# Microgrids Benefits and Opportunities

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# Overview



- Overview of DOE Microgrid R&D Program
- Microgrids as a Resiliency Resource
- Flexibility as a Resiliency Resource
- Project with Duke Energy on Flexibility as a Resource

# Overview of DOE Microgrid R&D Program



- A multi-laboratory program lead by Dan Ton, project manager DOE Office of Electricity.

- Three core technical areas:
  - Remote off-grid microgrids
  - Grid-connected single microgrids
  - Networked microgrids

- Two crosscut technical areas:
  - Resiliency tools for electric distribution systems
  - Microgrids standards and testing

# Overview of DOE Microgrid R&D Program Goals (From MYPP 2017-2021)



## Single Microgrids (<10MW)

- By 2020, develop commercial-scale singular microgrids capable of achieving the following:
  - > 98% reduction in outage time of critical loads at a cost comparable to non-integrated baseline solutions (such as an uninterruptable power supply [UPS] with backup generator),
  - > 20% reduction in emissions,
  - > 20% improvement in system energy efficiencies, and
  - Meeting individual community-defined objectives for electricity system resiliency.

## Networked Microgrids

- During extreme event outages, improve customer-level reliability and resilience by:
  - Extending duration of electrical service to critical loads by at least 25%;
  - Maintaining electrical service for all critical loads during a single generator contingency in any microgrid; and
  - Lowering capital expense by at least 15%.
- During normal distribution grid operations:
  - Reduce the utility cost of serving the microgrids by at least 10%.

# Microgrids as a Resiliency Resource



# Microgrids as a Resiliency Resource



- Microgrids are an effective tool to increase the resiliency of critical end-use loads.

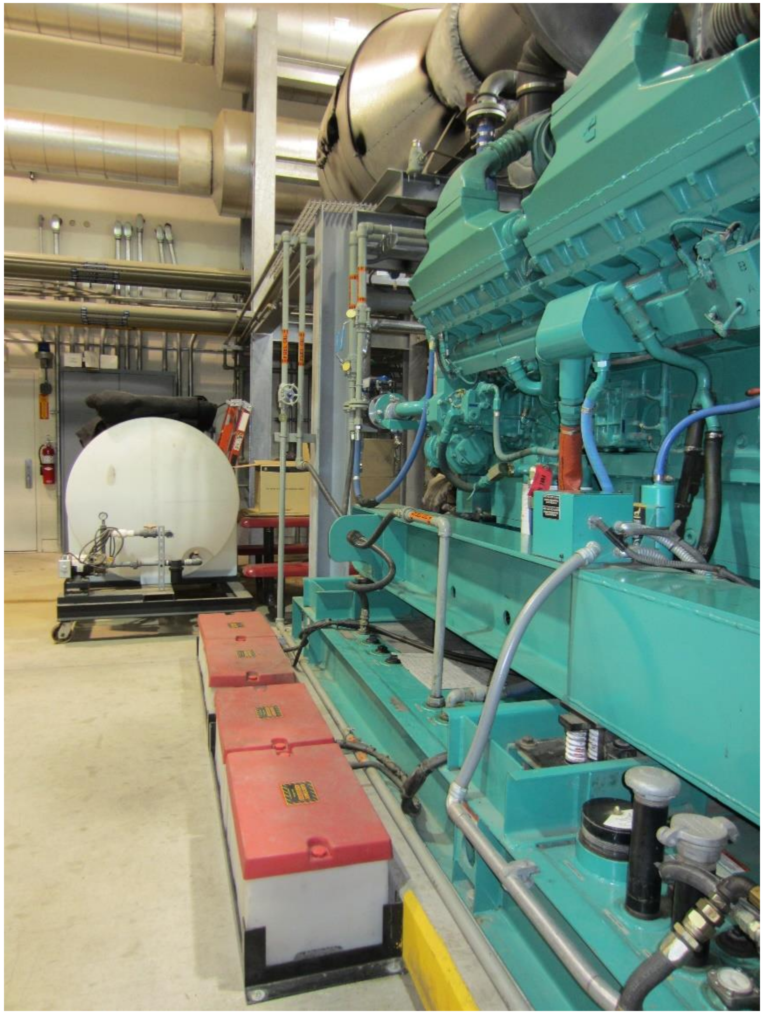
- The increasing number of distributed resources, and the advancements of control technologies, are making microgrids more cost effective.

