Beneficial Integration of PV, Energy Storage, and Controllable Loads

Sustainable and Holistic IntegratioN of Energy Storage and Solar PV (SHINES)

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The Right Combination: Solar, Storage, and Demand-Response Webinar
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SOLAR ENERGY TECHNOLOGIES OFFICE
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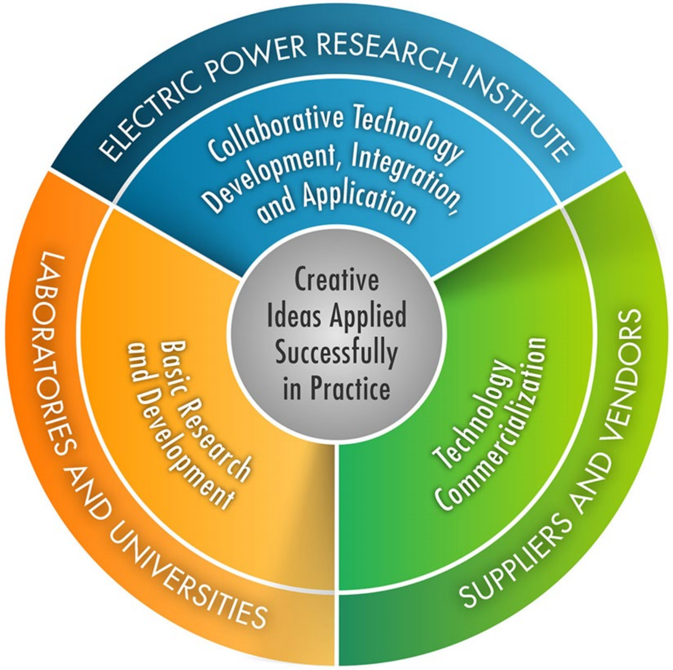
The Electric Power Research Institute, Inc. (EPRI, www.epri.com)

- Founded in 1972 as an independent, nonprofit center for public interest energy and environmental research
- 450+ participants in nearly 40 countries
- EPRI members represent 90% of the electricity generated in the United States



Independent
Objective, scientifically based results address reliability, efficiency, affordability, health, safety, and the environment

Nonprofit
Chartered to serve the public benefit

Collaborative
Bring together scientists, engineers, academic researchers, and industry experts

EPRI SHINES Project Team

Utility Partners

Host Utilities:
- FirstEnergy
- NYPA
- ConED
- Southern Co
- Gulf Power/NextEra

- LADWP
- AECC
- AEP
- Duke
- SMUD
- Gas Natural SDG
- CenterPoint Energy
- Saudi Electricity Company

University Partners

- Case Western Reserve University (CWRU)
- City University of NY (CUNY), Queens College

EPRI Research Programs

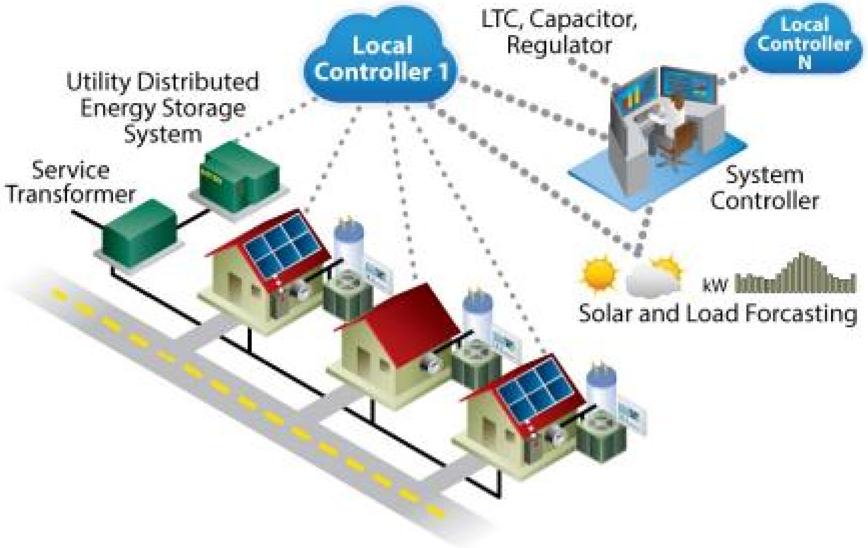
- Integration of DER
- Energy Storage and DG
- Customer Technologies
- Information and Communication
- Power System Studies
- Economic Analysis

Industry Partners

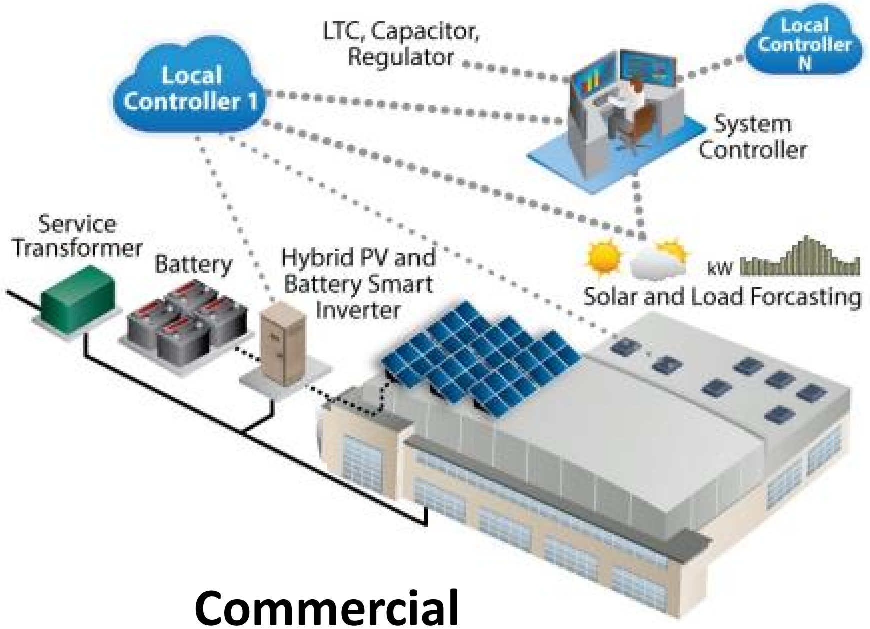
- Intwine Connect
- Clean Power Research
- Fermata Energy (PowerHub)
- LG Chem
- Eaton

Objectives

Beneficial Integration of solar photovoltaic generation, energy storage, load management, and advanced forecasting technique, with electric power delivery network through optimal control strategies at a minimized cost.



