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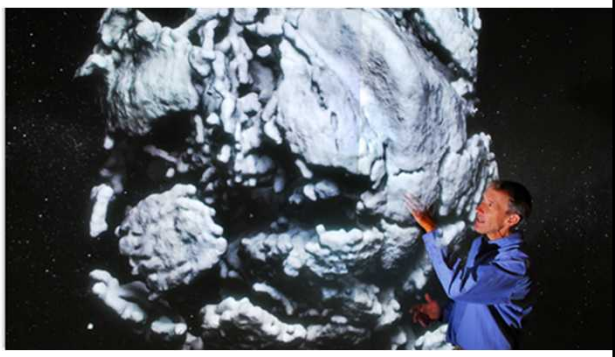

Virtual Power Plants and Large Scale Renewable Integration

New Mexico Regional Energy Storage and Grid Integration Workshop, 24 Aug 2016

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Photovoltaic and Distributed Systems Integration, Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Virtual Power Plants

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- VPPs are aggregations of DER assets controlled to provide identical (or superior) grid-support services compared to traditional generators.
  - Enables renewable energy, demand response, and energy storage to provide grid services
  - Improves grid reliability by providing additional operating reserves to utilities and ISO/RTOs
  - Removing renewable energy high-penetration barriers
- Goal: Develop a unified platform incorporating resource forecasting, standard communications, optimization, and control/dispatch to provide grid services with DERs.

Virtual power plant with communication network (EPRI)

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Lake Side natural gas turbine power station in Vineyard, Utah. (Wikipedia Commons)

VPPs will provide a range of grid services

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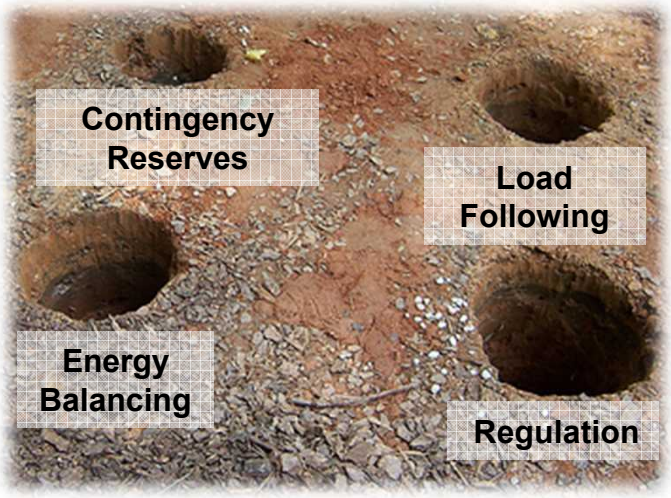
DER resources to fill in utility/grid operator needs



VPP Software System

Multi-domain Optimization
Objective: Minimize Utility Cost

Co-optimization determines the service(s) the VPP will provide grid operators.

Domains:

- Regulation
- Following Reserve
- Energy Market*
- Contingency Reserves*

* Current Research Focus

VPP Participation Updated as Needed

Optimization of DER Setpoints and Unit Commitment

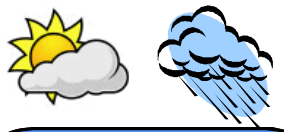
DER Feedback Control of DERs

Communications

DERs

VPP Architecture

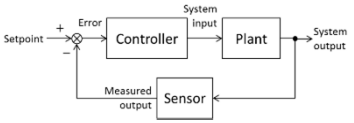
- Depending on the ancillary service(s) and the market, the VPP architecture and execution vary. Generally, there are 4 steps:



Forecasts of renewable energy generators and demand response units are created.

Stochastic optimization is run to determine market bids, precharge energy storage, and prepare demand response units.

