Duke Energy Emerging Technology Office

Simulation Requirements for the Future Grid

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Role of Emerging Technology

Emerging Technology's Mission:
To inform strategy on emerging technology trends; to harness internal innovation; and to identify resulting growth opportunities and risks in a shifting technology, customer, and regulatory environment.

Core Responsibilities

Inform corporate strategy on technology trends	Harness innovation and enhance Duke Energy's reputation	Drive strategic growth opportunities
• Develop strategic implications through scan, monitor, evaluation, and testing • Facilitate technology transfer and seamlessly integrate technology into business units	• Maintain Duke Energy's reputation as a technology leader • Facilitate idea generation & monetize resulting innovation	• Identify technology driven strategic investments

Today's Grid

- Distribution management system (DMS) supervises volt-var control
- Demand response utilizes relays in front of customer HVAC and is utilized for system level issues
- Limited deployment of FLISR, requires DMS and is slow to reconfigure
- Circuits configurations are static and the peak load is the main design consideration

Future Grid

- Control decisions can be handled locally utilizing distributed intelligence, creating hierarchy of optimized sub-systems
- Demand response utilized for reducing individual circuit load or cold load pickup
- Multiple types of loads contribute to demand response, continuously balancing comfort and cost
- Circuit not thought of as static configuration, designed to be reconfigured for optimization and resiliency
- Peer to peer energy transactions utilizing blockchain

Drivers of Innovation

- Increasing amount of "controllable" loads
- ROI beginning to encourage behind the meter distributed generation and storage
- Focus on energy efficiency in heating, cooling, appliances and building design
- Large scale solar and energy storage deployments
- More intelligence and connectivity being pushed to edge devices
- Access to more data than ever before, optimization opportunities are everywhere
- Utilities experiencing flat to declining load growth, must compensate by reducing costs and increasing customer value

Zero Net Energy Buildings

- A Zero Net Energy (ZNE) Building is an energy-efficient building where, on a site energy consumption basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy.
- ZNE buildings can have a net zero annual utility energy bill if they are in an area that supports net metering
- ZNE buildings have the potential to disrupt traditional utility operations and planning due to fundamental changes in their daily load profiles that the grid may not be equipped to handle

