Federated Architecture for Secure and Transactive Distributed Energy Resource Management Solutions (FAST-DERMS)

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January 20, 2022. Update to Industry Advisory Board.

Team and Resources Summary

National Laboratories

- National Renewable Energy Laboratory
- Lawrence Berkeley National Laboratory
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory

University Research Partners

- Iowa State University
- University of North Carolina - Charlotte

Total Budget: $6.773 million
DOE Portion: $5.225 million
Cost Share: $1.548 million (22.9%)

Utilities

- San Diego Gas and Electric (SDG&E)
- ComEd – An Exelon Company
- New York Power Authority (NYPA)
- Southern Company

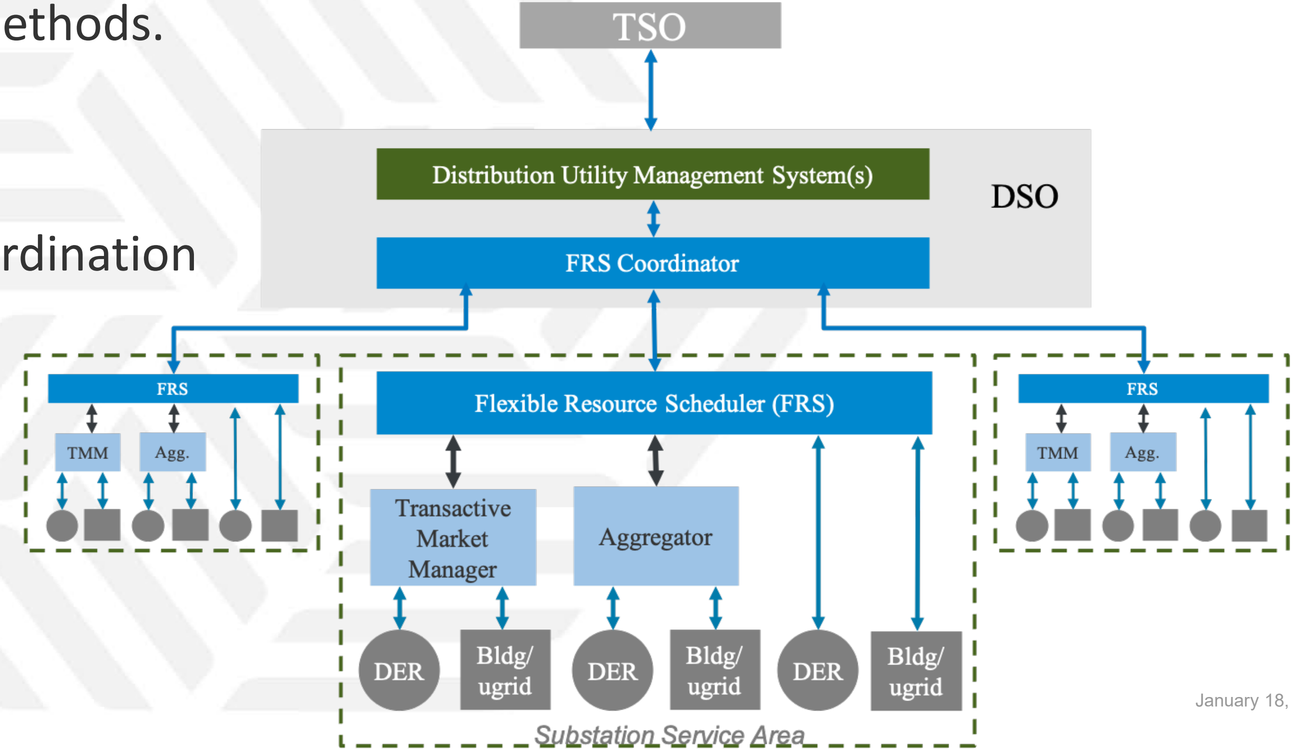
Industry Partners

- Electric Power Research Institute (EPRI)
- Oracle
- GridBright, Inc

Objective

Develop a controls architecture to manage a broad range of DERs across the grid for bulk system services through transactive, aggregation, and direct control methods.

- Total DSO
- Laminar Coordination
- Distributed



Thoughts on FERC Order 2222

- Recent DOE question: “How can we use the outcomes from FAST-DERMS to support FERC 2222?”
- Response summary:
  - FAST-DERMS addresses FERC Order 2222 by providing an architectural solution that enables DERs at the distribution system to participate in wholesale markets at scale.
  - FAST-DERMS aims to aggregate and coordinate the operations of these DERs to support transmission and distribution (T&D) grid operations.
  - The FAST-DERMS reference implementation recommends a Total DSO approach—i.e., the DER aggregators operating resources in a distribution system through the distribution system operator (DSO) to participate in the wholesale market.
  - FERC Order 2222 allows DERs to be aggregated by third parties for direct access to wholesale markets, and only requires a mechanism to inform the DSO of their participation. (“hybrid”)
  - FAST-DERMS can accommodate such an arrangement, but the added complexity of interactions would prevent such an approach from realizing the full potential of the benefits available from a FAST-DERMS implementation.
- 2-page document available
- Potential presentation to FERC in ~ March

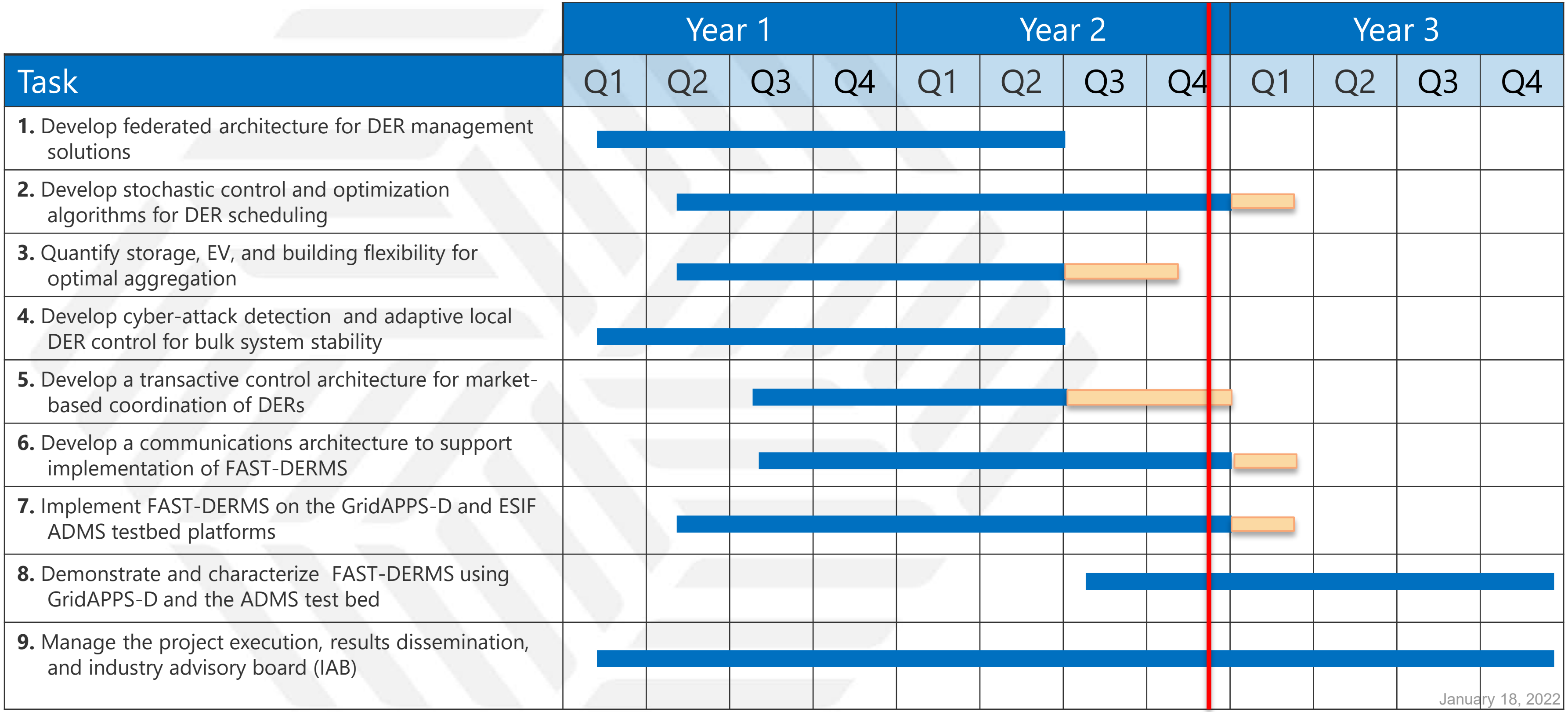
Outputs

- Architecture documents approved by GMI in November (submitted 7/30/2021)
  - Released as NREL and PNNL technical reports
  - https://www.nrel.gov/docs/fy22osti/81566.pdf
  - https://gridarchitecture.pnnl.gov/media/Grid_Arch_Guidance_for_FAST%20DERMS.pdf

- Evaluation plan was developed and delivered to DOE.

