Aggregating Distributed Energy Resources as Secure Virtual Power Plants

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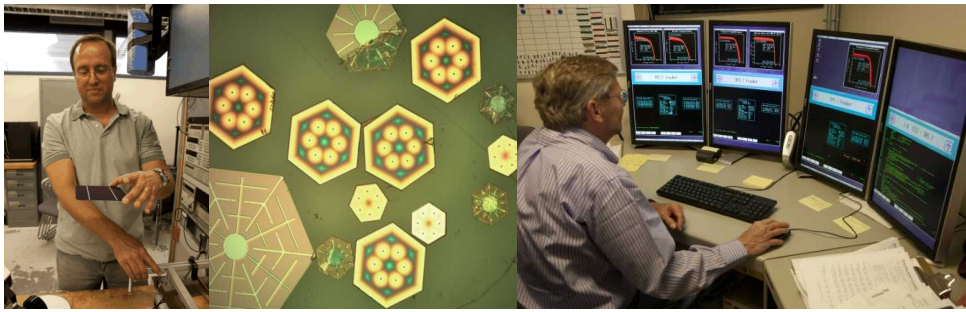

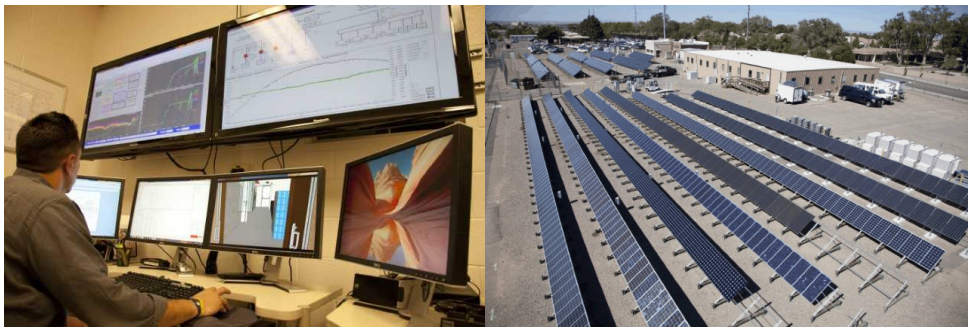

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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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)

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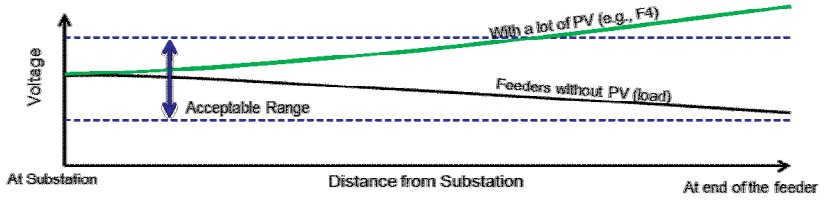
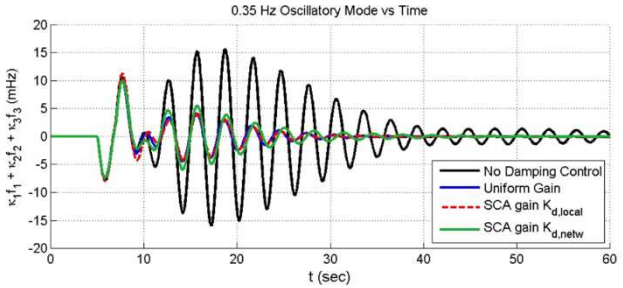
Lake Side natural gas turbine power station in Vineyard, Utah. (Wikipedia Commons)

Sandia is optimizing advanced DER functions to provide grid support capabilities

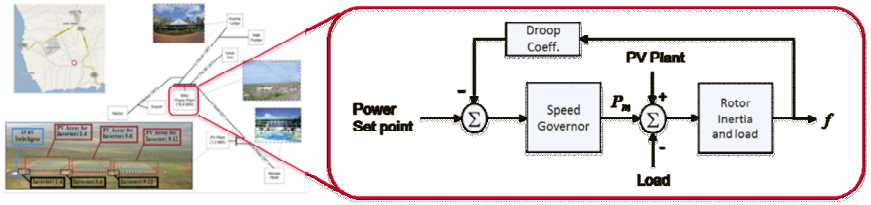
- Distribution-Level Voltage Control[1]



