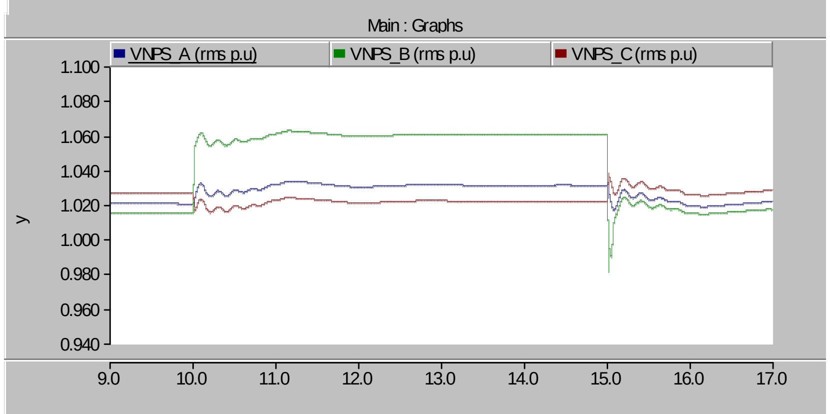
Loss of Load Case – Center Fayston Branch



Generator p.u. speed



Electrical torque



Generator p.u. voltage

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Current Mad River MicroGrid Project Status

- Local and regional approvals in place
- Finalizing utility MOU
- Vermont PSB Certificate of Public Good review approval anticipated in August timeframe
- Preliminary system installation underway
- DER and isolation switch installation in Q3 2005
- System commissioning in Q4 2005

Interactions and Collaborations

- NREL
  - Project funding support
  - Technical Monitor: Ben Kroposki
- State of Vermont
  - Public Service Board CPG review & approval
- Washington Electric Coop
  - Interconnecting utility
- E-Pro
  - Distribution system technical consulting
  - Environmental consulting
  - CPG testimony preparation
- Tarrant, Marks, & Gilles
  - Legal representation
  - Regulatory approval process support
- MicroGrid system power customers
  - Active commercial members, with connected DER assets
  - Passive commercial and residential members
  - All members gain power quality/reliability benefits