- Operationally, an individual microgrid can serve in a number of roles:
  - **Customer Resource**: The traditional application of microgrids where only the local loads are supplied.
  - **Community Resource**: An extended application of microgrids where critical loads outside of the normal microgrids boundaries are supplied.
  - **Black Start Resource**: A new application where microgrids are used to support the auxiliary loads of a thermal plant that does not have native black start capabilities.

# Microgrids as a Local Resource



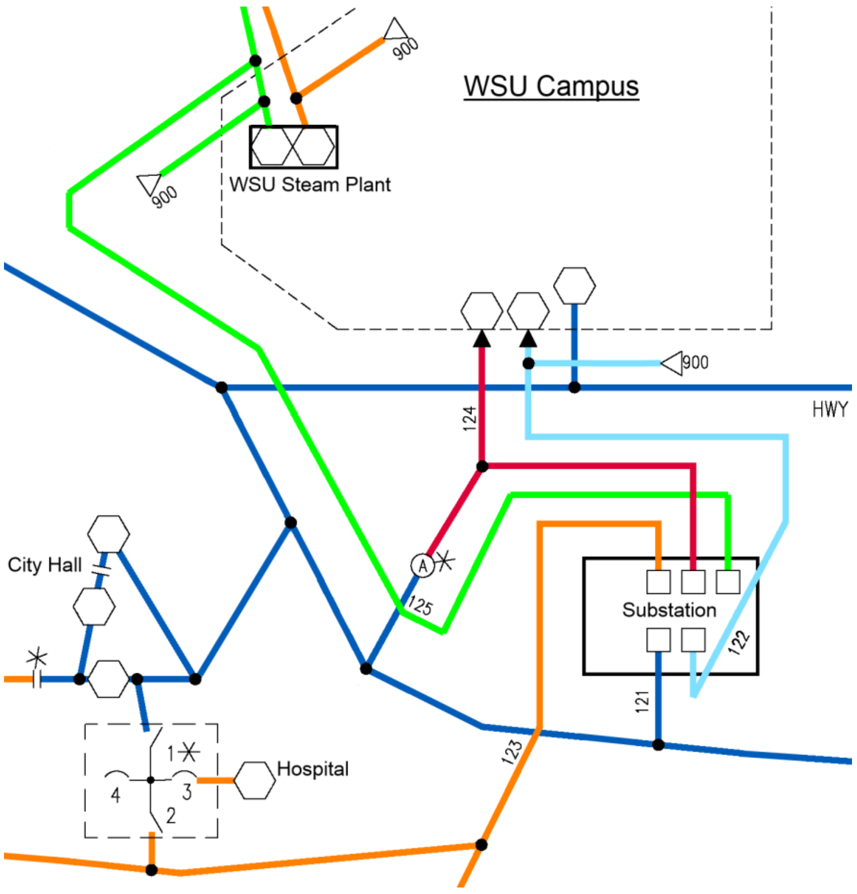
- Microgrids can either be isolated, or have the ability to connect to a bulk power system.
- When normally grid connected, microgrids have proven to be more effective than traditional backup generators during extreme events.
- Often there are significant renewable resources to offset fuel consumption.
- The most common grid-connected microgrids include:
  - Campus-type microgrids: behind the meter facility such as universities, military bases, and industrial facilities
  - Utility-owned microgrids: includes portions of the primary distribution system



# Microgrids as a Community Resource



- In addition to the ability to improve the survivability of distribution systems, microgrids can support recovery and restoration.
- A use-case was developed where the Washington State University (WSU) generation assets, and fuel supply, were interconnected with the Pullman Hospital and City Hall to form a community microgrid.
- This use-case examined how microgrids could operate in an extreme regional disaster, such as an earthquake, where the bulk power system is unavailable for weeks or months.
- This concept can be applied to any microgrid that supplies load outside of its original "fence line".



