MICROGRIDS

2017 Southeastern Tri Regional SAME Training Symposium

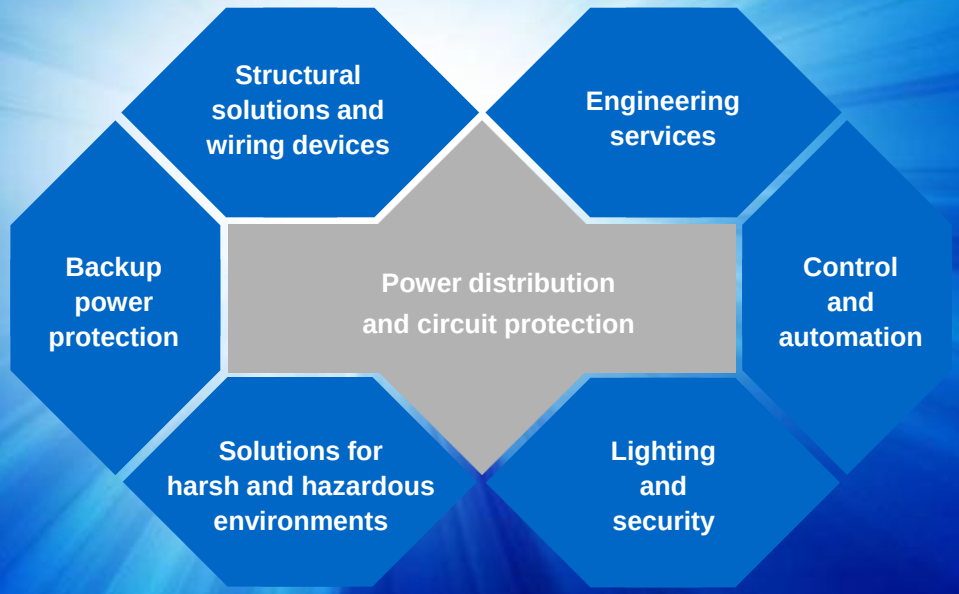
Microgrids – What are they, lessons learned

8/30/2017

Dan Dorn Eaton Corp

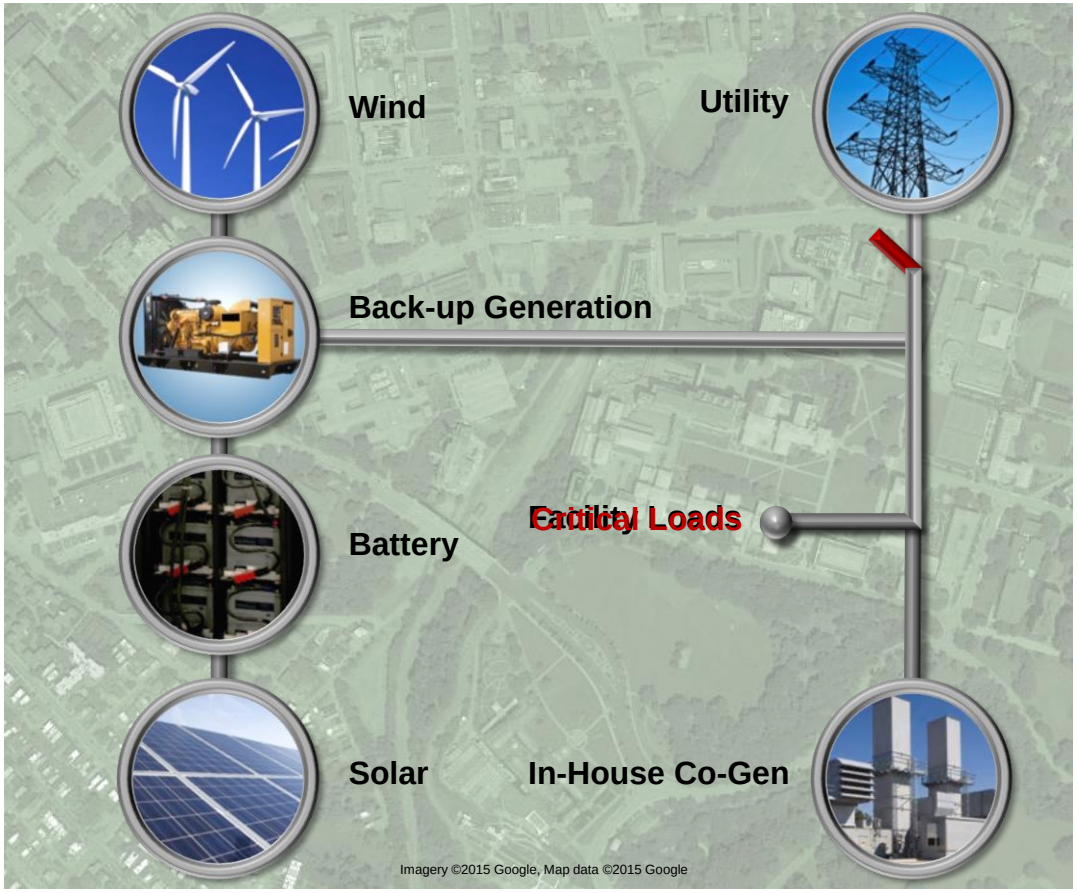
Powering Business Worldwide

Eaton: One brand with solutions for the entire power system and expertise spanning seven core competencies



Data centers | Industrial | Utility | Commercial | Residential | Machine building

The microgrid energy system concept



A group of generating assets and defined loads that can operate within the utility grid or islanded from the grid, as a self-sufficient stand alone application

Local "Grid Within a Grid"

- Delivers Power Resilience, Reliability and Uptime

Distributed Energy Sources

- Backup Generation
- In-House Co-Gen
- CHP (Combined Heat and Power)
- On-Site Renewables and Fuel Cells
- Energy Storage (Batteries)