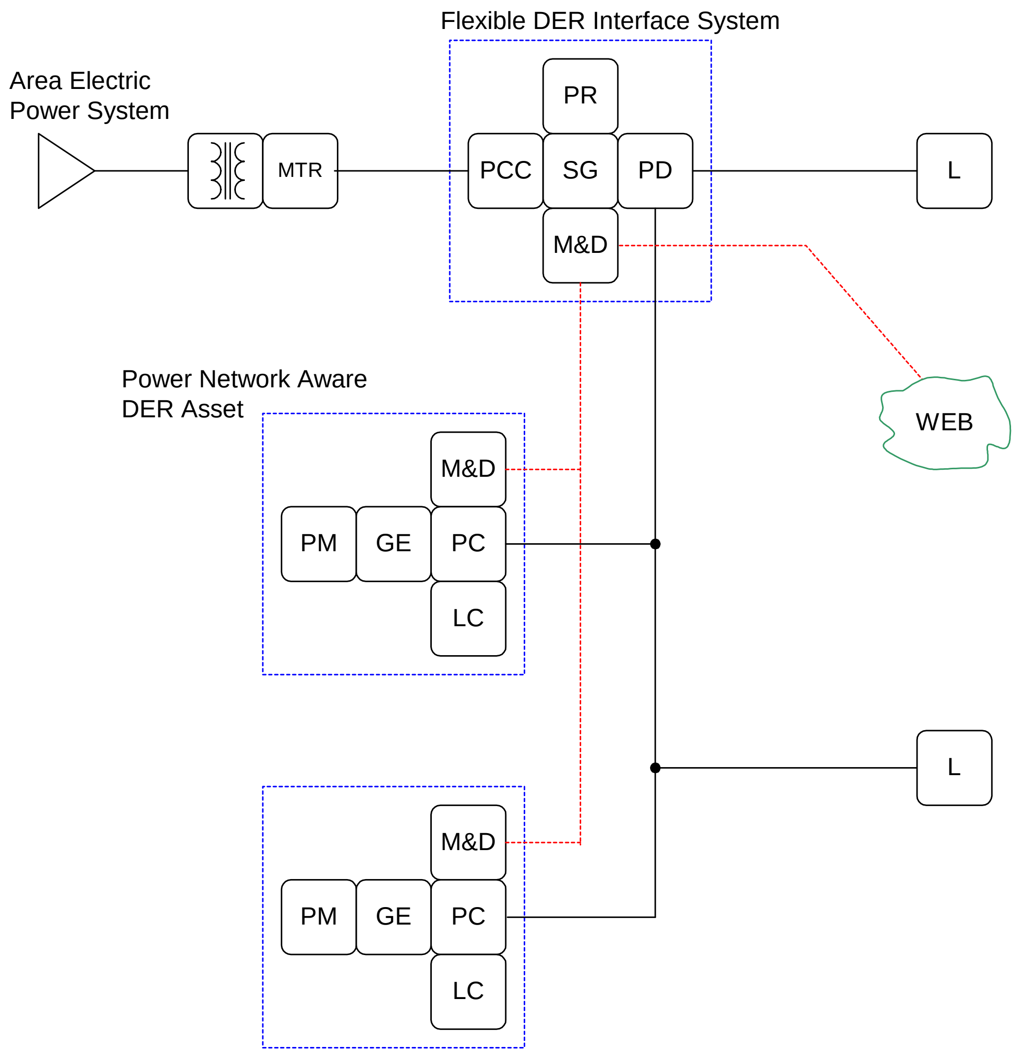
Other Related Programs

- Universal DER interconnection device
  - NREL/CEC support
- EnergyBridge™ energy storage system
  - CEC/PIER support
- CERTS microgrid test bed development

Universal DER Interconnection Device

- Funding support through NREL/CEC Distributed Power program
- DER SWITCH project objective:
  - Develop a DER Utility Interface System that provides a flexible, universal interface for connecting single or multiple DER systems to the utility
- DER SWITCH project scope:
  - Incorporate multiple control and power switching functions to interconnect multiple DER assets into overall system
  - Minimize custom engineering and site-specific approval processes
  - Applicable to DER assets with conventional generators or power converters
  - Modular system for maximum flexibility, with control, power and communication modules

Universal DER Interconnection Device

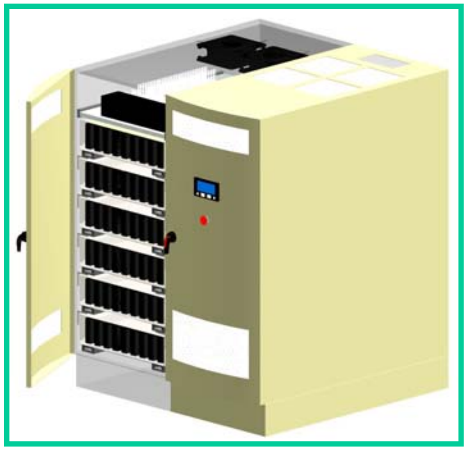


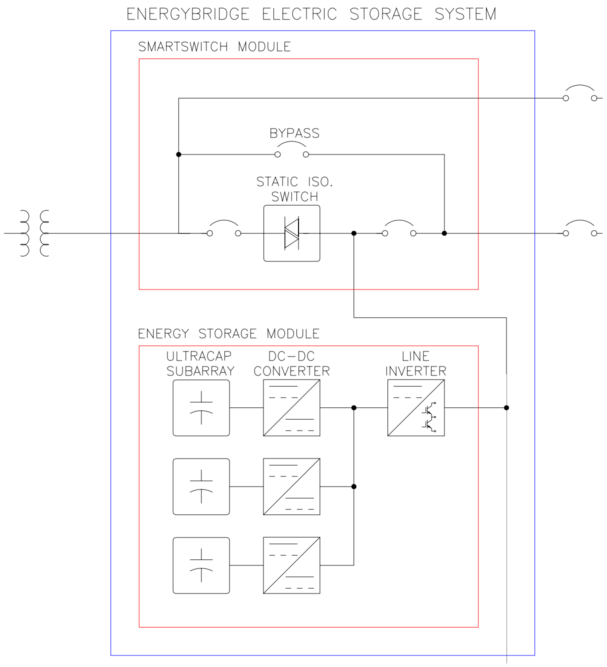
DER Power Network Block Diagram

MTR	Meter
PCC	Point of common coupling
SG	Switch gear (Power module)
PD	Power distribution (Power module)
PR	Protective relaying (Control module)
M&D	Monitoring & dispatch (Comm. module)
PM	Prime mover
GE	DER Generator
PC	Power Conversion
LC	Local DER device control
L	Loads