# Microgrids as a Black Start Resource



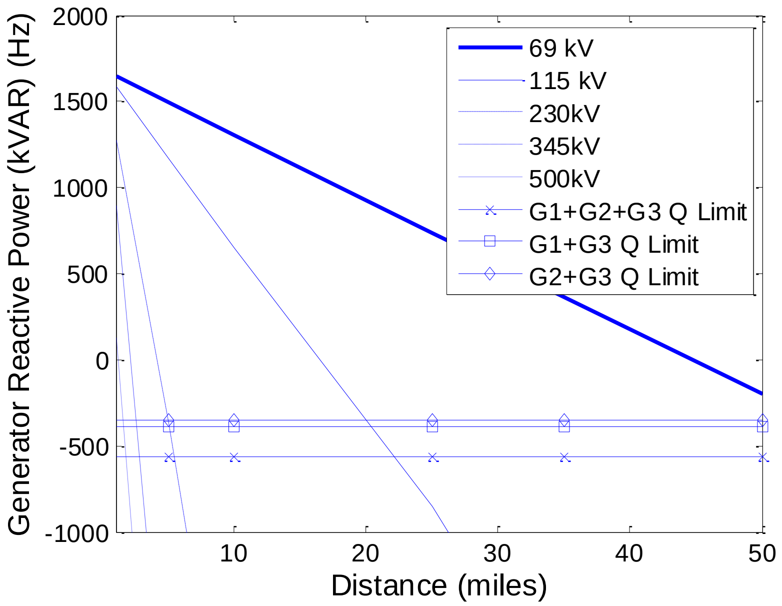
- Microgrids generally do not have the capacity to actively participate in the restoration of the transmission system.

- Microgrids with sufficient generation can support restoration by providing black start support to larger generating units.
  - Power for condensate and feed pumps
  - Power for air handlers

- This could involve energizing large portions of de-energized lines to reach the generation unit(s). This may include sub-transmission lines and their transformers.

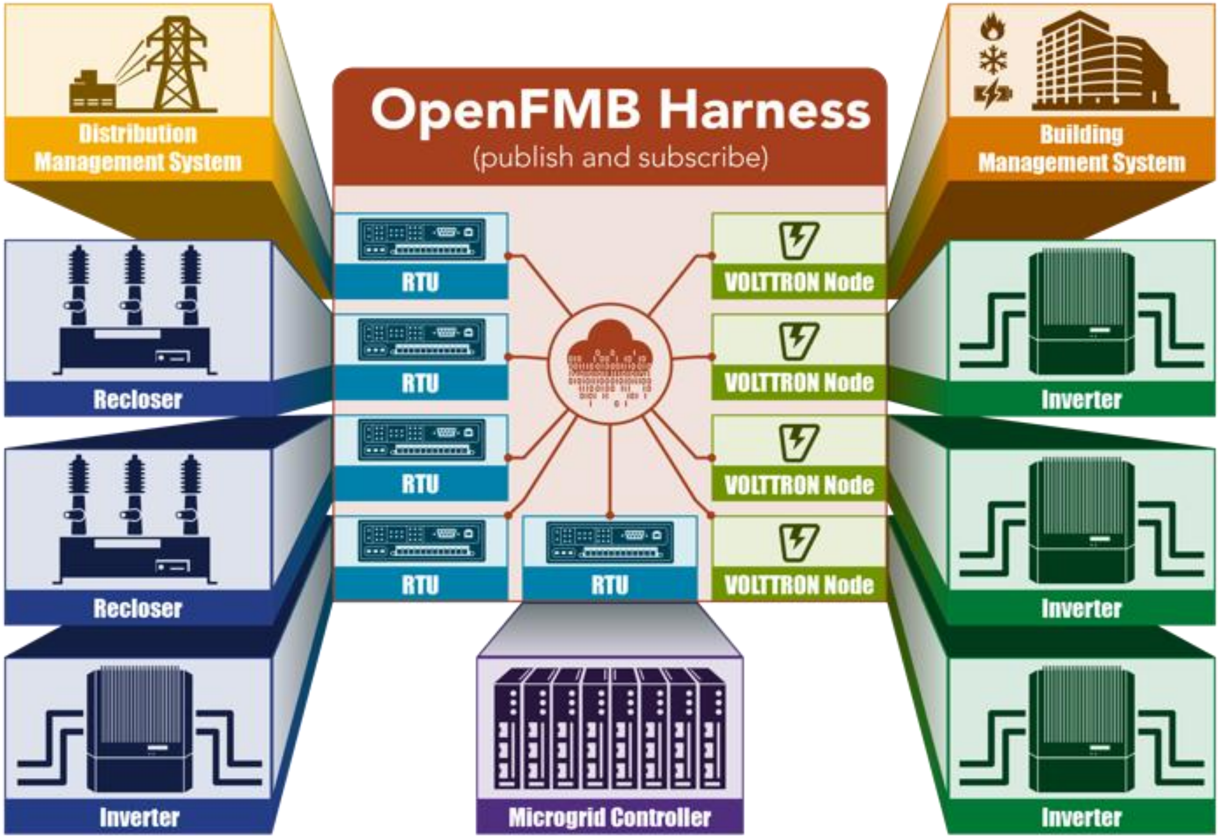
- Energization in-rush and reactive power absorption associated with charging larger transformers and high-voltage lines is the primary operational limitation.