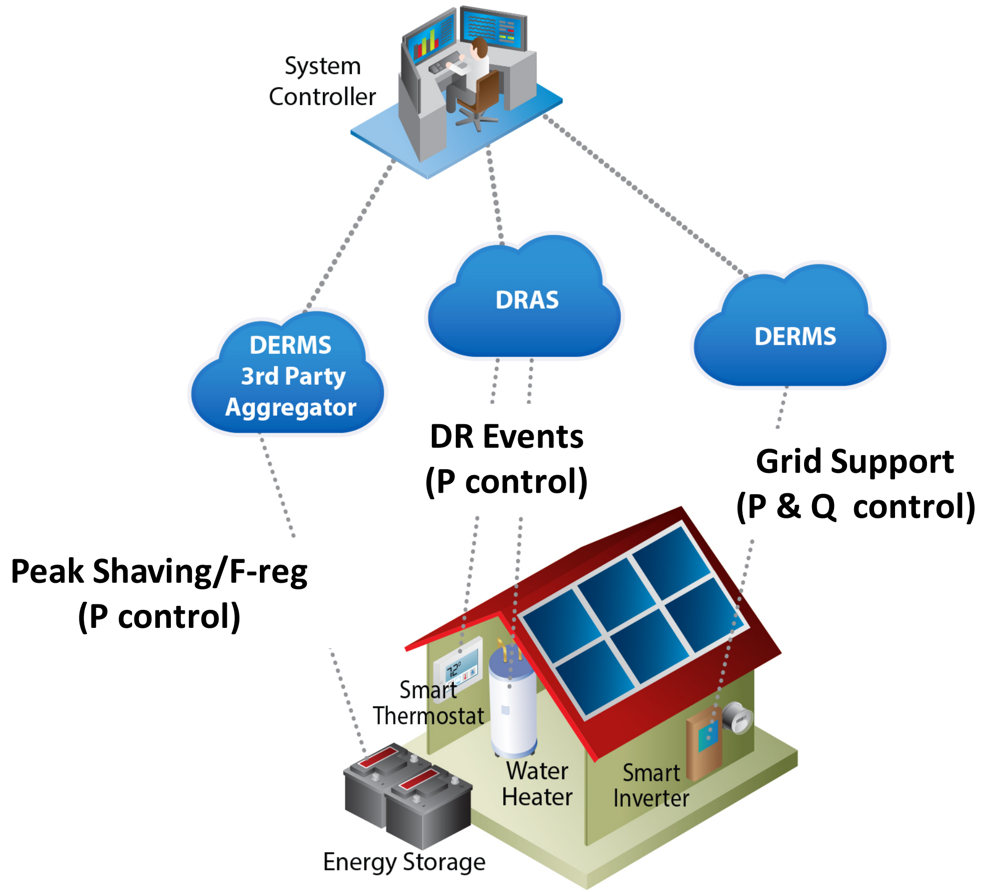
Residential



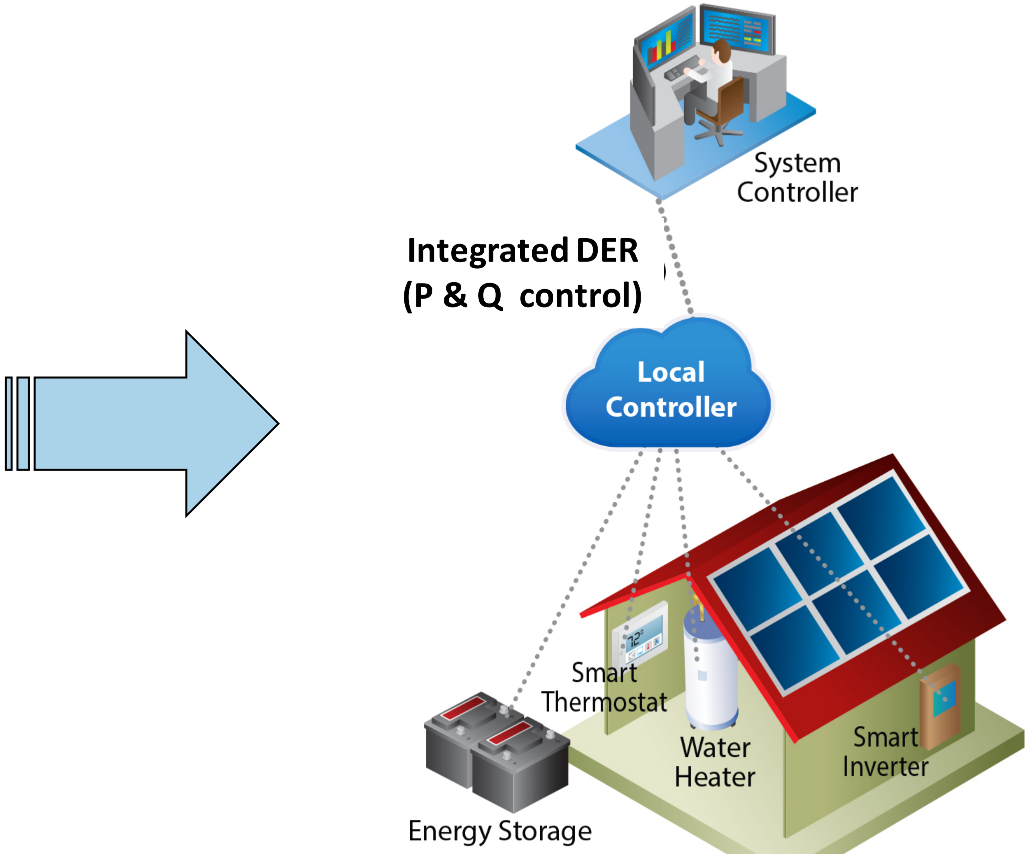
Commercial

Role of Local Control Optimization

Non-Wires Alternatives and Flexible Interconnection



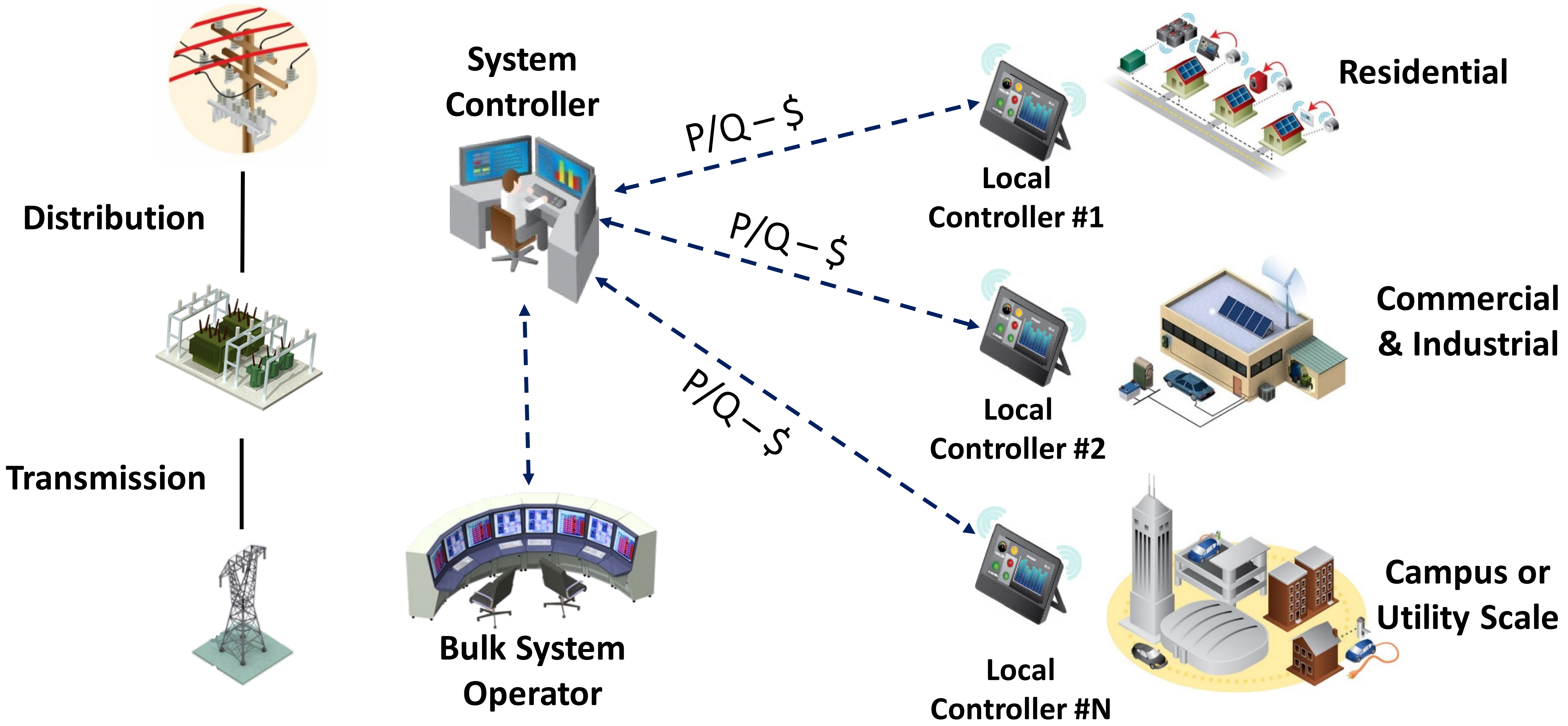
Often NWAs are offered for certain DER types and brands of product – ***narrower participation opportunity***



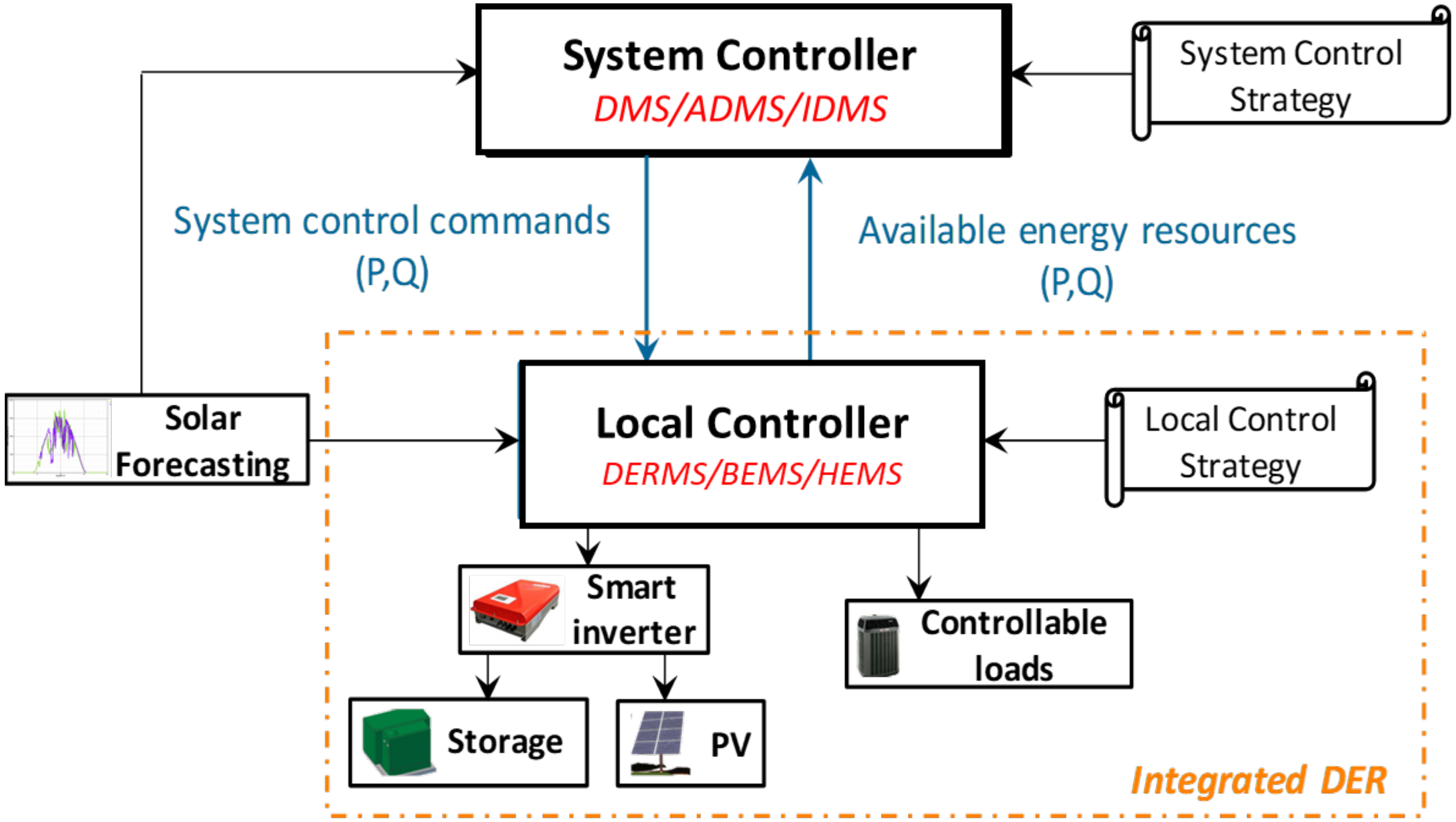
Grid services can be provided by a combination of variety of DERs managed together – ***broader participation opportunity***

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Integrating DER at Different Scale – Modular Approach



Local Controller to Maximize the Value of Integrated DER



- **Local controller** utilizes solar forecasting, real-time pricing information, and load models to maximize benefits for DER owner while responding to operational limits from system controller.
- **System controller** sends setpoints to local controllers and distribution system controllable equipment based on service and reliability needs identified.

Local Control Objective

Penalty Factors

MIN [price*(pwr imports) + A*(ES use) + B*(sys rqmts) + C*(comfort)]

Electricity bills are minimized.

DER contributing: PV, flexible loads

Violations of interconnection constraints are minimized.

DER contributing: PV, storage, flexible loads

Storage cycling is minimized.