- Paper on anomaly detection accepted to 2022 IEEE ISGT conference.

Technical Approach

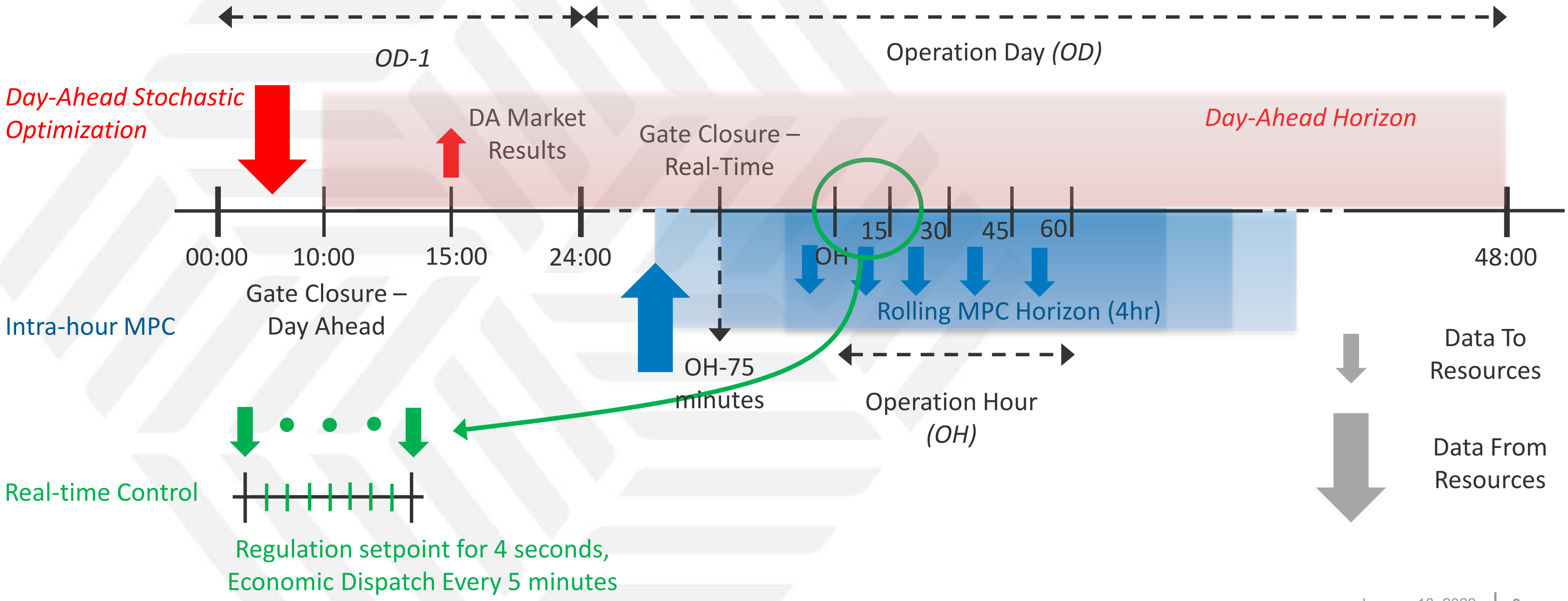


Upcoming Milestones

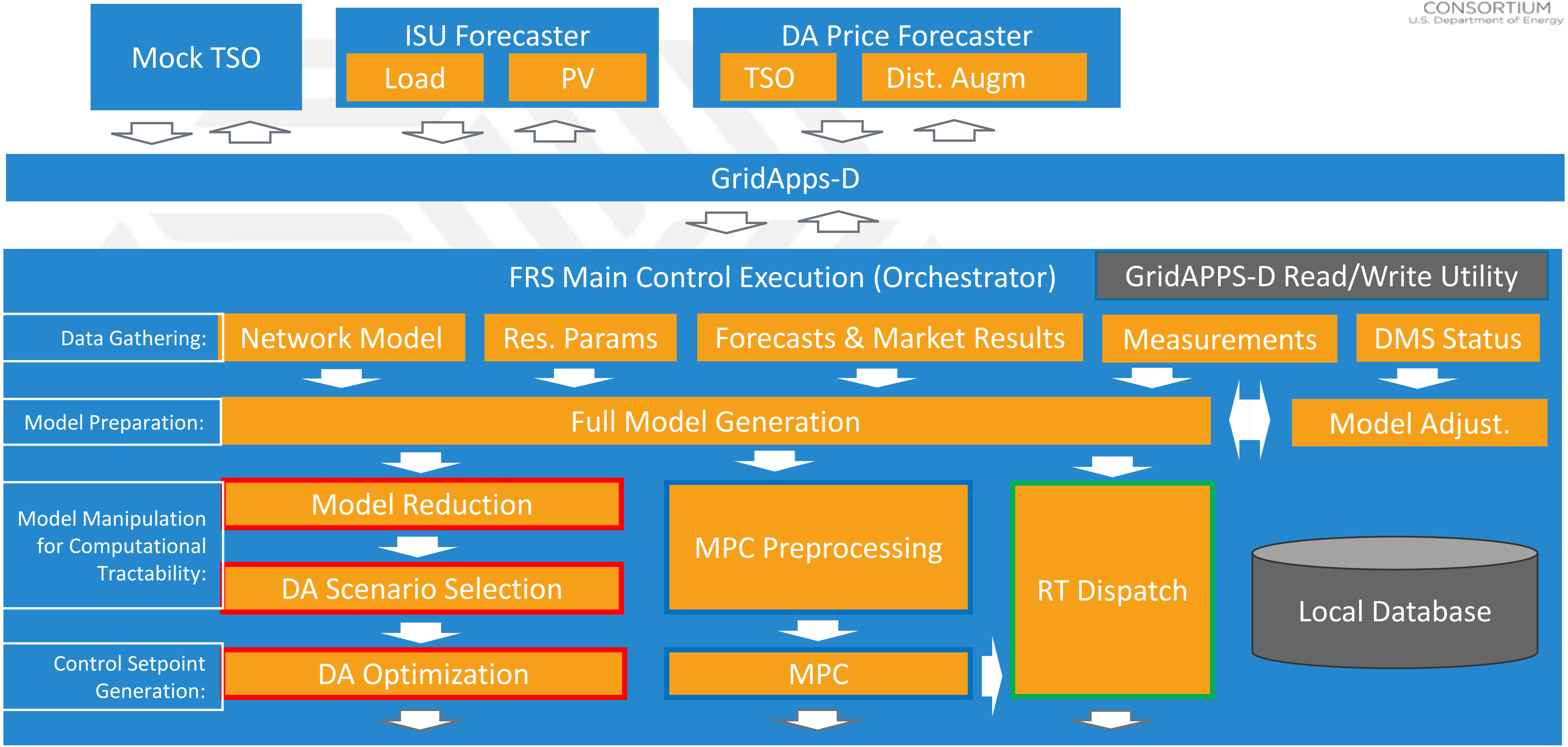
- 2/15/2022: **Go/No-Go**: 2.6 Demonstrate through a software simulation of at least 4 hours of operation of a small test system how at least two of the types of flexibility resources (selected from transactive agents, aggregators and directly controlled loads) are employed by the *FRS* to achieve operational performance within 5% of the objectives specified for at least one use case.
  - Will ask for extension to March 31, 2022, in part due to PNNL stop work in December & January
- 2/15/2022: 8.6 Local DER and aggregator controls integrated with the ADMS Test Bed and verified that controller outputs are within 2.5% of those achieved through software simulation with the same inputs
  - Will ask for extension to March 31, 2022 (Need simulation results)