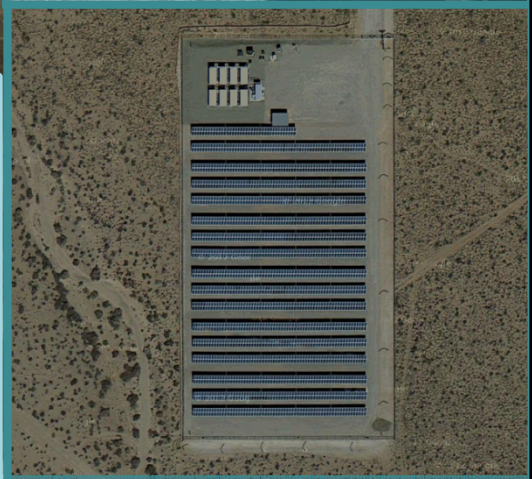
Based on commitments and updated forecasts, unit commitment optimization adjusts DER operations and maintains sufficient headroom for contingency reserves.



A controller is used to reach the VPP commitment target.

DETL-MdS-Prosperity VPP Use Case

Sandia's Distributed Energy Technologies Laboratory



PNM Prosperity Project

UNM Mesa del Sol Aperture Center

VPP Forecasting

Short-Term Forecasting

System data

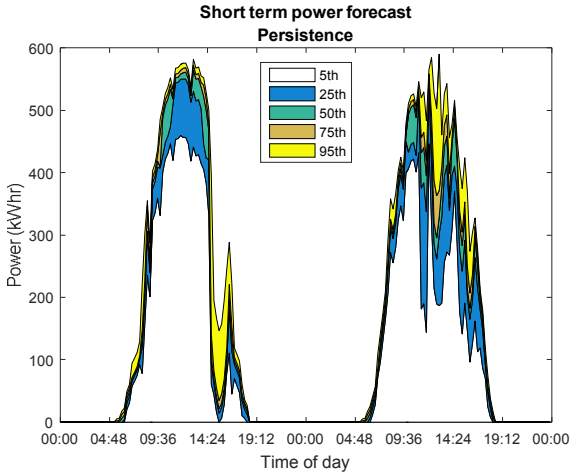
Statistical Forecast (e.g., persistence, ARMA)

Long-Term Forecasting

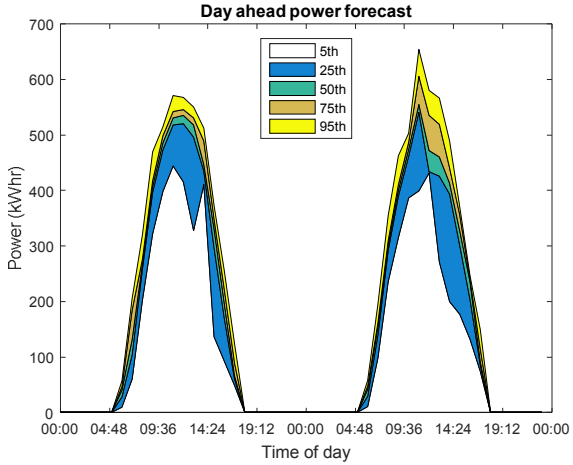
Forecast GHI, T_{amb}, RH

(hourly, +24h to +60h 10 km grid)

Irradiance to Power Model



Uncertainty from history of forecast vs. actual



Day-ahead Unit Commitment Co-optimization

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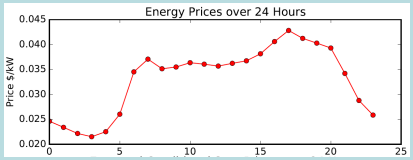
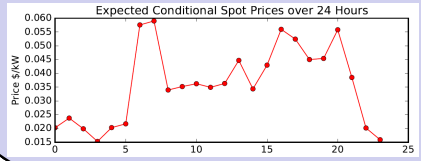
Energy Market