Zero Net Energy Buildings

Nexia Thermostats/HEMS

All LED lighting

3.5 – 4.5 kW PV

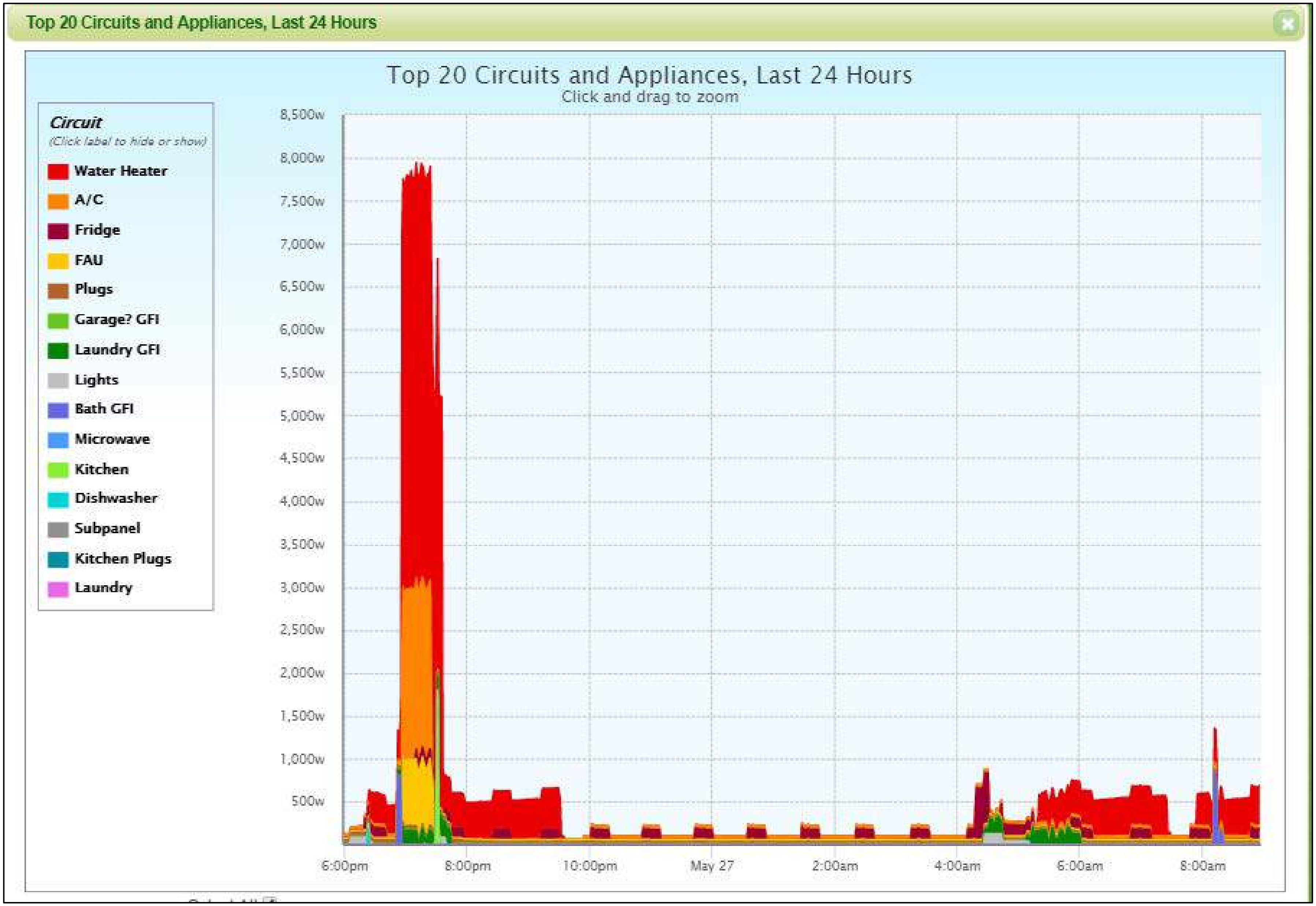
High Performance Envelope

Electric Heating and Water Heating

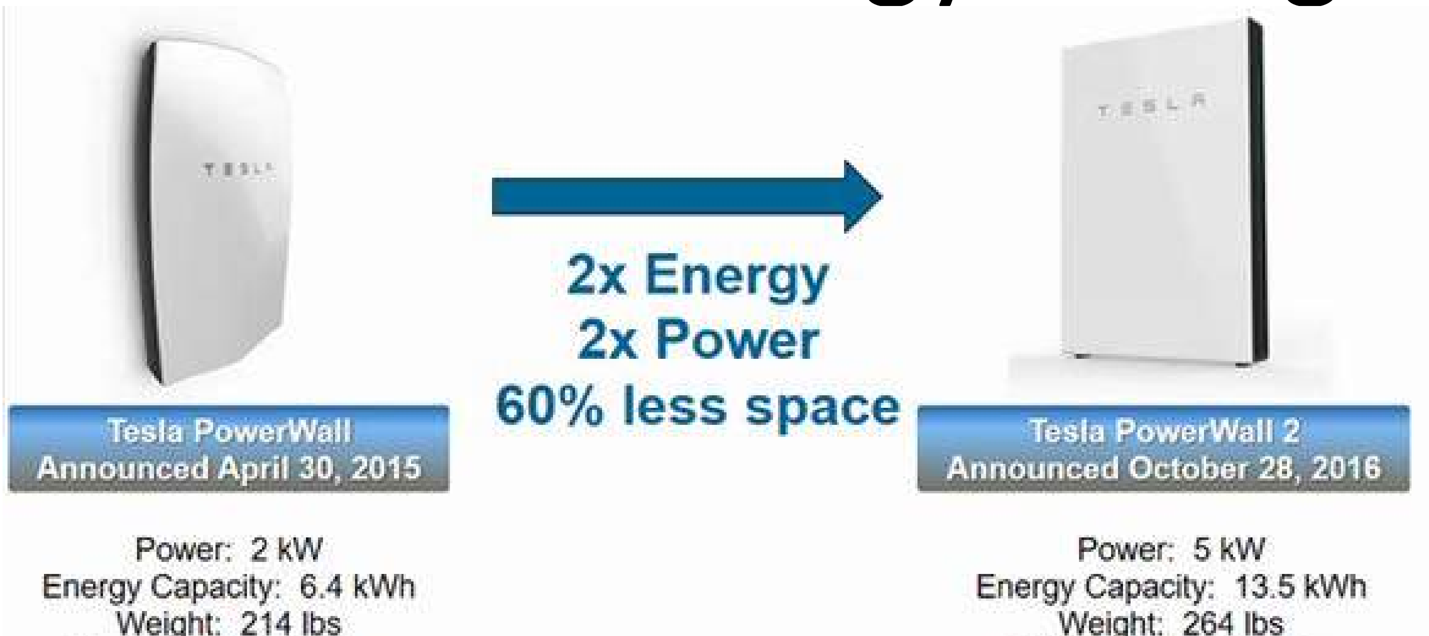
Foam Insulation

Battery Storage

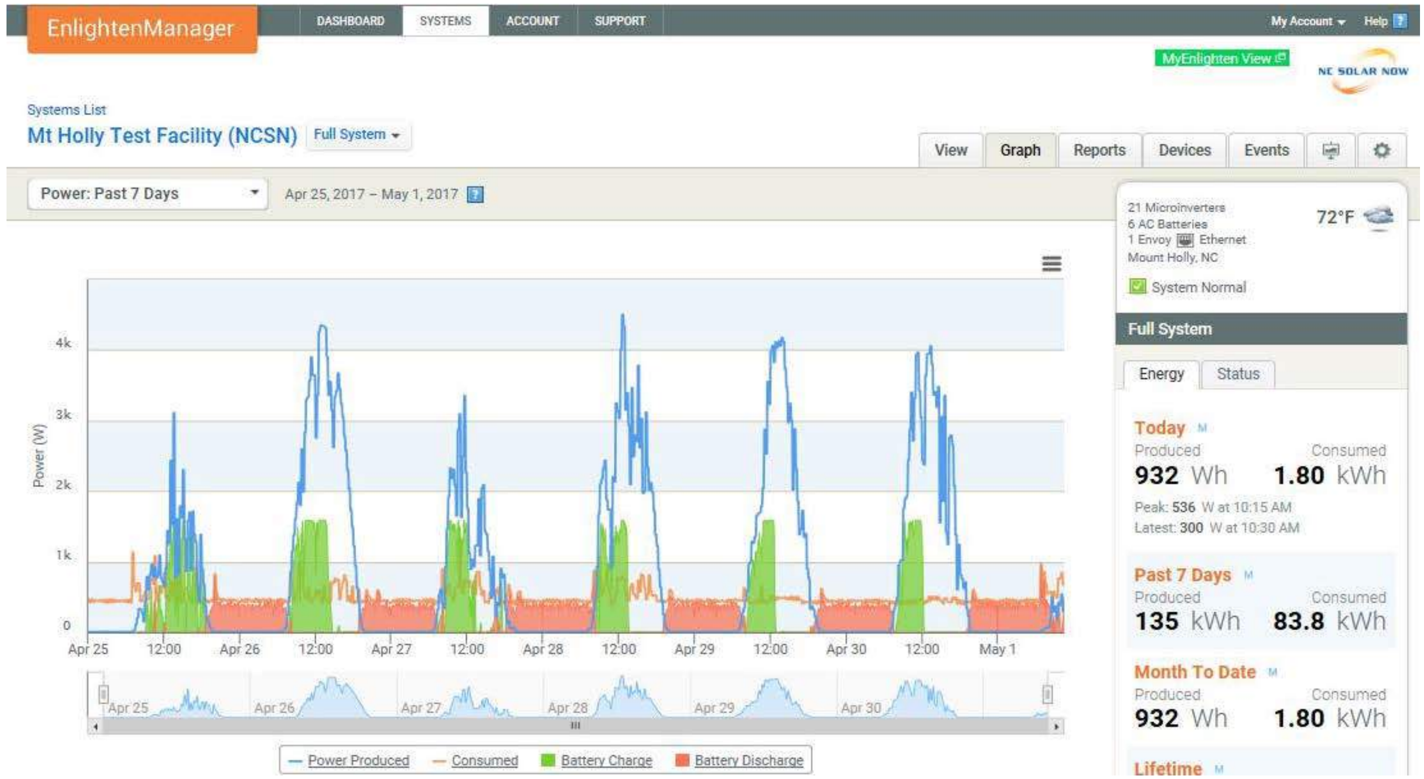
Zero Net Energy Buildings



Residential Energy Storage



Residential Energy Storage



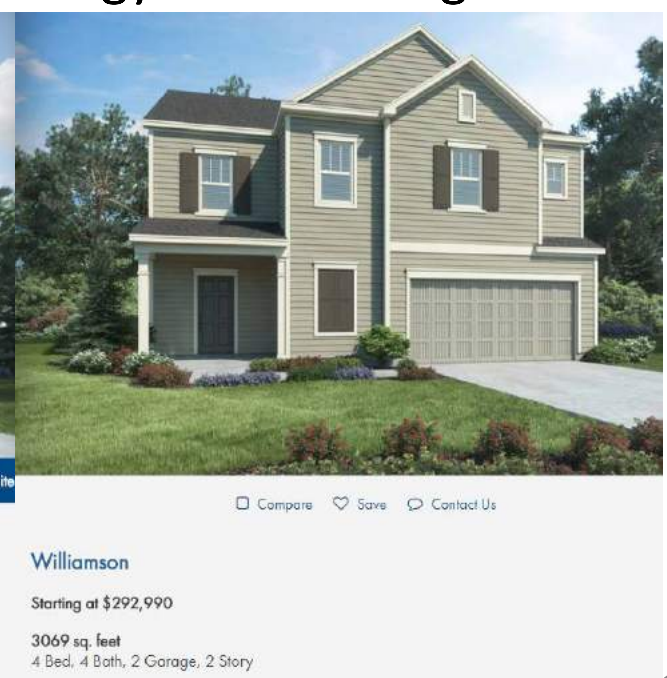
Summary of Energy Storage Impacts

	No ES		Self Consumption		TOU Peak Reduction		TOU Tariff Optimization	
	T1	T2	T1	T2	T1	T2	T1	T2
Peak kW	87.7	70	85.6	63.3	87.7	63.3	110	114
Rating (kW)	75	50	75	50	75	50	75	50
% of Nameplate	117%	140%	114%	127%	117%	127%	147%	228%

- Due to electrification of all loads, coincident usage/peaks of appliances become a larger issue
- Typical transformers are built to be overloaded for short durations, but shortens overall life span
- In this study the most economical dispatch of energy storage for the customer also caused the greatest transformer overload due to coordination of charging
- Large penetrations of energy storage can cause problems under a TOU rate
- Load control of A/C and water heater to keep them from being coincident would go a long way in reducing peak power demands

