2014 Smart Grid R&D Program Peer Review Meeting

Complete System-Level Efficient and Interoperable Solution for Microgrid Integrated Controls (CSEISMIC)

Yan Xu, Guodong Liu
Oak Ridge National Laboratory

June 11, 2014

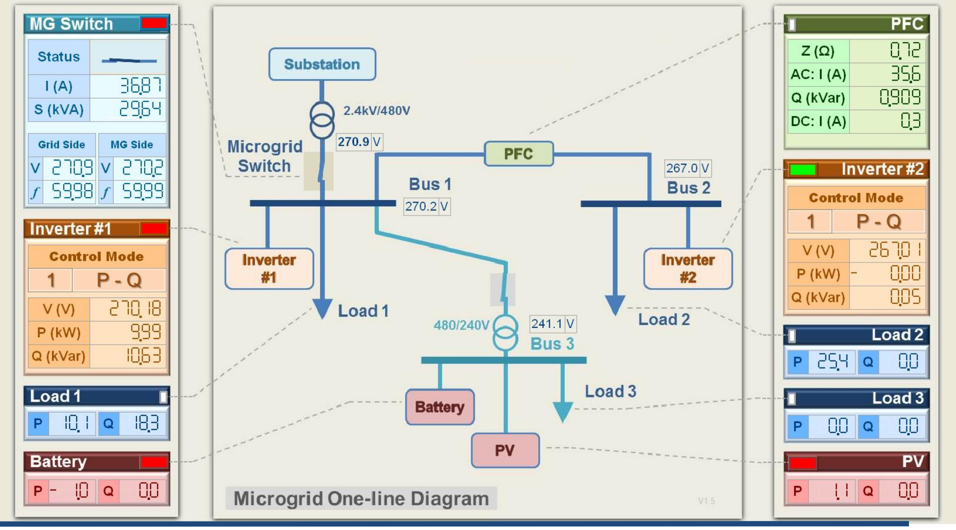
Complete System-Level Efficient and Interoperable Solution for Microgrid Integrated Controls (CSEISMIC)

Objective

Microgrids: future distribution system.

Develop a microgrid with the complete functions:

- Grid-connected and islanded modes
- Islanding transition
- Resynchronization and reconnection
- Energy management
- Protection



Life-cycle Funding Summary ($K)

Prior to FY 14	FY14, authorized	FY15, requested	Out-year(s)
560	475	500	500

Technical Scope

- Central controller: microSCADA and microEMS
- Component control: primary source, microgrid switch
- Microgrid communication
- Relay protection

Challenges & Needs

- Challenges: distribution system is evolving from a passive radial topology to a complex and active system.
  - Increasing requirements for higher liability, stability, and efficiency
  - Diversified components and their coordination
  - Voltage fluctuation
  - Current DMS or single-node energy management cannot address all issues
  - Uncertainty: both loads and generation
  - Safety concerns rise because of Ineffectiveness of conventional protection
- Need a microgrid controller with the functions:
  - Grid-connected and islanded operation
  - Islanding transition and resynchronization
  - Energy management and DER coordination
  - Participate in energy market and utility operation
  - Effective relay protection

CSEISMIC
Significance and Impact

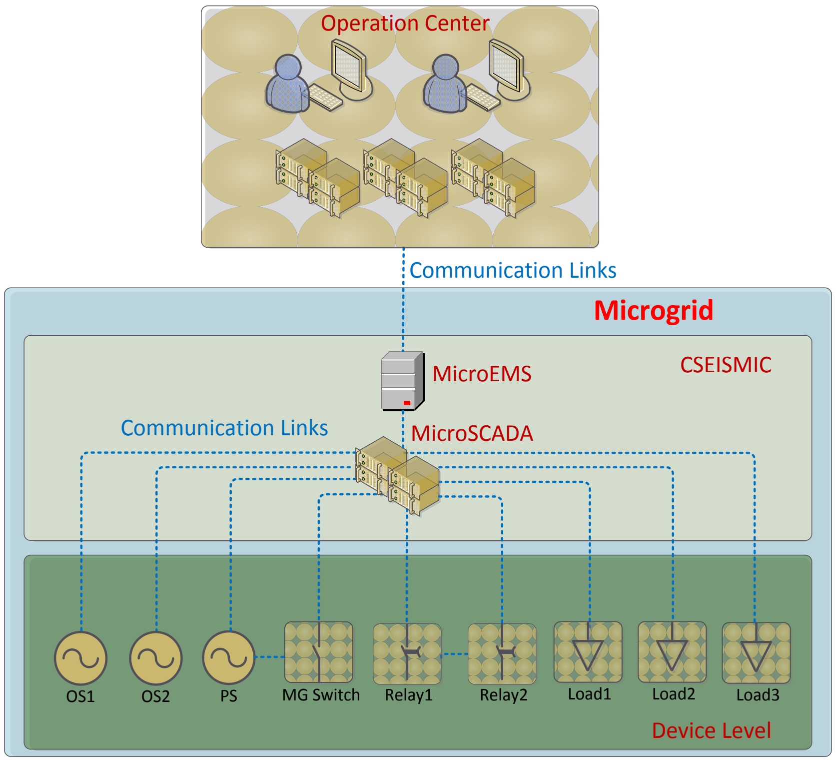
Significance: CSEISMIC microgrid controller is the complete and integrated solution for microgrid control, operation, energy management and protection.