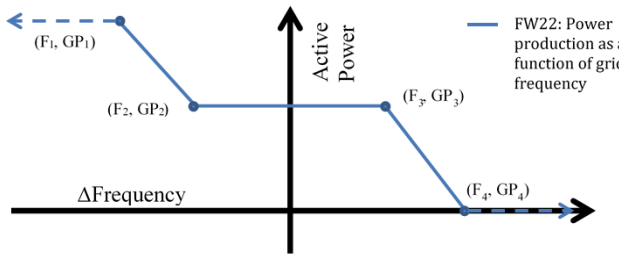
- Wide-area damping[2]



- Frequency Control[3]



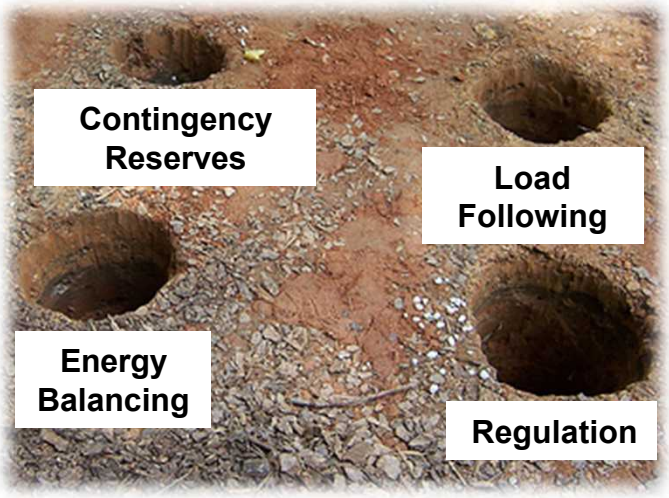
- Ancillary Reserves[4]