Future ZNE Research

- Community located West of Charlotte near Charlotte Premium Outlets
- Modeling Bradley, Chesterfield and Williamson elevations for load profile and solar sizing in BEopt
- Homes will utilize different combinations of high thermal mass, energy storage, solar, phase change material and other energy efficiency measures to determine impact on load profile and required changes to distribution planning paradigm
- Measure load shapes and customer operation with baseline non-ZNE homes
- Test ZNE homes for providing grid services such as energy time shifting



ZNE Simulation

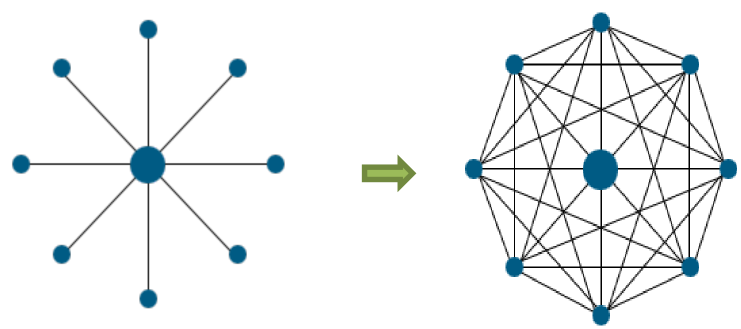
- How can we address the potential impacts of these new load shapes in simulation?
- How do we create a win-win relationship between customers and utilities by adjusting their load shape for optimal comfort and cost?
- How do utilities optimize BTM loads and generation to lower costs for all customers?

Distributed Intelligence

- **Distributed Intelligence (DI) is an architecture that supports building layered intelligence on the grid**
  - DI can occur at many locations, including the headend, node, and grid edge.
  - It is a method of optimizing the location a decision is made based on primary needs – sensitivity, timeframe, system updates. It dramatically reduces the transportation of data.
- **What does DI look like?**

Communications and Controls

Today **Future**



DI represents an opportunity to proactively and efficiently manage grid operations on distribution circuit segments to account for growing DER and microgrid activities