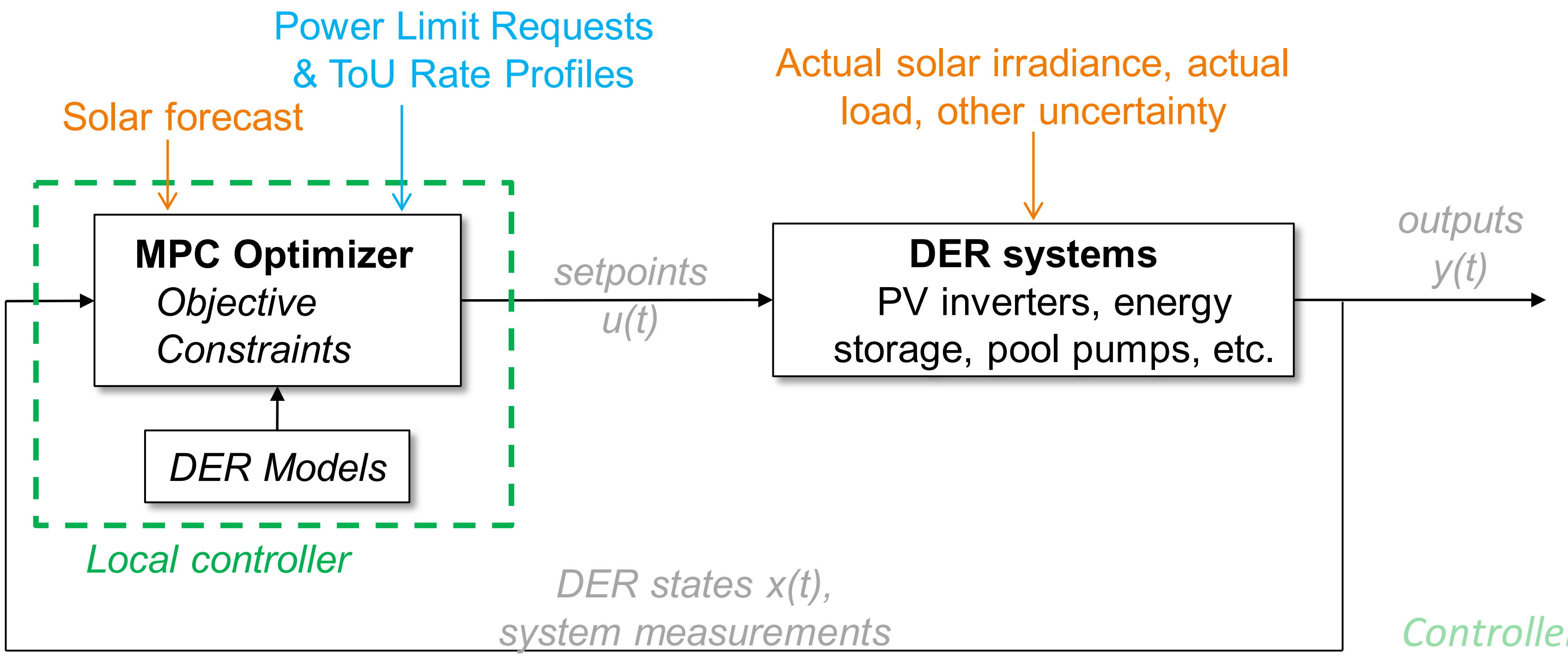
DER contributing: storage, flexible loads

Violations of customer comfort preferences are minimized.

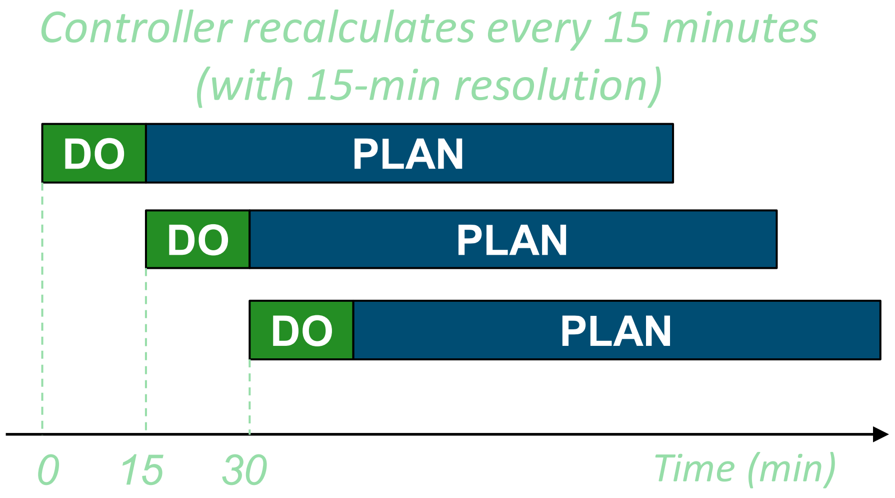
DER contributing: PV, storage, flexible loads

- Can change penalty factors of the control objective function to encourage or discourage certain behavior at the cost of others
  - *E.g., decrease battery use by increasing value of 'A'. This may cause system constraint violation.*

