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Virtual Power Plants and Large Scale Renewable Integration

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

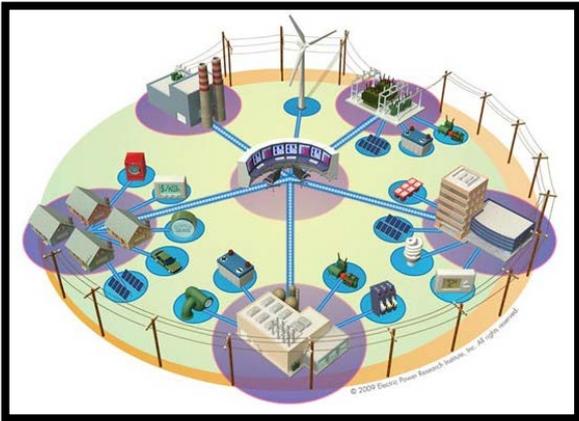
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Mohamed El-Khatib, David Schoenwald, Jordan Henry**
Photovoltaic and Distributed Systems Integration, Sandia National Laboratories



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Virtual Power Plants

- 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)

IV

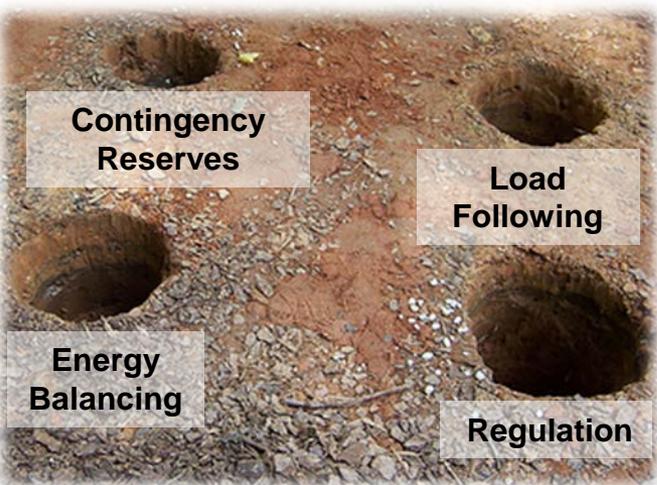
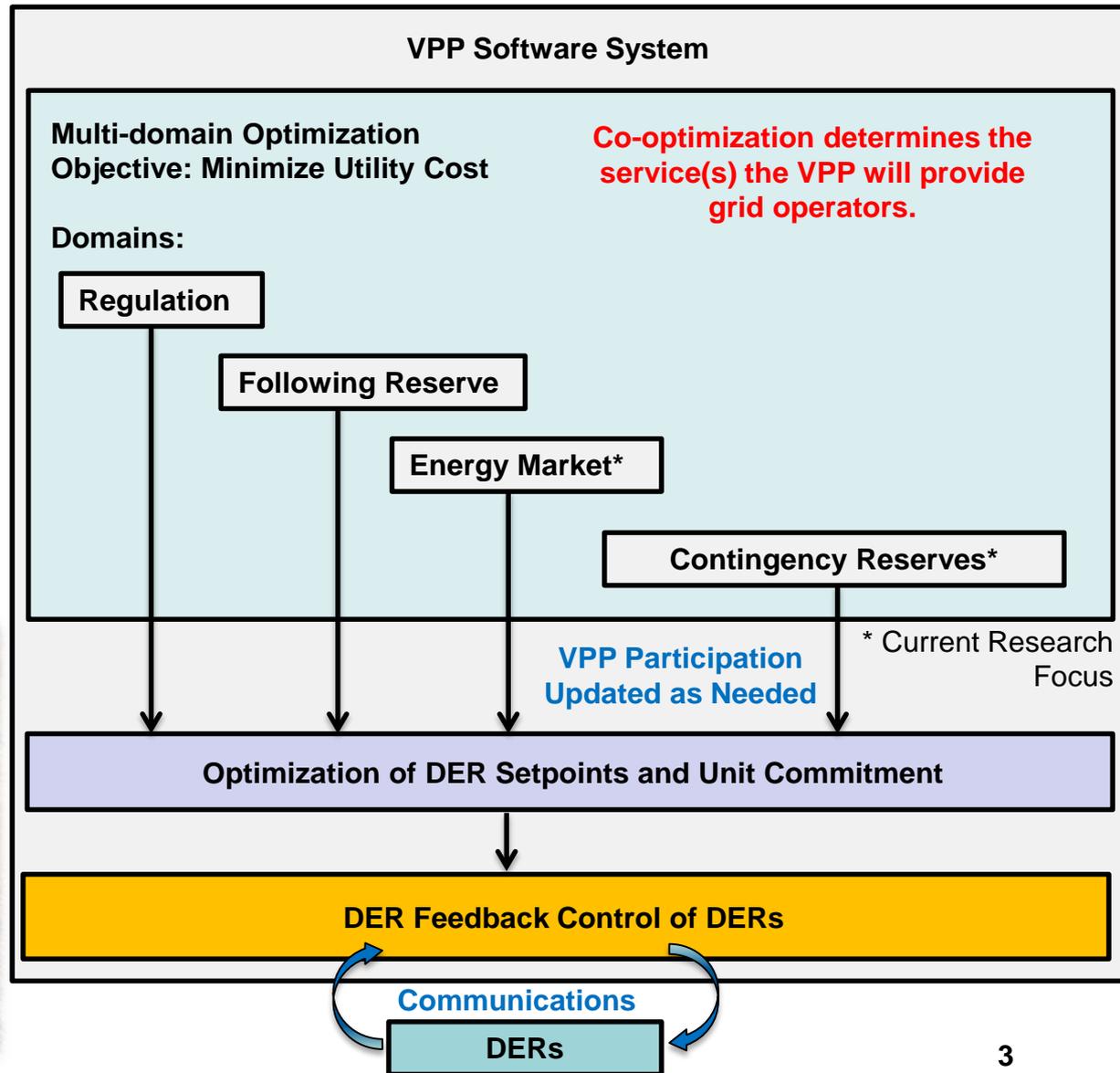