- Systematic approach to enable real-time control and operation: grid-connected and islanded operation, islanding transition and resynchronization
- Energy management to realize networked real and reactive power optimization
- Coordinate high penetration of DER, energy storage, electric vehicle, and demand response
- Provide ancillary services to main grid and participation in energy market
- Accommodate legacy components and architecture

Impact:

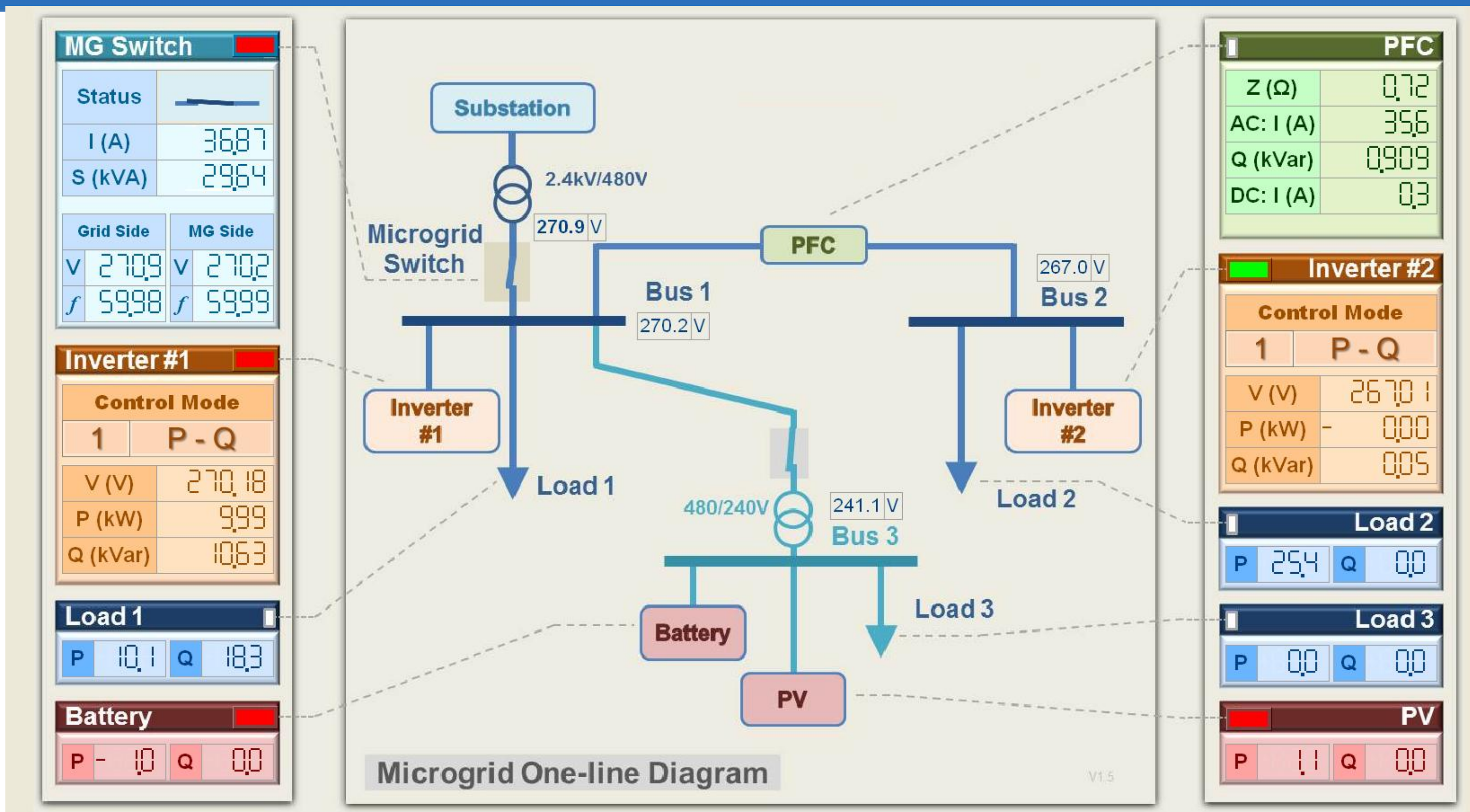
- Improve system reliability by enabling islanding operation
- Improve system stability using advanced monitoring and control
- Improve system efficiency by optimizing the power flow
- Reduce total energy cost by energy management

Technical Approach – CSEISMIC System Diagram



- Microgrid controller consists of microgrid SCADA and energy management (EMS)
- SCADA performs supervisory control for sources, loads, microgrid switch, protection relays, etc.
- Volt/freq control and transition control are performed at device level with control modes and setting points dispatched by microgrid controller.
- EMS dispatches operational optimization commands.
- Single-point interface between microgrid and system operator/energy market to participate in utility operation and energy market activities.