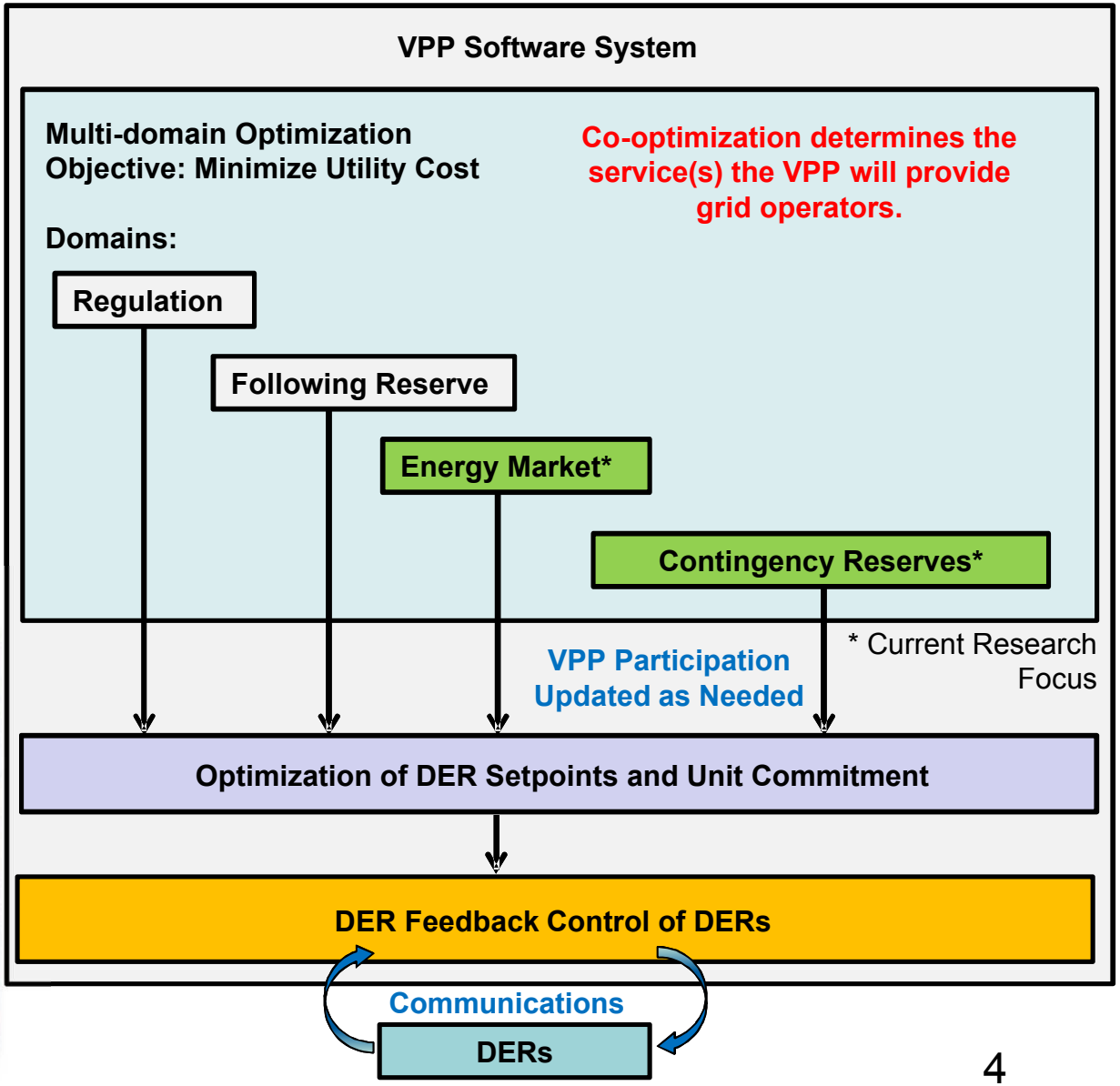


1. J. Seuss, M.J. Reno, R.J. Broderick, R.G. Harley, "Evaluation of reactive power control capabilities of residential PV in an unbalanced distribution feeder," 2014 IEEE PVSC, pp. 2094-2099, 8-13 June 2014.
2. J. Neely, J. Johnson, R. Bryne, R. T. Elliott, Structured optimization for parameter selection of frequency-watt grid support functions for wide-area damping, DER Journal, vol. 11, no. 1, pp. 69-94, 2015.
3. J. Neely, S. Gonzalez, J. Delhotal, J. Johnson, M. Lave, Evaluation of PV Frequency-Watt Function for Fast Frequency Reserves, IEEE Applied Power Electronics Conference (APEC), Long Beach, CA, March 20-24, 2016.
4. J. Johnson, J. Neely, J. Delhotal, M. Lave, "Photovoltaic Frequency-Watt Curve Design for Frequency Regulation and Fast Contingency Reserves," IEEE Journal of Photovoltaics, vol. 6, no. 6, pp. 1611-1618, Nov. 2016.