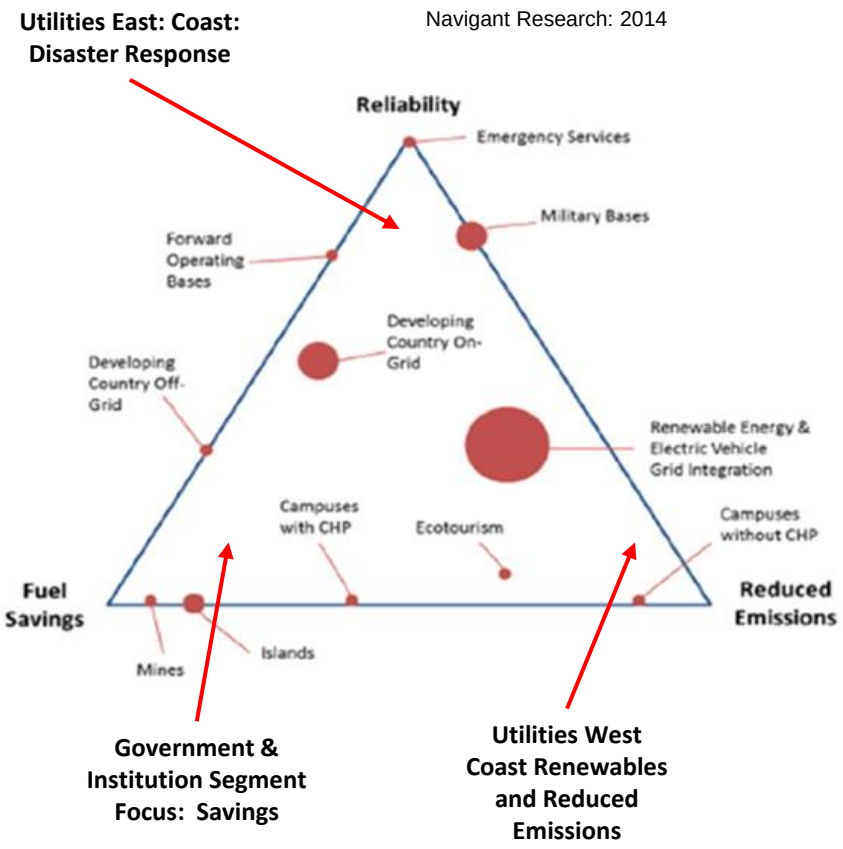
Microgrid Applications

- Islanding & Synchronization
- Black Start
- Generation/Load Balance Control
- Battery Energy Storage & Frequency Regulation