Task 2: Controls Refresher

FRS Timeline:

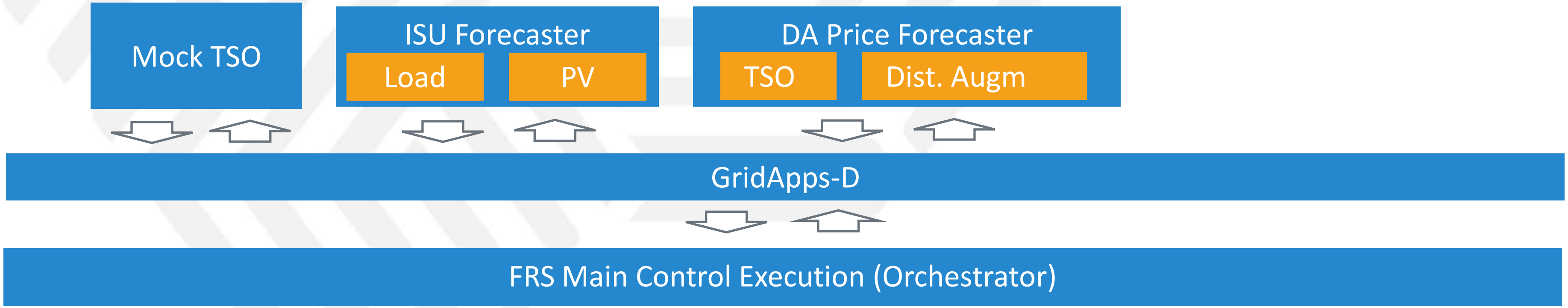


FRS Control Software Modules



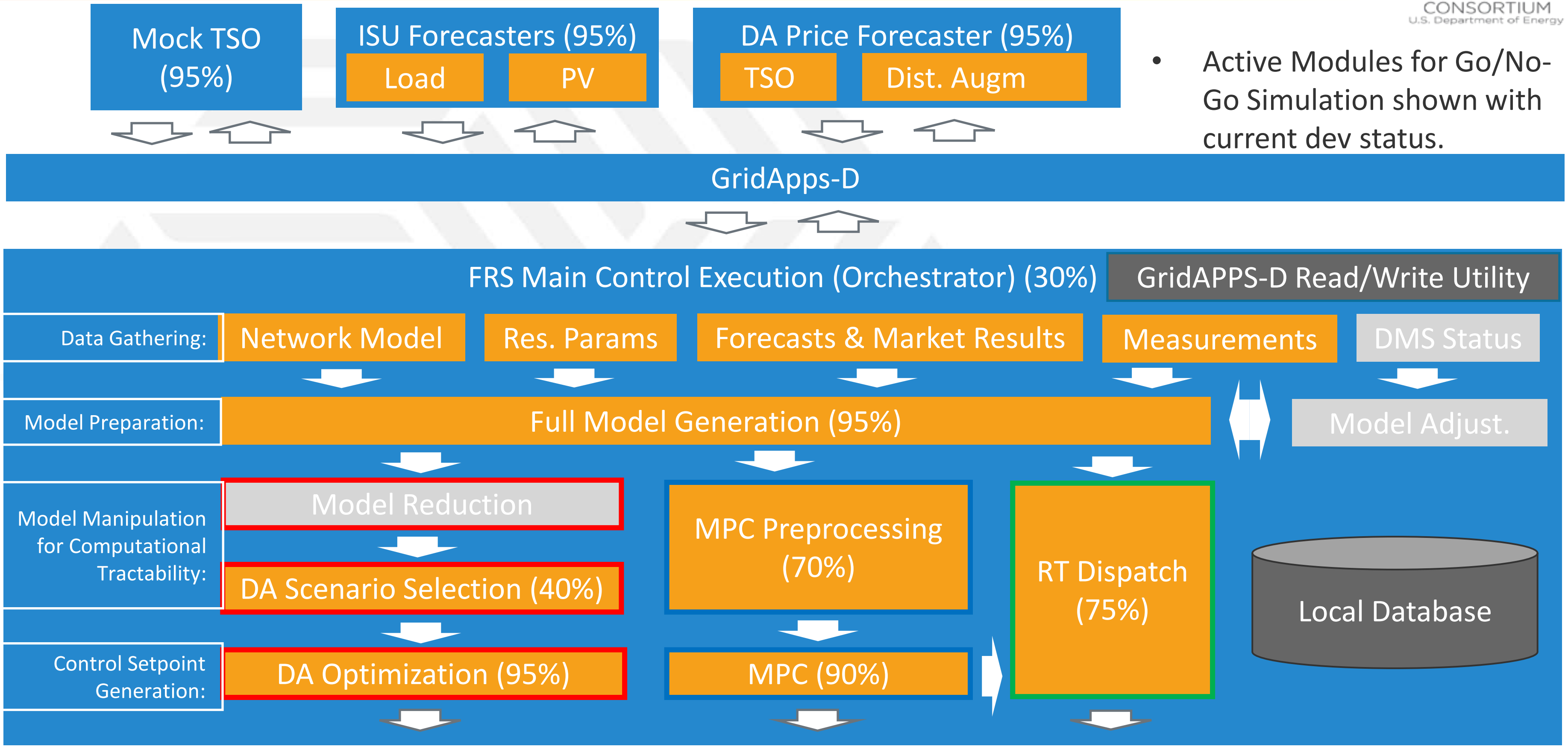
Forecasts & Market Modules

- ISU Forecaster
  - Developed the forecasting methods for PV generation and loads.
  - Demonstrated the forecasting module using Iowa utility data; Generalized training approach developed to apply to the data in our test cases.
- Mock TSO
  - Simple representation pushing historical prices and dispatch
- DA Price Forecaster
  - Basic persistence forecast with historical error distribution

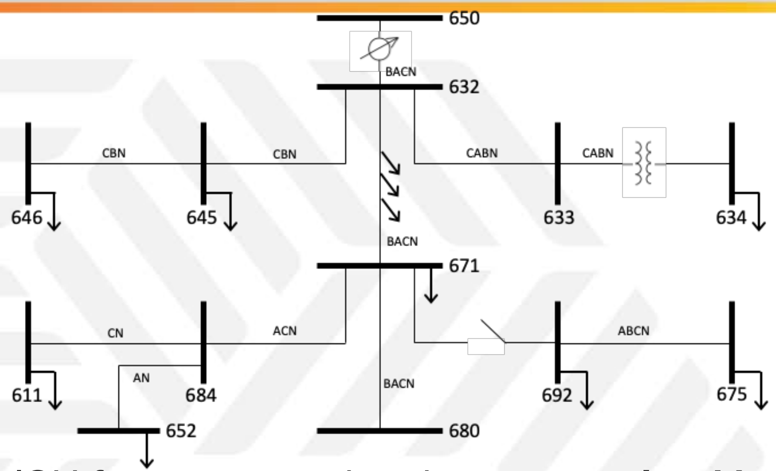


FRS Control Software Status for Simulation

- Active Modules for Go/No-Go Simulation shown with current dev status.