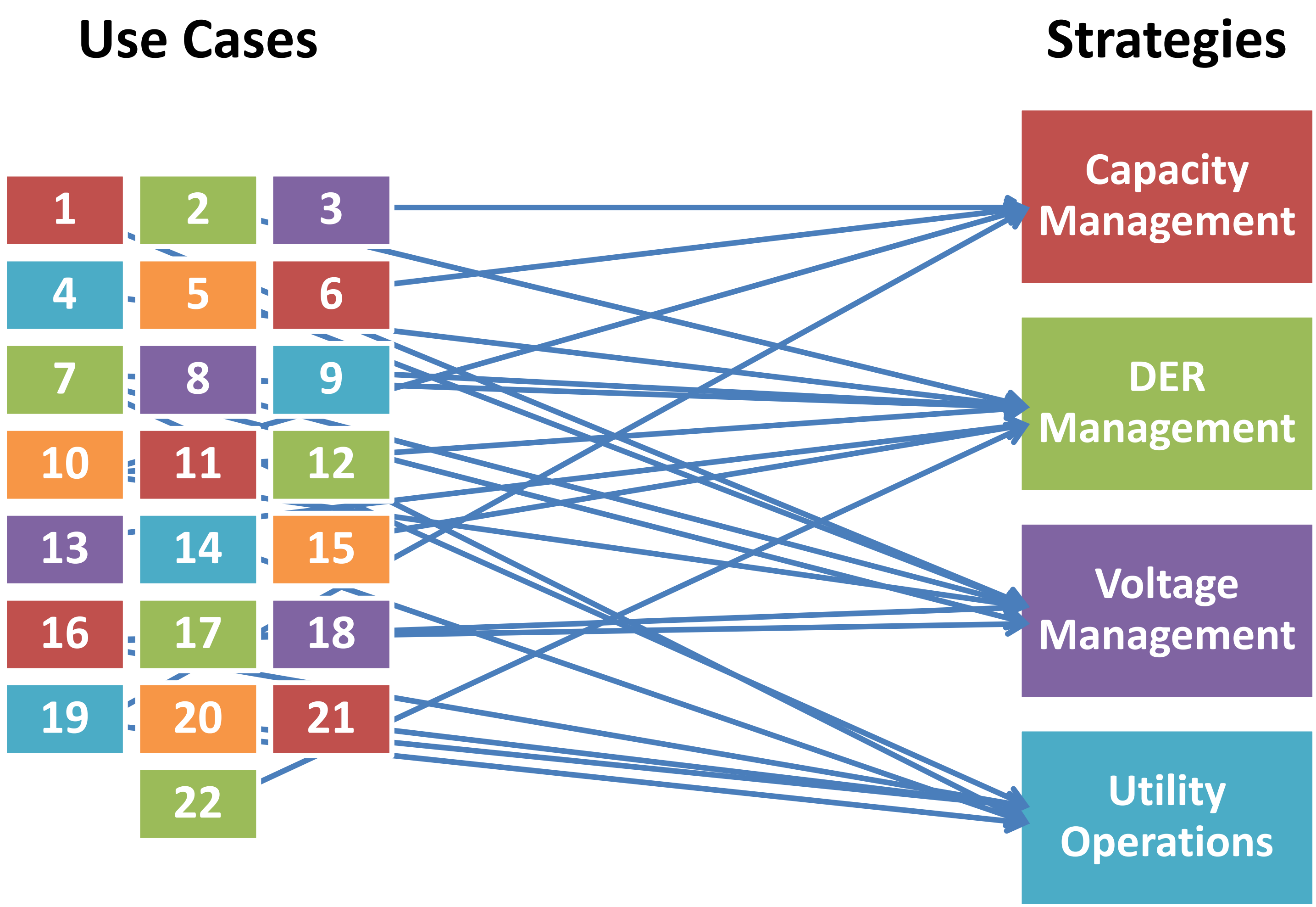
Traditional Approach

Conventional deployed assets support a single use case and outcome

Use Cases		Strategies
DER Circuit Segment Management	→	Capacity Management
DER Forecasting	→	DER Management
Volt-Var Management	→	Voltage Management
Remote Device Configuration	→	Utility Operations

Proposed Approach

Distributed Intelligence (DI) deployed assets support multiple use cases and outcomes leading to stacked benefits



Distributed Intelligence Functions/Use Cases for DER Integration

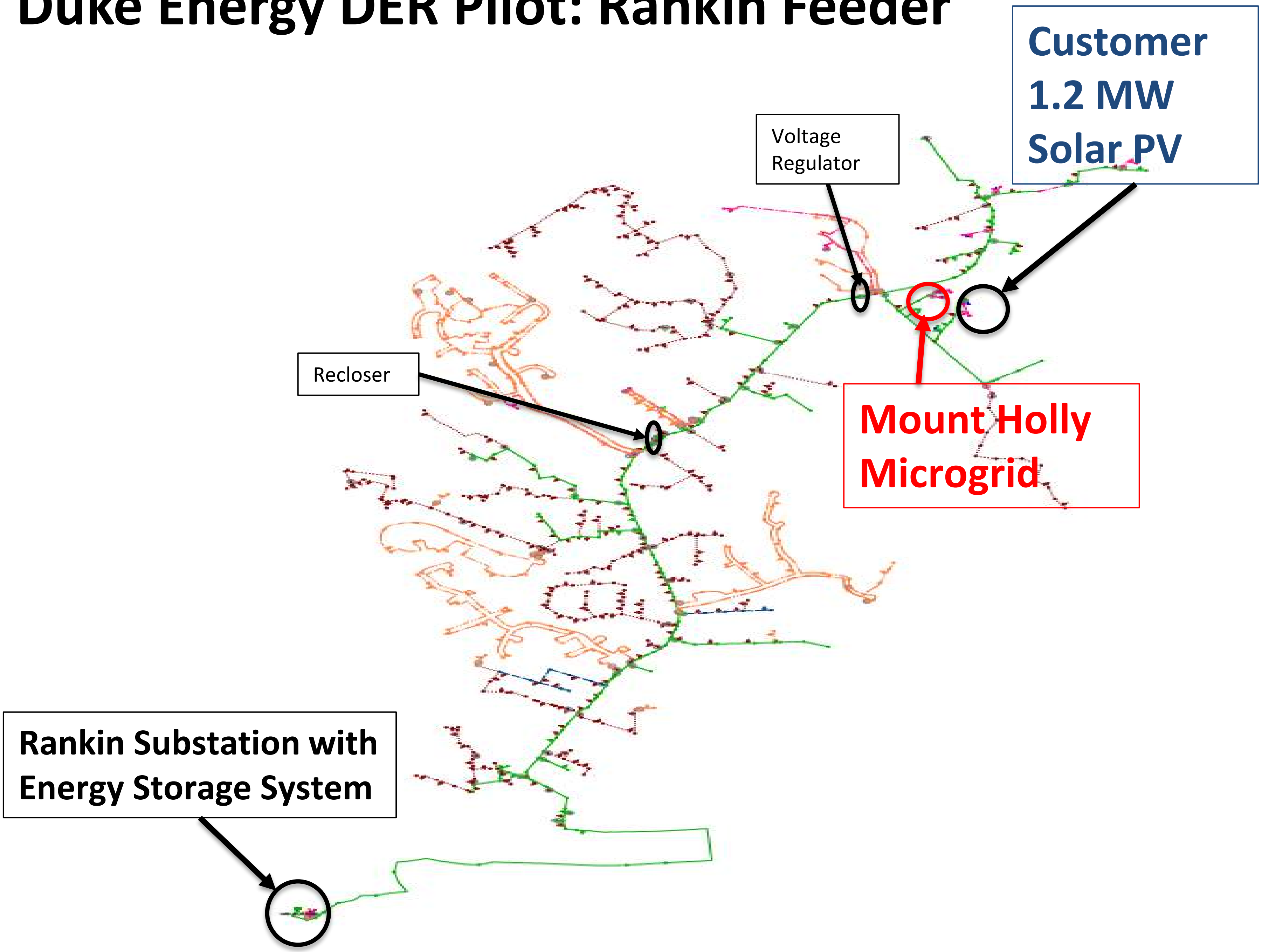
Function	Use Case
Voltage Management and Optimization	***1. DER Circuit Segment Management***
	2. Volt/VAR Management
	3. Solar Smoothing with PV, Advanced Inverter, & Energy Storage
Planning and Engineering	DER Integration and Interconnection
Capacity Management and Optimization	DER Optimization with Utility-Owned Inverter
	DER Optimization with Customer-Owned Inverter
	Demand Response Optimization
	DER Forecasting
Microgrid Management and Optimization	PCC Management of Utility-Owned Microgrid
	PCC Management of Customer-Owned Microgrid
Protection and Safety	Inadvertent Island Detection / Anti-islanding
	Localized Protection Alarms and Events
	Adaptive Protection
Operational Performance Improvement	Remote Device Configuration
	SCADA Point Aggregation
Resiliency & Reliability Improvement	Self Healing-Network, Radial