Model Predictive Control (MPC) Operational Strategy



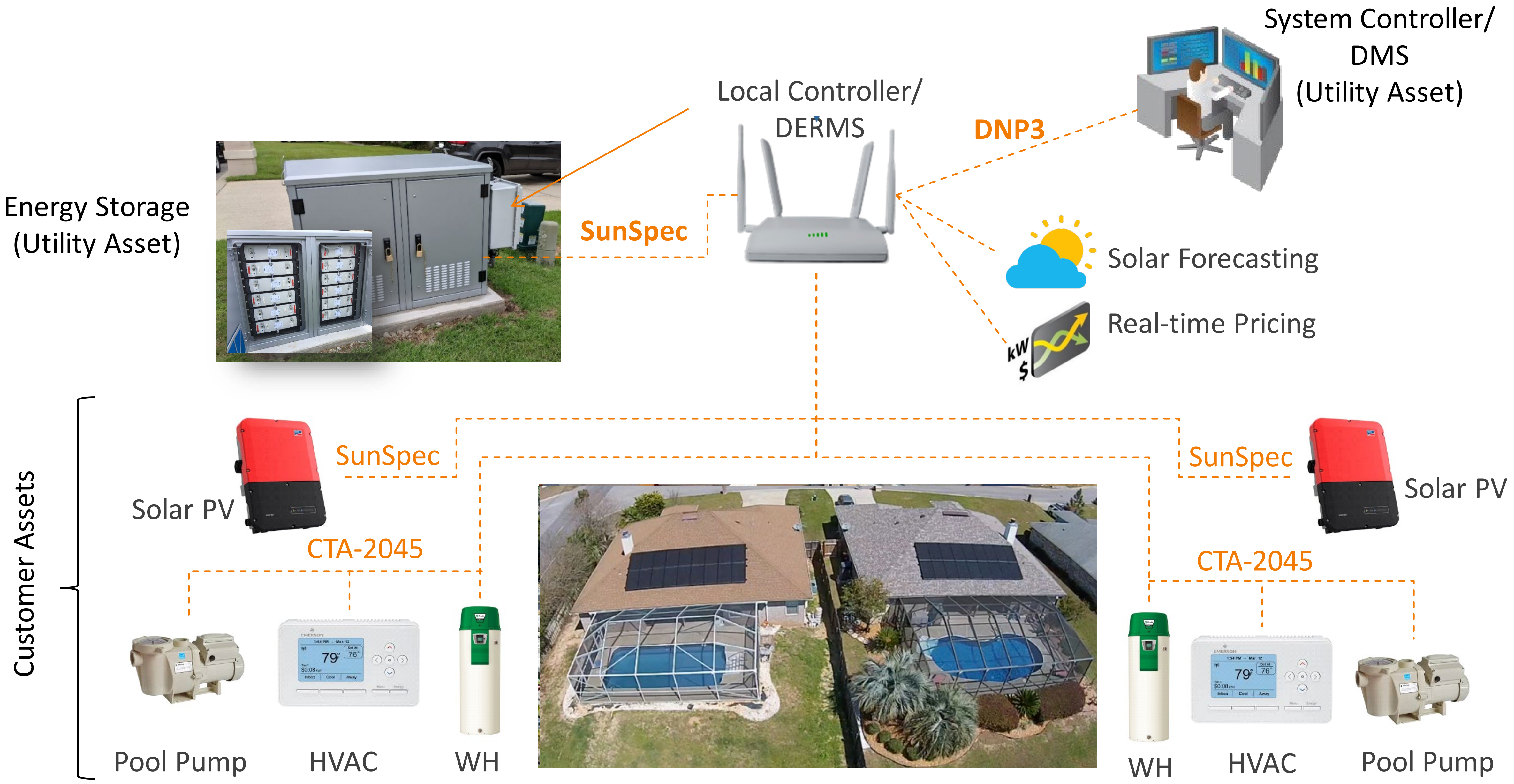
- Local controller utilizes **Model Predictive Control (MPC)** for **look-ahead control** of available DERs – 24hr planning horizon and 15min execution span



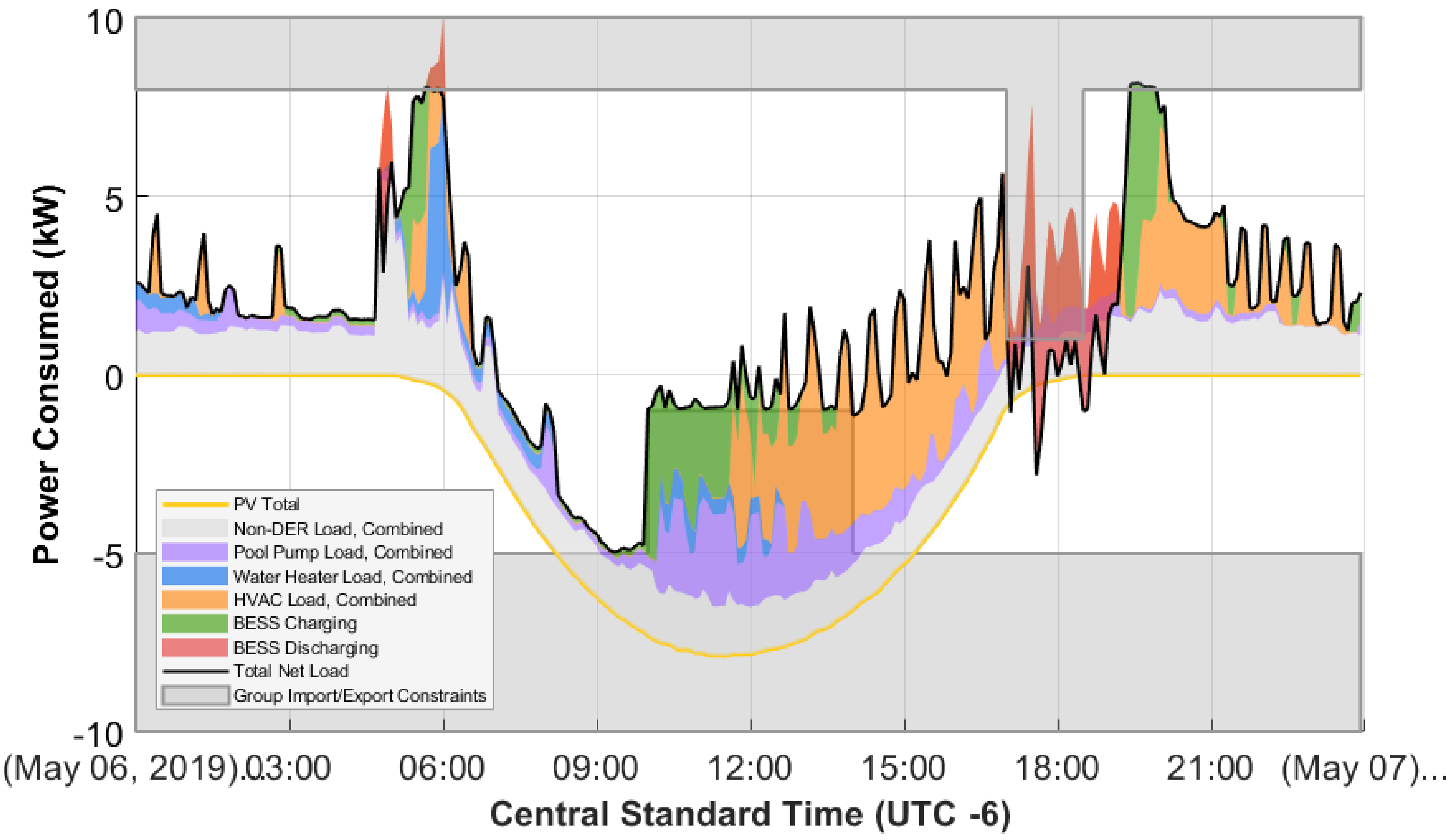
At each sample time:

1. Measure or estimate current state of load and other relevant variables
2. Find the optimal input sequence for the entire planning window
3. Implement the planned control action for the first time period only