- This type of procedure would need to be directed by the utility as part of a larger restoration plan.



# Flexibility as a Resiliency Resource





# Flexibility as a Resiliency Resource



- The nation’s electric power infrastructure is facing an increasing array of operational challenges. Increasing major storm events, cyber-security concerns, the interconnection of non-utility assets, and an increasing level of complexity is making it difficult for utilities to maintain a business-as-usual approach.

- Additionally, an increase in the scope and impact of events is requiring a re-evaluation of reliability, and how to evaluate resiliency.
  - Reliability: the ability to deliver electricity in the quantity, with the quality, that is expected by end-users. The Reliability of an electric power system is often tracked with IEEE std. 1366-2012 statistics.
  - Resiliency: the ability of the electricity infrastructure to prepare for, respond to, and recover from a major event. There is no common set of metrics for evaluating resiliency.

- Due to the wide-range of potential threats to normal operation, it is necessary to deploy systems that can adaptively respond, and not be fixed to a single set of responses.

- The U.S. Department of Energy Office of Electricity (DOE-OE), in collaboration with the Grid Modernization Laboratory Consortium (GMLC), has a number of research efforts to improve infrastructure resiliency.

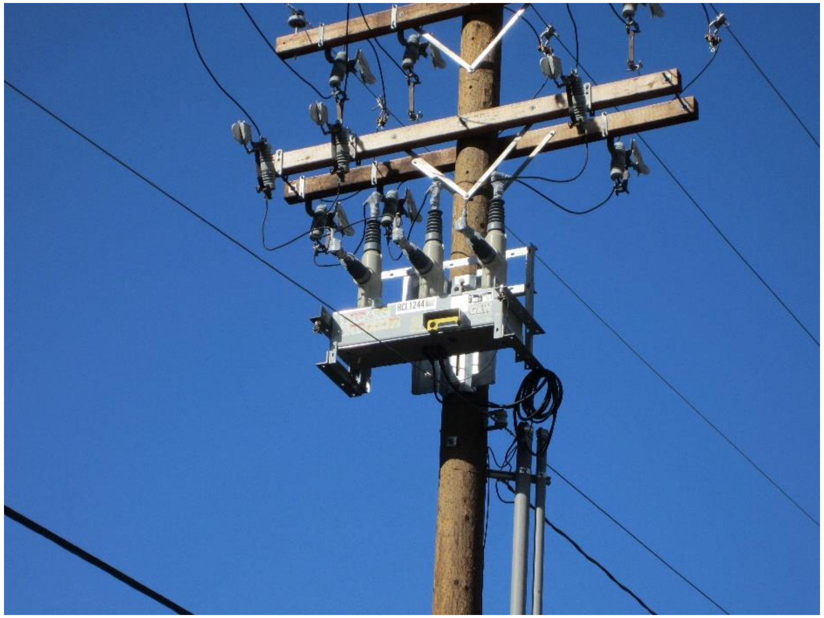
# Increasing the Flexibility of Utility Assets