Reserve Market



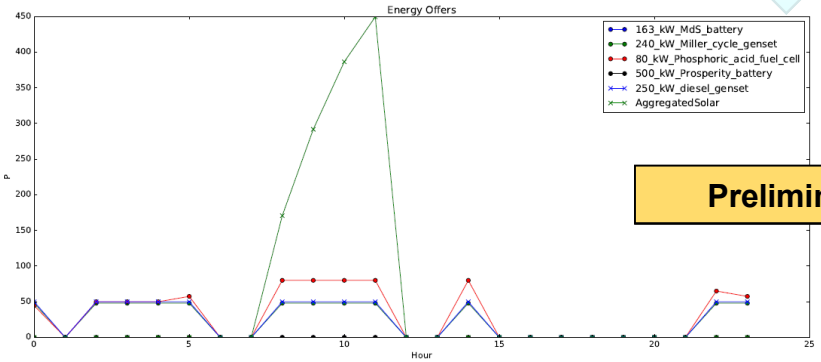
Solar Forecast Scenarios

VPP Stochastic Optimization

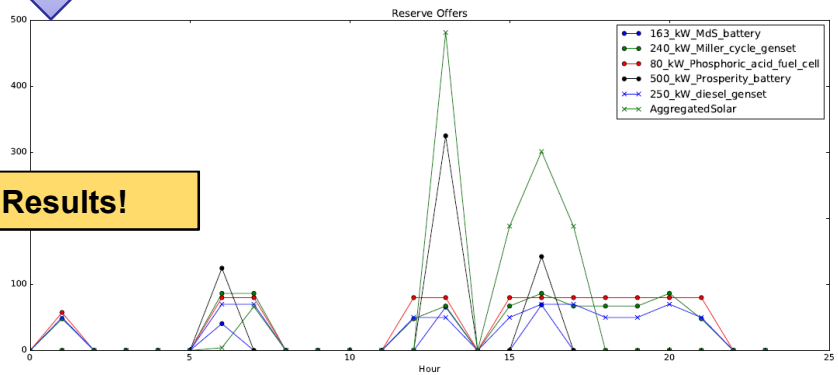
Objective Function:

$$\boldsymbol{Max}\ Profit = \sum_{G}^{DERs} (E_g * Price_{Energy} + R_g * Price_{Reserve} - Cost_G)$$

Subject to operational constraints



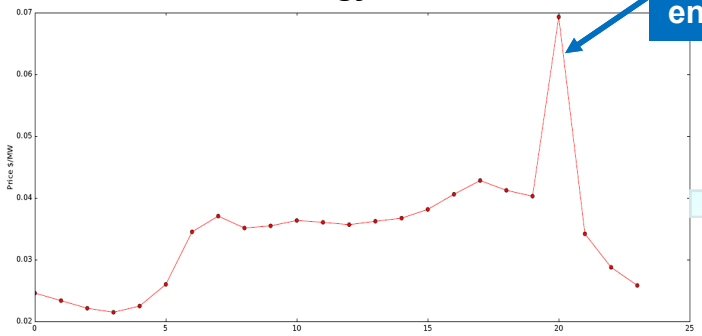
Preliminary Results!



Optimization

- Example of the optimization shifting solar energy to higher price point

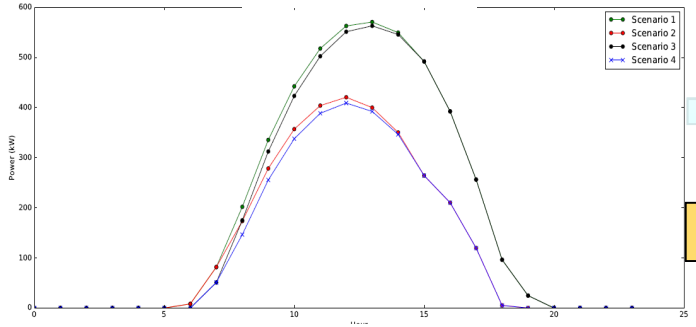
Energy Prices



Artificially high energy price.

A price spike is created at hour 20, which is outside the solar output hours for all 4 forecasted scenarios.