Lake Side natural gas turbine power station in Vineyard, Utah. (Wikipedia Commons)

VPPs will provide a range of grid services

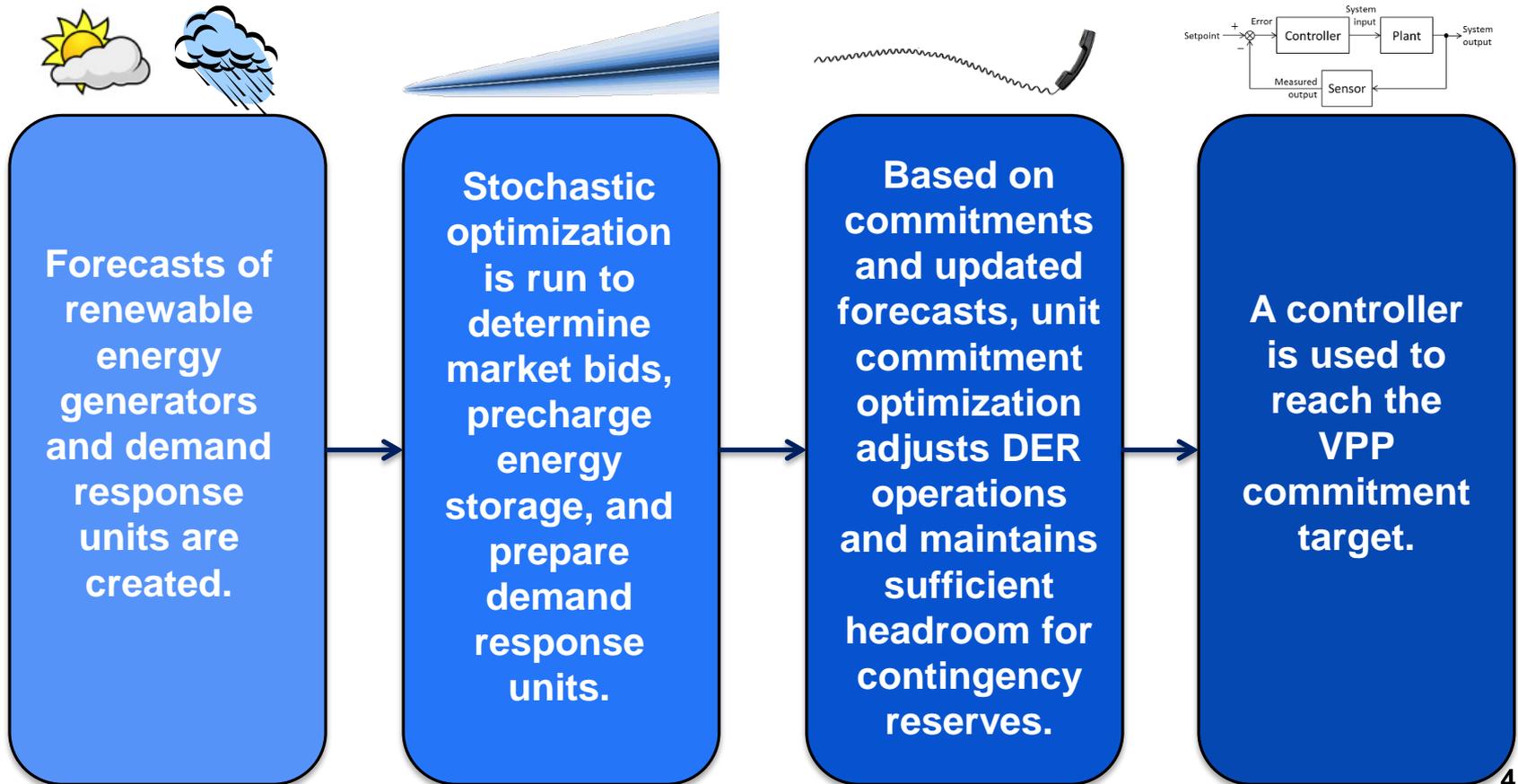


DER resources to fill in utility/grid operator needs



VPP Architecture

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



DETL-MdS-Prosperity VPP Use Case



Albuquerque Airport

Kirtland Air Force Base

Mesa del Sol



UNM Mesa del Sol
Aperture Center



Sandia's Distributed Energy
Technologies Laboratory



PNM Prosperity Project

VPP Forecasting

Short-Term Forecasting



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

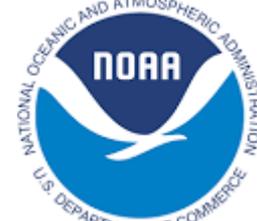
System data



Long-Term Forecasting