# Flexibility of Existing Utility Assets

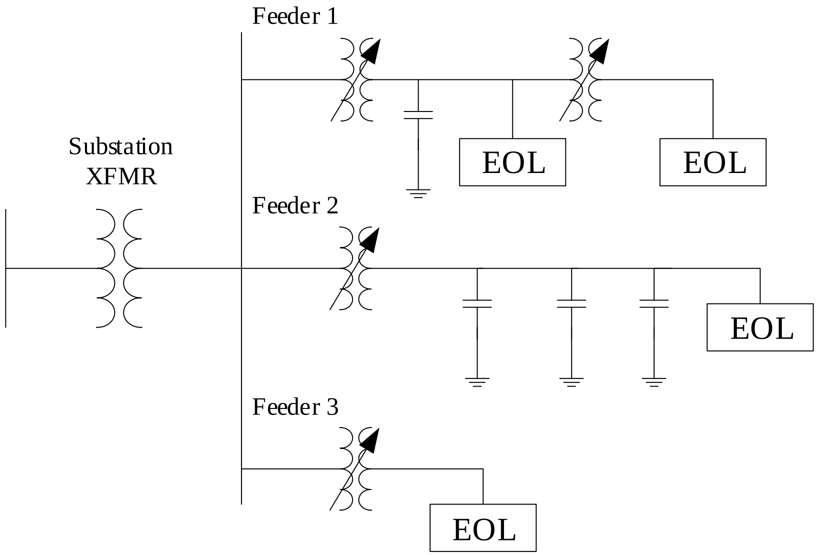


- Distribution systems prior to the 1980's had little-to-no visibility or control.
- As Distribution Automation (DA) became more common, systems were deployed to address specific operational objectives.
- In general, these systems worked well to address a single issue or set of conditions, but were not designed to operate outside of predetermined parameters.
- Newer, more advanced systems are becoming more flexible.
  - Voltage optimization
  - Networked microgrids
  - Advanced DMS



# Volt-VAR Optimization (VVO)

- A modern VVO system engages voltage regulators, shunt capacitors, and end-of-line (EOL) measurements. Advanced systems can engage other assets.
- The VVO system centrally operates distributed devices to achieve a number of operational goals. These can include:
  - Reduction of annual energy consumption
  - Reduced peak demand
  - Management of reactive power
- This is an example of engaging devices that historically served only one function, voltage regulation, and leveraging them for other uses to generate additional benefits.




# Advanced Distribution Management Systems

- Advanced Distribution Management Systems (ADMS) go by a number of names, but with a common philosophy.
- The integration of traditionally siloed operational systems to increase capabilities, and to decrease costs.
- The operational systems can include: DMS, EMS, OMS, SCADA, AMI, GIS, and many others.
- Common elements include:
  - Standardization and interoperability
  - Use of a common data structure/format across the various systems
  - Extensibility and flexibility

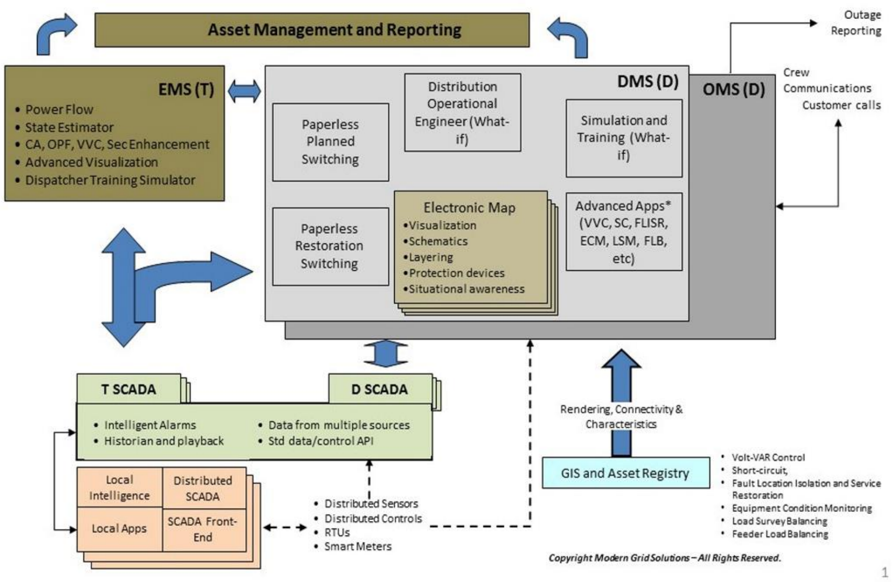



figure provided by Modern Grid Solutions

# Engaging Non-Utility Assets as a Resource




# Addressing the Need for *Grid Flexibility* from Distributed Assets: Transactive Grid Systems

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## The Problem:

- Generation is rapidly shifting from centralized to more distributed forms, and from being entirely dispatchable to significantly intermittent and stochastic.
- Operating such a grid with the reliability and affordability society demands will require new forms and vastly increased amounts of *operational flexibility.*


## The Opportunity:

- To provide this flexibility at reasonable cost, much of it is expected to be derived from distributed energy resources (DERs): responsive loads, electrical & thermal storage, smart inverters, electric vehicle chargers, etc.