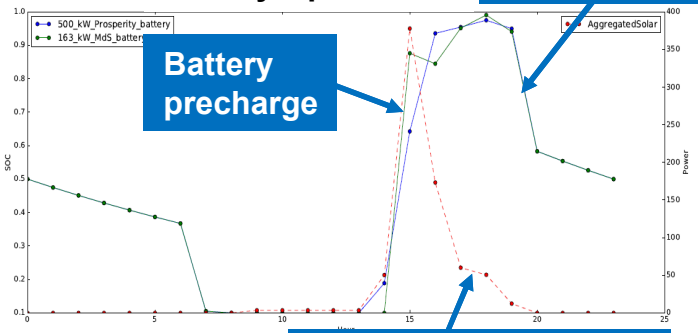
Solar Power



VPP Optimization

Preliminary Results!

Battery Operations



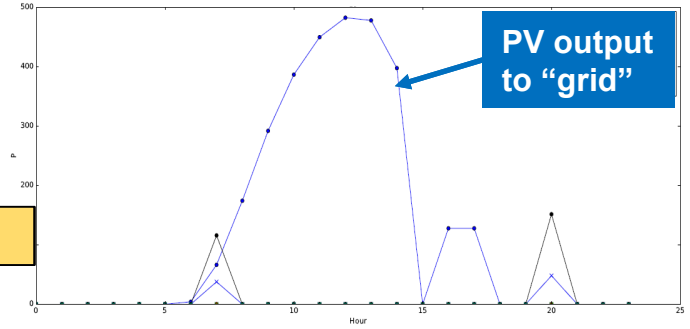
Battery discharge at high price

Battery precharge

PV Power to Batteries

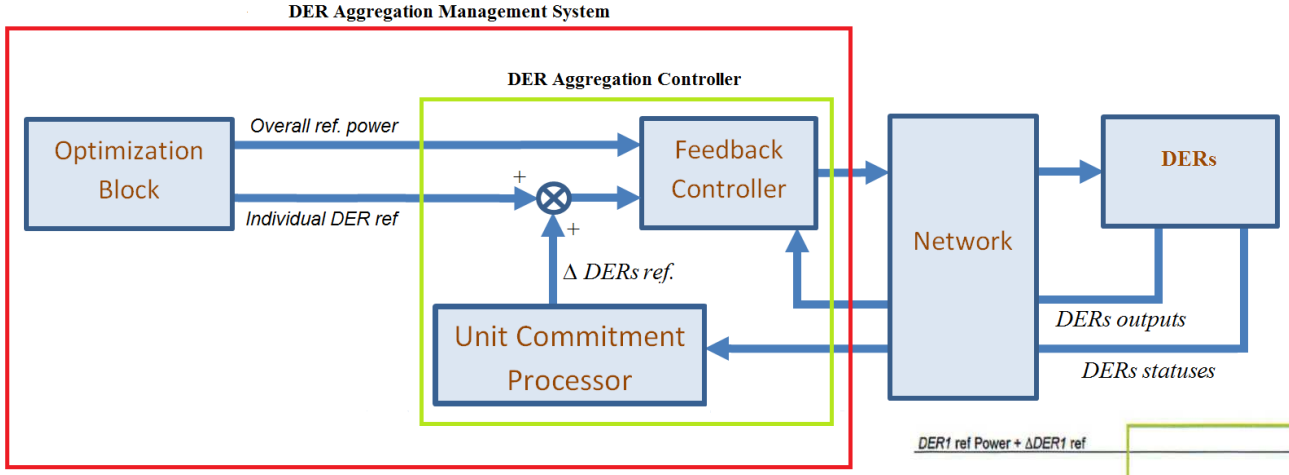
Solar energy is transferred to the batteries. The batteries deliver energy at the higher price point.