Foundational for Distributed Coordination (use cases 1–3)

Distributed Intelligence Opportunities

- Enhanced use cases over conventional, centralized approaches:
  - Voltage regulation, Volt/Var optimization
  - Frequency Regulation
  - Smoothing/firming capability
  - Circuit segment management (feeder management)
- Upgraded communications
- Upgraded security (root of trust)
- Time synchronization for DER asset coordination
- Can address protection limitations in today’s IEDs (2-way flow)

Duke Energy DER Pilot: Rankin Feeder



Rankin Substation Energy Storage

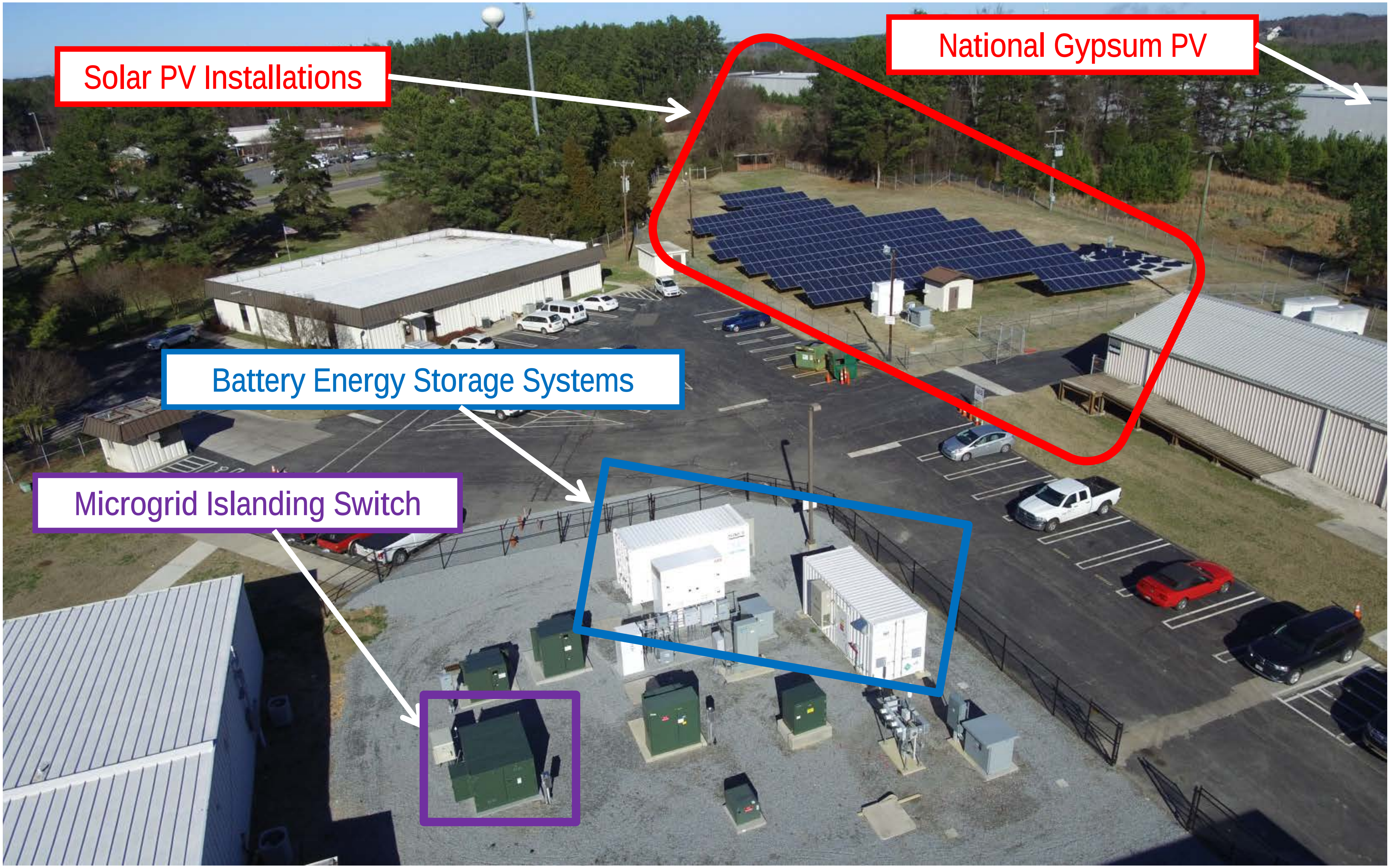
Aquion Battery Container

50 kW / 300 kWh aqueous hybrid-ion battery.