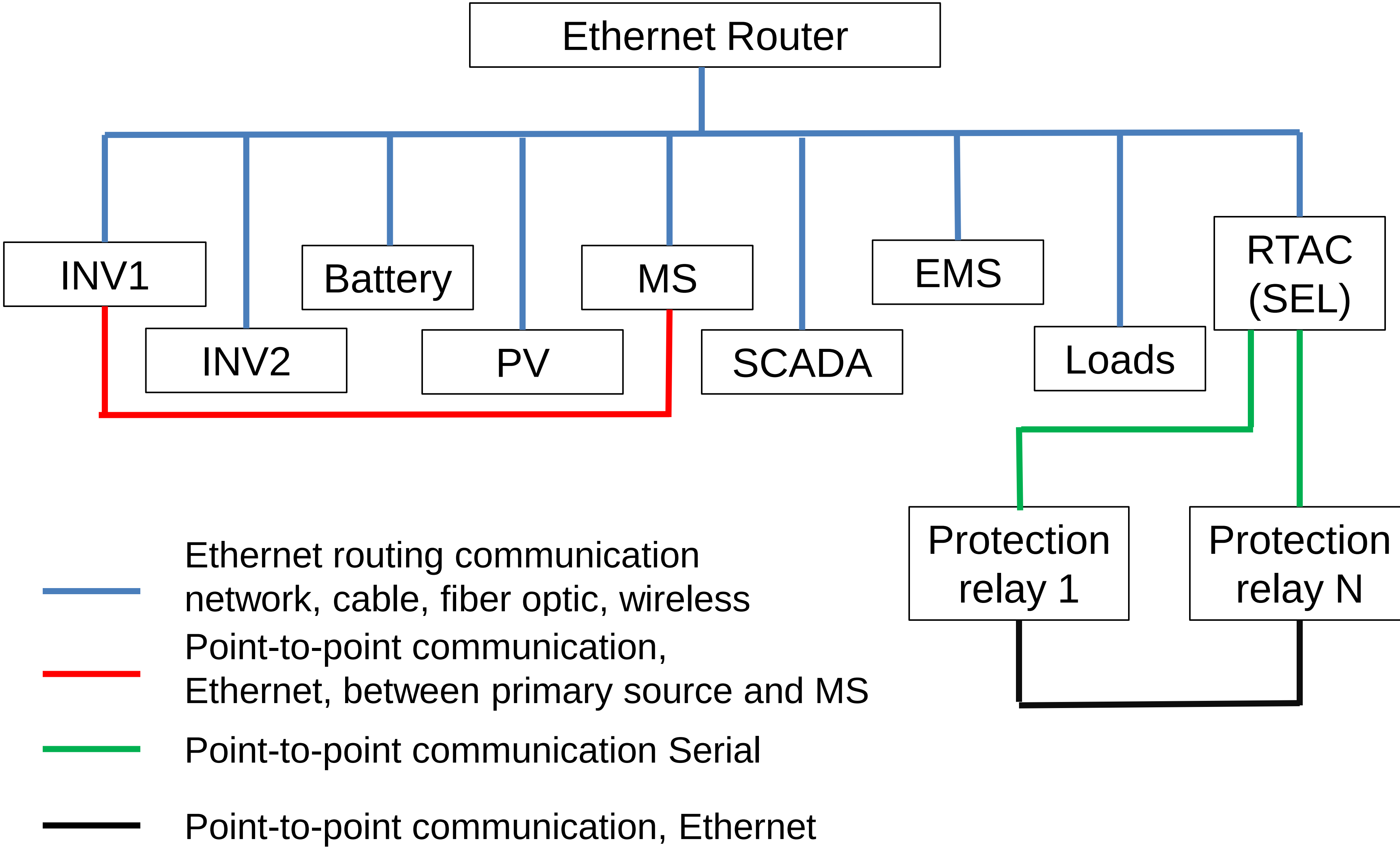
ORNL Microgrid



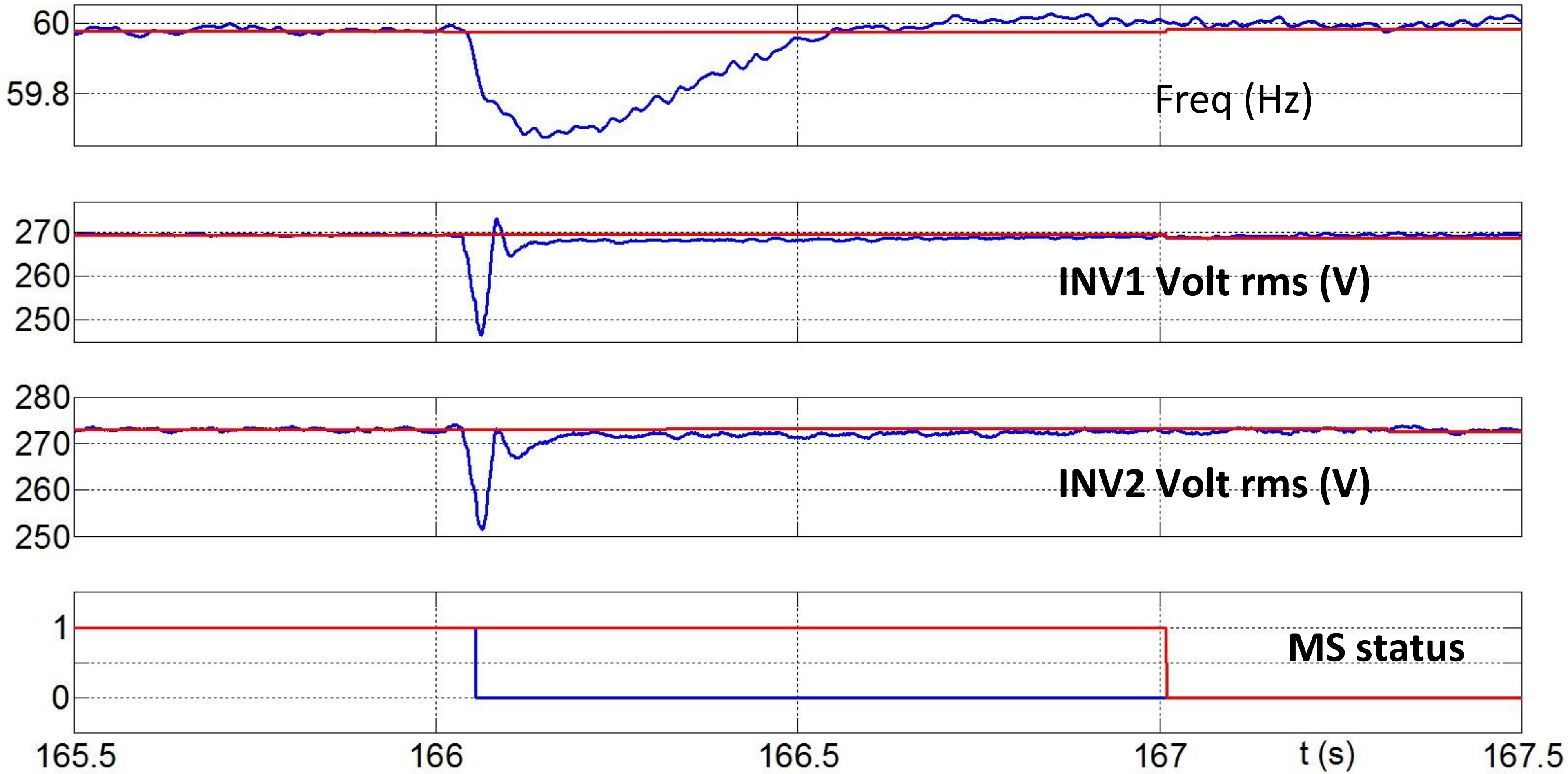
- Operational at the ORNL DECC lab
- Now 3 buses, 4 sources, 3 loads
- Will expend to 4 buses, loop/radial reconfigurable

- Leveraged projects:
  - Power flow controller
  - Community energy storage
  - Building technology
  - Advanced metering infrastructure
  - GridEye