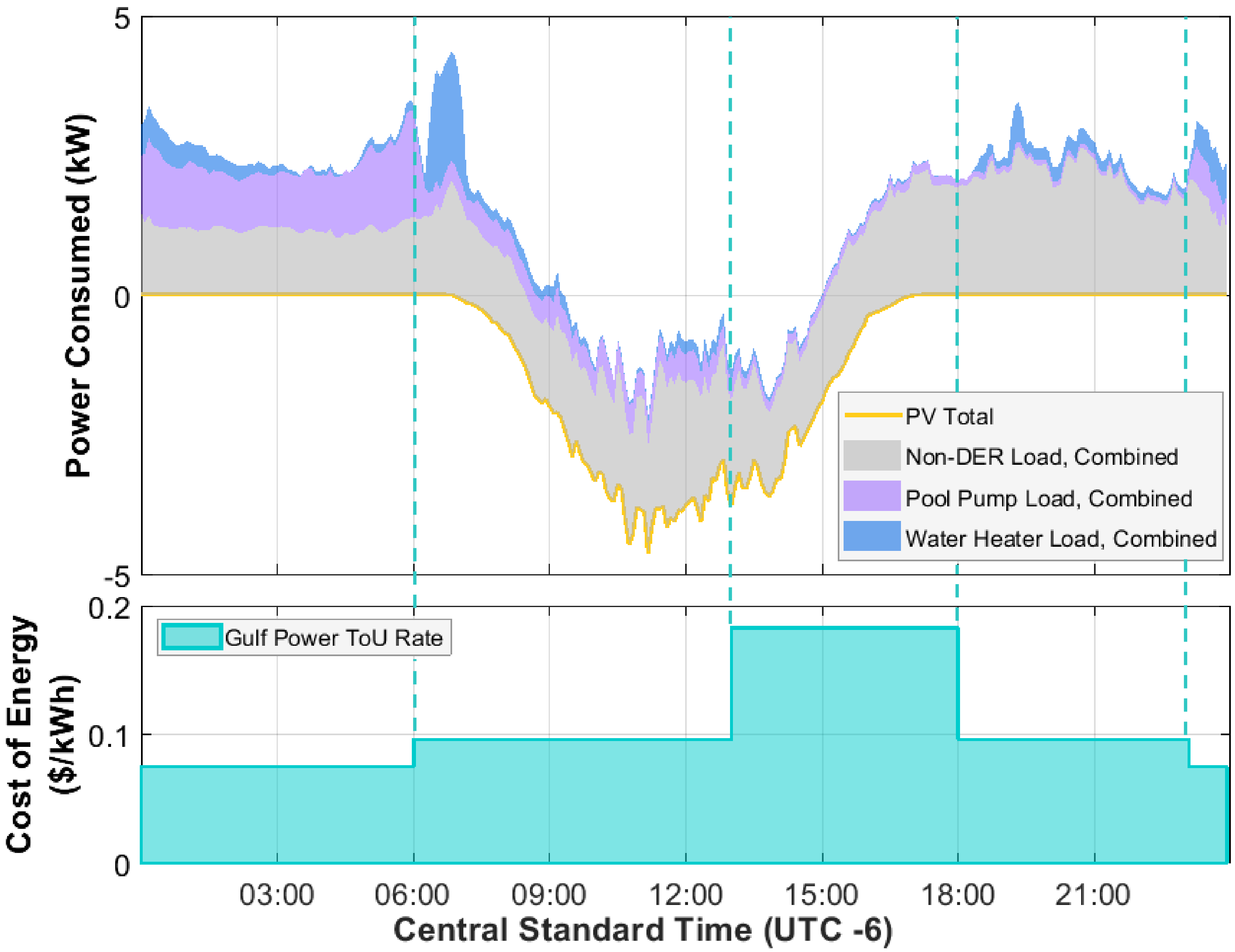
Field Deployment and Demonstration



Export & Import Constraints – Field Data



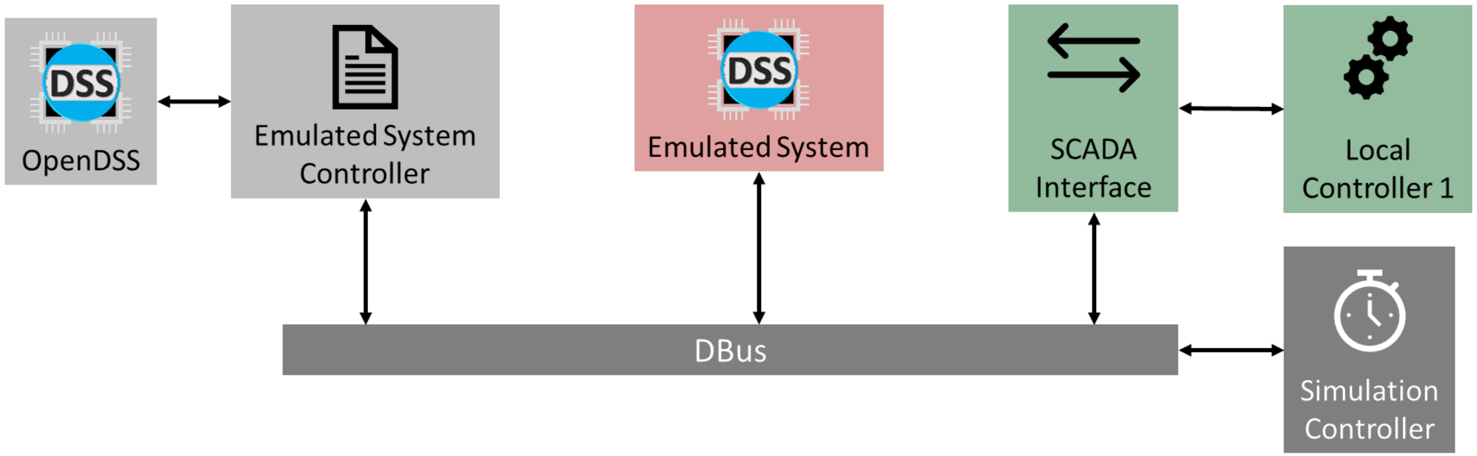
Load Shifting in Response to ToU Rates

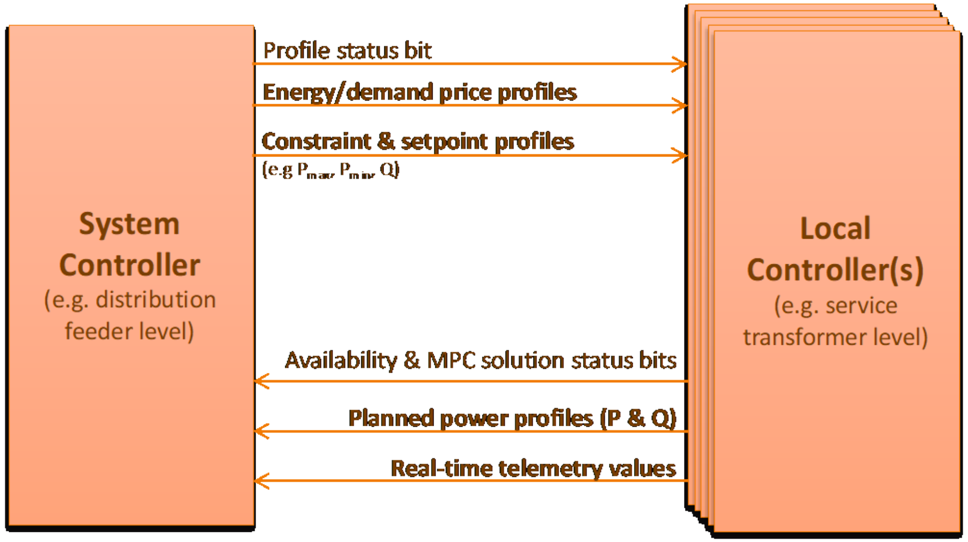


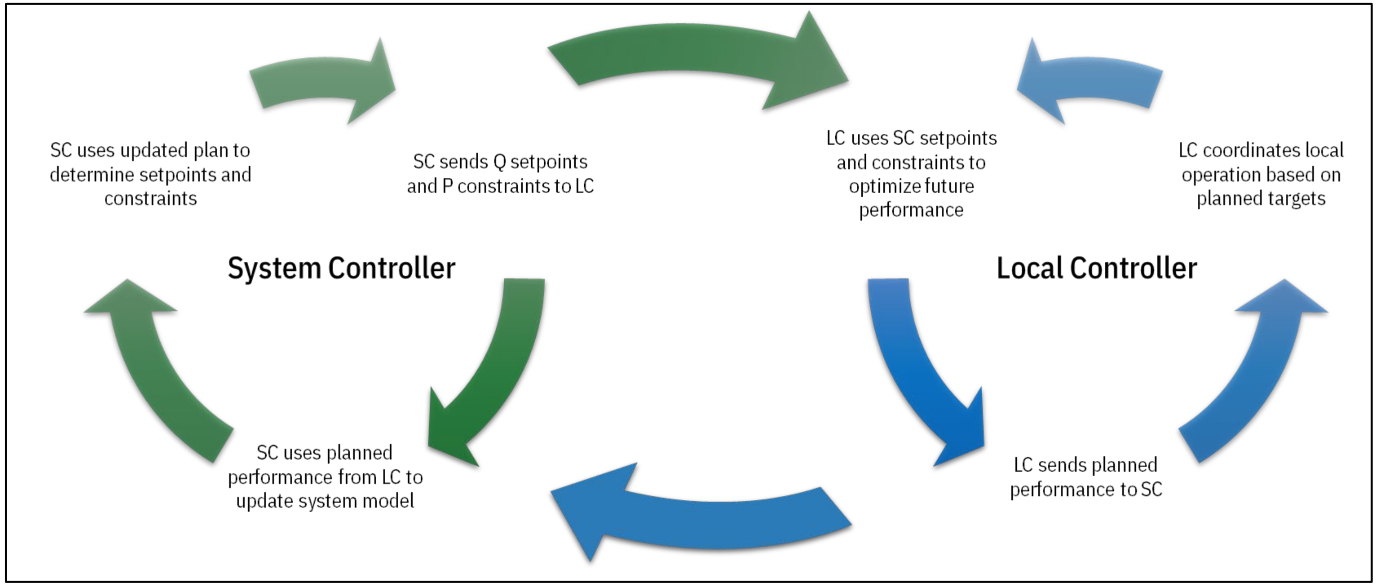
In response to pricing signals, the MPC moves controllable load usage to periods of less expensive energy

Real-time Interaction between Local and System Controllers

A system controller emulator is developed and an existing SCADA interface at EPRI Knoxville, TN lab is being used to establish real-time information and constraint/setpoint profile exchange interface with local controller in Pensacola, FL.







Cost & Benefit Streams

Cost stack

- Energy Storage system
- Local controller
  - Controller HW & SW
  - Communication with head-end systems
- Loads
  - Communication & control link
- PV-related costs; *Not* included
  - Assumed existing