VPPs simultaneously provide a range of grid services

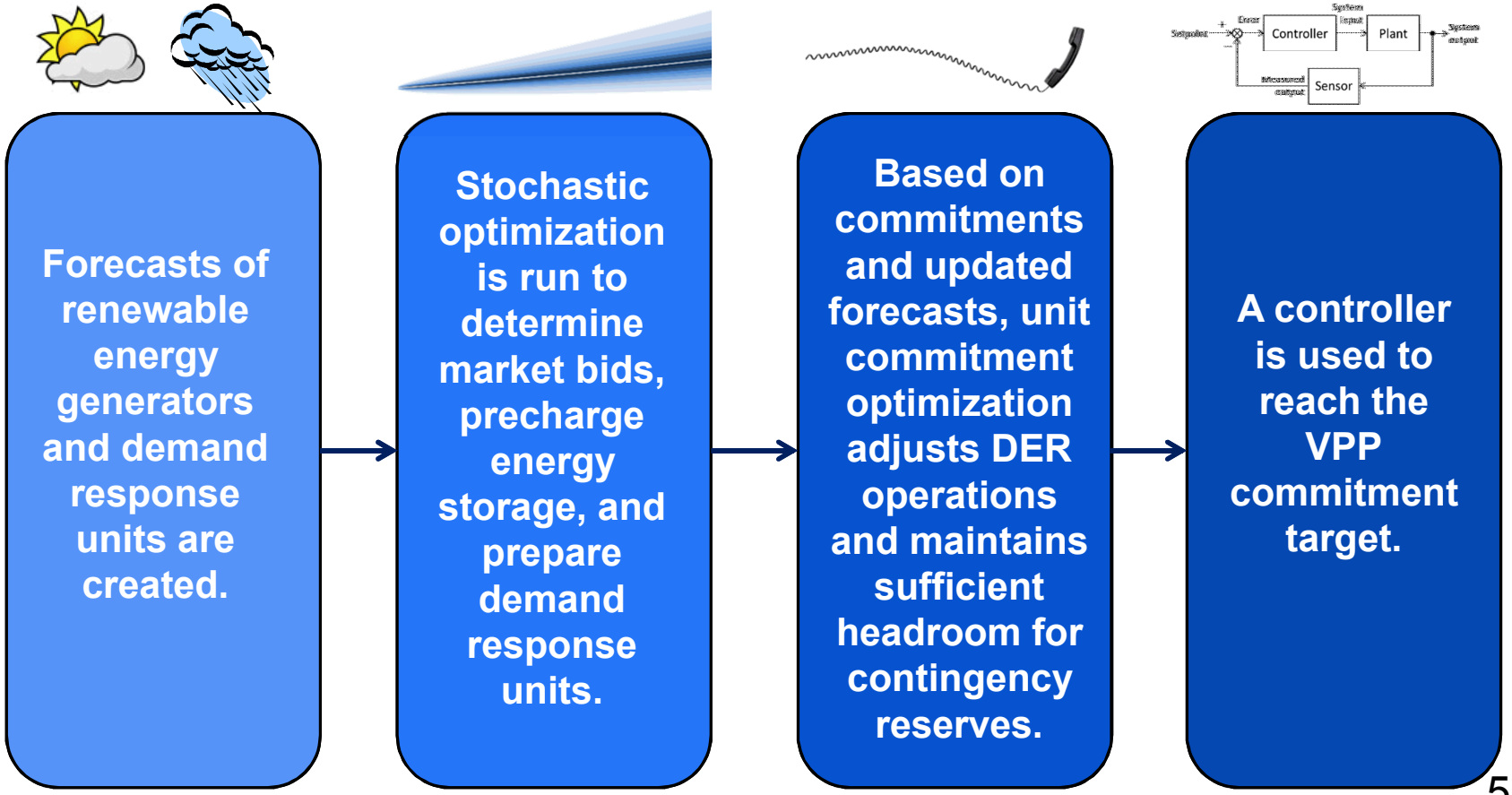
DER resources to fill in utility/grid operator needs