Technical Approach - Communications



Unintentional Islanding

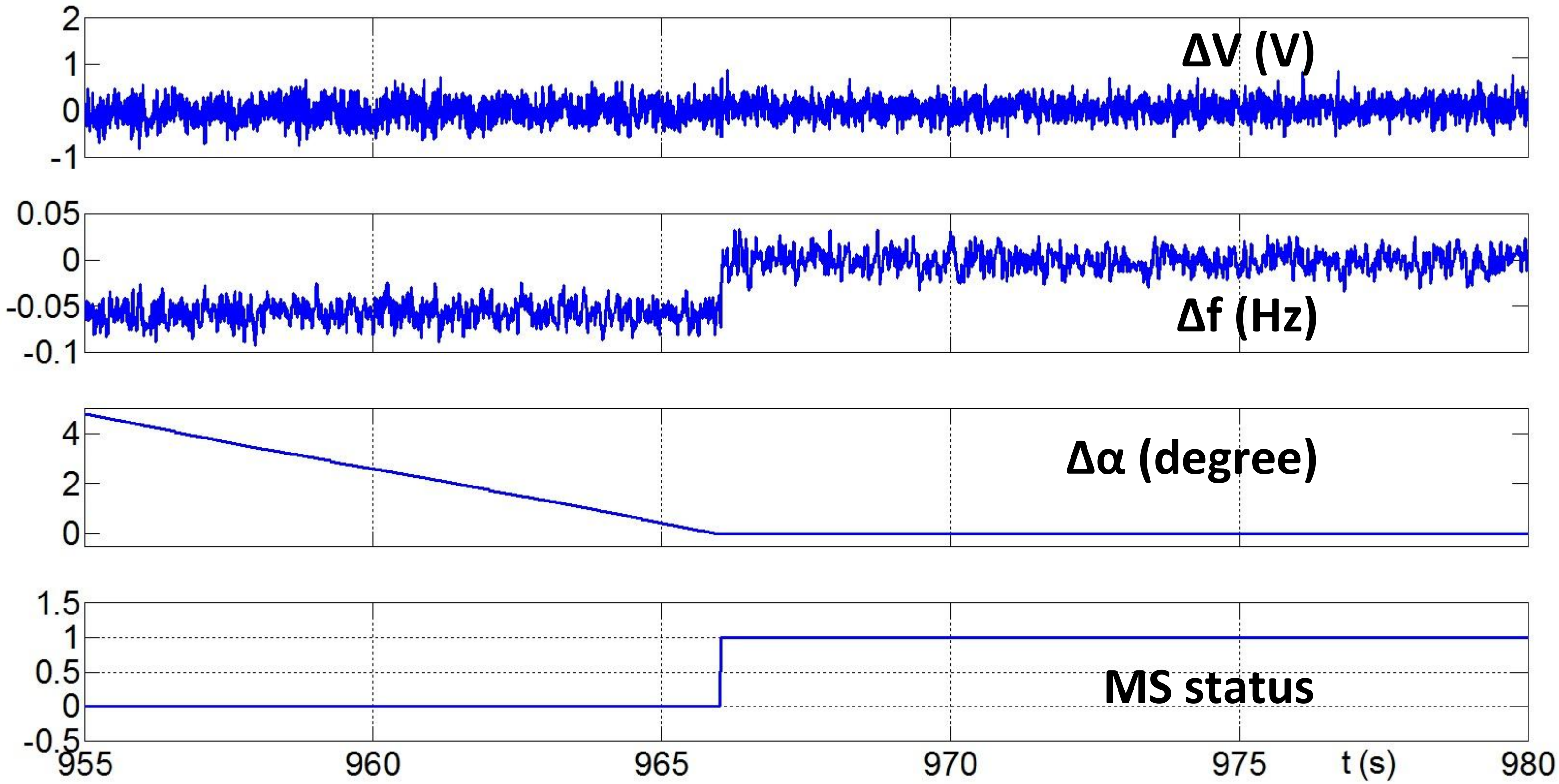


Blue: local measurement

Red: SCADA data acquisition

- MS switch is manually opened.
- SCADA data update speed is 3 seconds, and no transients are seen by SCADA.

Resynchronization and Reconnection



- INV1 controls its output to adjust PCC voltage magnitude and frequency.
- Thresholds: $\Delta V \leq 2$ V, $\Delta f \leq 0.1$ Hz, $\Delta\alpha \leq 1^{\circ}$
- f is controlled slightly higher (60.05 Hz) than grid frequency during resynchronization, maximum $T_{resyn} \approx 20$ sec.
- Phase angle control or larger frequency difference is needed for faster resynchronization.

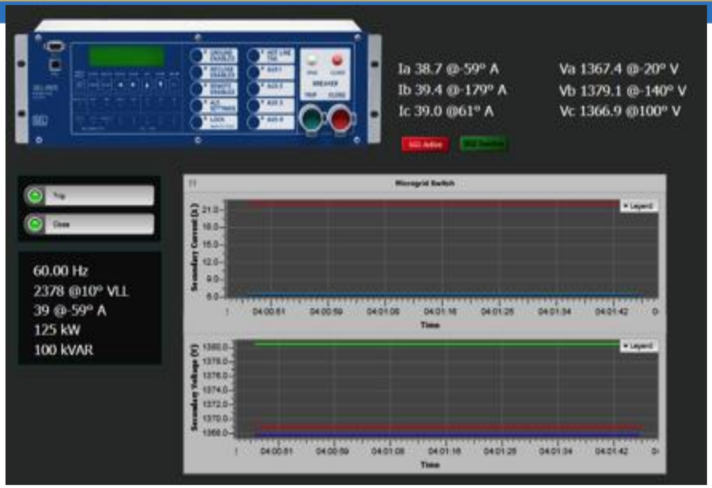
Microgrid Protection - Challenges

- Common distribution protection practice
  - Un-directional overcurrent protection
  - Electromechanical relays
    - Proven track record
    - Simplicity

