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CASE STUDY ON AN ALTERNATIVE APPROACH TO DISTRIBUTED ENERGY DEMAND DISPATCH

ESIG 2019 Spring Technical Workshop

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Serving:

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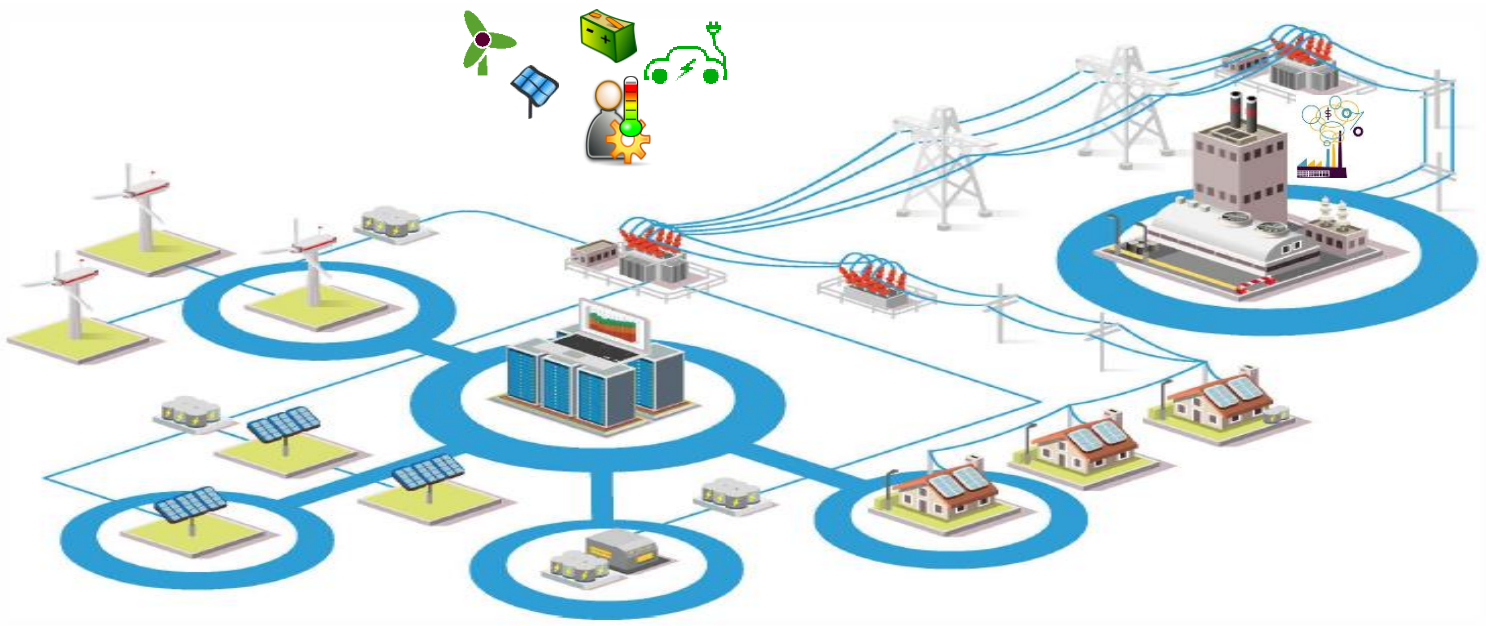
Electric Power Engineers, Inc. (EPE) : a leading global power system engineering and consulting firm headquartered in Austin, Texas, with services covering the entire spectrum of GENERATION, TRANSMISSION and DISTRIBUTION.