Requires Control System "Glue" to Achieve System Performance

Market segments differ on their goals for microgrids and energy storage

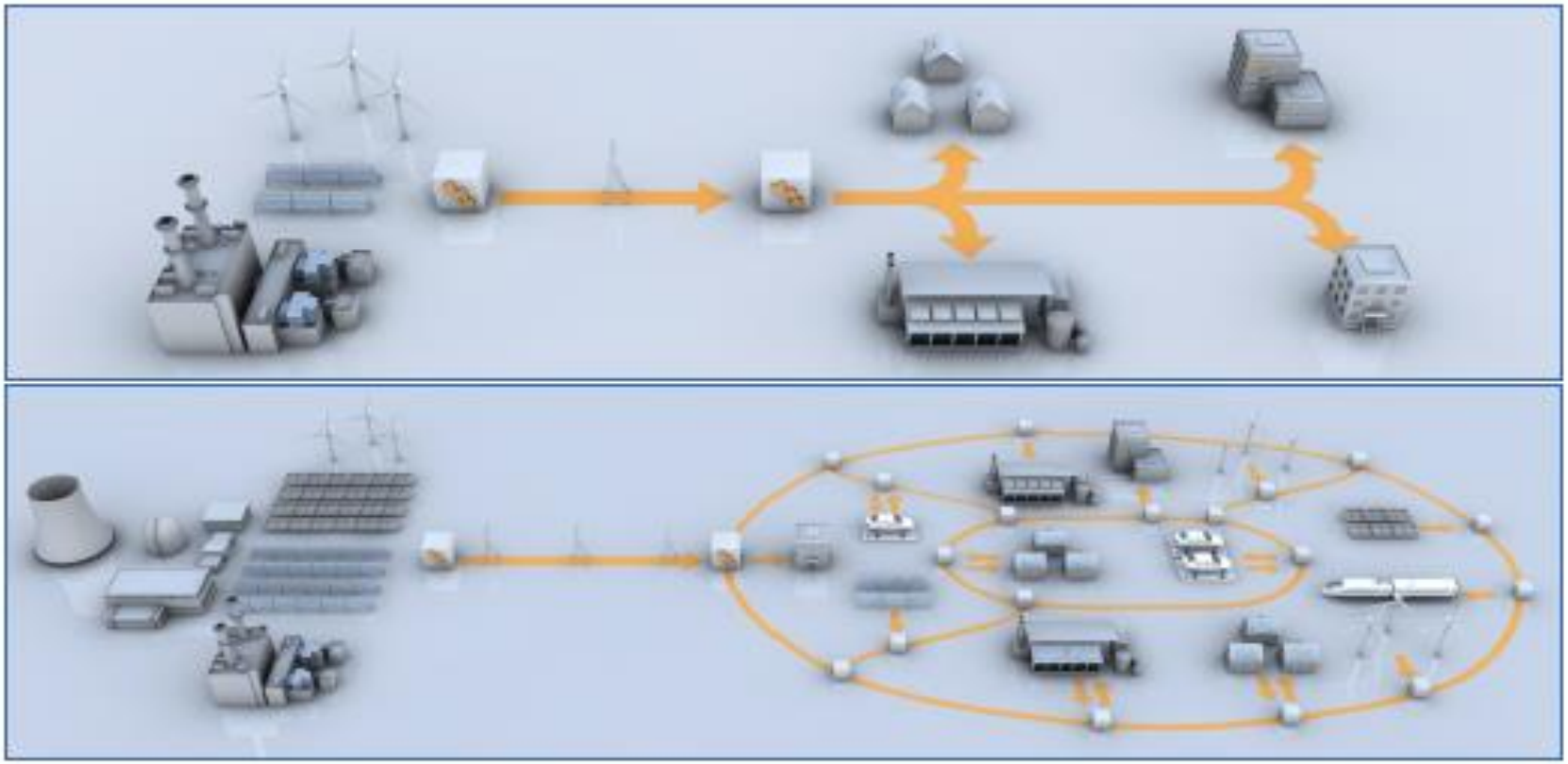
Segment Goals



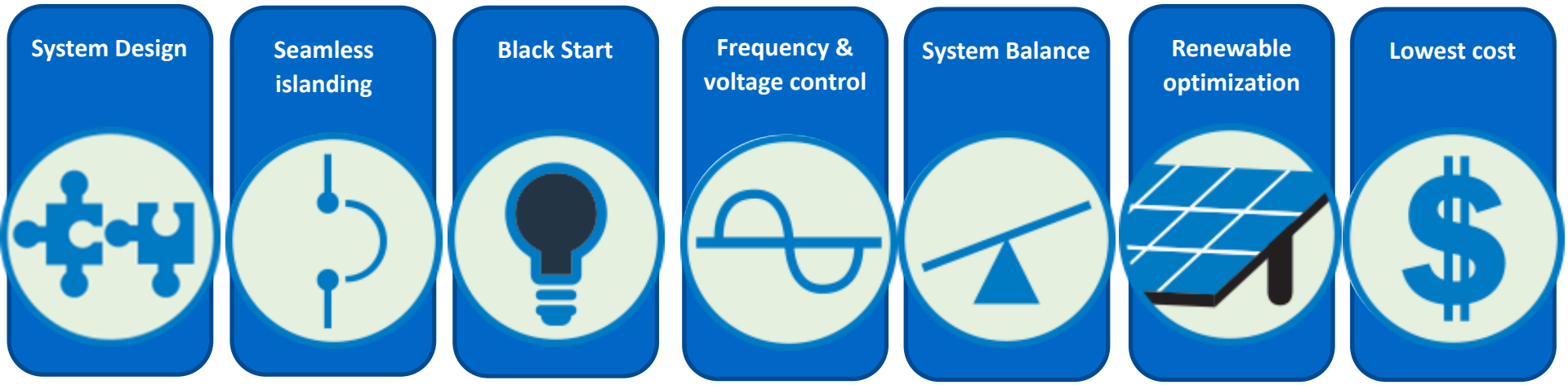
Microgrid/ES Business Cases

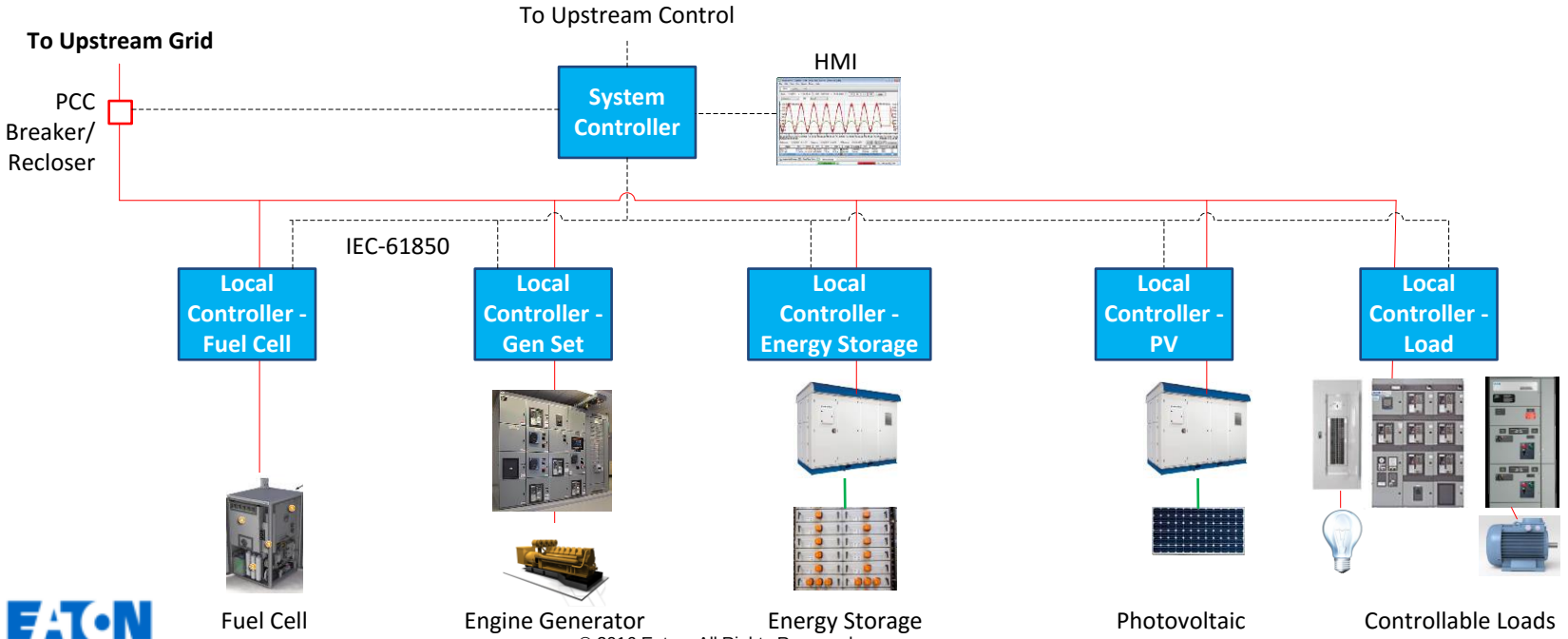
Driver	Description	Detail	Business Focus
Energy Storage Regulations	Fills need for grid storage to complement intermittent renewables	California AB 2514- IOUs to install 1400 MW by 2020 to mate with 33% RPS reg. 400 MW in 2015	California- Battery installations
Resiliency Regulations	Limits outages due to natural events (weather)	NY REV, numerous state programs & regs to implement microgrids	East Coast Sandy States- CT, Mass., NJ, NY, MD
Frequency Regulation	Supplants loss of coal-fired base load power plants	PJM- Wholesale price creates viable business case for short duration ES. ERCOT emerging	PJM territory- OH, PA, KY WV, VA, NJ; Ontario; ERCOT- TX
Dependency on imported fossil fuels	Need to embrace renewables to offset high fossil cost & environmental impact	Impacts remote and island grid environments using renewables and ES to minimize diesel use	HI, PR, AK, Canada
Need for energy surety and independence	Military and government drive for energy surety at key bases and facilities	Military bases and mission-critical facilities critical to national defense	DOD bases and key facilities

Energy and Grid Transformation



Eaton's Microgrid Energy System (MES)





Microgrid Design and Use Cases

- Key Features

System Design

- Open Comm standards
- SCADA & enterprise interface
- Modular, Pre-engineered templates
- Legacy asset compatible
- Adaptable to future asset changes

Seamless islanding

- Unintentional (Seamless) islanding
- Fast grid-fault detection, isolation and safety interlocks
- Load shedding
- Source management
- Grid reconnection

Black Start

- Safety interlock for grid isolation
- Gen and renewable source start-up
- Paralleling sources
- Power Quality stabilization
- Load sequencing & management

Frequency & voltage control

- Islanded generator Freq. control
- Generation-demand balancing
- Supporting renewable dynamics
- Ramp rate control
- Ancillary services
- Energy storage