PV Power "to Grid"

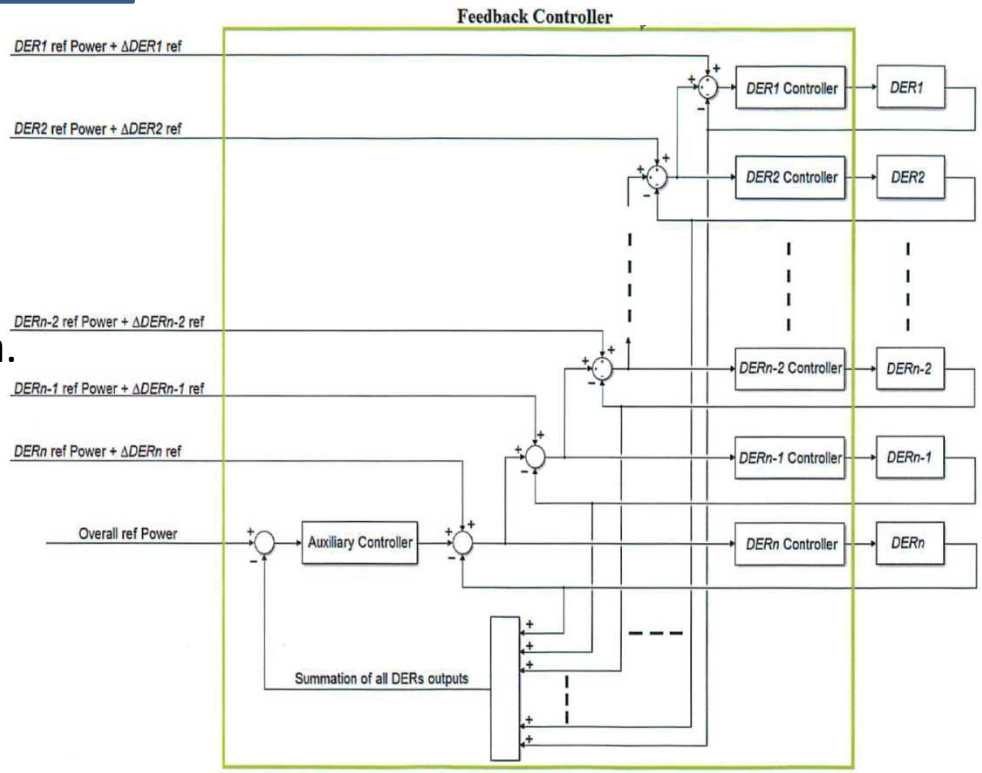


PV output to "grid"