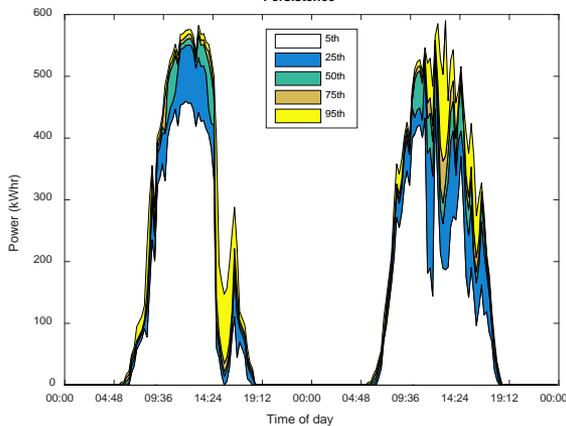
Forecast GHI,
 T_{amb} , RH

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



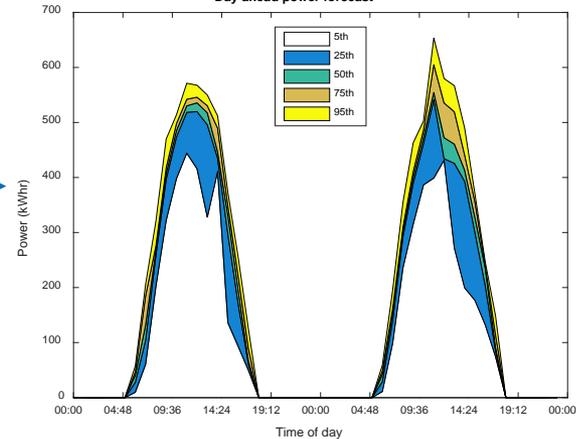
Irradiance to Power
Model

Short term power forecast
Persistence



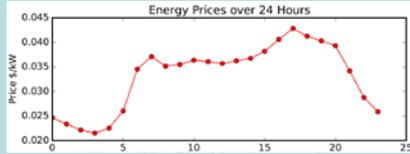
Uncertainty
from history
of forecast
vs. actual

Day ahead power forecast

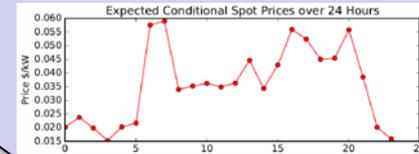


Day-ahead Unit Commitment Co-optimization

Energy Market



Reserve Market



Solar Forecast Scenarios

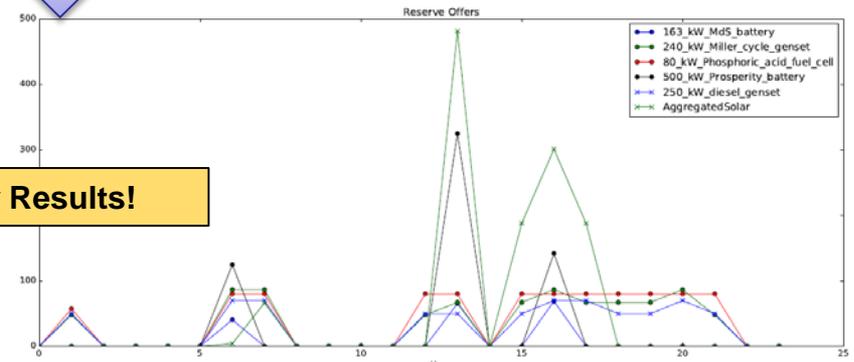
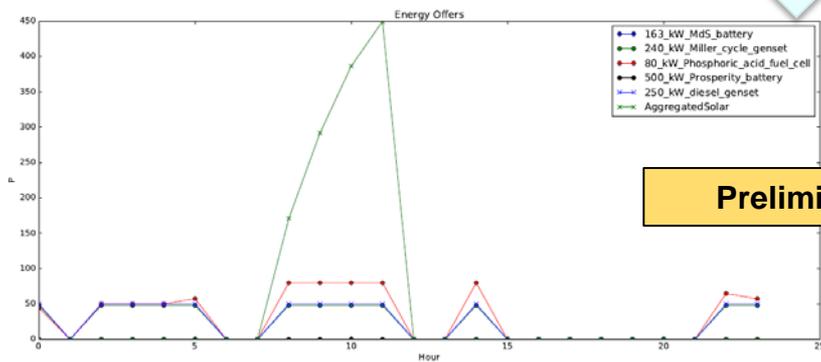
VPP Stochastic Optimization

Objective Function:

$$Max Profit = \sum_G^{DERS} (E_g * Price_{Energy} + R_g * Price_{Reserve} - Cost_G)$$

