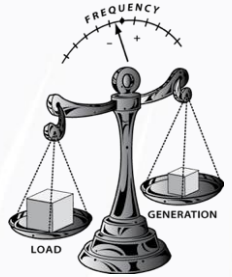
SOLAR ENERGY
TECHNOLOGIES OFFICE
U.S. Department Of Energy

Dynamic Building Load Control to Facilitate High Penetration of Solar Photovoltaic Generation

Teja Kuruganti, Ph.D.
Senior R&D Staff

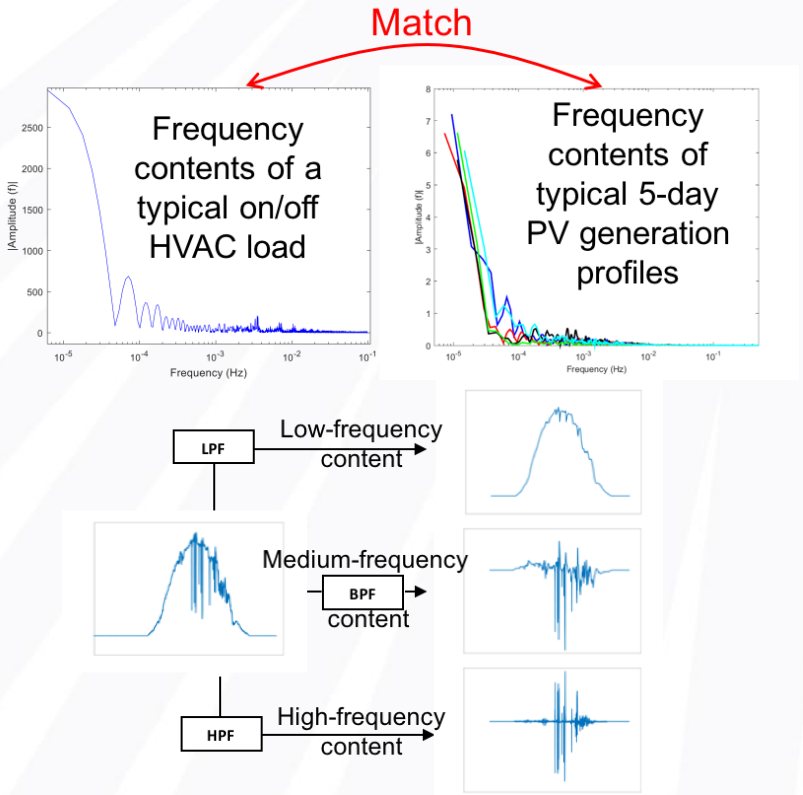
Motivation

- Variability in solar photovoltaic (PV) power production introduces
  - Two-way power flow on the distribution circuit
  - Voltage variations temporally and spatially on feeder and substation
- Typically loads act autonomously without any coordination with the grid or PV
- Traditional electric grid is load following (temporally)
- Responsive loads that can be controlled temporally and spatially to minimize difference between demand and PV production



Spectral Analytics of PV and Loads – Timing Requirements

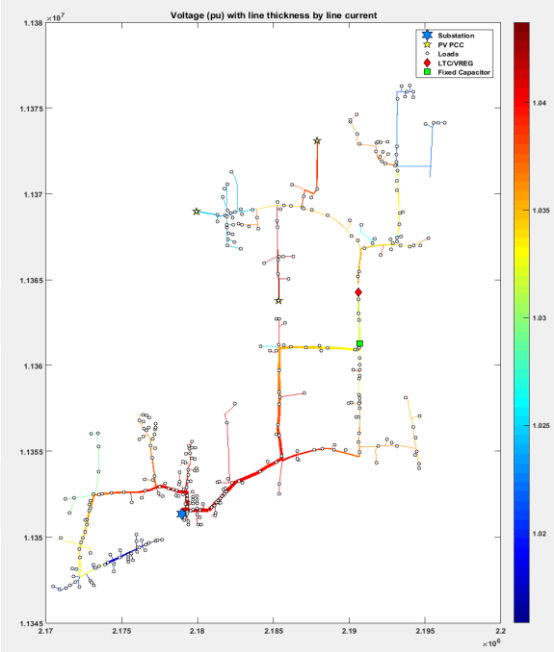
- One year of solar PV power output and HVAC, WH, and refrigeration analyzed
- >95% of power in low frequency content with > 15 min response times
- Derived time and magnitude response from DERs



