Microgrids and Power Quality

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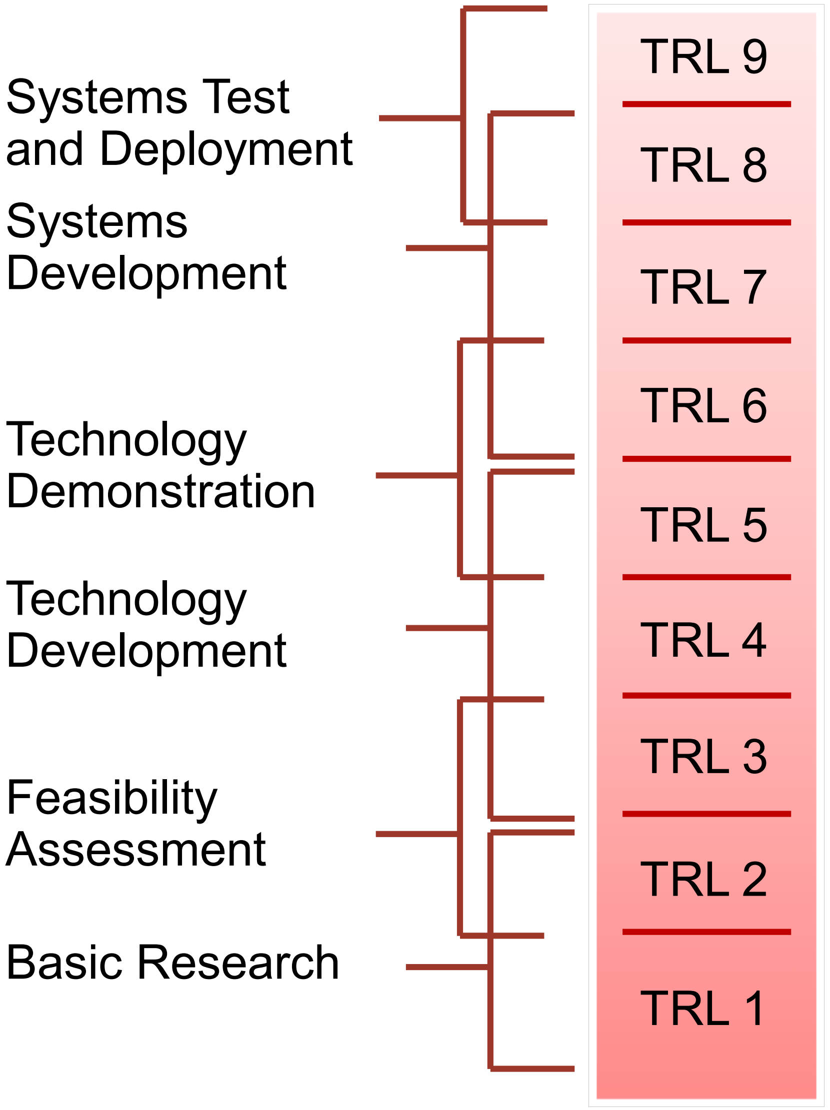
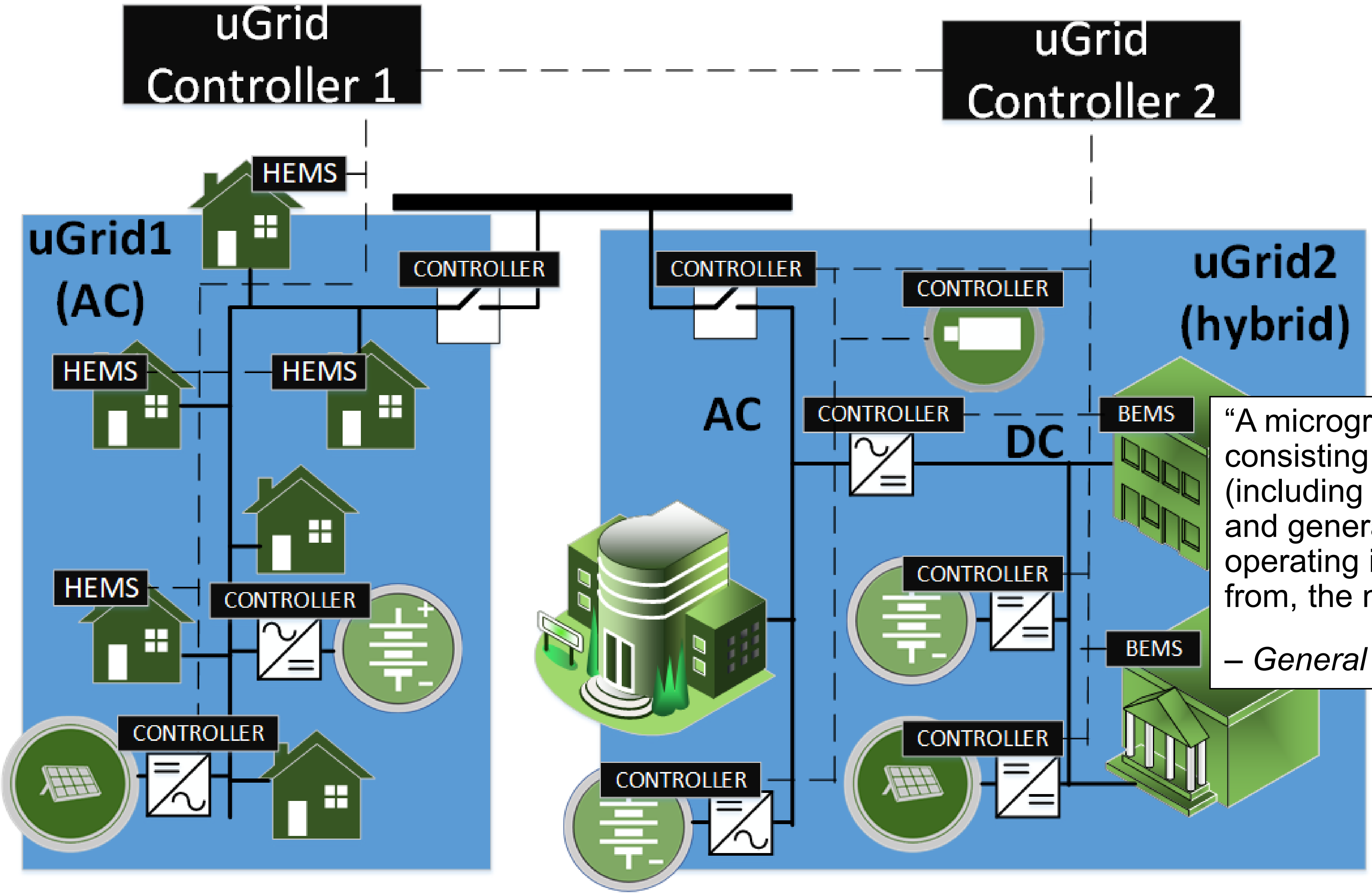
ORNL Research

- Funded by Department of Energy
  - Building technologies
  - Renewable integration
  - Energy storage
  - Smart grid and microgrids
- Target technology readiness at different levels
  - Fundamental science to deployments of technology with industry partners



