The Impact of Behind-the-Meter Heterogeneous Distributed Energy Resources on Distribution Grids

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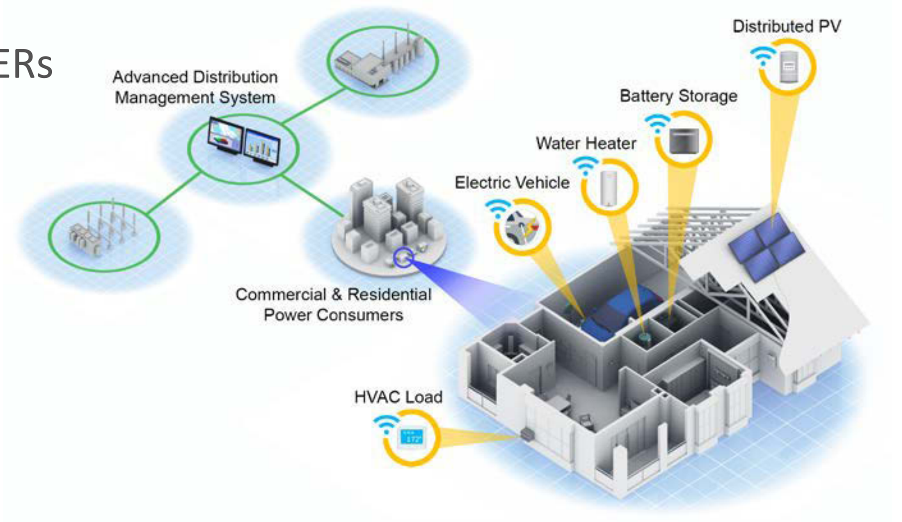
Contents

Introduction

Distributed energy resources (DERs) on the grid

- Increasing trend of behind-the-meter DERs integration on the distribution grid
- DERs accounted for 2% of total installed generation capacity in the U.S. in 2016
- Challenges : could cause grid issues
- Opportunities : could leverage DERs to provide grid services with proper management and control

- This work investigates impacts of DERs on a utility distribution grid in Colorado



BTM DERs Modeling

Distributed PV

- PV array sized to generate 120% of total annual load consumption

Distributed energy storage

- Sized and controlled to maximize self-consumption of PV generation

Schedulable loads

- Heating, ventilation and air-conditioning (HVAC)
- Electric water heater (EWH)
- Model implemented accounts detailed factors such as outdoor temperature, size of the house, size of water tank, flow rate, inlet water temperature, etc.

Electric Vehicle

- Depends on charging location, time, initial SOC, etc.
- Residential, work location and public charging



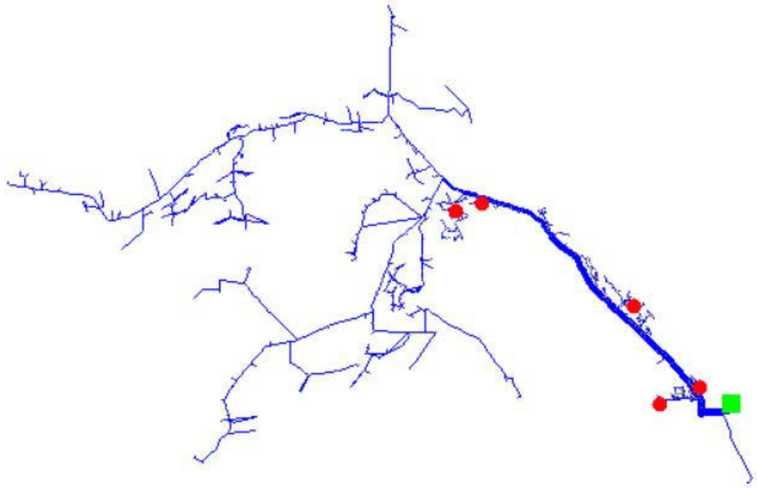


Grid Impact Study

Simulation study

Test system

- A distribution feeder from Colorado



Simulation scenarios

- S1: no PV no energy storage (ES)
- S2: With PV no ES
- S3: With PV with ES
- S4: With PV, ES, and EV

Simulation parameters

- January 27th (peak load day) and May 3rd (minimum load day)
- Standard values used for HVAC and EWH model parameters
- Actual outdoor temperature and solar radiation data adopted for this region in Colorado
- Standard time-of-use rate used for electricity cost calculation for all scenarios

Simulation result : voltage profile

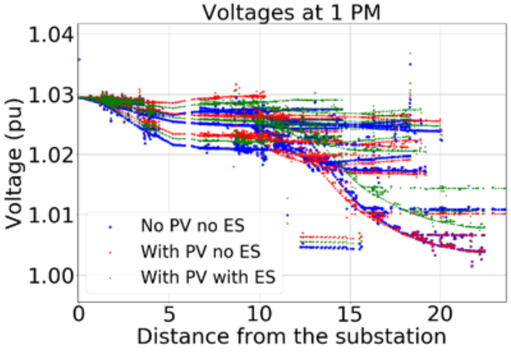
Feeder voltage profile during high PV generation time of day