Go/No-Go Simulation Setup – IEEE 13-bus

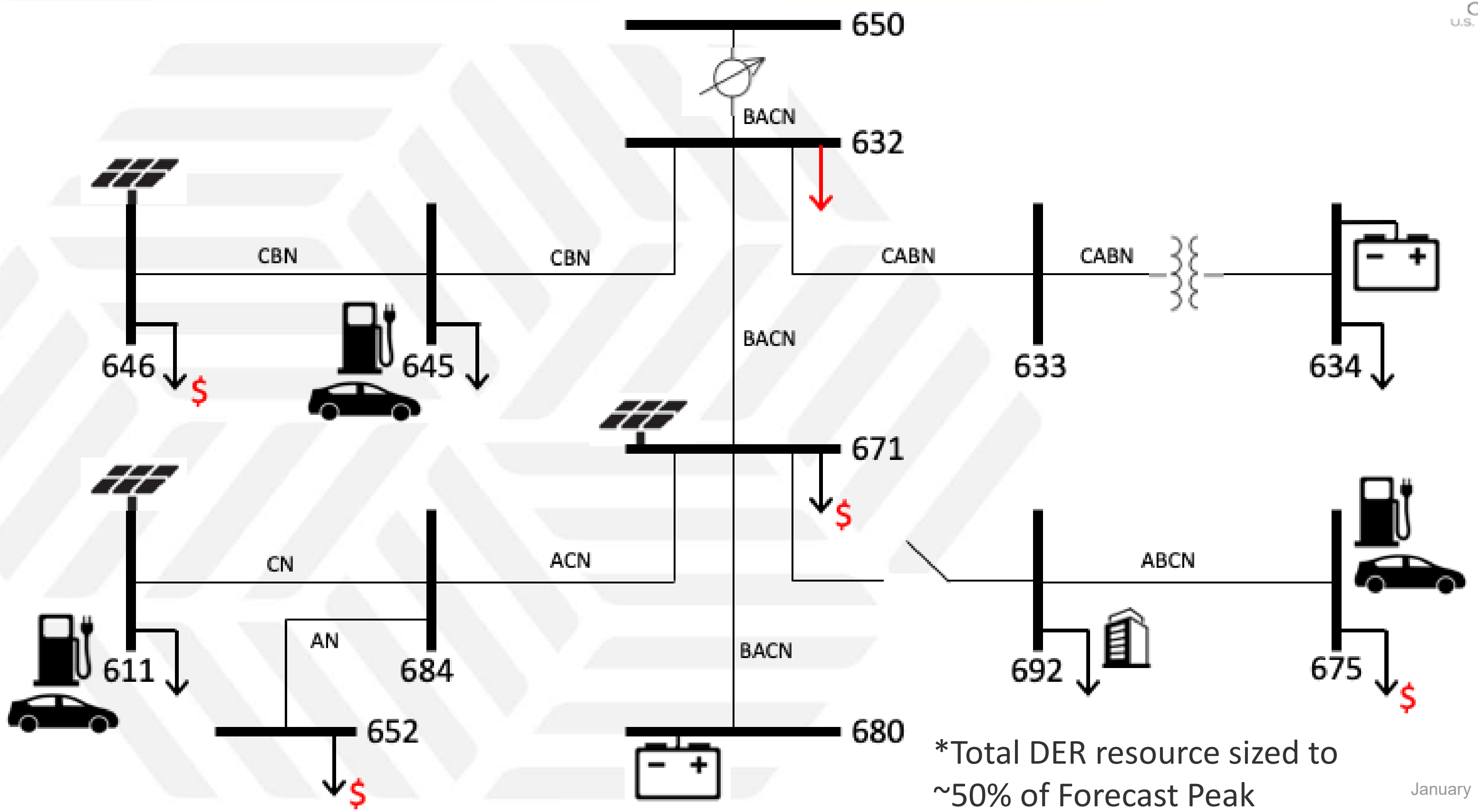


Node	Ph-1	Ph-2	Ph-3
	kW	kW	kW
632	8.5	33	58.5
634	160	120	120
645	0	170	0
646	0	230	0
652	128	0	0
671	393.5	418	443.5
675	485	68	290
692	0	0	170
611	0	0	170

*Original IEEE13 Load (3.5MW total)

- **Load profiles**: sized in ISU forecaster so that the **average load in 24-hr DA forecasts** is **equivalent** to original **IEEE feeder spot load** (Iowa Utility Data)
- Nodal Load PF from IEEE 13 is maintained to create Q profiles.
- Single PV forecast - scaled for PV across feeder.
- Utility-scale battery, PV, and battery aggregator included.
- EV Aggregator, Commercial Bldg, and Transactive Resources will be added to simulation if available and time allows.

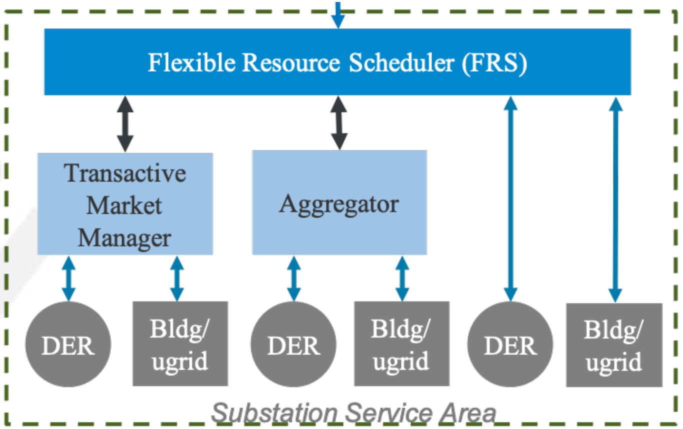
Simulation Setup – IEEE 13-bus with DER



*Total DER resource sized to ~50% of Forecast Peak

Tasks 3 & 5: DER Flexibility & TMM Updates

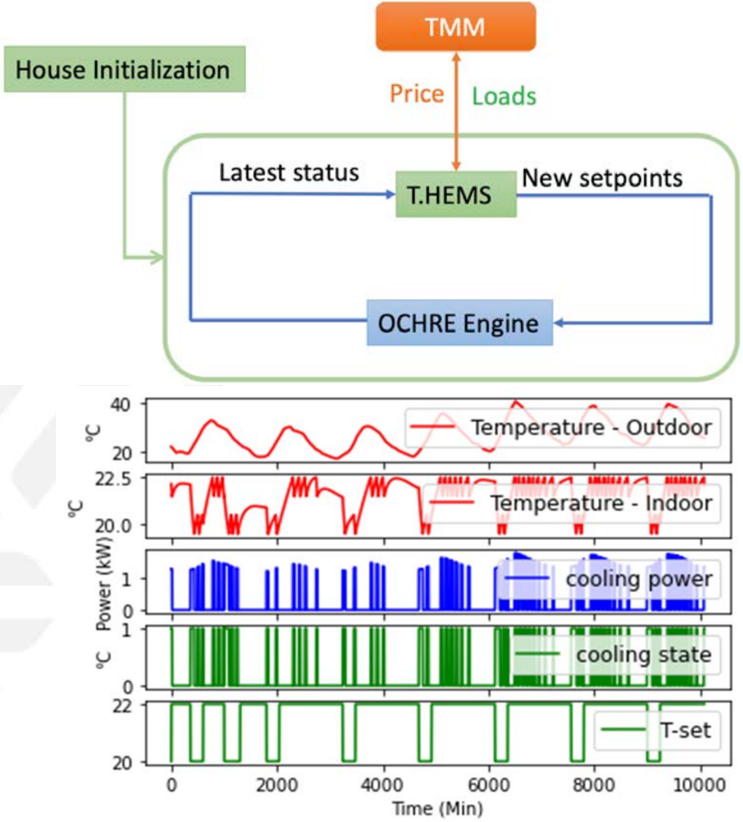
- EV aggregator (LBNL):
  - Aggregator implemented in Python
  - Fleet simulator near completion (80%)
  - Beginning GridAPPS-D implementation (10%)
- Battery aggregator (NREL):
  - Python implementation complete
  - Finishing up GridAPPS-D implementation (80%)
- TMM & Transactive HEMS (ORNL):
  - Working on GridAPPS-D implementation (70%)



TMM/T.HEMS updates

- The TMM manages multiple individual buildings with controllable HVAC systems, and communicates with the FRS. It can:
  - Aggregate energy bids from a set of T.HEMS that are controlling HVAC systems modeled in OCHRE; and
  - Pass down the forecasted/settled prices coming from FRS to T.HEMS.
- The T.HEMS controls individual HVAC systems and communicates with the TMM:
  - Collect the latest pricing curves from TMM
  - Predict the optimal load profile corresponding to each pricing curve and report to the TMM based on MPC with a desired indoor comfort; and
  - Dispatch new setpoints to the individual HVACs
- The codebase can be found on:

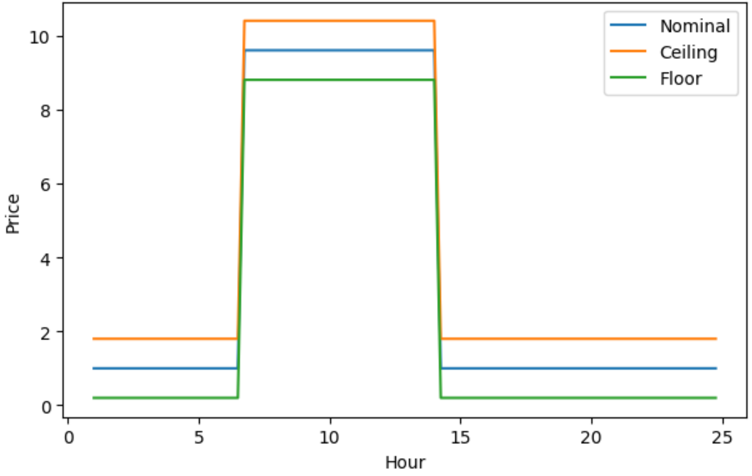
https://github.com/NREL/FAST-DERMS-Transactive



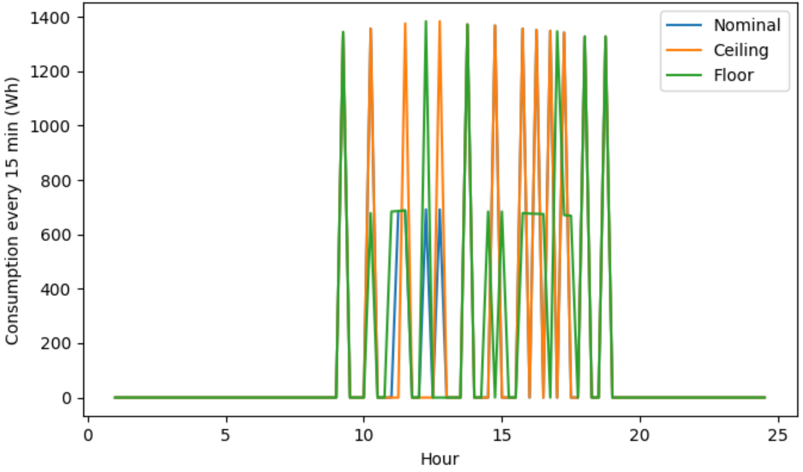
TMM/T.HEMS simulation results

- Completed T.HEMS design to work with OCHRE simulation model
- Completed initial integration test between OCHRE and TMM/T.HEMS on GridAPPS-D
  - Built the agents for T.HEMS & TMM
  - Established the messages for communication in GridAPPS-D
- Python simulation setup: 1 TMM with 2 T.HEMS

Price forecasts passed to T.HEMS by TMM



Aggregate bids sent back to FRS by TMM

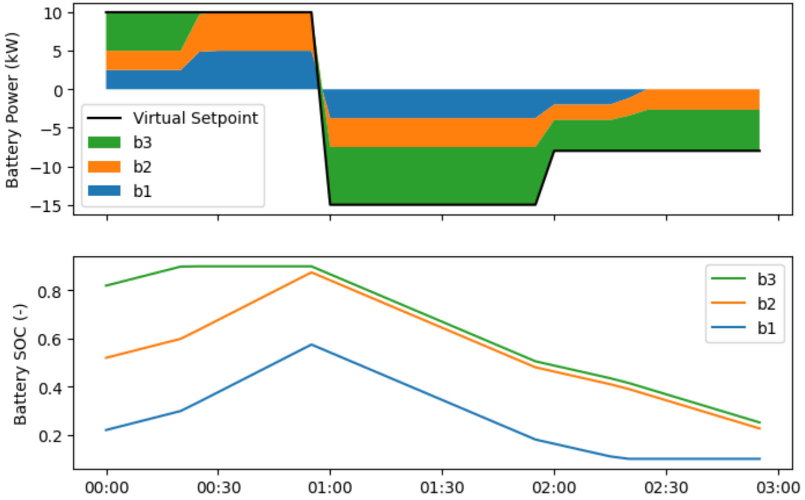


Battery aggregator simulation results

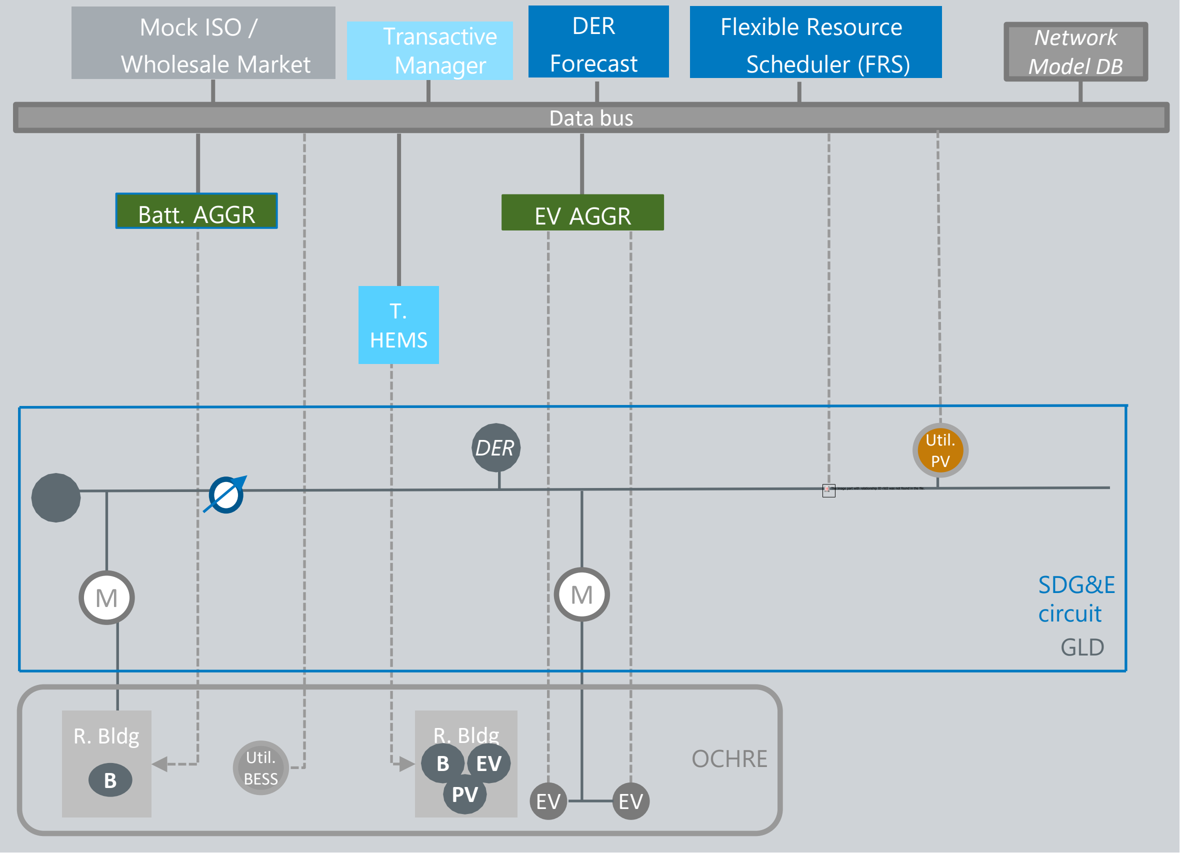
- The battery aggregator controls multiple individual DERs and communicates with the FRS. It can:
  - Aggregate a set of DERs that can be modeled as batteries;
  - Create a virtual battery model from a set of individual battery models; and
  - Dispatch power setpoints to the individual DERs based on a desired virtual power setpoint received from the centralized grid control.

- The codebase can be found on: https://github.com/NREL/virtual-battery-aggregator

- Example dispatch simulation results for three batteries.