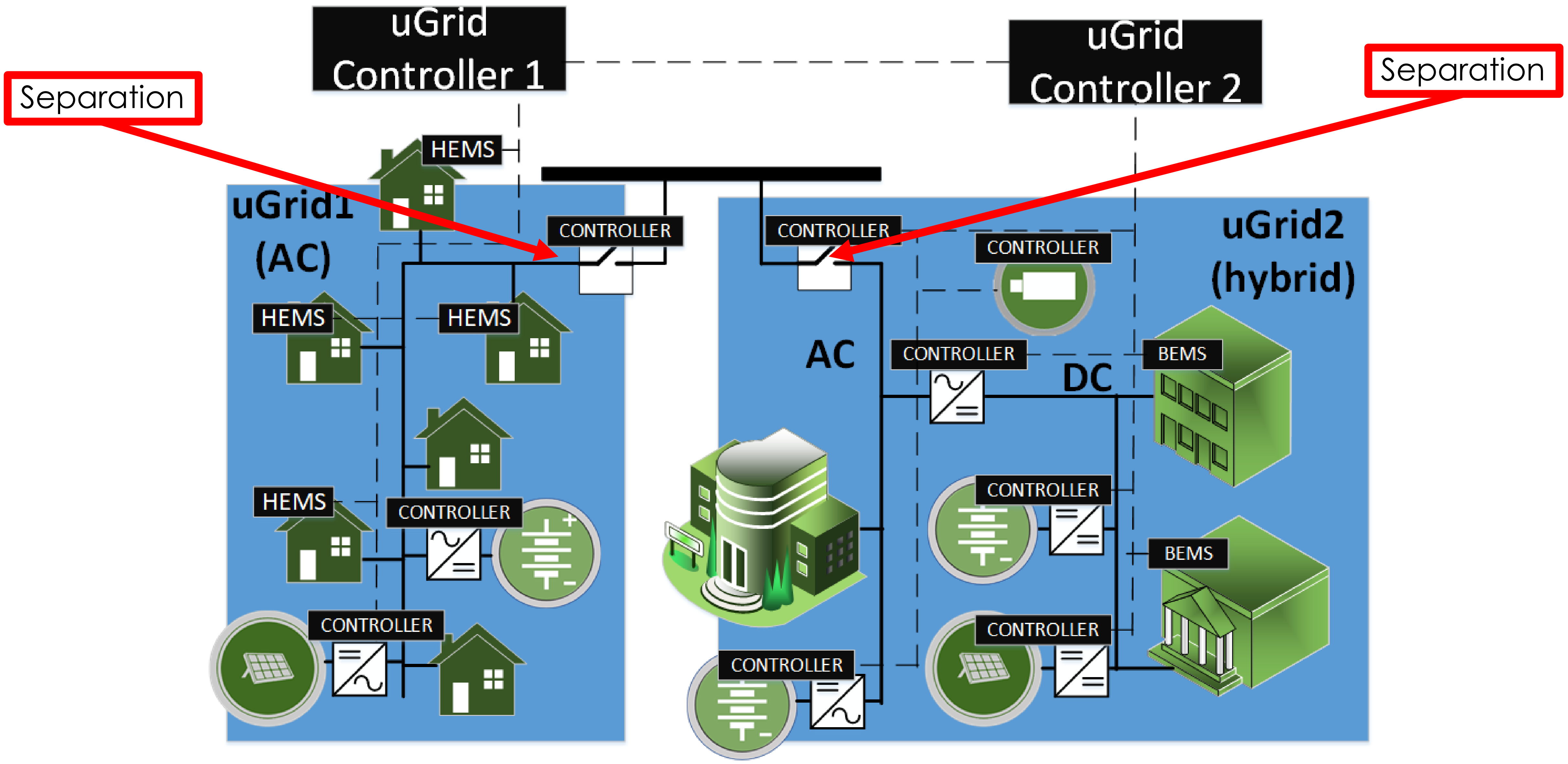
What is a Microgrid?



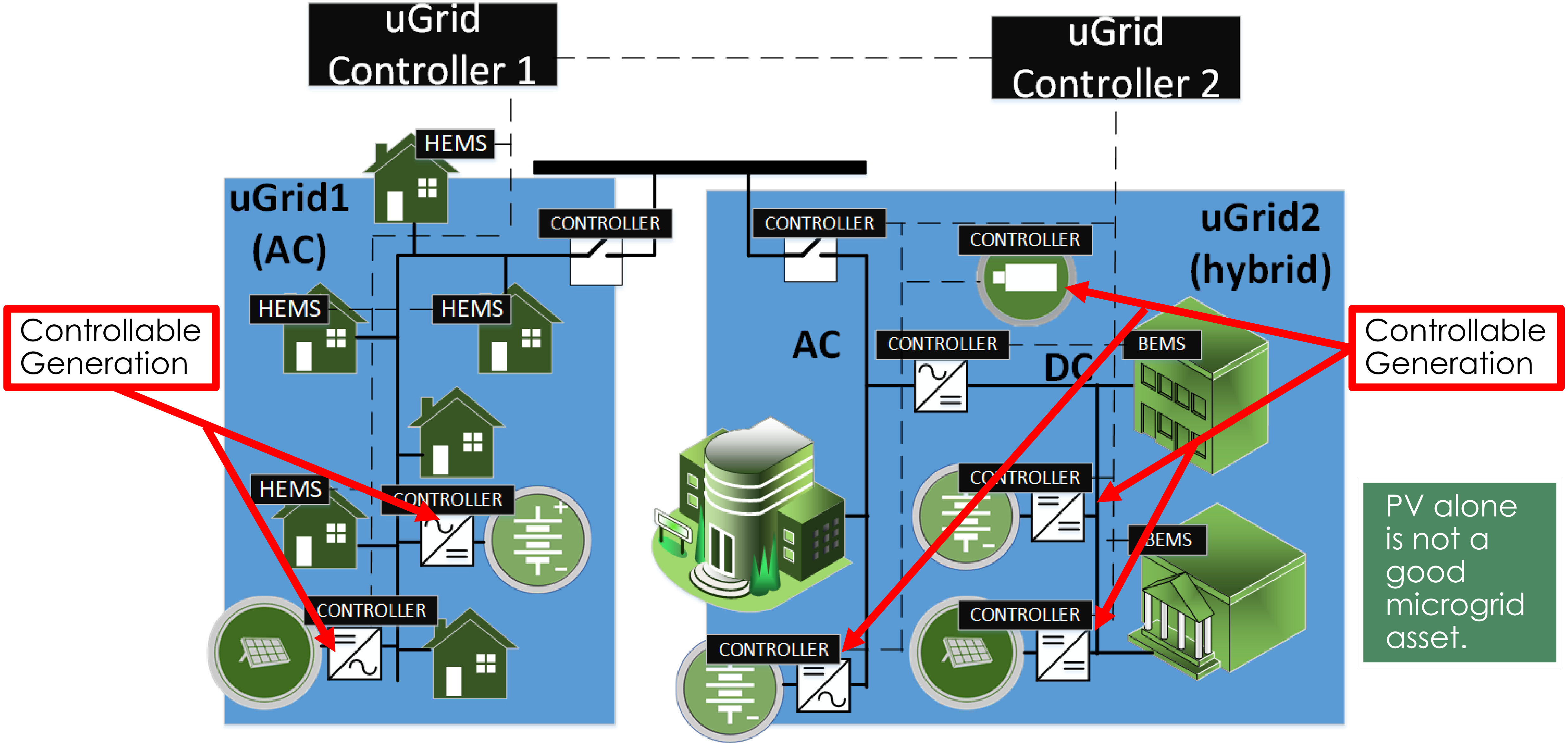
"A microgrid is a discrete energy system consisting of distributed energy sources (including demand management, storage, and generation) and loads capable of operating in parallel with, or independently from, the main power grid"

– *General Microgrids*

What Makes up a Microgrid?