Ultra Caps/Inverter/Controls

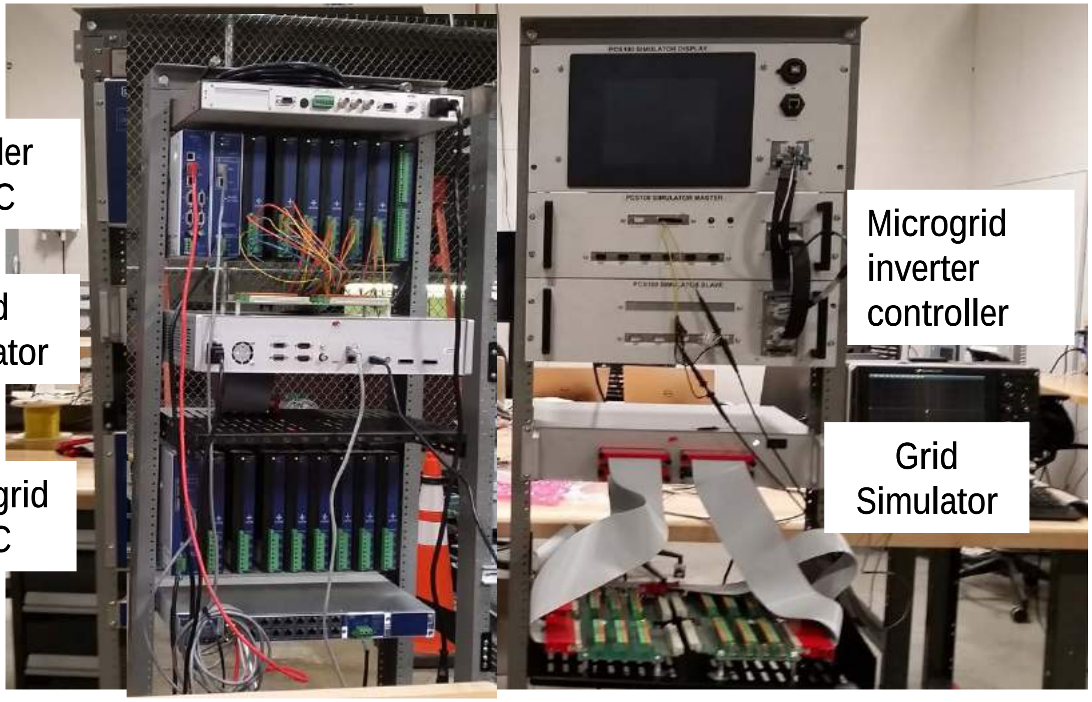
DC Bus integration of 250 kW Ultra Caps and Aquion battery. Also contains EMS, DC/DC converter and Inverter.

Duke Energy Microgrid Test Site: Mount Holly, NC



Mount Holly Hardware-in-the-Loop (HIL) Simulation Test Harness

DUKE ENERGY.