System Balance

- Generation and demand priority management
- Fast load shedding
- Dynamic demand response
- Dynamic energy storage management
- Protection and fault

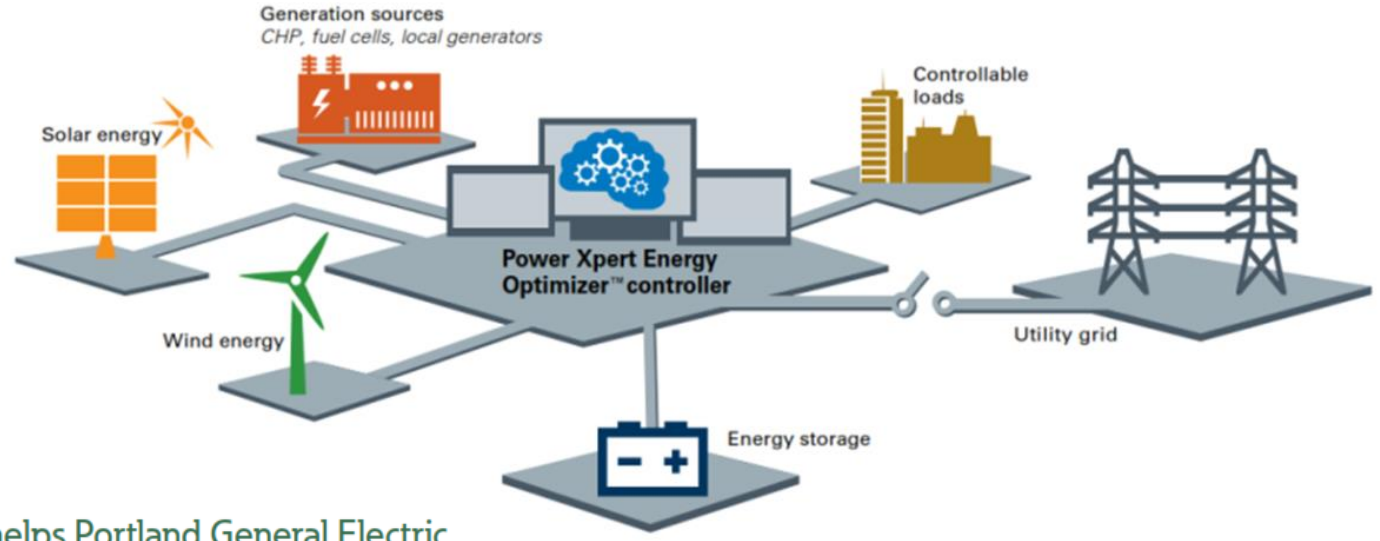
Renewable optimization

- Smart inverter controls
- Energy storage integration
- Adaptive system to weather and price forecast
- Renewables maximization option to save fossil fuel

Lowest cost

- Utility Demand Response functionality
- Energy arbitrage
- TCO optimization
- Fossil fuel conservation
- Peak shaving
- Load shifting
- Conservative voltage regulation

Utility storage / microgrid demonstration project



Eaton helps Portland General Electric make tomorrow's smart grid a reality

Project goals

- Investigate energy storage and islanding to supply energy to customers during an outage
- Coordinate utility feed with distributed generators, battery storage, solar PV and wind power

Primarily two methods of operation

- **Grid connected** - for load support, peak shifting, spinning reserve, wind firming, solar firming, kVAR supply
- **Islanded / disconnected from grid** – disconnect from grid and pick up load and regulate frequency and voltage and reconnect back to the grid

5 MW utility battery storage system components

Batteries

- 1 MW / 1.25 MWh EnerDel Lithium-Ion battery blocks and battery management system (x 5 for total of 5 MW)

Inverters

- 20 Eaton PowerXpert 250 kW inverters, adapted for battery storage application

Associated AC Power System

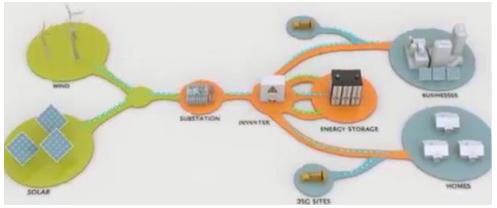
- Low-Voltage switchboards
- Step-up transformers
- Medium-voltage switchgear, metering, protection
- UPS (for control)

Storage Master Control System

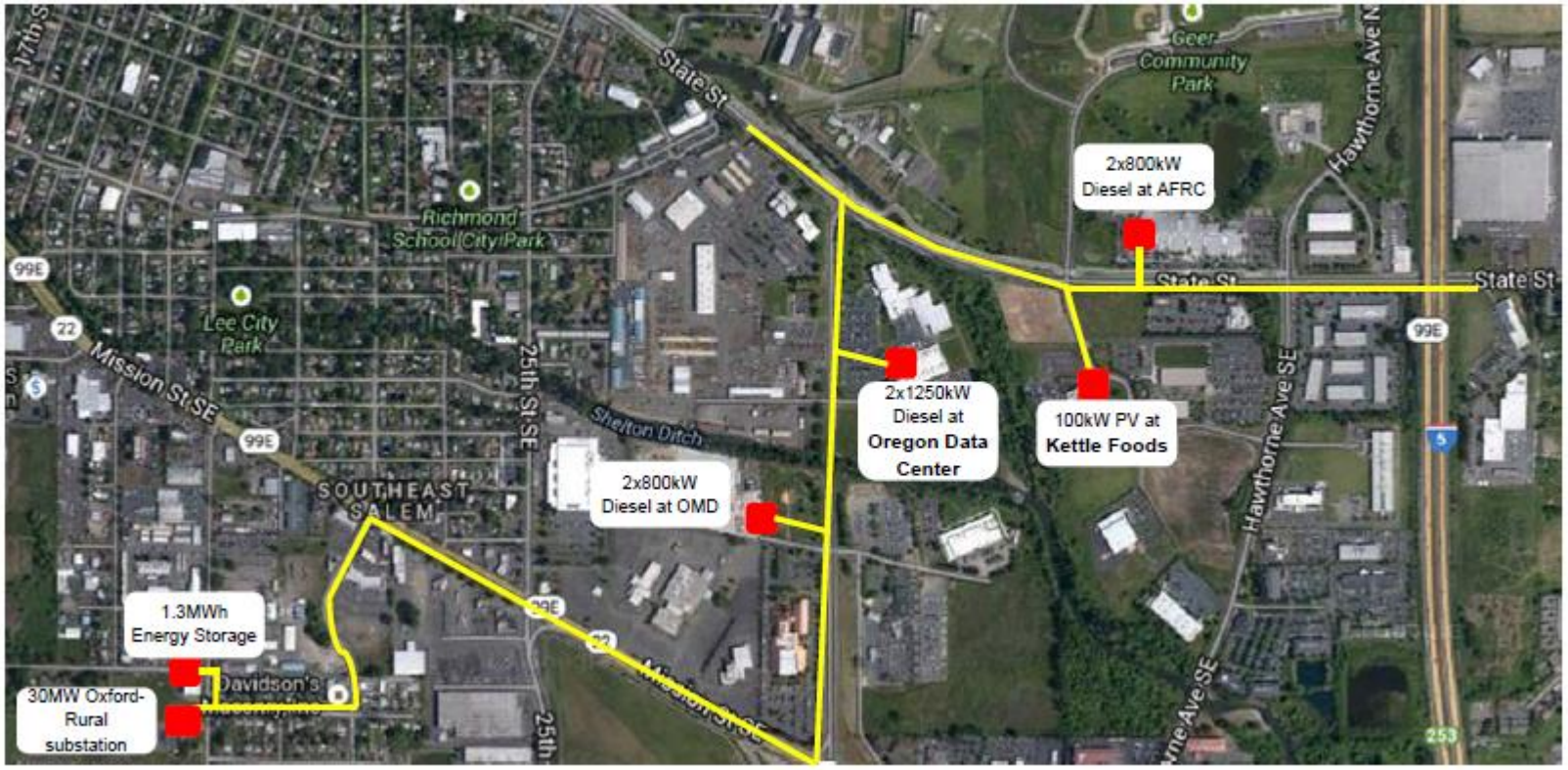
- Integration services to coordinate and regulate operation of multiple inverters and battery banks and interface with utility control system