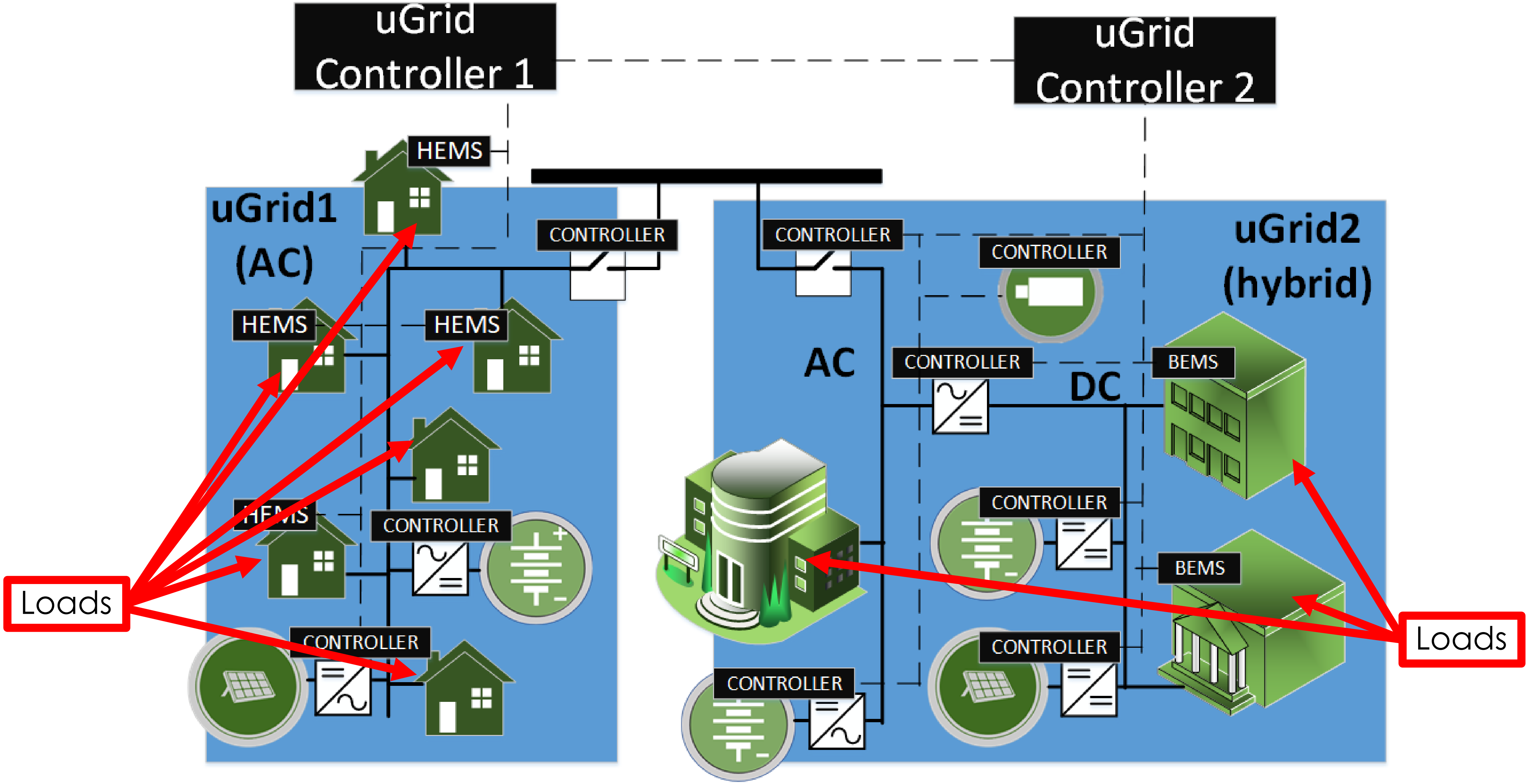


What Makes up a Microgrid?



PV alone is not a good microgrid asset.

What Makes up a Microgrid?



What is Needed to Make a Microgrid Successful?

Defined Functionality

- **Clear expected functionality of the microgrid**
  - Should the microgrid be able to island successfully without a blackout?
  - Blackout ok and blackstart is expected upon that condition?

Generation Capacity

- **Enough local and controllable generation and resource capacity**
  - Standard generators?
  - Power electronic resources (PV, energy storage, fuel cells?)

Coordinated Control

- **Multiple levels of controls**
  - Devices and controls that support the control and coordination to meet this functionality
  - Communications to support optimization and device coordination

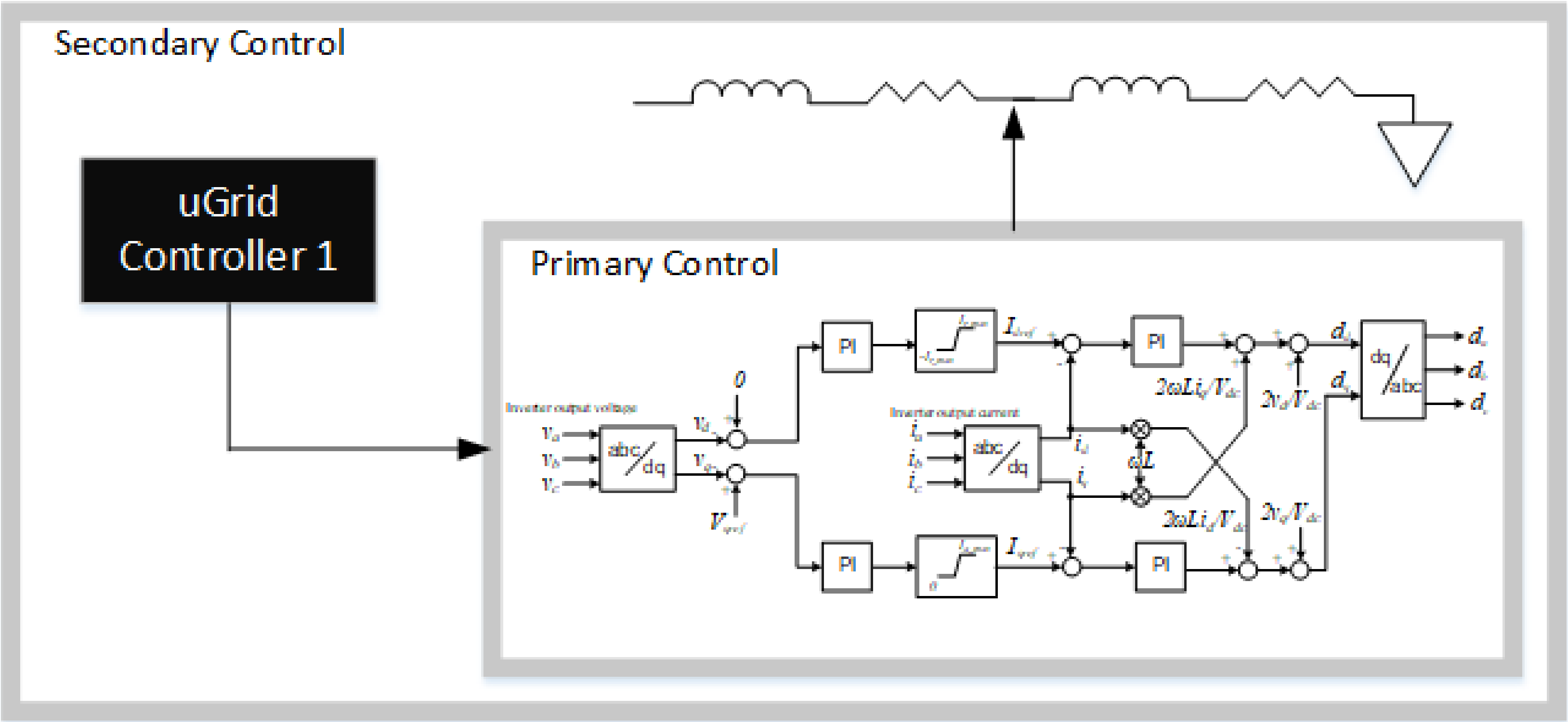
Layers of Controls (Inverters)

Primary Control –

- Converter and generation system level controls that are done automatically in response to measurements
- Typically fast in nature

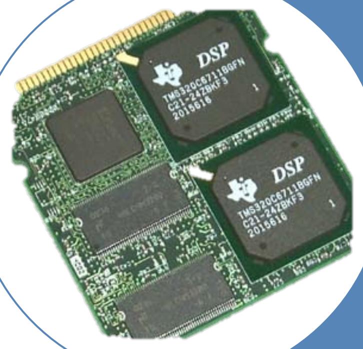
Secondary Control –

- Microgrid controller works with assets to ensure voltage and frequency of system are regulated.
- Typically slower in nature



Typical Structure of Inverter based Devices

- **Controller –**
  - Lowest level is field programmable gate array (FPGA) or digital signal processors (DSP)
  - Very fast computation and signal generation in 1-10 us range
- **Interface –**
  - Real-time layers that support interaction to controller and usually performs the communications interface and state representations
  - Can be done on the controller level, but controller is resource limited