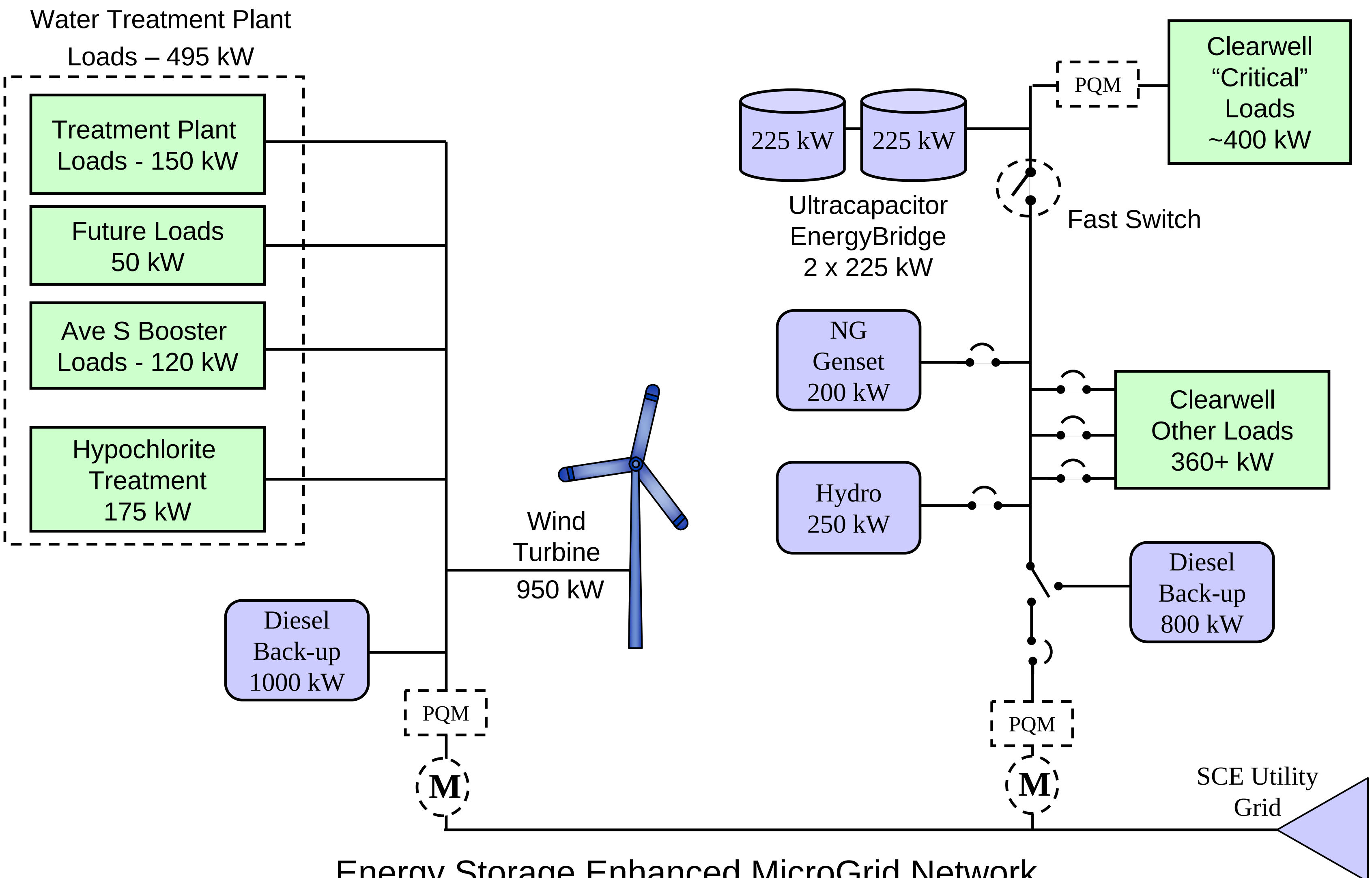
EnergyBridge™ Energy Storage System

- Funding support through CEC/PIER Advanced Energy Storage program
- Ultracapacitor-based energy storage asset
- Focused on short time duration
  - 10s of seconds, 95% of outage cases
- Multiple applications & benefits:
  - Power quality support for critical loads
  - Support of slower response DG assets in MicroGrids
  - Enables higher penetration of DG into both grid connected and isolated grids





Palmdale Power System



Energy Storage Enhanced MicroGrid Network

Other Related Development Activity

- Advanced power converter development
  - DER applications
  - Wind turbine applications