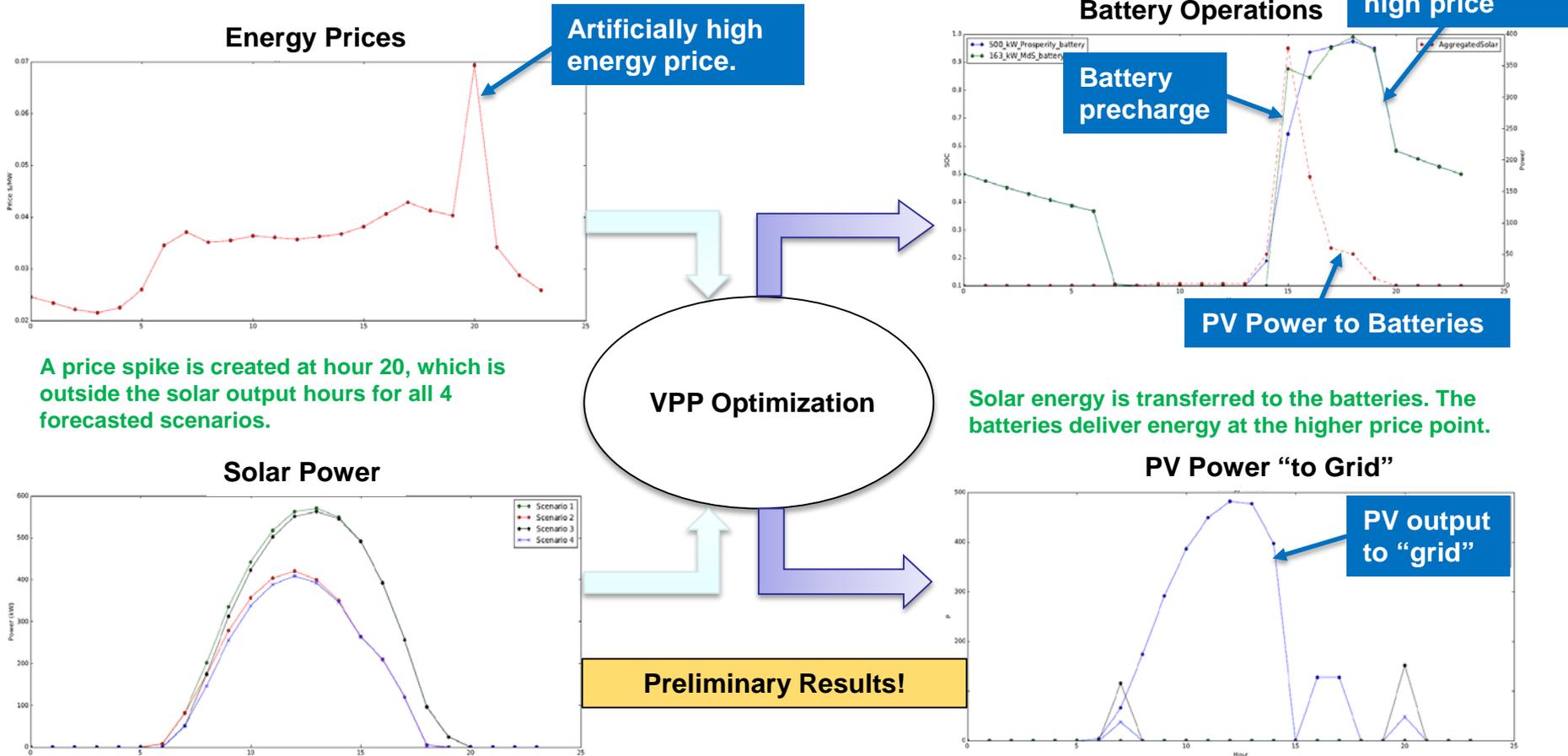
Subject to operational constraints

Preliminary Results!