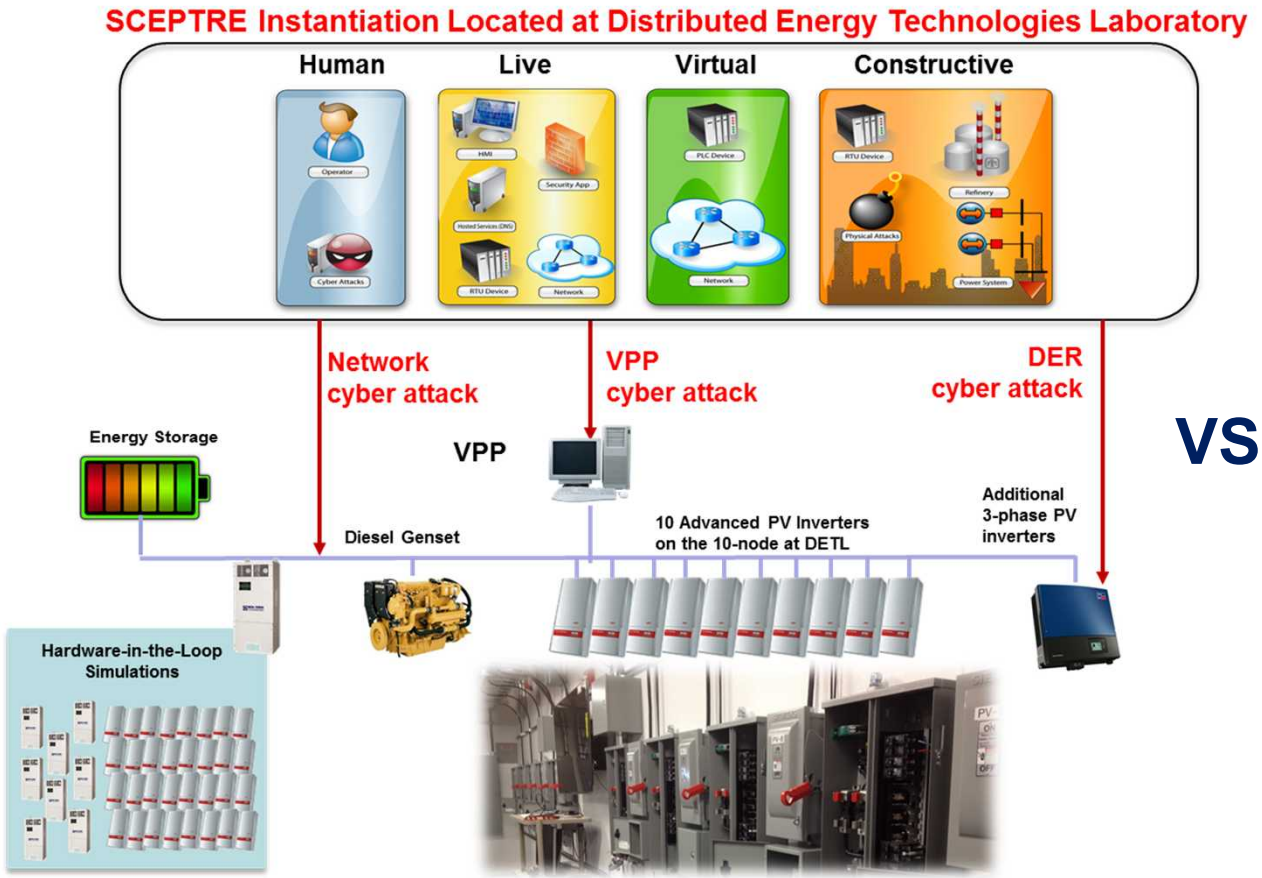
Controls



- Feedback Controller must:
  - Ensure that the VPP reaches the unit commitment target.
  - Handle large #s of DERs over a wide area.
  - Be robust to variable DER power output.
  - Compensate for the drop out of any DER in real time.
  - Be resilient to communication network impacts including latencies, data loss, and cyber security vulnerabilities.

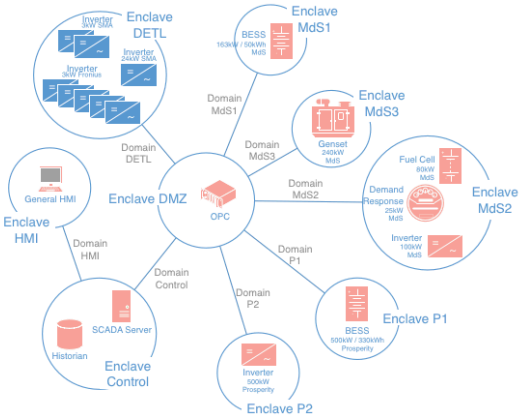


Red Team Demonstrations at DETL

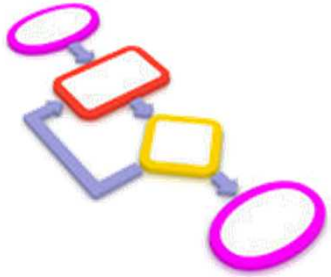


VS.

Enclaving Strategy



Intrusion Detection Algorithms



Goal: protect the VPP through enclaving of VPP DERs and intrusion detection algorithms.

Conclusions

- Sandia development of Secure Virtual Power Plants will:
  - Increase the quantity of renewable energy on the grid
  - Improve the electric grid resiliency in high-penetration solar situations
- Sandia is researching different aspects of VPP technology:
  - Stochastic optimization
  - Advanced coordinated DER controls
  - Secure communications and cybersecurity
  - DER interoperability
- Conducting demonstrations at Sandia in 2017 with real hardware!

Questions?

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