- SmartView™ DER energy management system

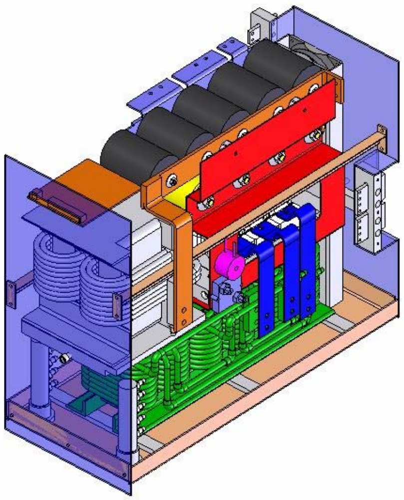
Advanced Power Electronics

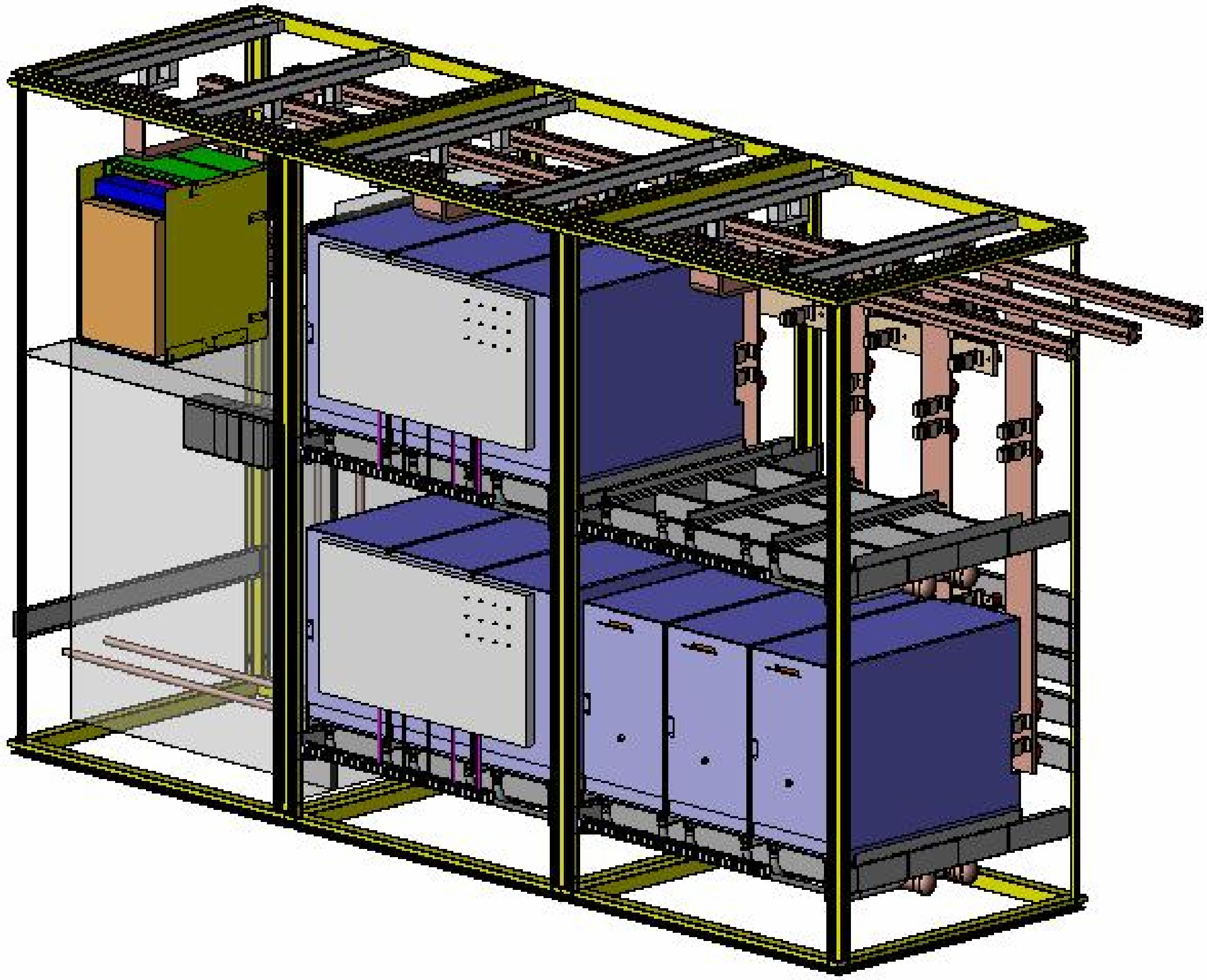
Power converter development by NPS team

- 100 kW wind turbine converter system
- 15 kW MicroGrid inverter test bed
- 1500 kW DDPM wind turbine converter
- 2200 kW DDPM modular wind turbine converter
- 850 kW DG converter
- 450 kW energy storage system converter