Controller

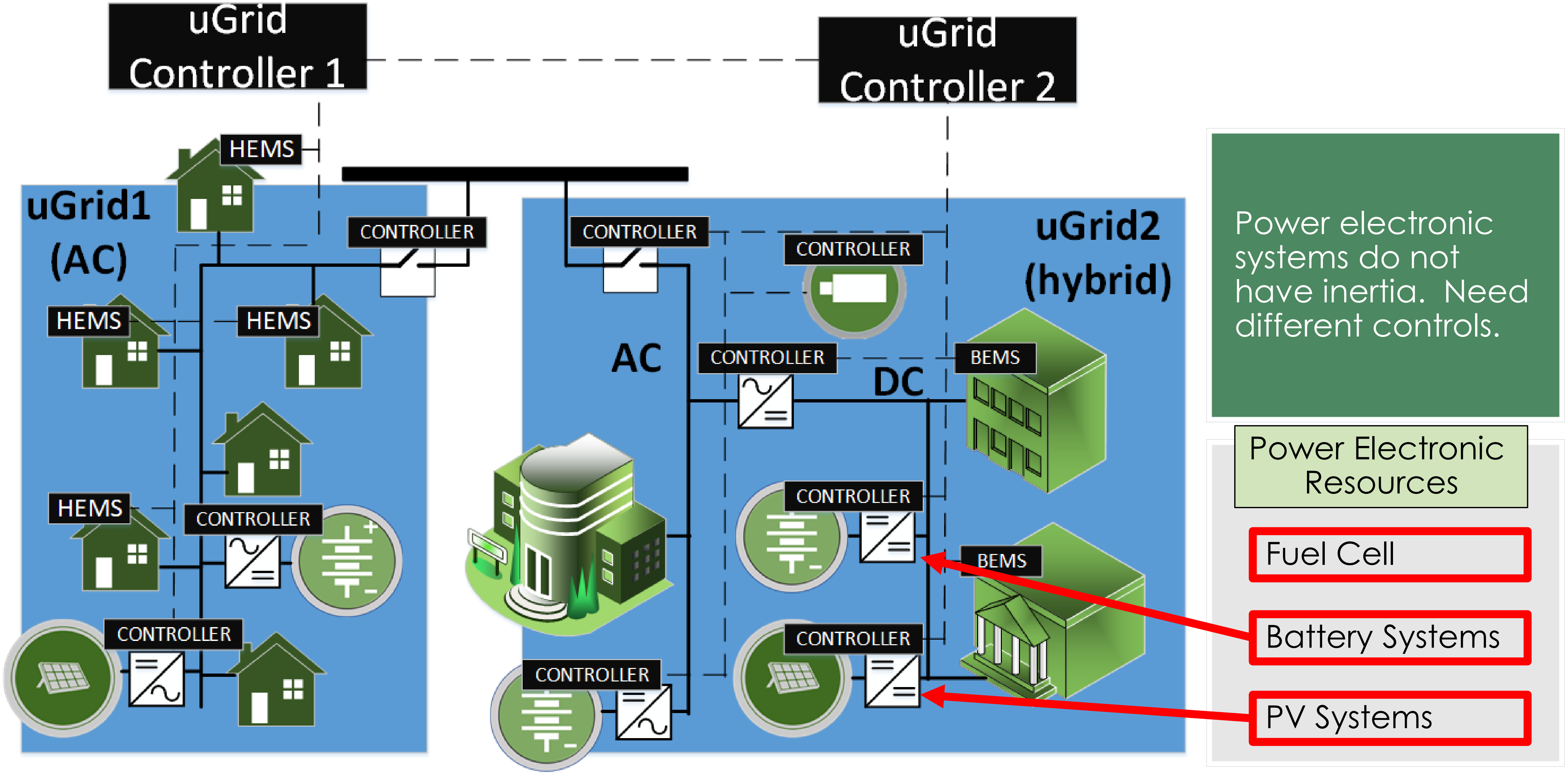
- Measurements I/O
- Inverter controls
- PWM generation
- Fault detection
- System state decision (normal conditions)

Interface

- Communication layer
- System state decision making (normal conditions)
- System coordinator

Main Message: These systems can be complicated!

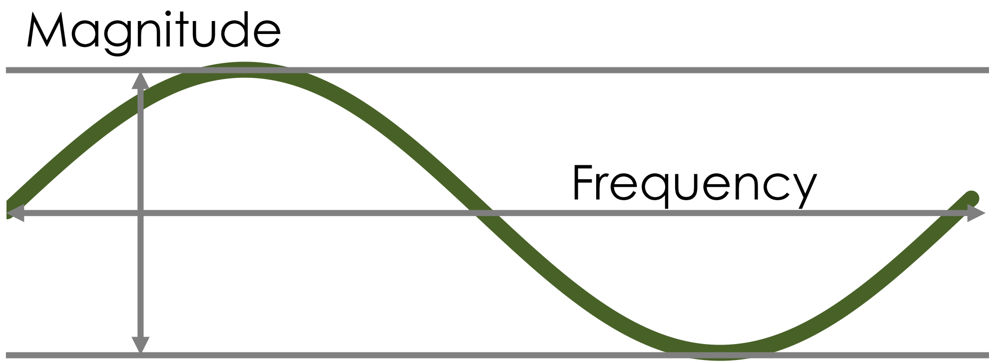
Microgrids Transitioning to Power Electronic Resource



Power electronic systems do not have inertia. Need different controls.

Power Quality

- A measurement of the ‘fitness’ of the power delivered
- For US electric grid, usually like to think of a voltage sine wave operating at 60Hz
- Many standards are available to support defining power quality and technology solutions

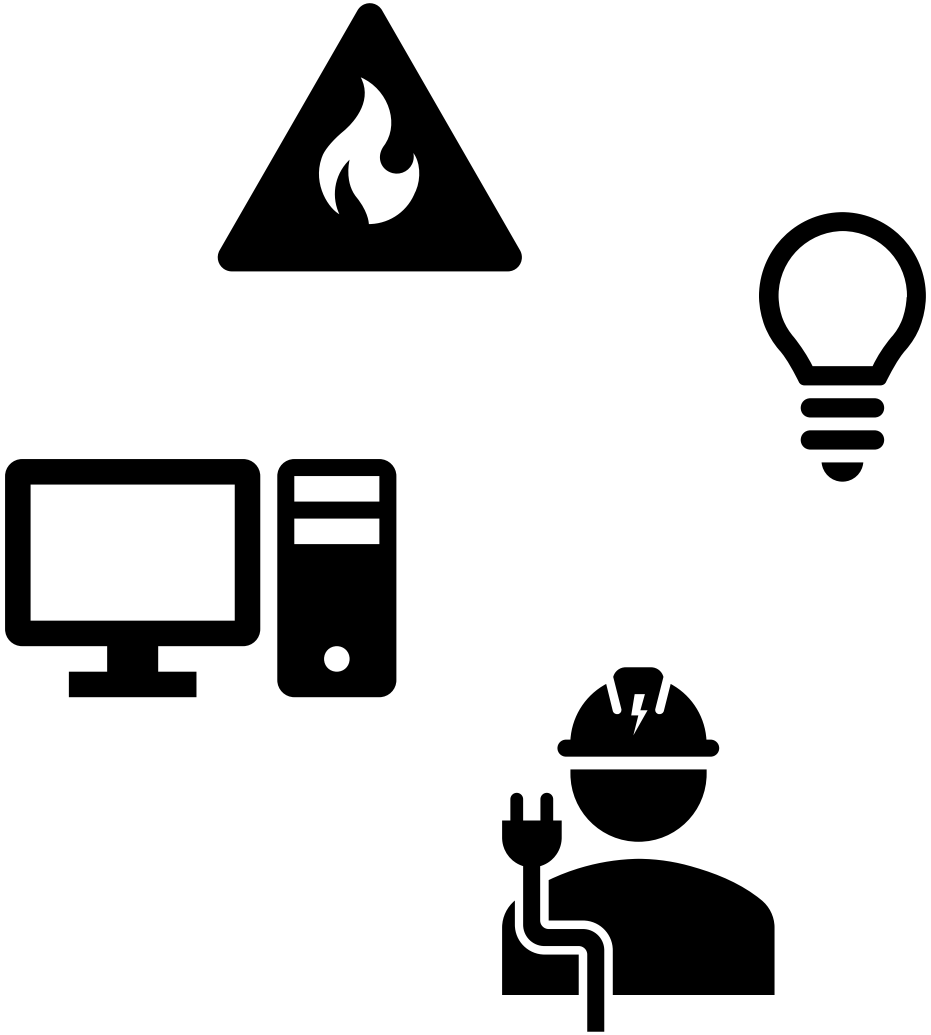


IEEE/IEC	NFPA/NEMA	UL
IEC 61000 IEEE 519 IEEE 1159 IEEE 1433 IEEE 1531 IEEE C2 IEEE C62.41 IEEE 1433 IEEE 1564	NEMA LA 1 NEMA LS 1 NEMA PE1 NFPA 70 NFPA 780	UL 96A UL 1283 UL 1449