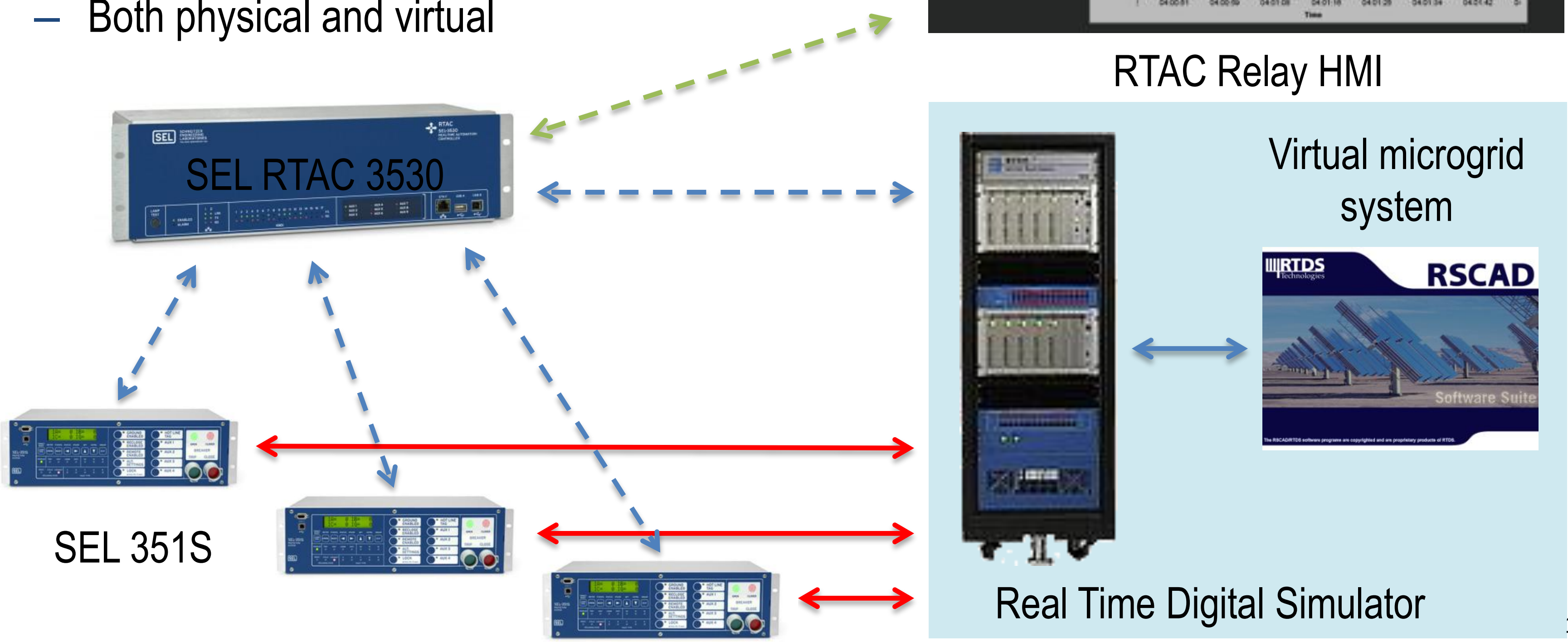
- Challenges of DERs and microgrids
  - Bidirectional power flow
    - More complex coordination
    - Faults more difficult to isolate
  - Severely reduced fault current when disconnecting from utility
    - Fault current from TVA: 7.4 kA on 480 V circuit
    - Fault current from DECC lab inverters: 0.33 kA on 480 V circuit
    - Need to protect system for both cases without tripping on load current!

RTDS-Based Microgrid Protection HIL Test Bed

- Real Time Digital Simulator
- Hardware-in-the-loop microgrid test bed
- Real Time Automation Controller (RTAC)
  - Protection control control
- SEL 351S relays
  - Both physical and virtual