One of the first Li ion projects of this size, active since 2012

Portland General Electric MicroGrid

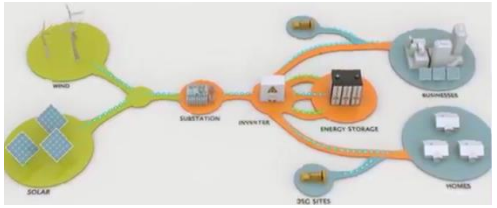


PGE Salem High Reliability Zone



The Yellow line is a 2.5 mile 12kV over head line

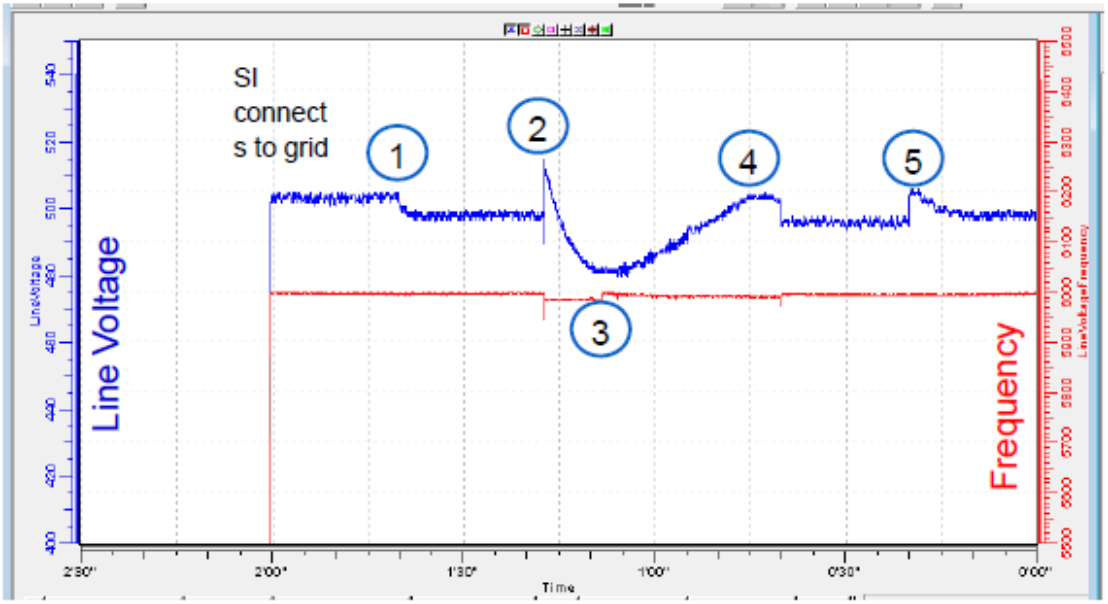
Portland General Electric MicroGrid



Un-intentional Islanding and Return to Grid

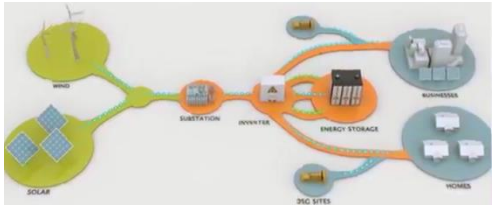
1. SI connects to grid and charges battery
2. A grid-loss event occurs and MISS opens. SI maintains frequency and voltage
3. Utility returns and ISO controller provides frequency and voltage correction signals to SI
4. SI with ISO synch to grid and close MISS
5. SI charges battery

Voltage and Frequency Data Captured During an Storage Inverter Unintentional Islanding