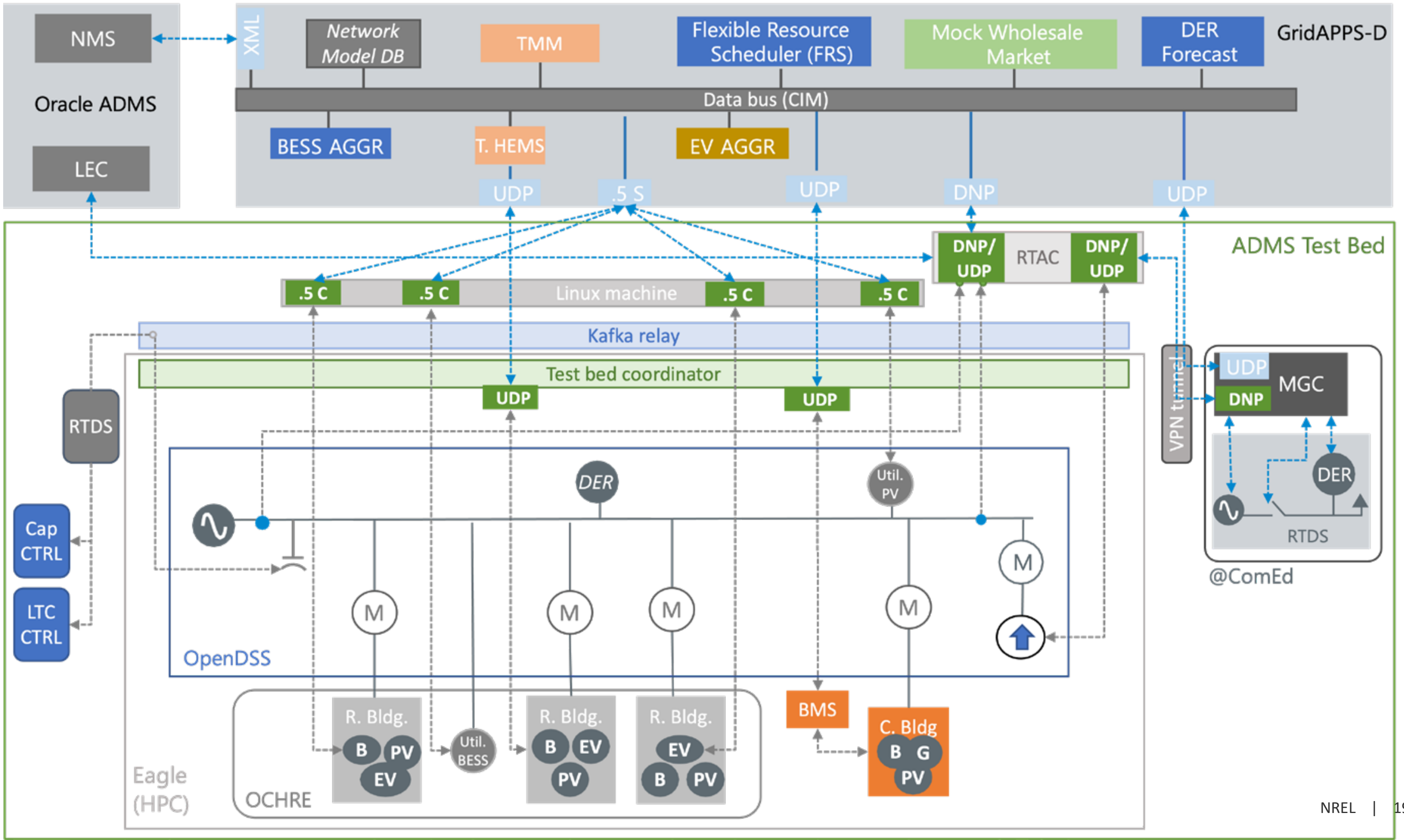


Controls Simulation



- Target simulation results with small feeder on GridAPPS-D by Mar ’22

- Then transfer to ADMS Test Bed


NMS
Oracle ADMS
LEC
XML
Network Model DB
TMM
Flexible Resource Scheduler (FRS)
Mock Wholesale Market
DER Forecast
GridAPPS-D
Data bus (CIM)
BESS AGGR
T. HEMS
EV AGGR
UDP
.5 S
UDP
DNP
UDP
ADMS Test Bed
DNP/ UDP
RTAC
DNP/ UDP
.5 C
.5 C
Linux machine
.5 C
.5 C
Kafka relay
Test bed coordinator
UDP
UDP
RTDS
VPN tunnel
UDP
MGC
DNP
DER
RTDS
@ComEd
Cap CTRL
LTC CTRL
DER
Util. PV
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OpenDSS
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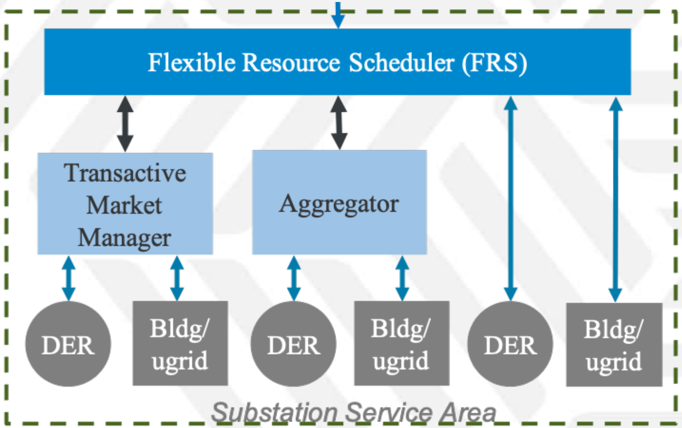
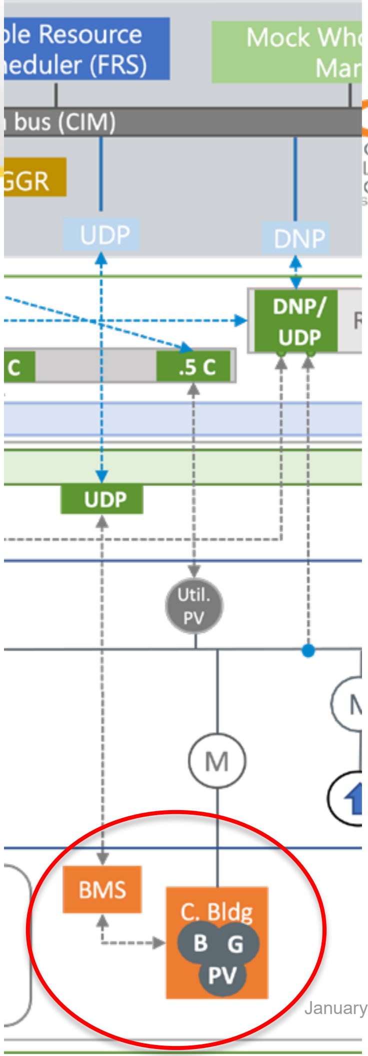
B
PV
EV
Util. BESS
R. Bldg.
B
EV
PV
R. Bldg.
EV
B
PV
BMS
C. Bldg
B
G
PV
Eagle (HPC)
OCHRE