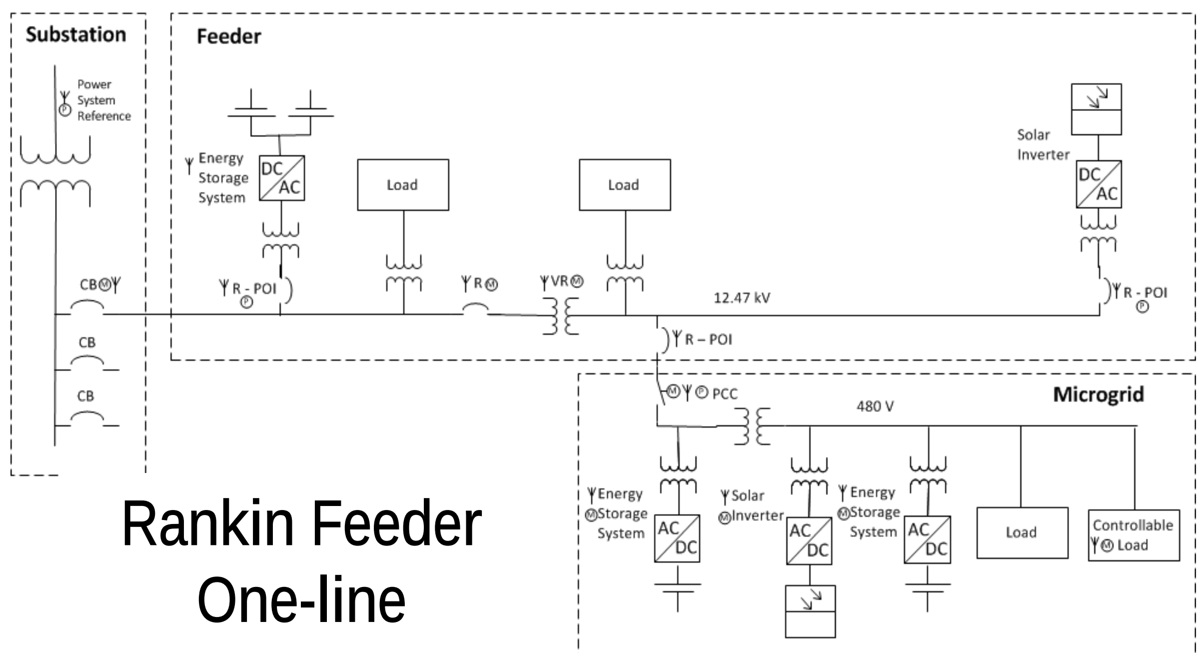


Conventional Simulator Solutions

- Prior work with UNCC leveraging their Real-time Data Simulator (RTDS) , OpalRT, and OpenDSS solutions.
- Steady-state simulation validated with CYME and Rankin measurements.
- Precision (>10us) and scaling (requires multiple racks) of existing simulation solutions was insufficient for full Feeder with dynamic power electronics needed for seamless microgrid islanding.

Benefits of Simulator Solution

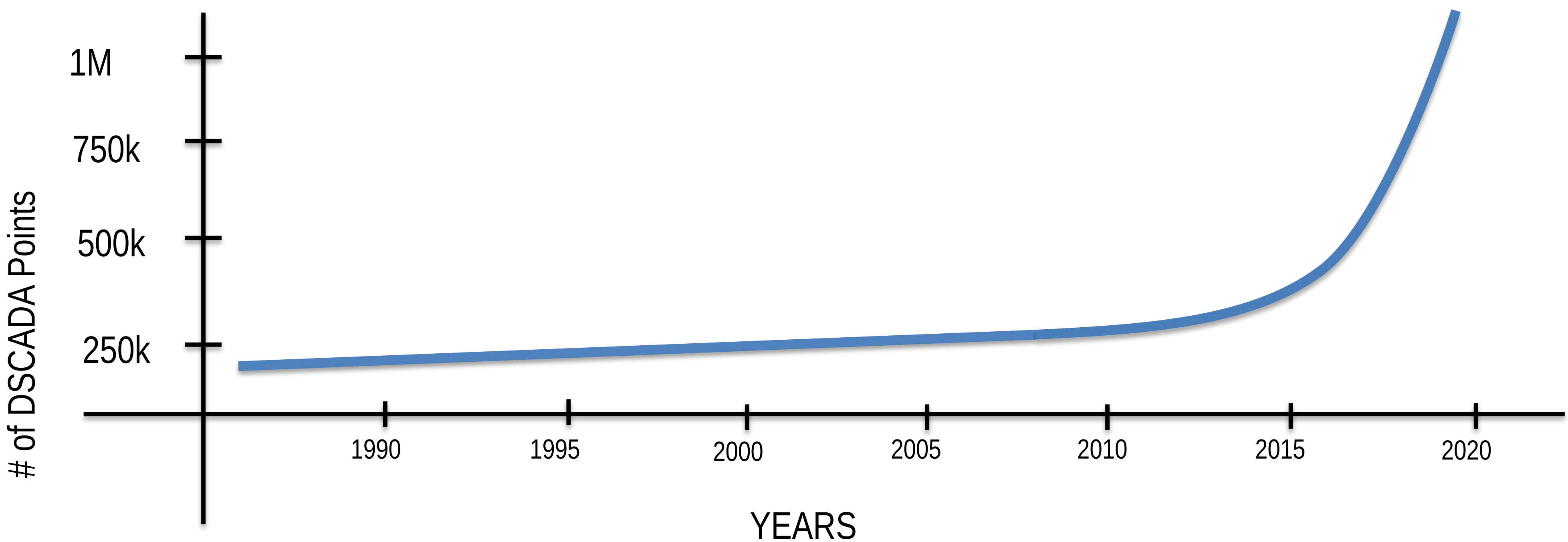
- New TyphoonHIL simulator scales much better (1 box for full feeder) with high precision (<5us) simulation steps
- Agile power electronics simulator modeling tools for tuning of actual vendor hardware
- Supports seamless microgrid islanding
- Easy virtual user interface with complete library of power system assets and DERs.
- Compatible with OpenFMB DI use-cases



Rankin Feeder One-line

What Gaps Need to be Addressed?

- Interoperability between field devices to allow seamless M2M data exchange in the field
- New business and regulatory models to address influx of new technologies and life cycle issues
- Refine planning and system dispatch modelling
- Distributed intelligence with cyber security measures on the edge
- Training and retaining a workforce with a new set of required skills
- Data analytics to parse disparate data sources
- New ways of reaching the customer to provide the products and services that customers want



One Model to Rule Them All

- Integrated model for:
  - Communications (ns-3)
  - Cyber security
  - Protection and Control (CYME, ASPEN, CAPE)
  - Steady state and transient power flow (PSSE, Gridlab-D, CYME, OpenDSS)
  - Building and home energy models (BeOpt, DOE-2, EnergyPlus)
  - Rate Structure and Behavioral Models

Questions?