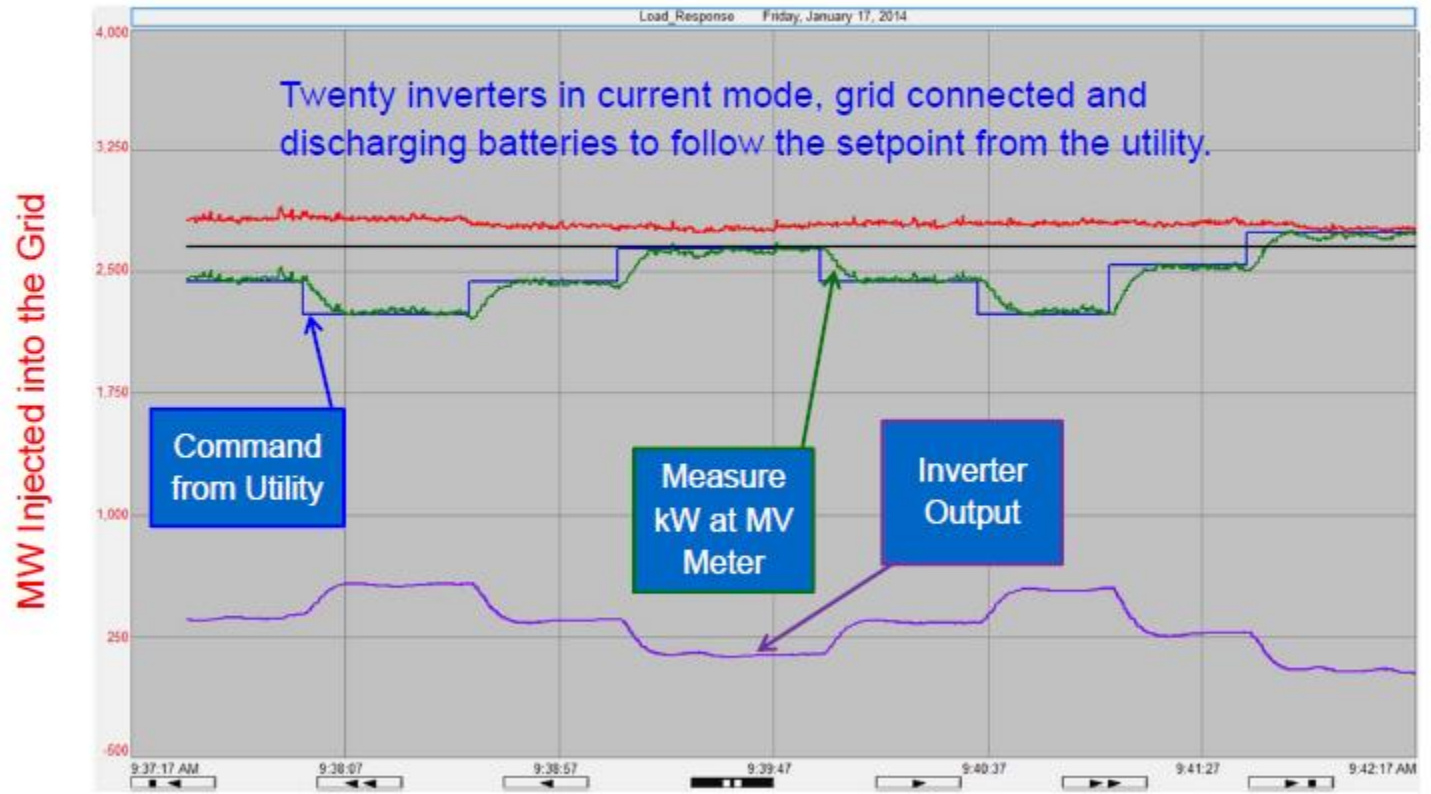


SI: Storage Inverter
MISS: Microgrid Interconnection Static Switch
ISO: Intelligent Switchgear Organization

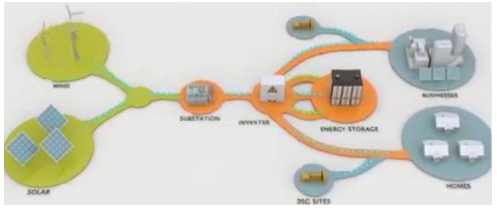
Portland General Electric MicroGrid



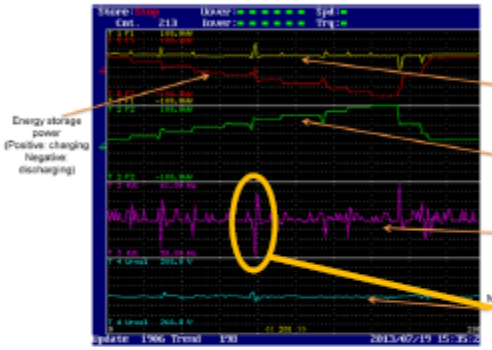
Supporting Grid Connected Renewables



Portland General Electric MicroGrid

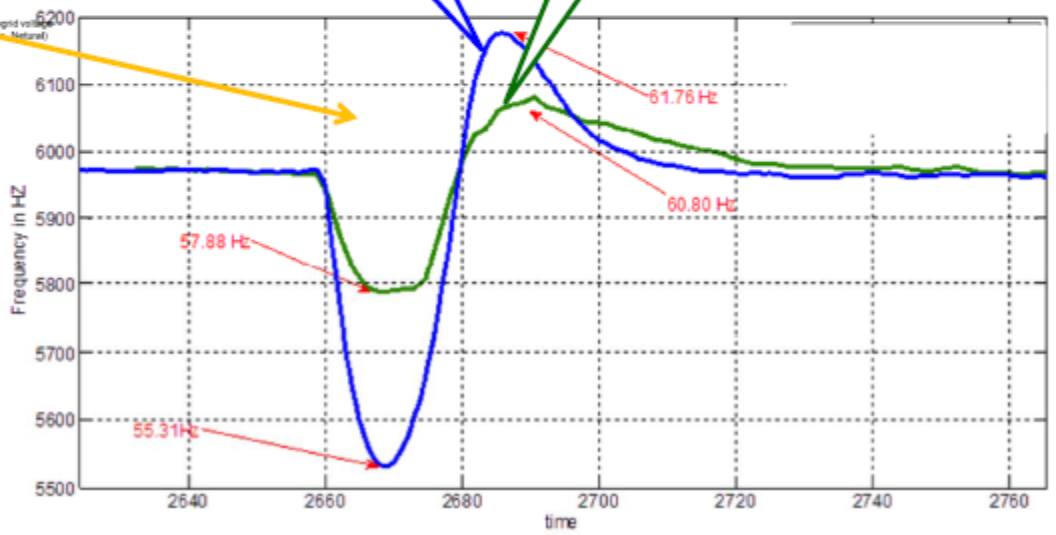


Frequency Support in Microgrids



Microgrid frequency during a step load without support from energy storage

Frequency with Energy Storage for the same step load



Without support

Frequency drop 4.41Hz

Frequency overshoot 2.02Hz

With Support

Frequency drop 1.84Hz

Frequency overshoot 0.8Hz

Utility storage / microgrid: increases reliability of electricity for business and residential customers