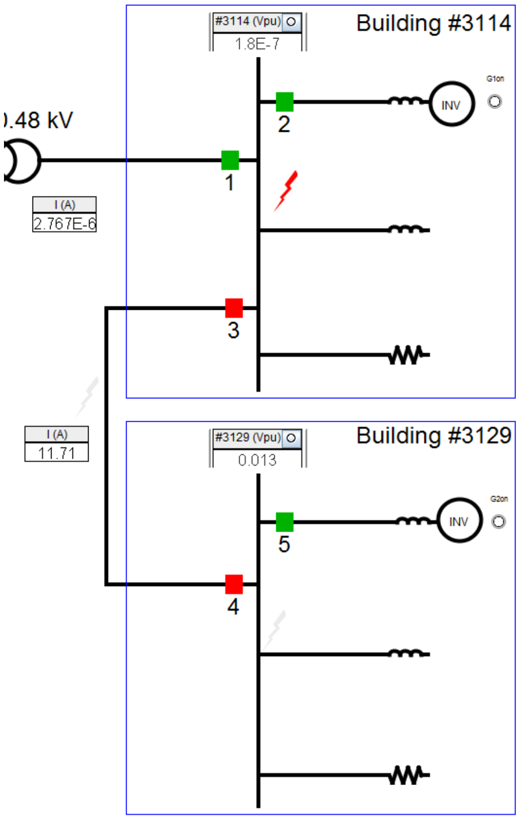


RTAC Relay HMI



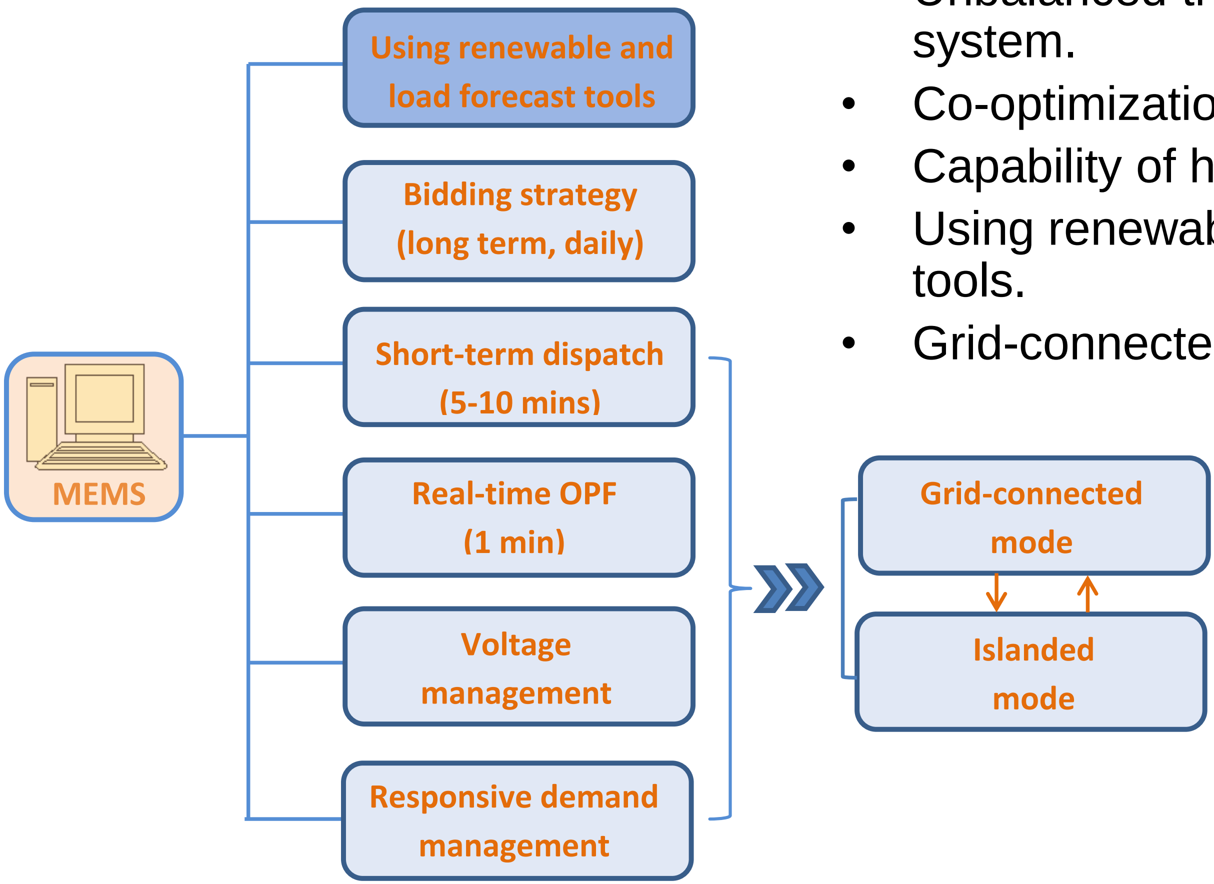
Microgrid Protection Scheme Development and Testing

Protection Schemes	Microgrid Status	Fault Locations	Effective Protection?	Notes
Single setting OC	On-grid	External	Yes	Faults cleared in 15-21 cycles.
		Internal	No	Relay unable to detect fault current from downstream DERs.
	Islanded	Internal	No	Unable to isolate the faults. Microgrid is shutdown.
Adaptive OC	On-grid	External	Yes	Faults cleared in 15-21 cycles.
		Internal	Yes	
	Islanded	Internal	Yes	
Differential OC	On-grid	External	Yes	Faults cleared in 3-6 cycles. No need to change settings.
		Internal	Yes	
	Islanded	Internal	Yes	
Directional control			No	Problems with voltage polarization during faults.