## The Challenge:

- How can we coordinate DERs to provide grid services when they are neither owned nor controlled by the power grid operator?
- *Transactive grid systems* coordinate DERs through transparent, competitive means using real-time transactions involving prices or incentives to provide the feedback to close the "control" loop.

# Increasing Distribution System Resiliency using Flexible DER and Microgrid Assets Enabled by OpenFMB

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- This project is part of the DOE Grid Modernization Laboratory Consortium (GMLC).
- The objective of the project is to accelerate the deployment of resilient and secure distribution concepts through the flexible operation of traditional assets, DERs, and Microgrids.
- The central theme of the project is increasing the flexibility of distribution assets, to address the uncertainties of operations:
  - Short term: variability of load and DERs
  - Mid term: extreme weather events
  - Long term: planning time-frame

## Project Team

- PNNL – Kevin Schneider
- ORNL – Mark Buckner
- NREL – Murali Baggu
- Duke Energy – Stuart Laval
- UNC Charlotte – Madhav Manjrekar
- University of Tennessee – Yilu Liu
- Smart Electric Power Alliance (SEPA) – Aaron Smallwood
- GE Grid Solutions – Avnaesh Jayantilal

**Industry Advisory Board Members**

- Entergy – Cat Wong
- Avista – Curt Kirkeby
- APS – Ivan Aguilar
- North America Energy Standards Board (NAESB) – Elizabeth Mallet

# Technical Approach

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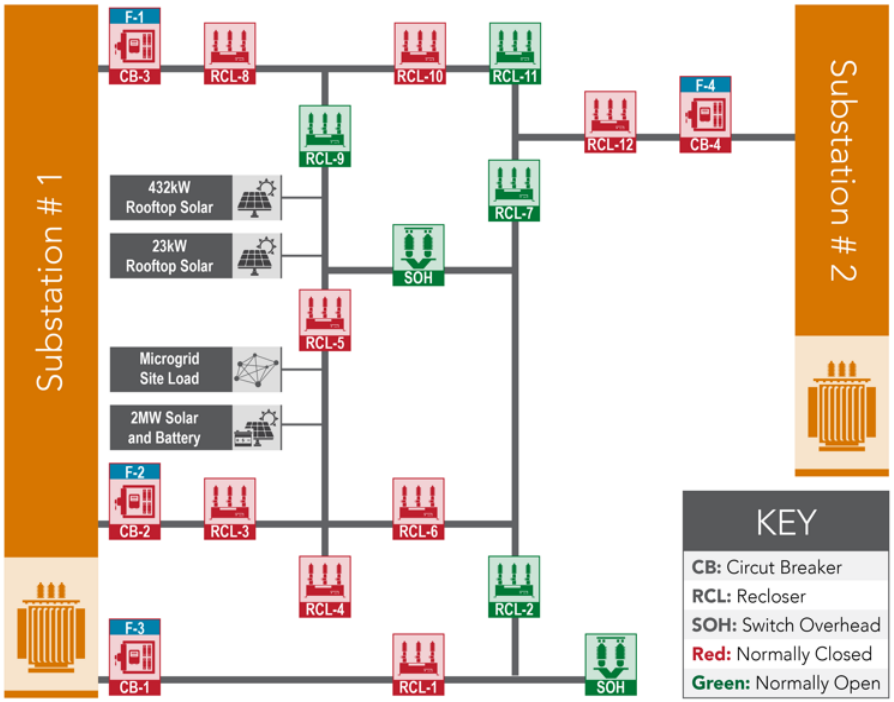
- The key technical approach to this project is to engage the greatest number of assets, utility and non-utility, using an architecture that enables flexible operations. This moves away from the traditional "one device, one function" mentality.