Pioneering solutions

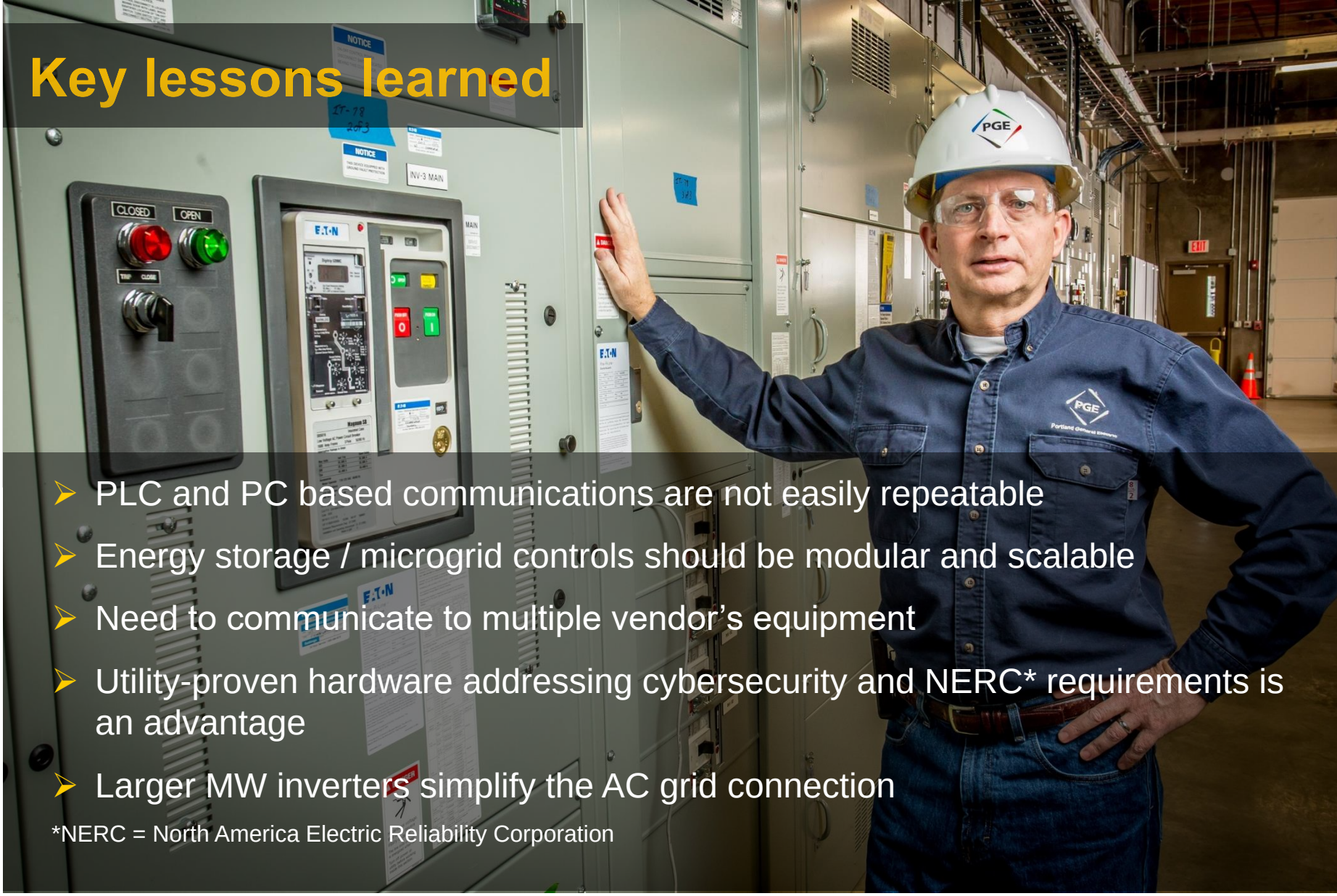
- Seamless transition from utility to battery storage system power
- Dynamic load sharing and transitioning from utility feeder to island mode
- Coordination between generators, battery storage, solar PV, wind power

Outstanding results

- Using lithium ion batteries with rapid charge discharge cycles
- Demonstrating reliable, safe management of batteries and inverters
- Help stabilize grid frequency during power sags

Image credit: Portland General Electric Co.

Key lessons learned



- PLC and PC based communications are not easily repeatable
- Energy storage / microgrid controls should be modular and scalable
- Need to communicate to multiple vendor's equipment
- Utility-proven hardware addressing cybersecurity and NERC* requirements is an advantage
- Larger MW inverters simplify the AC grid connection

*NERC = North America Electric Reliability Corporation

Image credit: Portland General Electric Co.