  - Diverse factors motivate consumers to adopt solar PV

Benefit stack (potentials)

- Customer domain
  - TOU bill management
  - Demand charge management
  - Enhanced back-up power management

Customer benefits

- Distribution domain
  - Distribution capacity
  - Reliability (back-tie) services
  - Voltage support
- Wholesale market
  - Ancillary services (FR, reserves, etc.)
- Resource adequacy

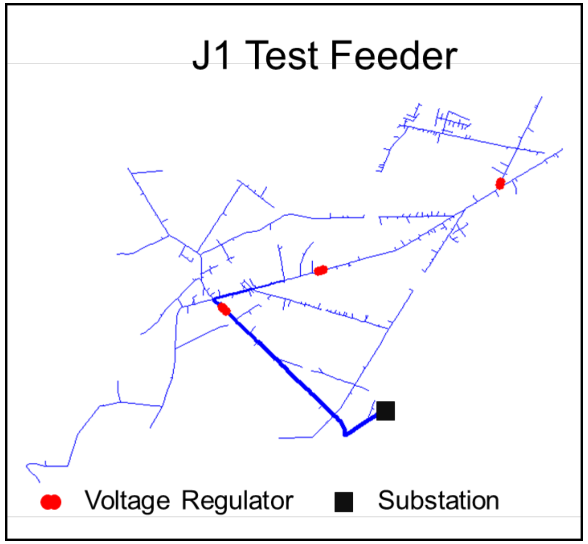
Ratepayer benefits

- Potentially... other non-energy-related services enabled by local controller (broadband backup, automation, monitoring, security)

Customer benefits

Distribution Hosting Capacity

Question: How to calculate cost benefit of SHINES solution over traditional system upgrade options to increase distribution circuit hosting capacity?



Approach

① Start from a feeder with no DER and assume no upgrades are made prior to hosting capacity analysis.

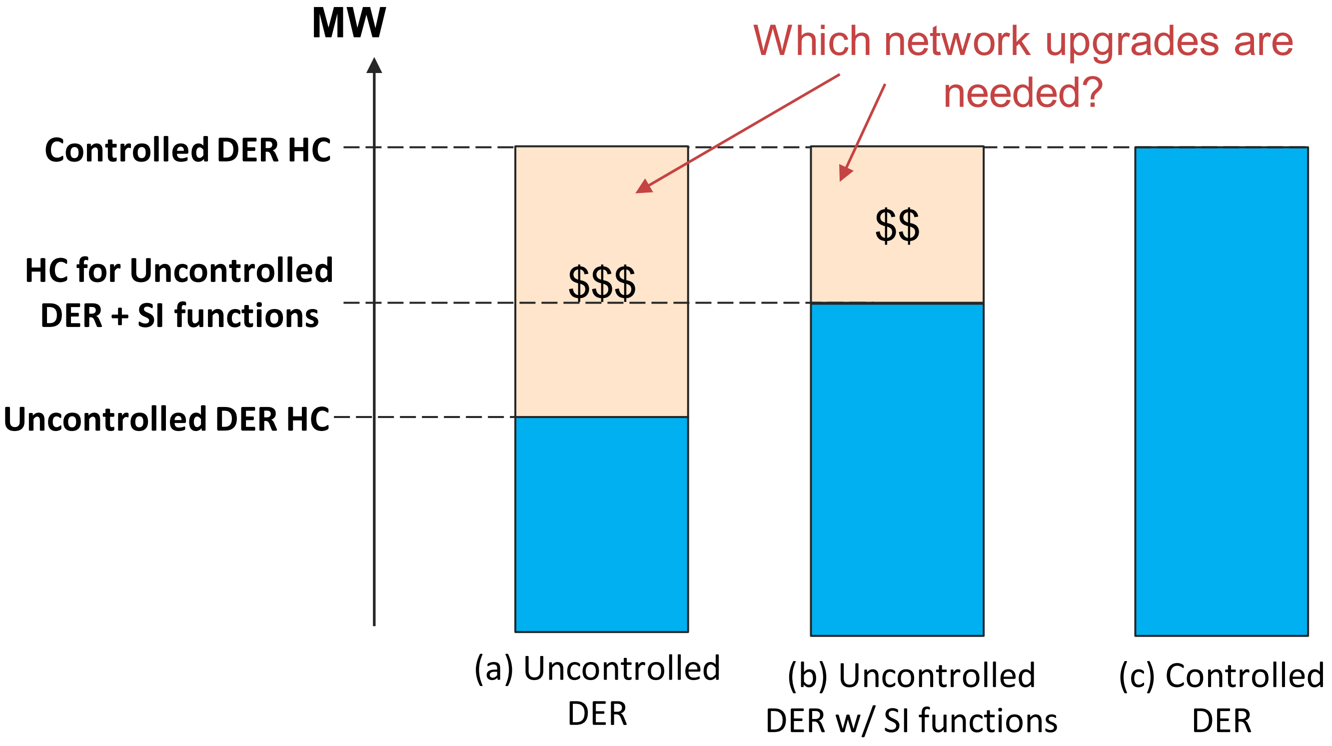
② Analyze these cases:

(a) Hosting Capacity for uncontrolled DER,

(b) Hosting Capacity for uncontrolled DER with various Smart Inverter (SI) settings,

(c) Hosting Capacity for controlled DER *(SHINES solution)*.

③ What would be the system upgrades required to integrate uncontrolled DER to the same capacity as controlled DER?



Economic Feasibility of Deploying SHINES Solution

DER Owner Perspective

- Energy/demand bill savings
- Reduced battery size and cycling by leveraging load control - lower capital and replacement cost
- Self consumption of local generation and/or "zero export" compliance with reduced cost
- Enabling Flexible Interconnection with minimal generation curtailment
- Ability to provide Non-Wires Alternatives (NWA) grid services - increased value proposition

Grid Operator Perspective

- Engaging DER customers into grid modernization process
- Increasing feeder hosting capacity with reduced system upgrade cost by leveraging customer investments
- Lowering fast ramping generation reserve capacity need to address evening ramp (neck of "duck curve")

ENGAGE Project Overview

***En**able BTM DER-provided **G**rid Services that M**a**ximize Customer and **G**rid B**e**nefits*

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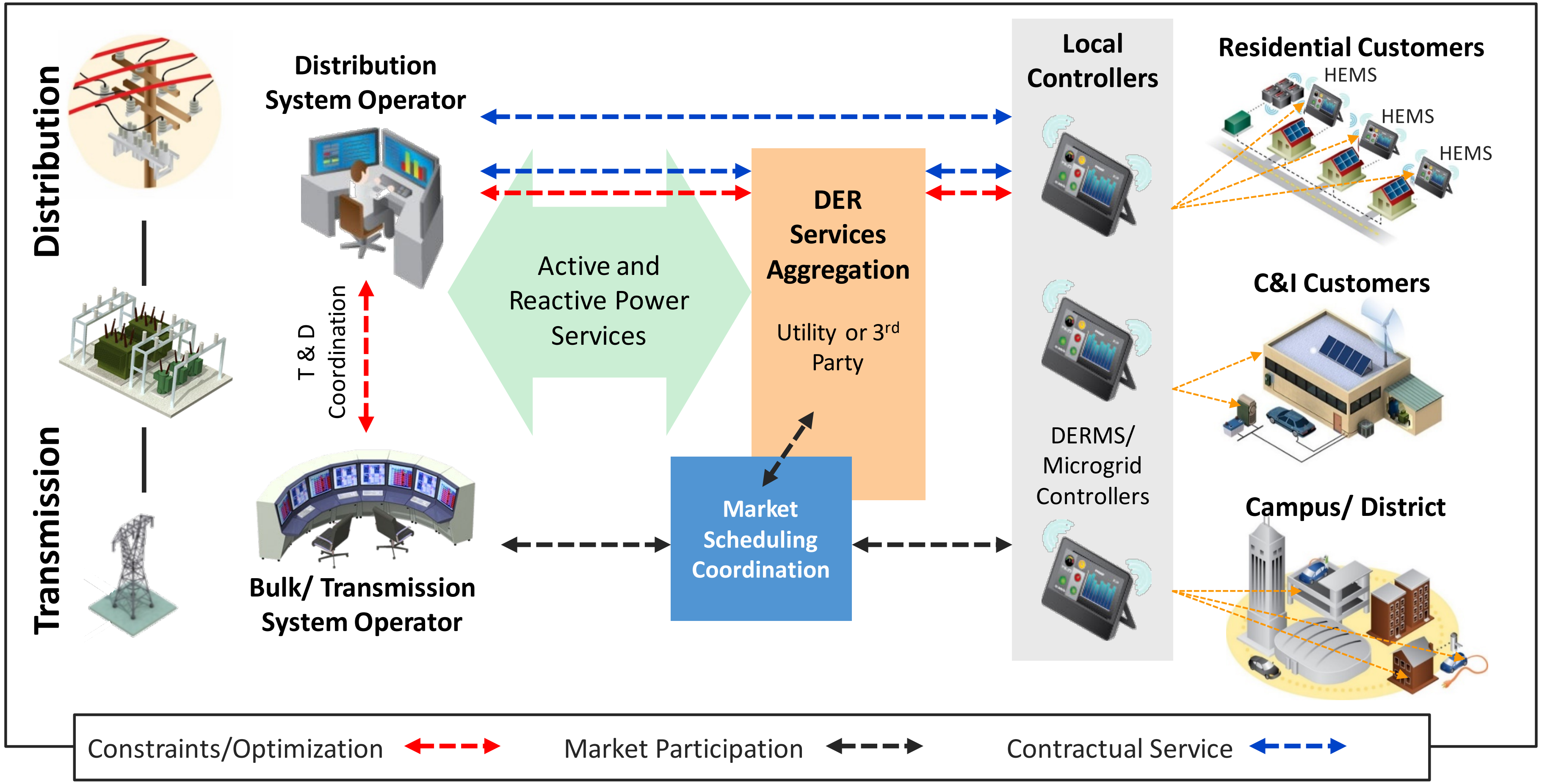
A new project started in 2020 to apply the research outcome of SHINES



ENGAGE aims to enable ***transmission*** and ***distribution*** grid services provision by ***BTM DERs*** while maintaining economic efficiency and reliability through:

(1) local and hierarchical controls,
(2) optimization of end-user and system benefits, and
(3) application of standardized interaction and coordination between TSOs, DSOs and Aggregators.

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Together…Shaping the Future of Electricity