- Utility-owned assets
  - Controlled using a hierarchical OpenFMB-based control system
  - Operated using a "segment-based" approach which reduces fixed boundaries and enables flexible operating strategies

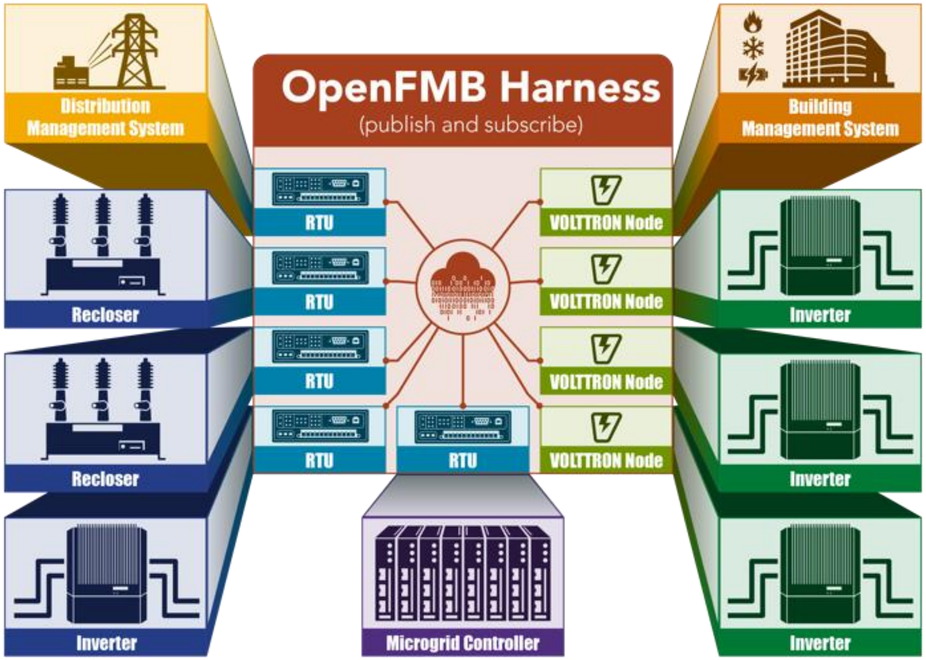
- Non-utility-owned assets
  - Engaged using an incentive signal using VOLTTRON agents
  - Can include distributed generation and end-use loads
  - Provide a range of resources based on current system conditions
  - Customers retain choice in that they are not required to participate



# Laminar Control Architecture



- A laminar control architecture is implemented to coordinate the system:
  - Layer 1: Local recloser fault isolation
  - Layer 2: OpenFMB communications for protection coordination
  - Layer 3: Centralized self-healing scheme
  - Layer 4: Distributed transactive
- The laminar control allows for coordination of high-speed local operations, slower-speed centralized optimization, and the transactive signal.
- This architecture enables a flexible system that can be operated to increase resiliency, while actively engaging PV as a resource.



# Impact and Benefits of the Project



## Impact/Benefits to Duke Energy

- **Short-term**: The deployment of a self-healing system that is based on the flexible-segment operating concept, which is able to actively engage distributed assets, such as microgrids.
- **Mid-term**: Provide Duke Energy the ability to increase the number of high-PV-penetration locations where self-healing systems can be deployed, leading to a broader increase in distribution resiliency across their service territory.
- **Long-Term**: Provide Duke Energy a basis for integrating other resiliency-based multi-technology deployments within Duke Energy's service territory.

## Impact/Benefits to Nation

- **Short-term**: The project will provide a framework of how a resiliency-based system can be operated by engaging utility- and non-utility-owned assets. An increase in the resiliency of a single area within Duke Energy.
- **Mid-term**: The benefits of the work conducted in the project will be transitioned to other areas of Duke Energy, and to the utilities that are represented on the industry advisory board. An increase in resiliency across Duke Energy, and at utilities that are on the advisory board.
- **Long-term**: Through the industry advisory board, publications, and outreach activities, the work developed in the project will be transitioned to utilities across the nation. Broad increase in resiliency for the nation.

# Conclusions

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- Flexibility is essential for reliable, resilient, and efficient operations of a modern power system.
- Flexibility must exist at a number of time-frames:
  - Short term: variations in loads and DERs
  - Mid term: extreme events
  - Long term: planning time-frame
- To achieve flexibility, there are key requirements:
  - Integration
  - Interoperability
  - Extensibility