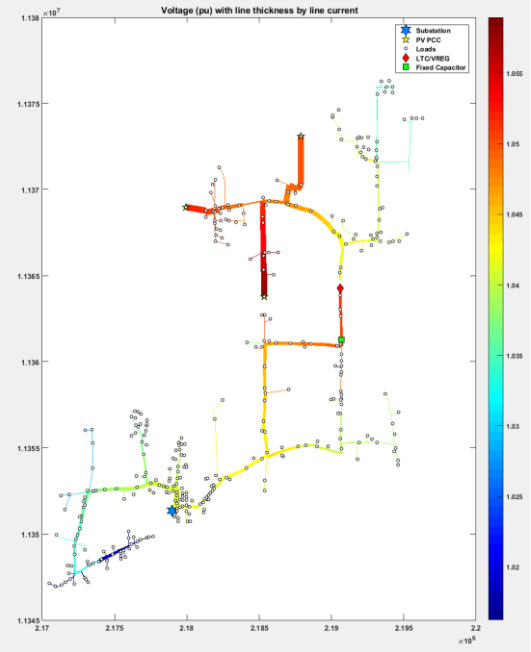
M. Olama, I. Sharma, T. Kuruganti, J. Dong, J. Nutaro, and Y. Xue "Spectral Analytics of Solar Photovoltaic Power Output for Optimal Distributed Energy Resource Utilization," *2017 IEEE PES General Meeting,* Chicago, IL July 16-20, 2017

Voltage Impacts – High Penetration of PV

- Simulations for one year were conducted at 1-min. time step - PV penetration from 0% to 150%
- Below 20% PV penetration, the cumulative load tap changes are roughly the same
- At 30% PV penetration, the cumulative load tap change counts are doubled compared to base case, and then increases linearly with increase in solar PV penetration level at a rate of about 1500~1600 counts every 10% penetration increase



30% solar PV

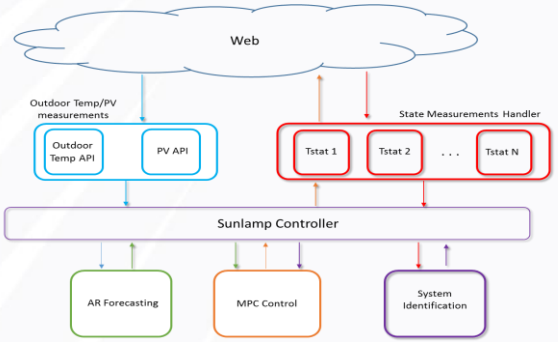


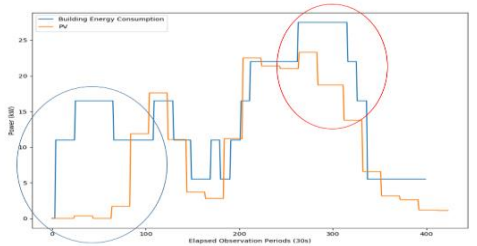
100% solar PV

J. Dong, Y. Xue, T. Kuruganti, I. Sharma, J. Nutaro, M. Olama, J. Hill, and J. Bowen, "Operational Impacts of High Penetration Solar Power on a Real-World Distribution Feeder," IEEE Innovative Smart Grid Technologies, Feb 12-22, 2018, Washington DC

End-to-End Control Architecture

- Coordinated response of discrete and continuous loads - PV following. Controller consists of five components:
  - Weather API
  - State Measurements Handler
  - Autoregression (AR) Solar Forecasting
  - System Identification (Building Thermal Zone)
  - Model-predictive Control and Dispatch
- Supervisory interaction between smart inverters
  - Minimal information exchange between inverters
  - Provide reactive power and voltage support using distributed optimization
- Control performance depends on SysID and forecaster performance





J. Dong, M. Olama, T. Kuruganti, A. Melin, J. Nutaro, C. Winstead, Y. Xue, "Model Predictive Control of Building On/Off HVAC Systems to Compensate Fluctuations in Solar Power Generation," 9th International Conference on Power Electronics for Distributed Generation Systems (PEDG2018), Charlotte, NC, June 2018.

Net-Load forecasting – Distribution System Operation

- Real-time prediction of PV power - Temporal variability challenges of solar radiation
- Stochastic time series forecasting is capable of capturing irradiance fluctuations
  - Observability and controllability
- Uncertainty boundaries of the load/PV forecasting is needed for accurate “net load” projections
- Non-orthogonal parameters – It’s a trade off
  - Computational Complexity
  - Forecast accuracy
  - Control response time
- Forecasting accuracy varies with the scale and size of PV penetration changes – what are the limits