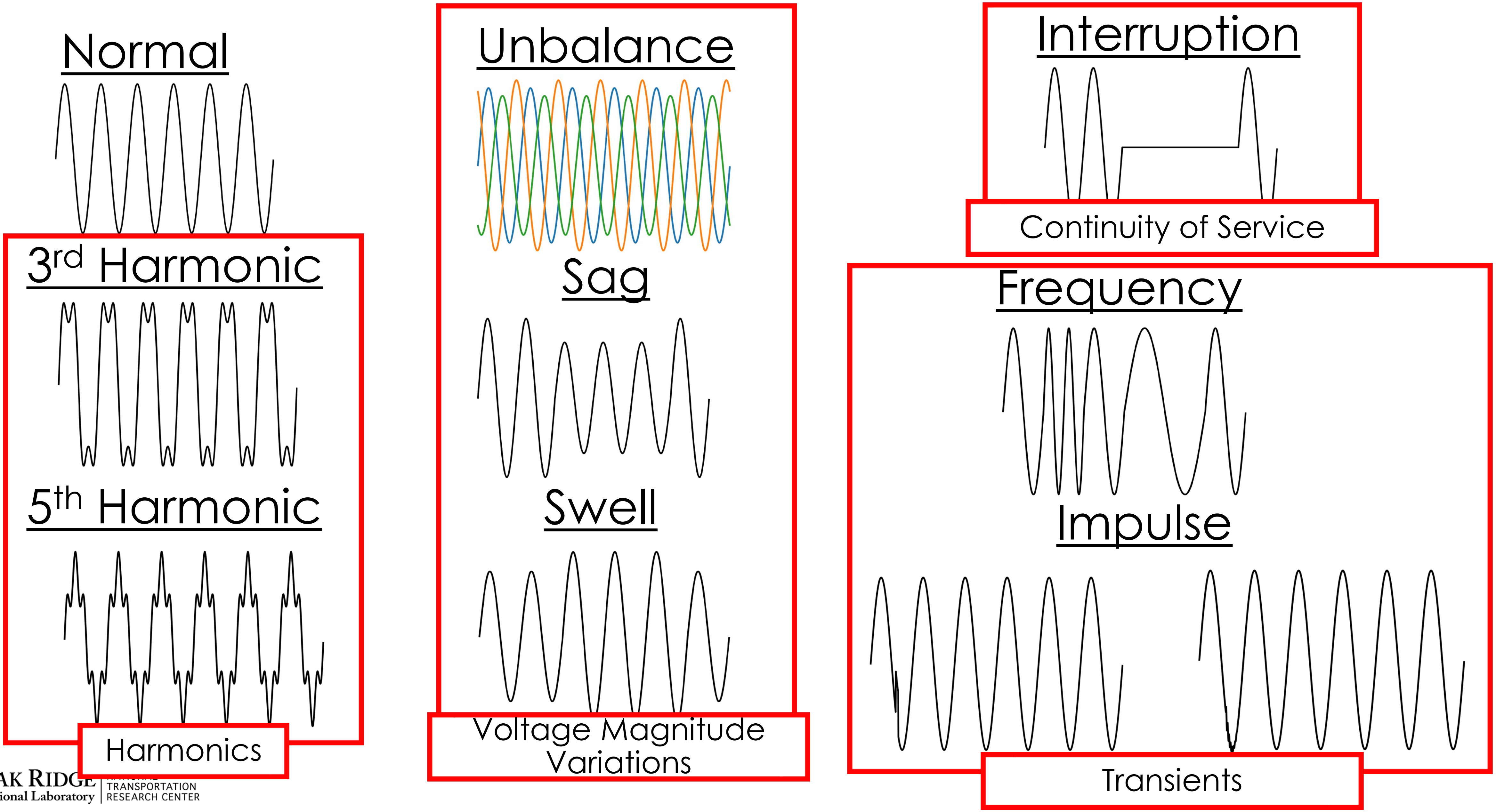
Theo Laughner, Intro to Power Quality, TVA Presentation, 2017

Why is Power Quality Important?

- Poor Power Quality Impacts:
  - Premature failure of devices
    - Capacitors
    - Motors
    - Transformers and cables
  - Energy efficiency with increased heating and losses
- Can Trigger Tripping of Devices
  - Computers
  - Relays
- Can Lead to Charges from your interconnected utility.



Different Electrical Power Quality Signatures



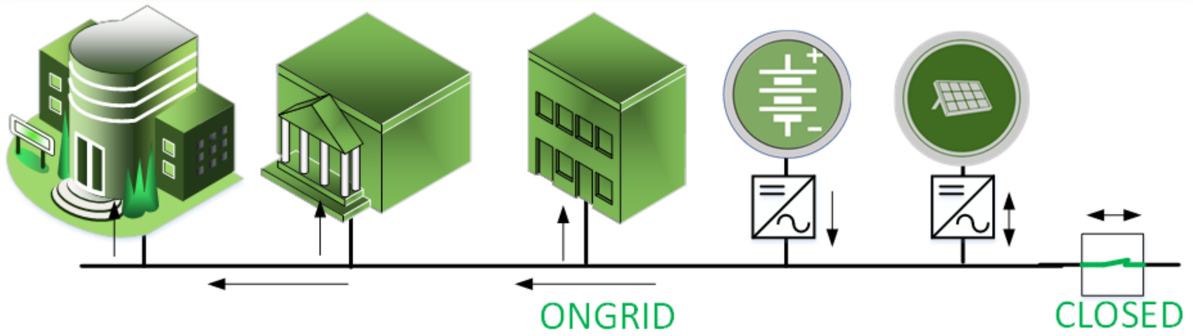
Challenges with Power Quality in Microgrids?

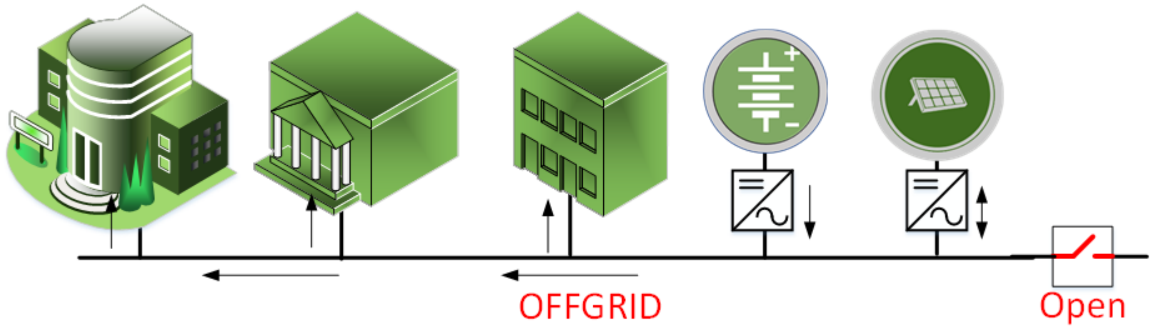
Ongrid:

- Voltage support focused
  - Control reactive power of assets to support voltage
- Supporting the grid for use cases such as
  - demand reduction
  - local electricity cost reduction.
- Power Quality issues can come from main grid

Offgrid: [ISLANDED MODE]

- Voltage control and frequency focused
  - Control reactive power for voltage
  - Control real power for frequency
- Must deal with system imbalance
  - Any imbalance now must be locally supported
- Power quality issues are generated locally





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What can cause power quality issues within Microgrids?