Commercial building

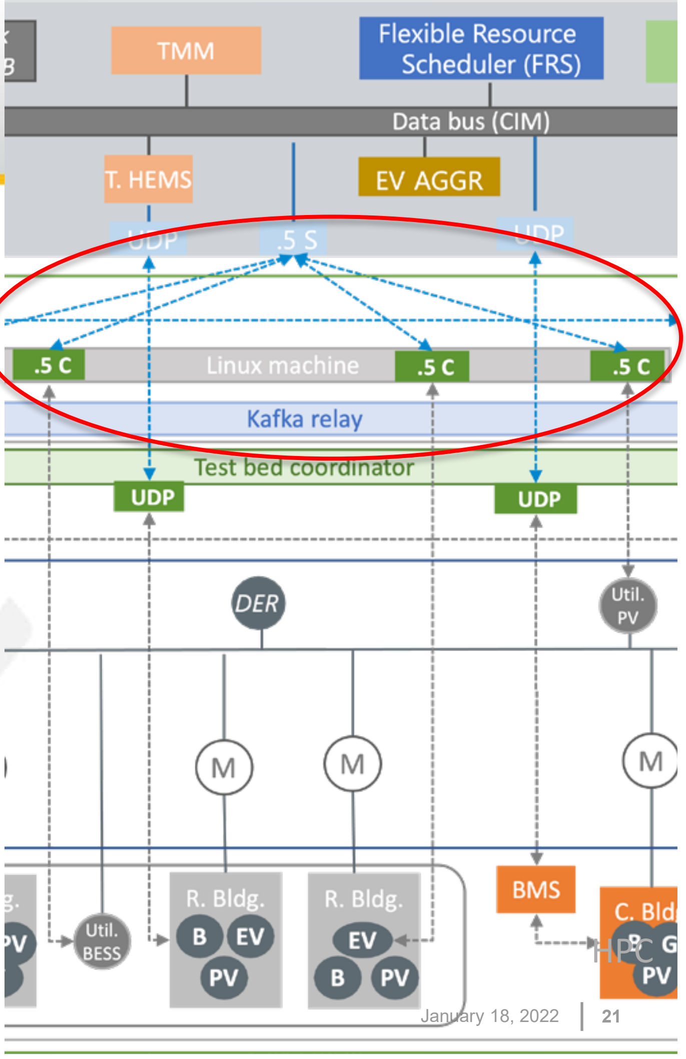
- Commercial building models and controls (UNCC)
  - Completed the equipment and control models for commercial buildings.
  - Demonstrated in stand-alone Python codes for five different building types.
  - Working on integration with ADMS Test Bed





Task 6: Communications Updates

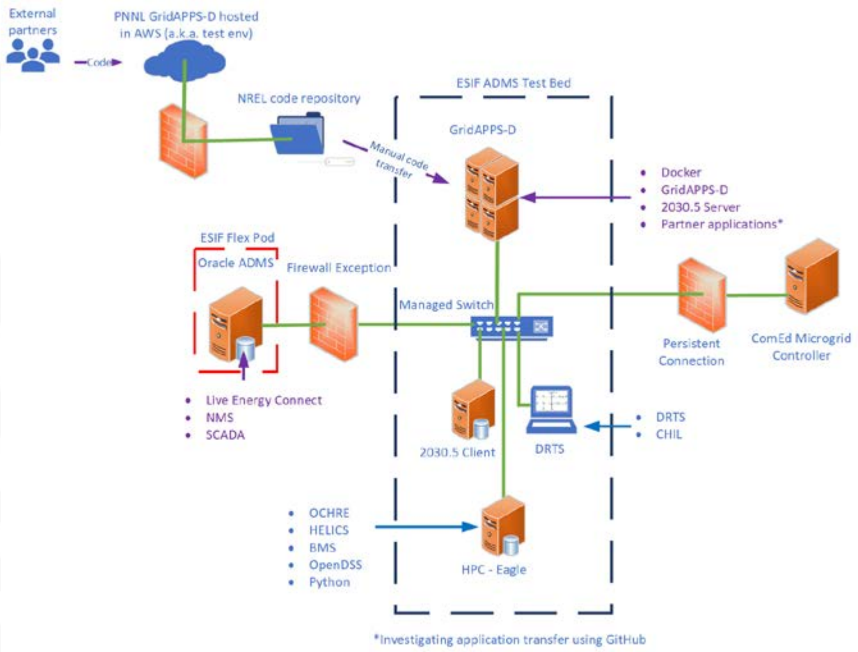
- 2030.5 Client (DER level)
  - Basic version developed by EPRI and provided to NREL
  - Does not include flexibility information, but we have identified structure for including flexibility
- 2030.5 Server (Aggregator level)
  - EPRI has developed stand-alone version
    - Using for initial testing at NREL
  - PNNL is developing a separate GridAPPS-D instance
- Currently testing basic client & EPRI server at NREL
  - Single client working; need to set up multiple clients



Task 7: Implementation Updates

- Progress
  - GridAPPD-D Platform released with IEEE 13-node feeder model, SDG&E feeder model and integrated OCHRE simulator
  - Added capability to automate configuration for GridLAB-D and OCHRE to address application developers' feedback

- Upcoming
  - Integration of PNNL-developed 2030.5 standard server on GridAPPS-D with 2030.5 clients.
  - 2030.5 extensions to support FAST-DERMS flexibility data elements to be implemented in 2030.5 server and client.



Physical Implementation Diagram at NREL ESIF

Task 8: Evaluation Updates

- Evaluation plan
  - Completed and delivered to DOE
  - Worked with Oracle to add use cases that demonstrate value of FRS-ADMS interactions
- ADMS
  - Deployed at NREL with SDG&E feeder
  - Basic communications with test bed in place
- ADMS test bed implementation on HPC
  - SDG&E feeder running on HPC
  - Preliminary testing of communications through Kafka relay complete
- House model development in OCHRE
  - 40 unique house models developed: 20 in one neighborhood ~ 1950s vintage + 20 over region
- Microgrid remote cosimulation
  - ISA/MOU for interlaboratory communication with ComEd is moving very slowly → possible schedule impacts.

Summary

- Wrapping up 2nd year of project, entering last year
- Working on controls implementation on GridAPPS-D
- Targeting software simulation (on GridAPPS-D) by 3/15/22
- Readying ADMS Test Bed for laboratory evaluation phase
  - Feeder and house models
  - Integration with GridAPPS-D and Oracle ADMS
  - Remote cosimulation with ComEd microgrid

Thank you

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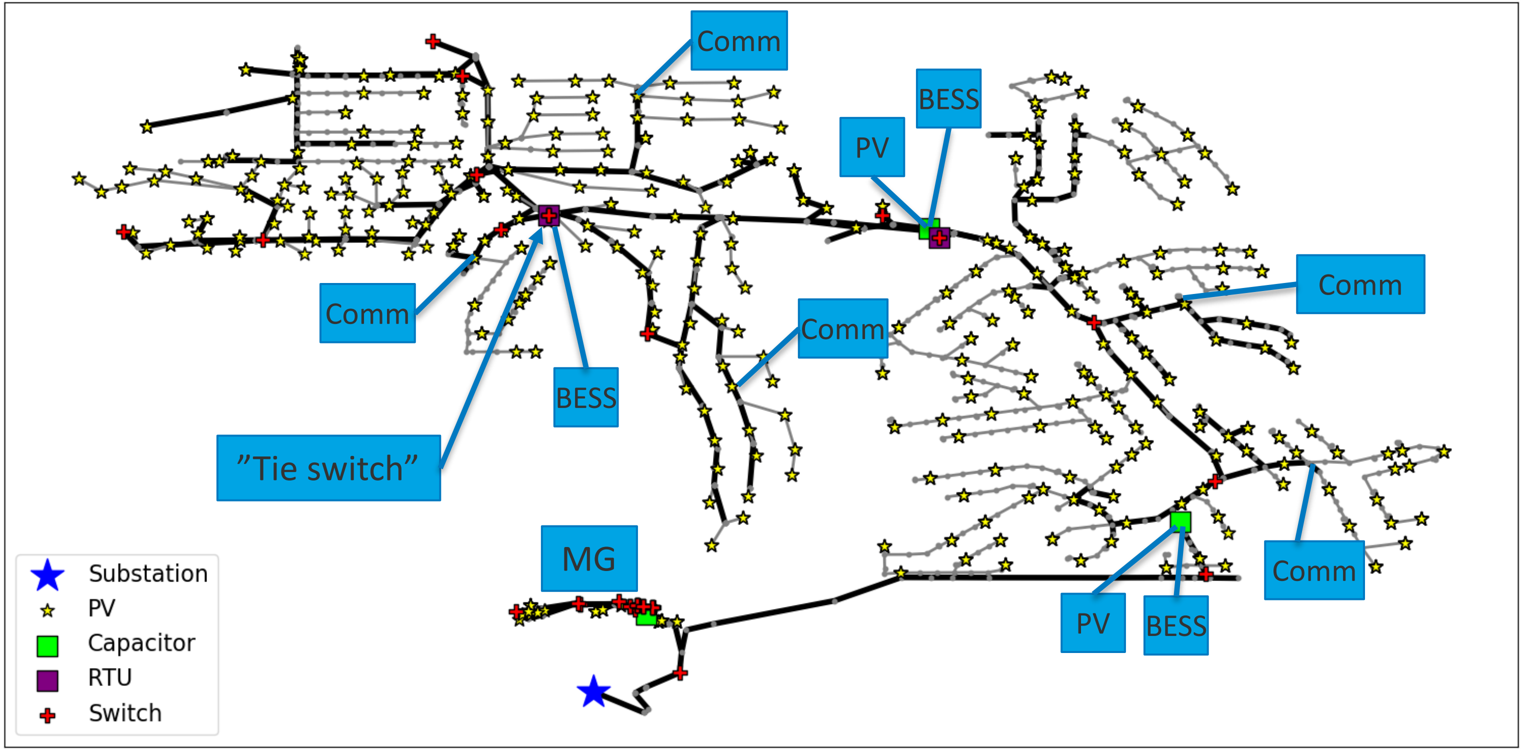
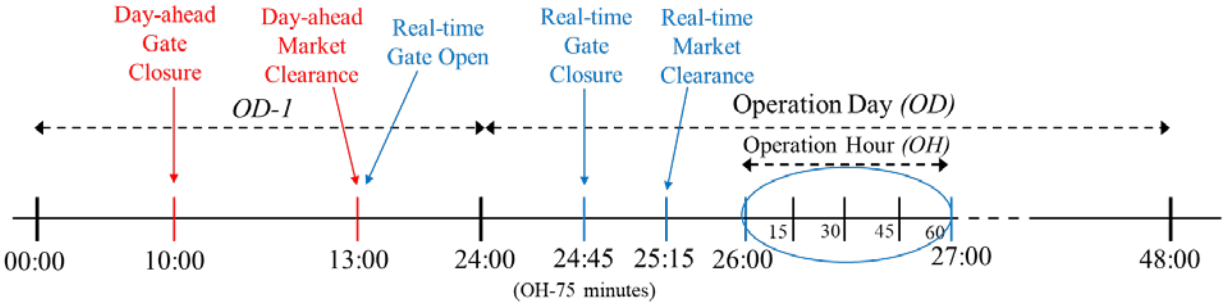
NREL/PR-5D00-81898