- Voltages within standard limits of [0.95, 1.05]

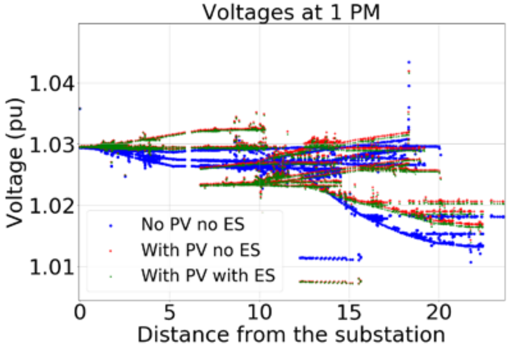
Voltage at one selected node

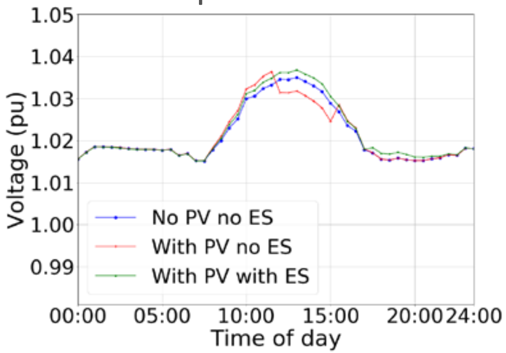
- January 27: Voltage regulator operates to reduce the local voltage during high PV output without ES; with ES scenario -- ES charges to lower the voltage during high PV
- May 3: Due to minimum load and high PV, voltage regulator operates to reduce the local voltage