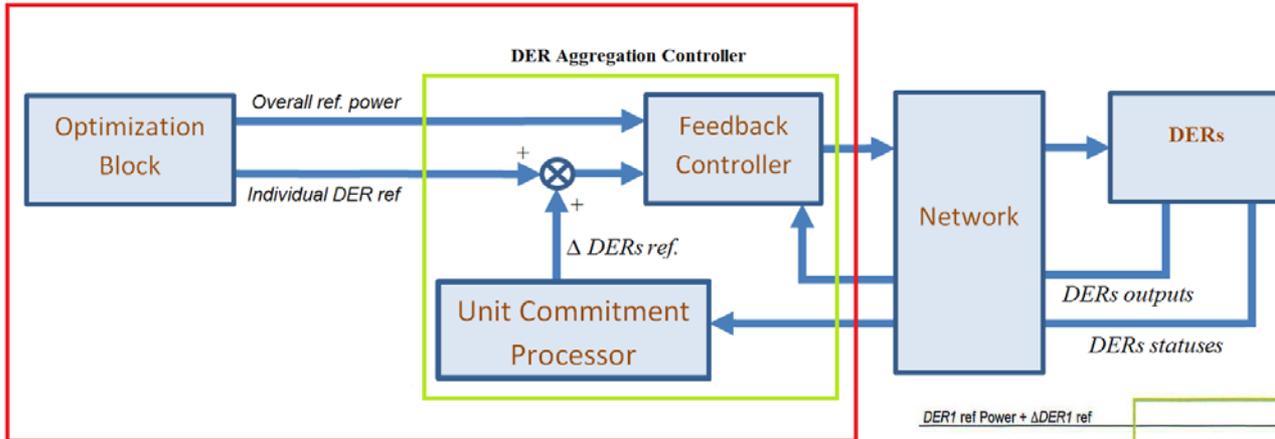
Optimization

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

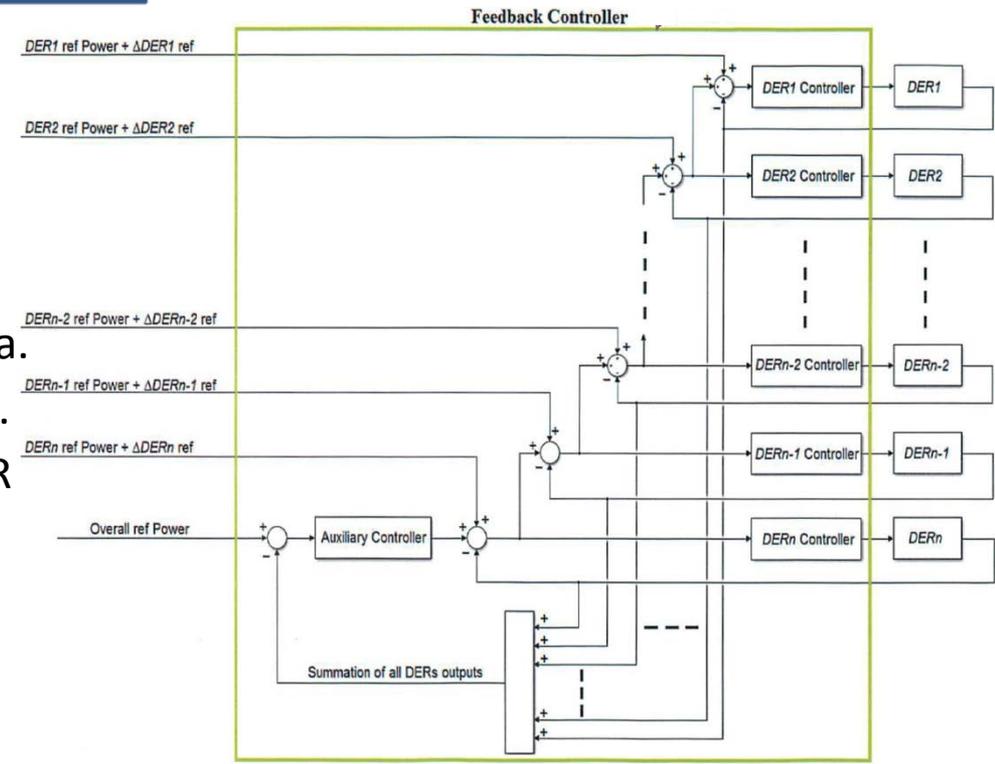


Controls

DER Aggregation Management System

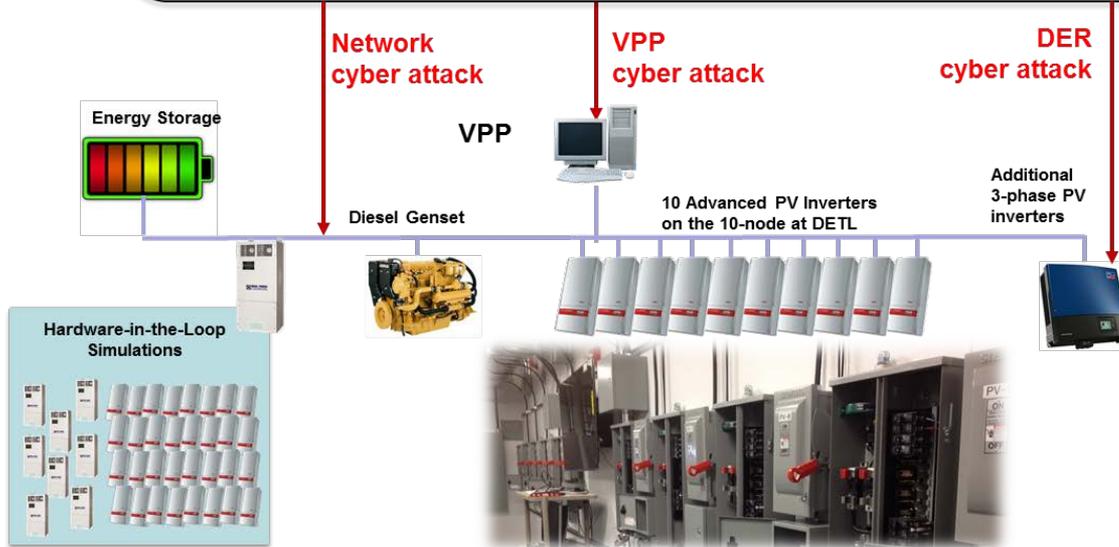
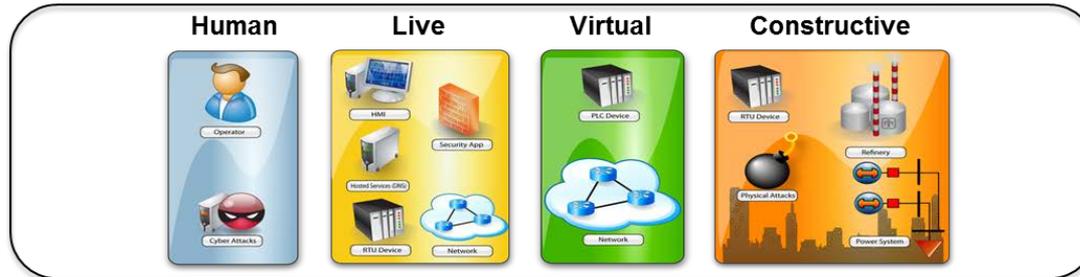


- Feedback Controller must:
 - Ensure that the VPP reaches the unit commitment target.
 - Handle large #s of DERs over a wide area.
 - Be robust to variable DER power output.