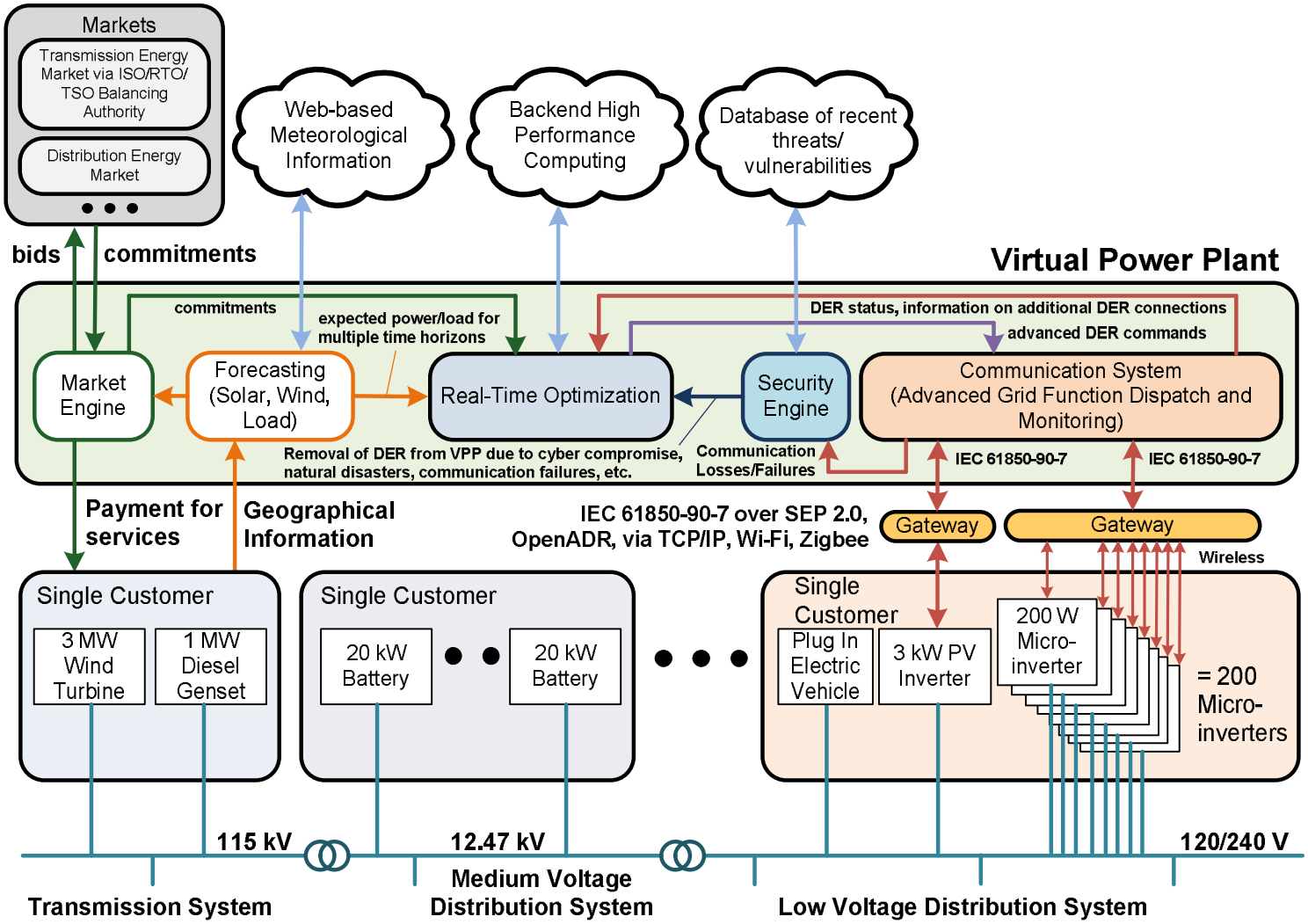


VPP Architecture

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



Sandia's Virtual Power Plant



VPP Forecasting

Short-Term Forecasting

System data

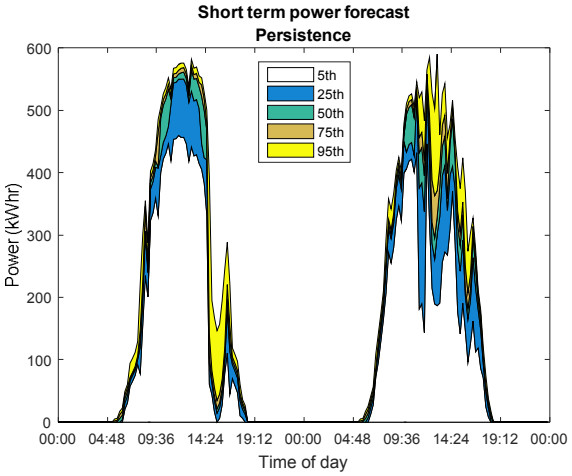
Statistical Forecast (e.g., persistence, ARMA)