Powering Business Worldwide

Military MicroGrid by Eaton

Natural Gas Generators

Project Focus: Energy Surety / Resiliency for a military campus

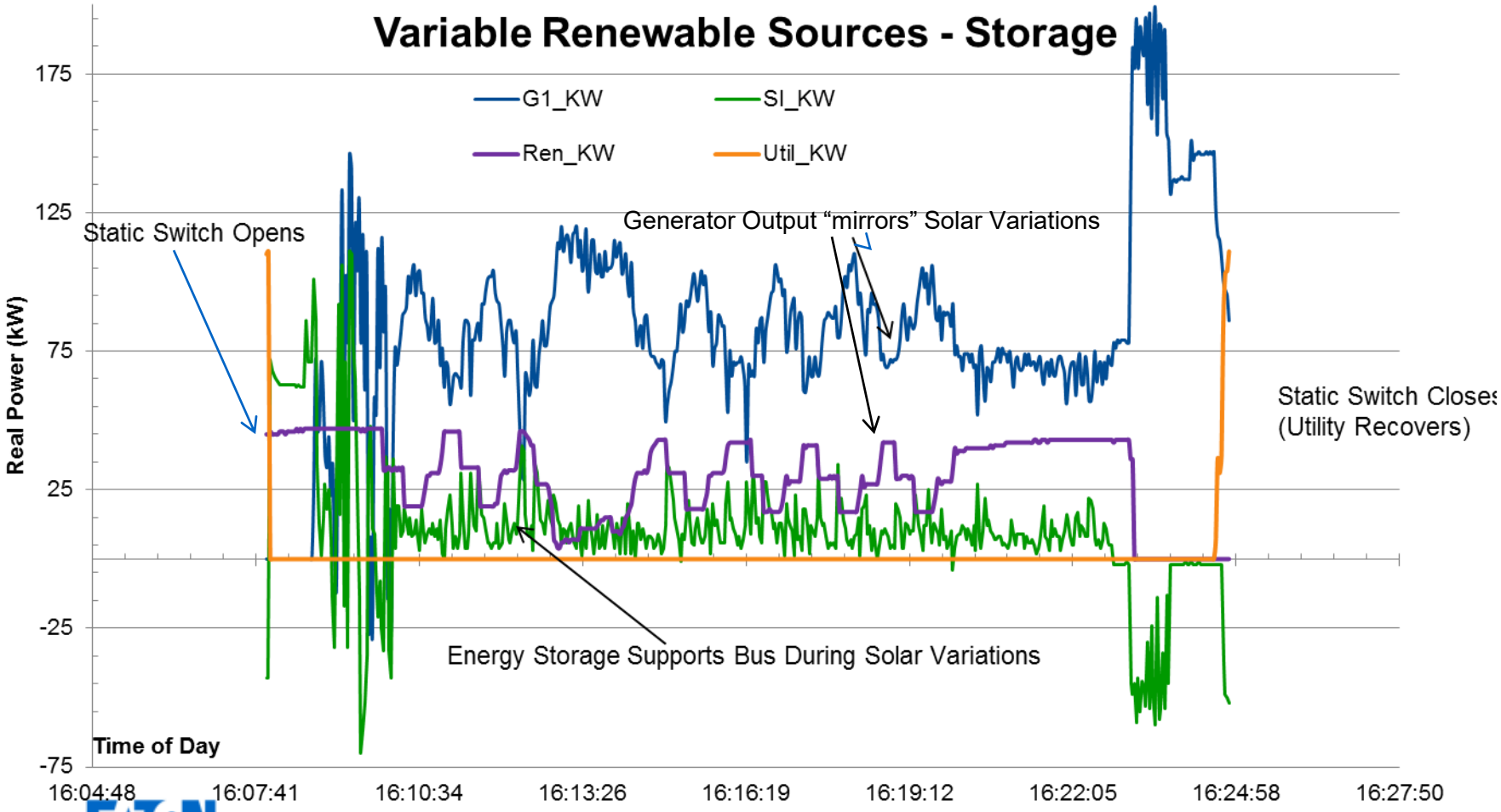
Solution developments:

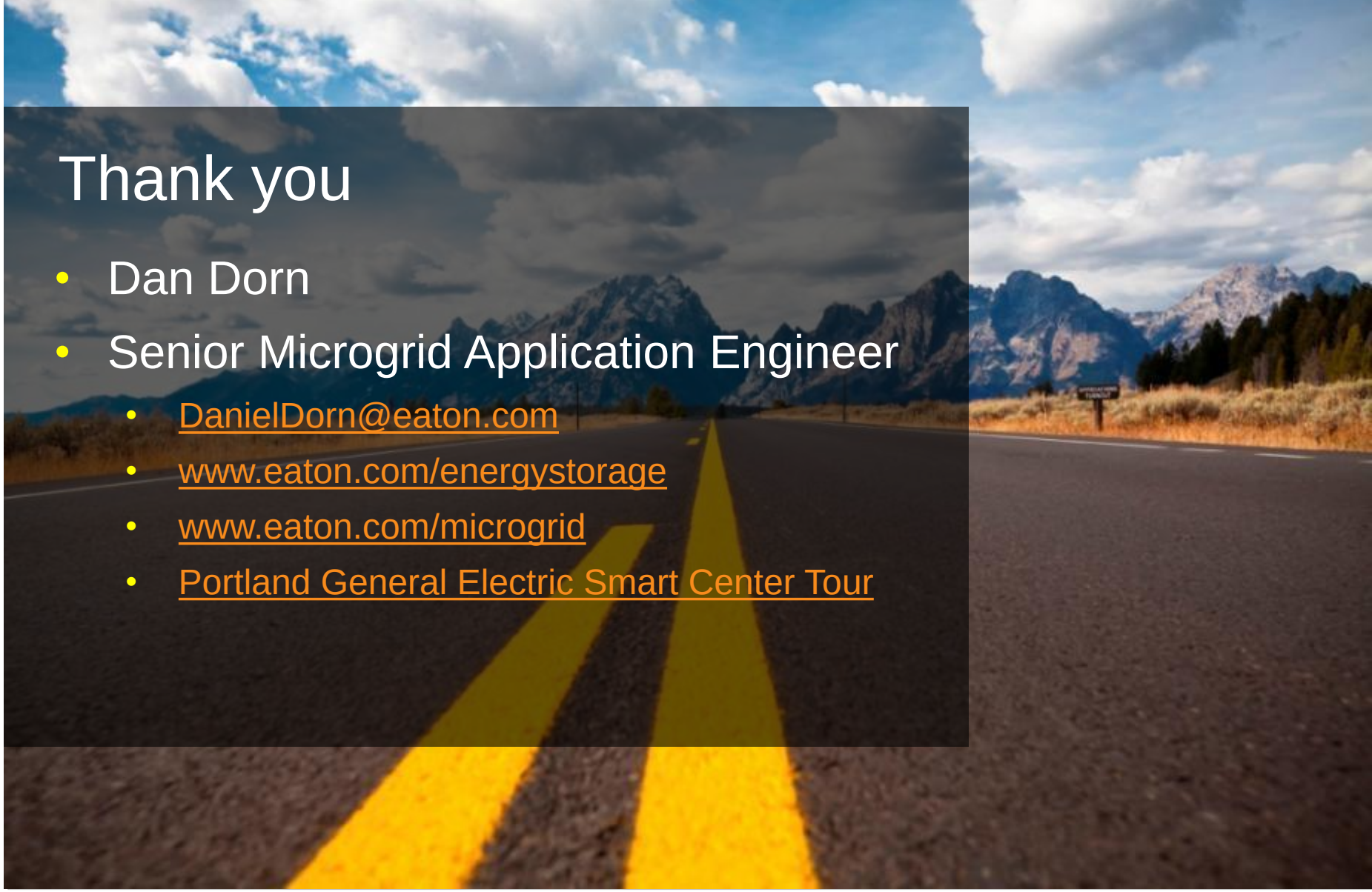
1. Manage multiple generation sources – natural gas generators, solar pv, wind, battery storage
2. Optimized capital and operating costs via microgrid system design
3. Seamless islanding and reconnection to the grid

Eaton provides the "glue" to seamlessly connect and island the microgrid

How do you deal with variable energy sources?

Addressing variable energy sources if they make up the bulk of available DERs?





Thank you

- Dan Dorn
- Senior Microgrid Application Engineer
  - DanielDorn@eaton.com
  - www.eaton.com/energystorage
  - www.eaton.com/microgrid
  - Portland General Electric Smart Center Tour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