January 27

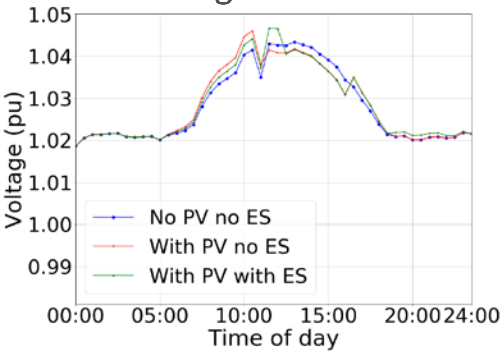


May 3





January 27

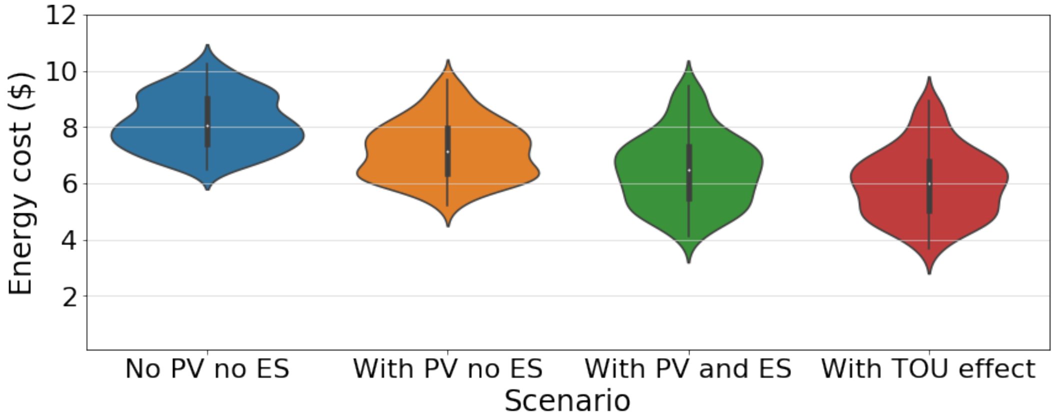


May 3

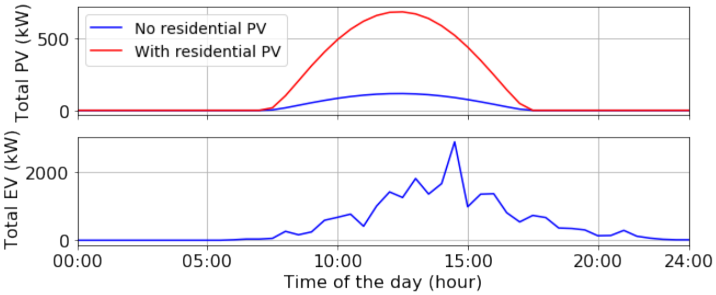
Simulation result : Electricity cost

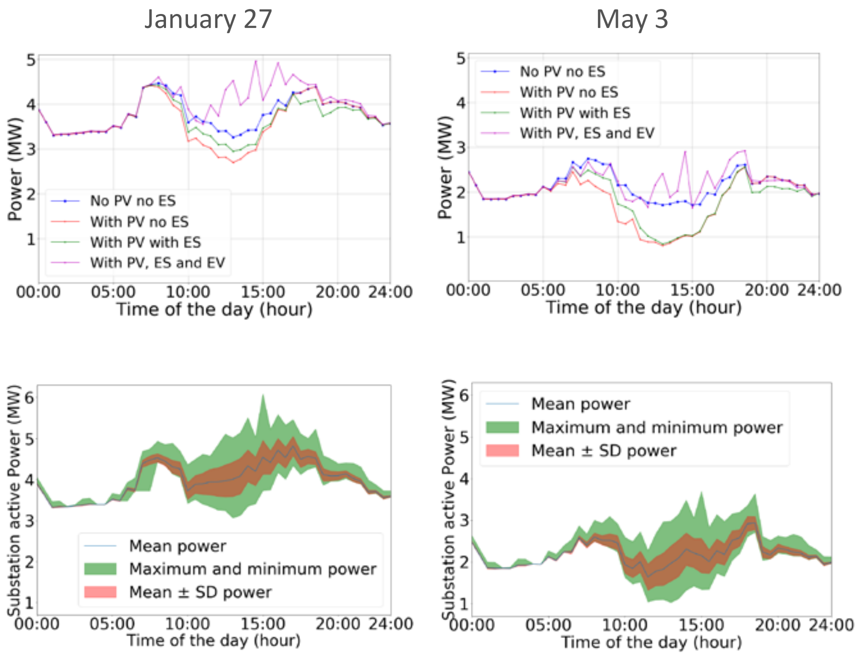
Electricity cost calculation for different scenarios (Jan 27)

- Electricity cost calculation considering 164 residential houses
- Daily cost could be reduced with PV and energy storage
- With TOU effect: special case when the residential controllable loads (HVAC and EWH) responded to the TOU price – electricity cost could further be reduced



Simulation result: Scenario with PV, ES and EV





With EV charging load

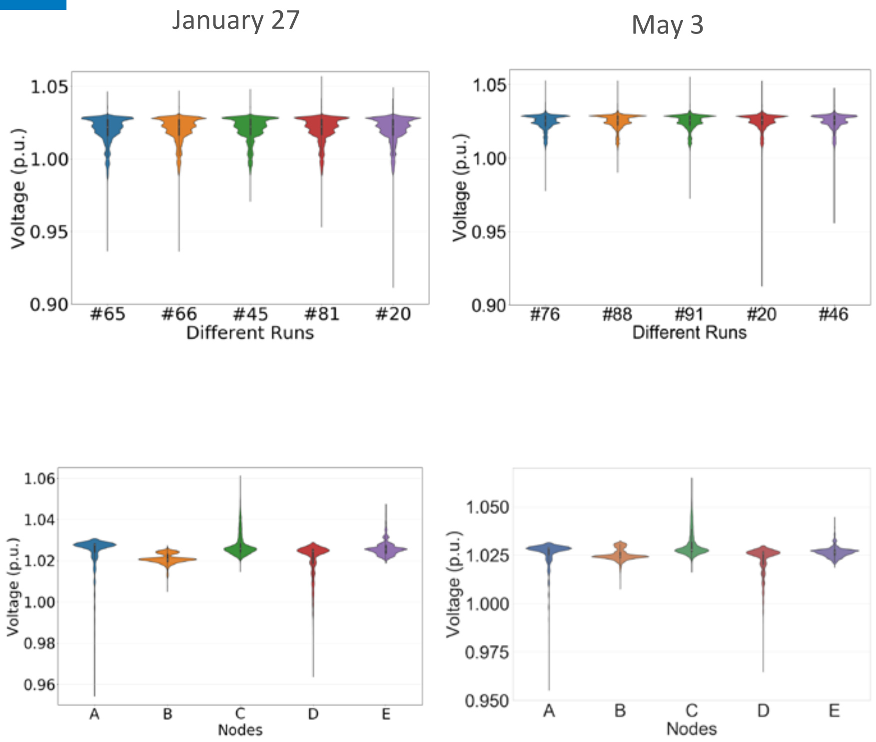
– 100 simulations were conducted to capture the stochastic nature of EV load

– Uncoordinated EV charging could significantly increase the total power at the substation

Simulation result: Voltage distribution

Voltage distribution with EV charging load

- Different simulation runs present varying effect on the voltage
- Voltage violations observed in this feeder with uncoordinated EV charging
- Control strategies for coordinated EV charging required to fulfill the increasing EV charging demand



Conclusions

- Analysis of the effect of deploying a mix of DERs in a utility distribution feeder is essential to enable resilient and reliable grid operation
- Electricity cost for a day could be reduced by 20.7% on an average with addition of PV and energy storage in the residential houses
- Random EV charging most likely creates voltage issues in this feeder
- Distribution system monitoring and strategic controls are needed to adopt the increasing EV charging load

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