MicroGrid Power Network Test System

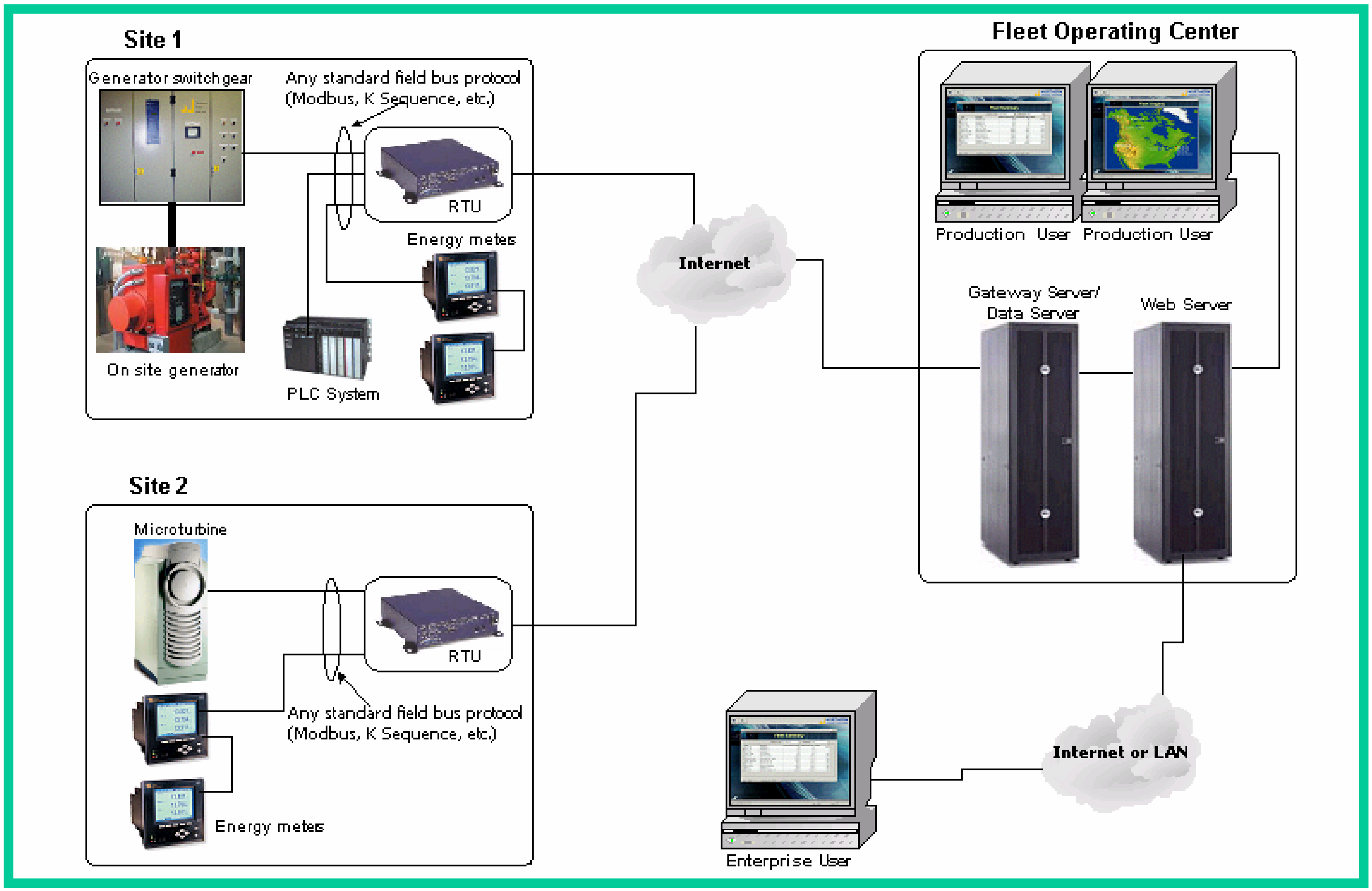
Modular MW converter for DG & wind markets





SmartView® DER Management System

Northern system for monitoring and controlling remote power systems



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