1. Transient conditions such as that of an islanding event due to a grid problem.

3. Increased non-linear loads or rectified loads.

2. Renewable generation due to transient changes in weather.

4. Changes in local impedance that can impact filtering and power electronic controls.

5. Increased loading on one phase over another during an island.

The Connected Community

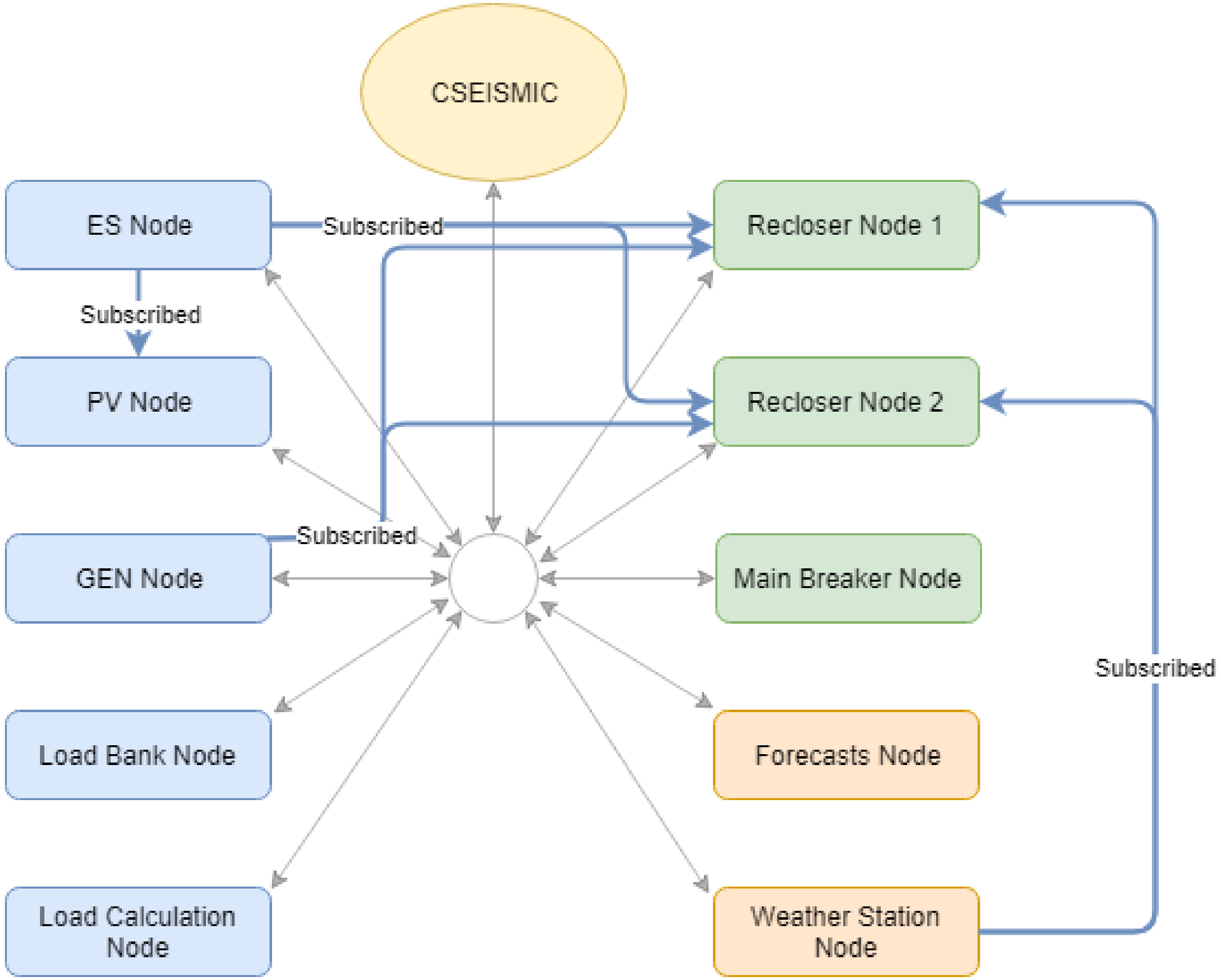
- 62 Residential buildings (occupied)
  - HVAC
  - Water heaters
- PV system: 330kW
- Energy storage: 300kW, 681kWh
- Generator: 400kW