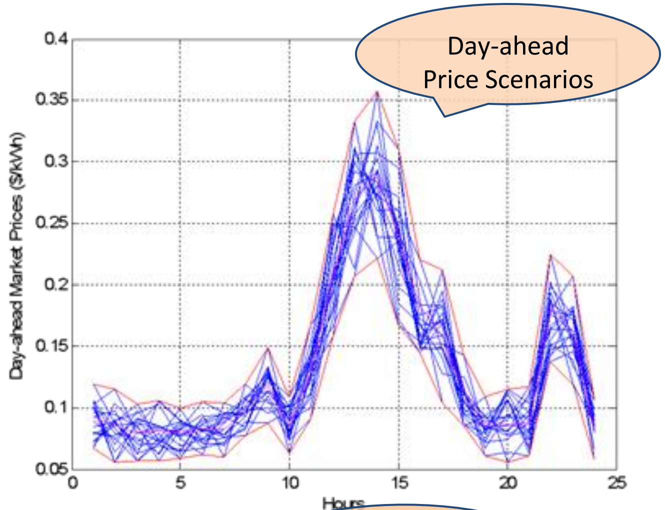
Technical Approach – Microgrid EMS

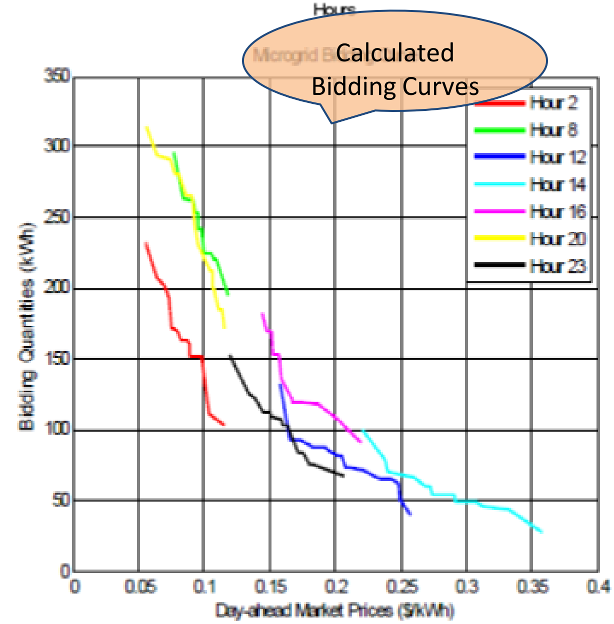
- Coordinated three-stage scheduling: day-ahead bidding, hour-ahead dispatch and real-time optimal power flow (OPF).
- Unbalanced three-phase distribution system.
- Co-optimization of real and reactive power.
- Capability of handling uncertainties.
- Using renewable energy and load forecast tools.
- Grid-connected and islanded modes.



Prior Year Progress and Results – Microgrid EMS

- Development of DER economic models
- Integration of forecast results of Wind, PV and market prices.
  - Scenario generation and reduction.
- Microgrid optimal bidding strategy in the day-ahead market
  - Included intermittent DERs, storage and responsive loads.
  - Considered uncertainties of DERs, day-ahead and real-time market prices.
  - Proposed a hybrid stochastic/robust optimization model.
  - A journal paper is ready for submission.





FY 2014 performance and results, against objectives and outcomes

- FY13: individual component controller development
- FY14: microgrid system integration and communication
  - Functional microgrid with real-time control capabilities
  - EMS development will be completed by FY14.
  - 3 papers submitted.
- Milestones are met or on track.

Due Date	Milestone Type	Milestone Description
12/31/2013	Process Milestone	Implementation and testing of communication network.
03/31/2014	Process Milestone	Implementation and testing of grid-connected and islanded modes, islanding transition and reconnection in the DECC microgrid.
06/30/2014	Process Milestone	Implementation and testing of microgrid protection.
09/30/2014	Final Deliverable	Development of microgrid EMS. Final annual report.

FY 2015 Plan

1. CSEISMIC, collaborate with NIST, IREQ, and NI
    - Complete development of the microgrid controller – EMS implementation, communication standardization, microgrid controller development for field demonstration.
    - Participation on Technical Advisory Committee.
    - Standards – collaborate with NIST on microgrid standardized test bed, microgrid controller standard development.
2. Hardware-in-the-loop microgrid test bed, collaborate with RTDS
3. Networked microgrids, collaborate with Chattanooga Electric Power Board
4. Integrated communications, controls and connected devices for DC microgrids (I3CDC). Partners: LBNL, Virginia Tech, and Emerge Alliance
5. De-coupled microgrid control, collaborate with OSIsoft

Collaborations

- **NIST**: Microgrid standardized test bed, microgrid controller standard
- **Hydro-Quebec IREQ**: microgrid protection
- **Chattanooga EPB**: networked microgrids
- **National Instruments**: microgrid control for field implementation
- **OSIsoft**: de-coupled microgrid control

Contact Information

Power & Energy Systems Group

Electrical & Electronics Systems Research Division

Oak Ridge National Laboratory

One Bethel Valley Road P.O. Box 2008, MS-6070

Oak Ridge, TN 37831-6070

Yan Xu

(865) 574-7734

(865) 574-9323 fax

xuy3@ornl.gov

Guodong Liu

(865) 241-9732

(865) 574-9323 fax

liug@ornl.gov

Q & A