Long-Term Forecasting

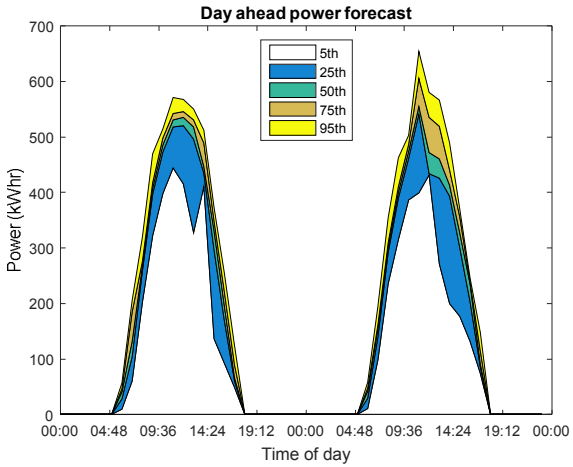
Forecast GHI, T_{amb}, RH

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

Irradiance to Power Model

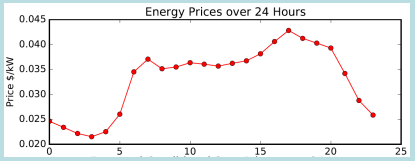


Uncertainty from history of forecast vs. actual

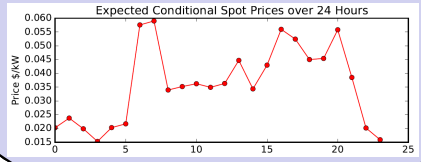


Day-ahead Unit Commitment Co-optimization

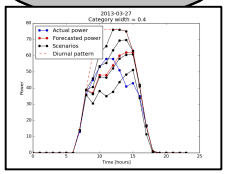
Energy Market



Reserve Market



Solar Forecast Scenarios

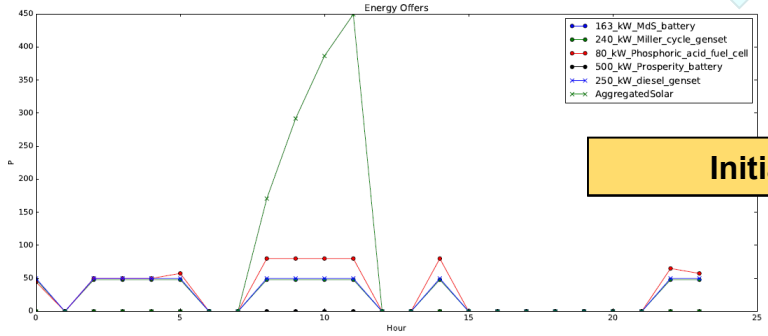


VPP Stochastic Optimization

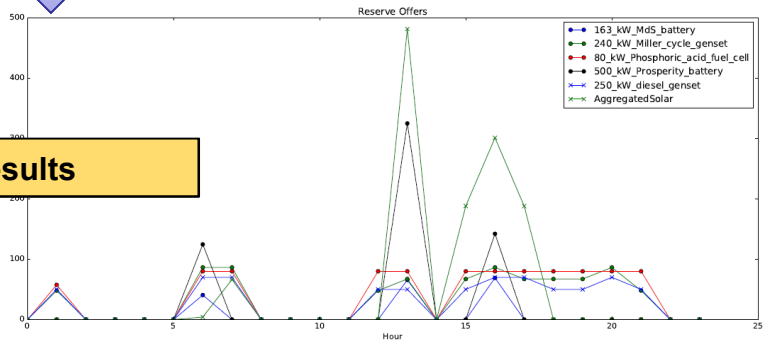
Objective Function:

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

Subject to operational constraints

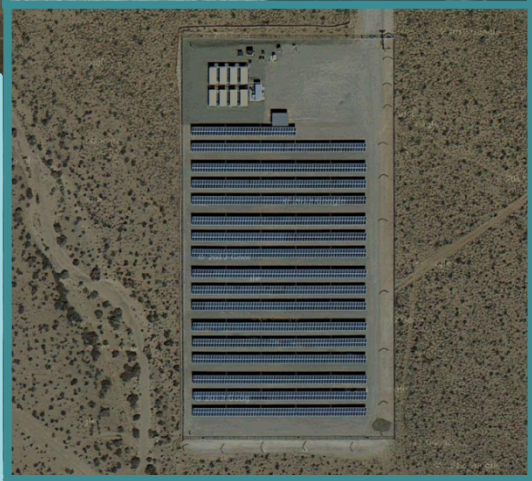


Initial Results



DETL-MdS-Prosperity VPP Use Case

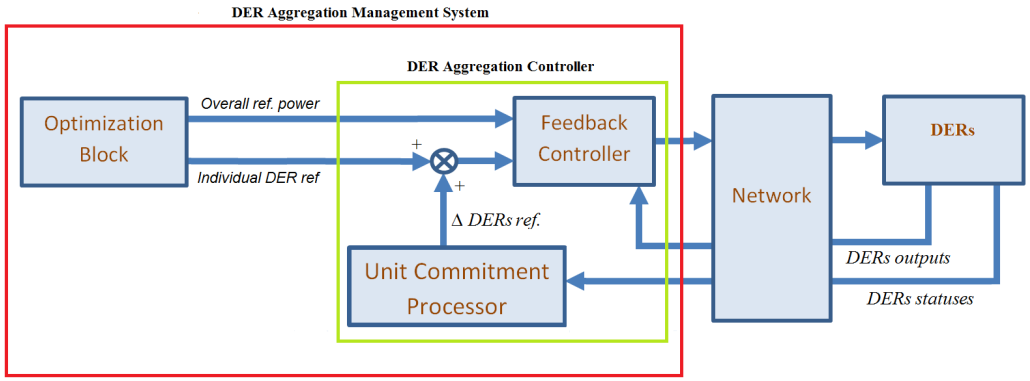
Sandia's Distributed Energy Technologies Laboratory

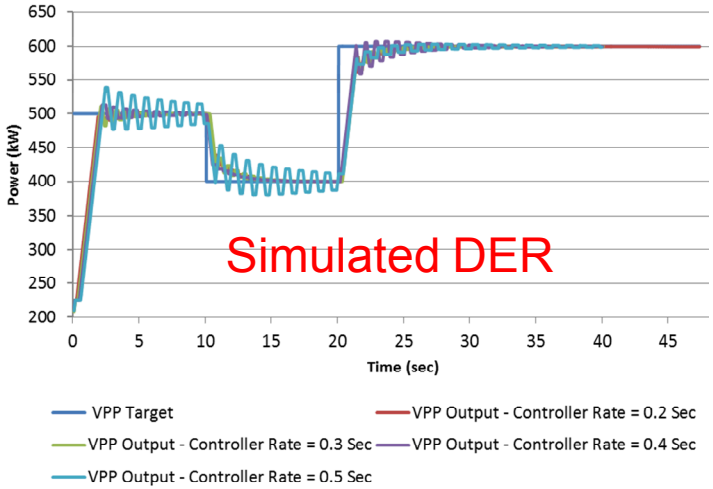


PNM Prosperity Project

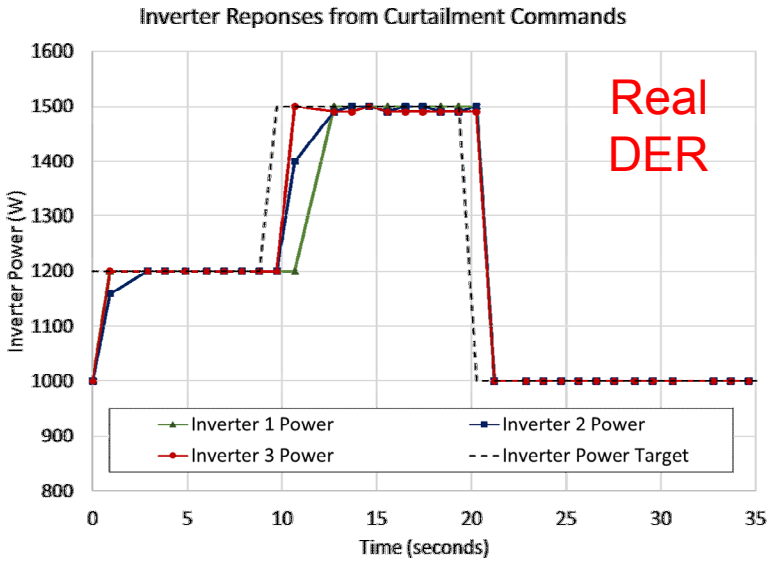
UNM Mesa del Sol Aperture Center

Controls for DETL-MdS-Prosperity VPP





- VPP feedback controller:
  - Ensures VPP reaches the unit commitment target.
  - Compensates for the drop out of any DER in real time.
  - Is resilient to communication network impacts including latencies, data loss, and cyber security vulnerabilities.



Modbus TCP latencies a major challenge for VPP control!

Conclusions

- Virtual Power Plants will:
  - Increase the quantity of renewable energy on the grid
  - Improve the electric grid resiliency in high-penetration solar situations

- Sandia researched different aspects of VPP technology:
  - Stochastic optimization
  - Advanced coordinated DER controls
  - Secure communications and cybersecurity
  - DER interoperability

- VPP demonstration at Sandia with real hardware revealed difficulties when working with communication networks.

Questions?

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