Alabama Power: Neighborhood

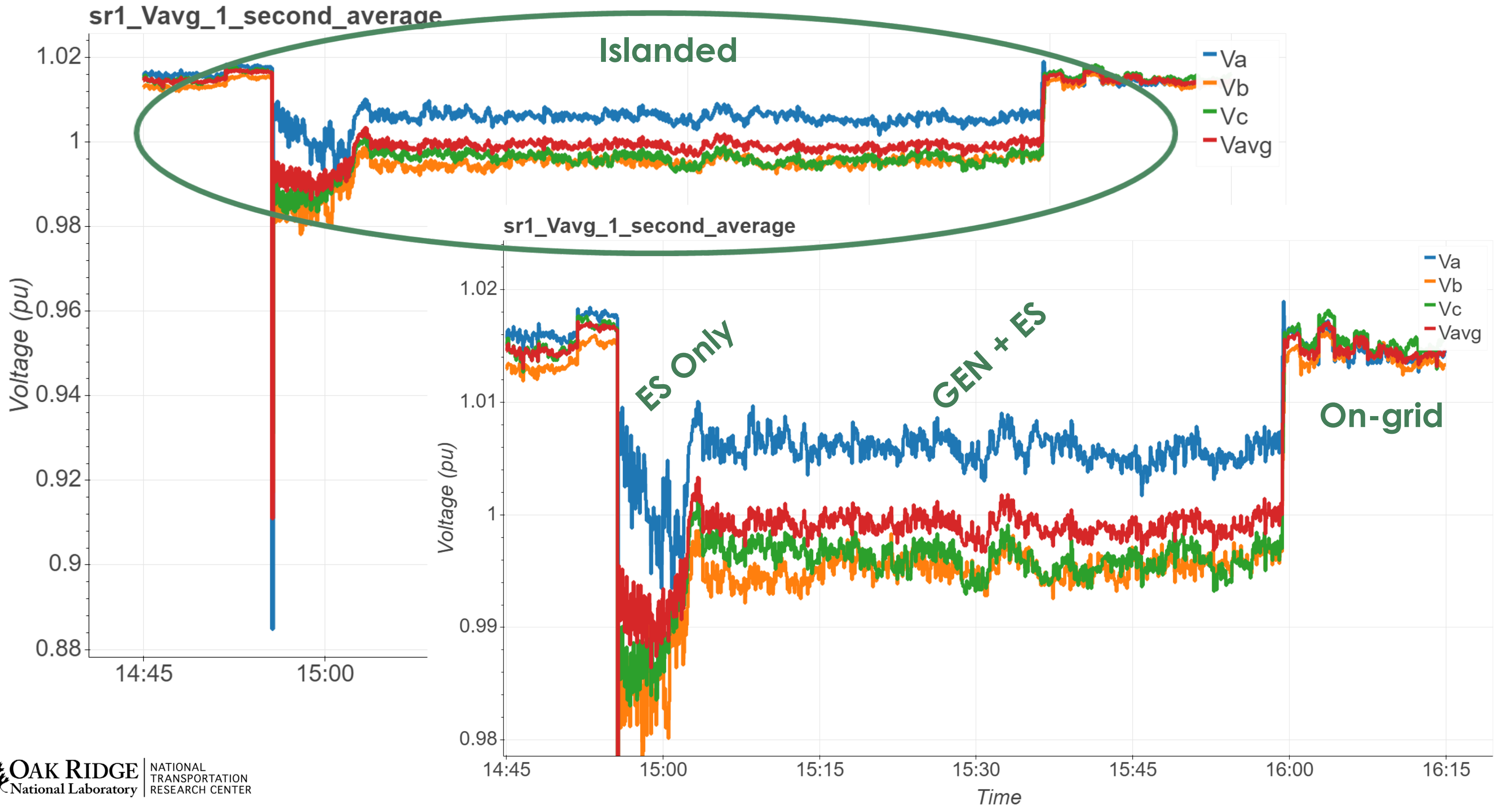
Alabama Power: Microgrid

Distributed Control Features

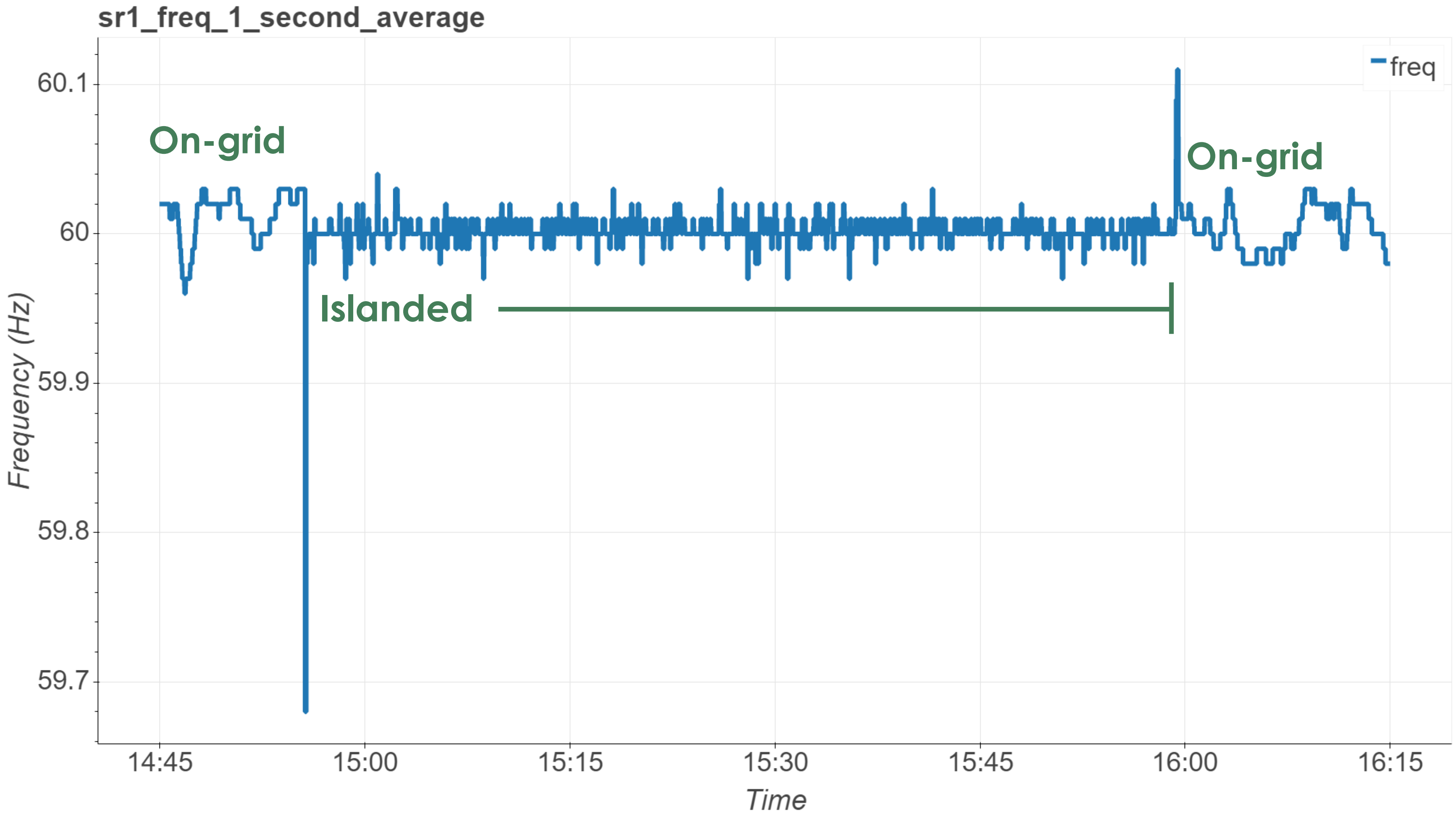
- Generation assets support multiple control modes (on grid/grid forming/voltage-frequency source)
- Energy storage system and generator can detect system issues and transition to grid forming controls
- Microgrid control can also coordinate islanding and resynchronization



Islanding (Often Observe Short Duration Voltage Surge/Sags)



Microgrid Island Frequency



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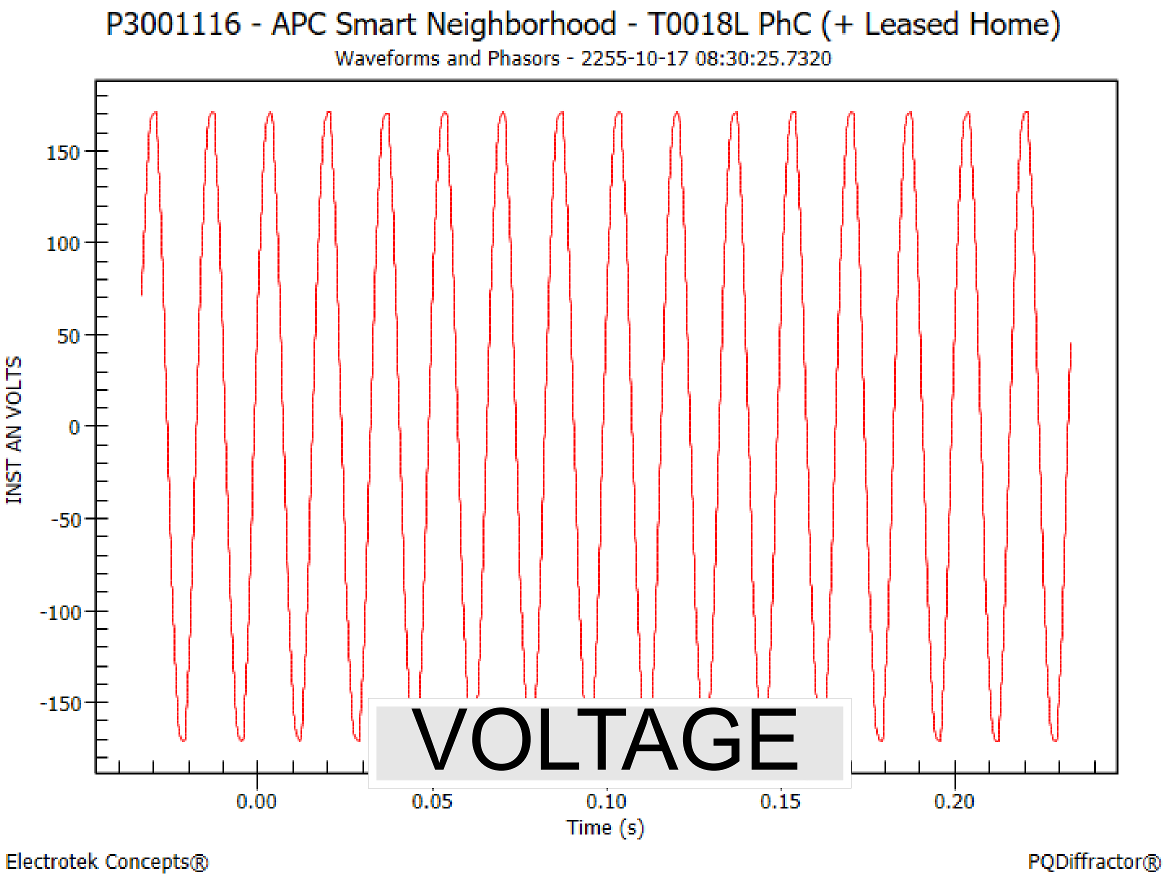
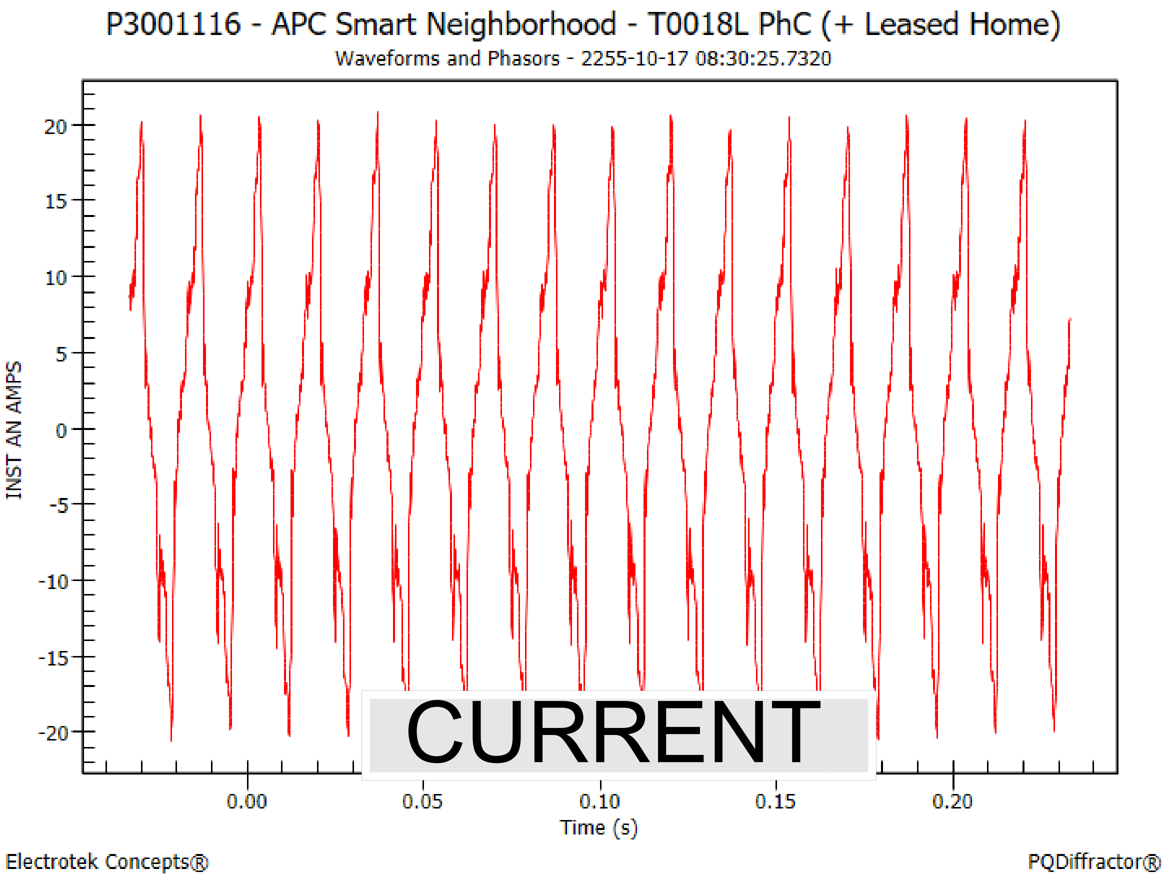
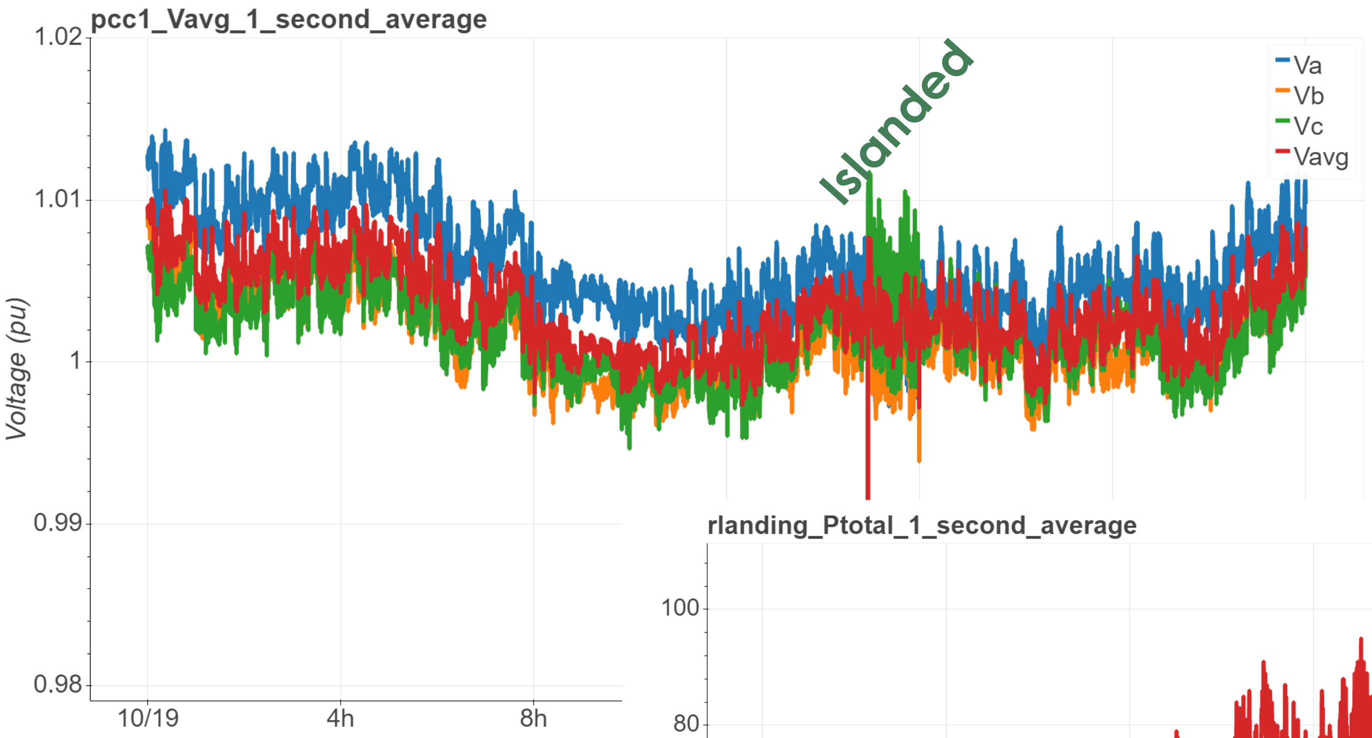
Waveform distortion following island