 - Compensate for the drop out of any DER in real time.
 - Be resilient to communication network impacts including latencies,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



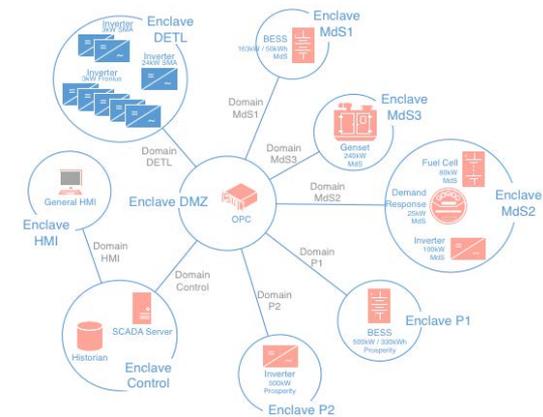
Red Team Demonstrations at DETL

SCEPTRE Instantiation Located at Distributed Energy Technologies Laboratory

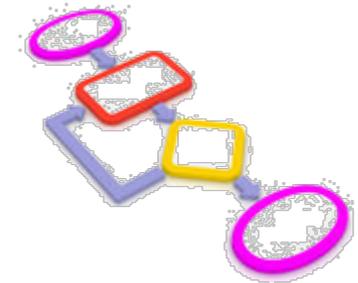


VS.

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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