Task 8: SDG&E Feeder and DER for Simulation



Task 8: Evaluation plan: Use case

- We will simulate a use case where FAST-DERMS controls are used to aggregate DERs and provide transmission grid services in a competitive market environment.
- We aim to demonstrate:
  - That the FRS can generate the information required to participate in a day-ahead and real-time market. The TSO markets (day-ahead and real time) will be simplified.
  - That the FRS can successfully dispatch DERs, directly and through an aggregator and a transactive market.
  - That the FRS can deliver a cost-effective solution. We will set up a scenario in which distribution DERs can provide benefit to the DSO.



Use case scenarios

- Very high peak price in the late afternoon when PV production is tapering off.
- Demonstrate how controls plan ahead to reduce the DSO's electricity cost

1. Normal system conditions ("blue sky").
2. Load change such that it results in an overload in part of the network. This will allow us to evaluate how the FRS attempts to mitigate this condition.
3. Normal system conditions with planned transfer of load to another feeder/substation.
4. Normal system conditions with planned transfer of load to another feeder/substation and add an unexpected extension of the planned load transfer.
5. Repeat one of the above scenarios with constraint or request issued by the ADMS.
   - ADMS provides a power flow constraint at the substation. This could be in response to planned maintenance scheduled on an upstream transformer. To avoid an overload on the remaining transformer, the ADMS calls upon the FRS to limit demand.
   - The ADMS runs VVO and requests the FRS to reduce/increase voltage by x% for next y hours due to expected light/heavy loads and high/low DER output

Use case scenarios (2)

- For Normal system conditions:

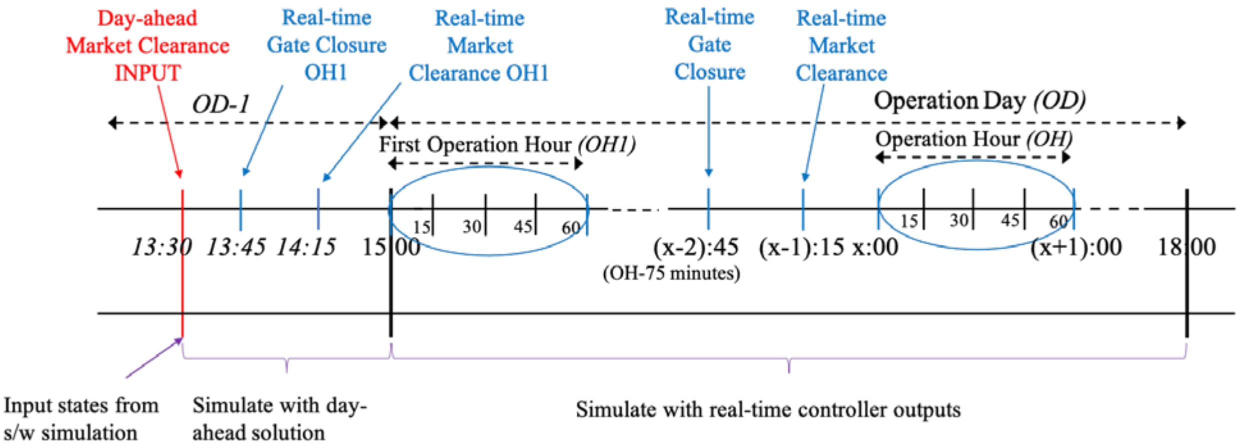
a. baseline simulation where DERs are not managed by the FRS or aggregators and no transactive market is running.
    i. Legacy equipment will be set to autonomous controls with default setpoints
    ii. EVs are set to charge when? Assume they all charge when plugged in in the morning?
    iii. Batteries are managed how? Or not used at all? OCHRE has some default controls.
    iv. PV systems operated with maximum power point tracking (MPPT) and unity PF
    v. Buildings operate with ideal setpoints for air and water temperature

b. simulation with the FRS directly controlling DERs, an EV and a battery aggregator and a transactive market.

- For the other scenarios: perform simulations only with all levels of controls engaged

Simulation timeline

- We will only simulate the late afternoon, for example from 15:00 to 18:00.
- Run the real-time market during that time
  - requires starting >75 minutes earlier to include real-time market for first hour
  - use the day-ahead solution for controls during those >75 minutes.
- Day-ahead market bid and clearance will need to be run separately beforehand
  - make available to the real-time simulations and the Oracle NMS
- Need to run in simulation time, i.e., start at 9 a.m. for a simulation start time of 2 p.m.



Evaluation Criteria

- Reduces DSO cost of electricity
- $C = \sum_{\mathrm{N}} \mathrm{P}_{\mathrm{grid,n}} \cdot \tau \cdot c_{grid,n} + \sum_{k} \{ \sum_{\mathrm{N}} \mathrm{P}_{\mathrm{DER,k,n}} \cdot \tau \cdot c_{\mathrm{DER,k,n}} \}$
  - P_{grid} : power supplied by the grid
  - c_{grid} : cost of grid power
    - wholesale rate + adder
  - $P_{DER,k}$: power supplied by the k^{th} DER
  - $c_{DER,k}$: cost of supplying power from the k^{th} DER, and
    - natural gas tariffs and/or diesel fuel costs, as applicable
    - assume zero cost for PV and utility-scale batteries
    - include cost associated with contract for BTM batteries

Distribution system metrics

Test Metric	Description	Measurement
Voltage exceedances	Number of voltages recorded beyond the acceptable range of 0.95 p.u.–1.05 p.u.	RMS voltage at every node collected
Average absolute deviation	Sum of absolute voltage deviation at each node divided by number of nodes	RMS voltage at every node collected
Capacitor bank operations	Number of times the cap banks were turned on or off	Capacitor bank status or reactive power output
LTC tap position changes	Number of times the LTC tap position was changed	LTC tap position
Energy loss	Difference between feeder energy consumption and load energy consumption	Feeder head active and reactive power measurements and load active and reactive power measurements
Power factor	Power factor will be computed at selected nodes	Voltage and current or active and reactive power measurements
PV curtailment	PV energy output difference from baselines simulations	Active power measurements collected from PV systems