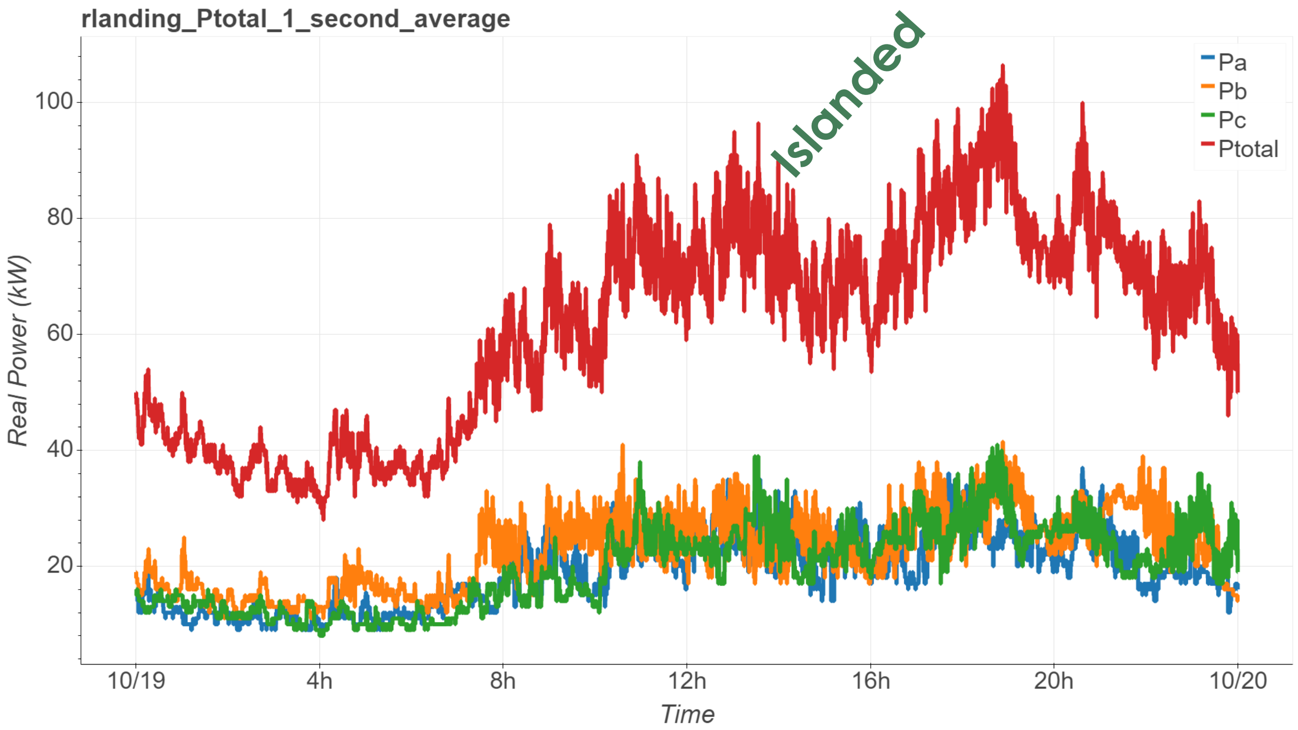


Voltage Imbalance

Voltage imbalance at the microgrid is consistent throughout the day at approximately 0.005 pu.



Load imbalance is inconsistent throughout the day but is somewhat balanced amongst phases.



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