4 years of R&D

ENERGY INTEGRATED

Grid Analytics &

Planning PLATFORM

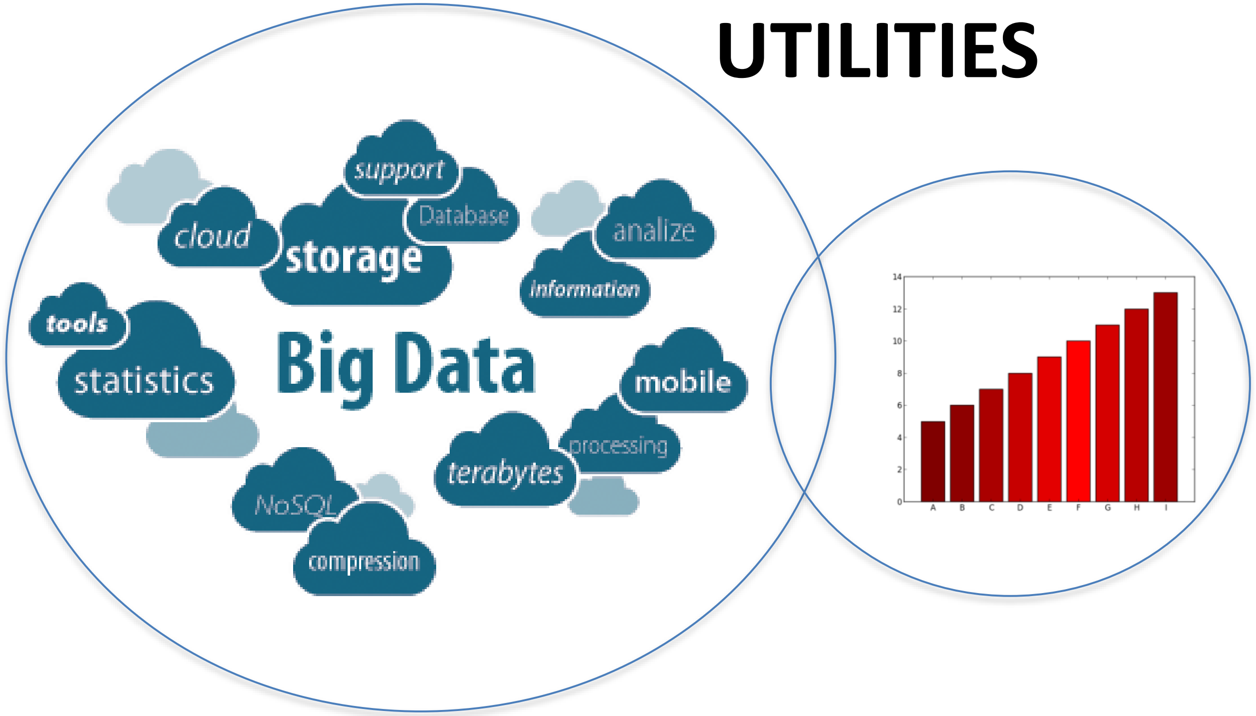
CONSULTING + SOFTWARE

Integrated Planning

OUR VISION

Be the leader and innovator in the application of a holistic approach to study, design, and implement of an infrastructure that enables an integrated grid of the future across G, T&D

- Why do the analysis?
- What is Demand Dispatch?
- How is it modeled?
- Optimization and Constraints
- Results & Conclusions
- What's Next



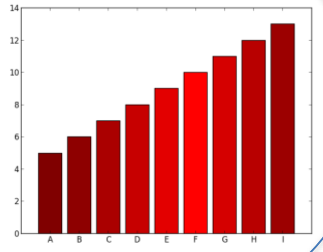
Data Rich

Information Poor

Our Goal:

- Identify low-hanging fruits for informative analysis
  - Transformer Loading
  - Line Loss
  - Phase Balance
  - Etc.
- Find and explore new frontiers with the available data for planning
- Test information theory in real-world applications

UTILITIES



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- Identify low-hanging fruits for informative analysis
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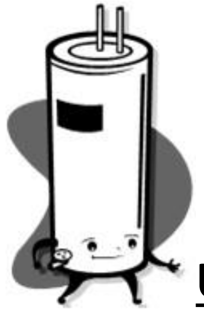
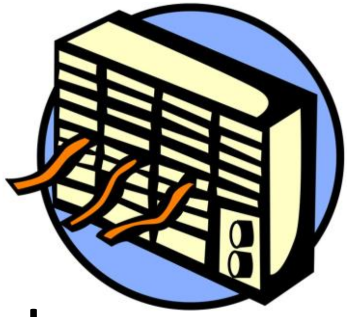
ALTERNATIVE APPROACH TO DEMAND

Demand Dispatch is an emerging science for controlling flexible loads to provide grid services. With the proper design, a distributed control approach can improve the utilization of the power grid while satisfying consumer preferences. This study explains how a Demand Dispatch analysis is conducted and provides results from simulations based on a physical system.





LOCALIZED DEMAND RESPONSE

Customers set the comfort level

Utility shapes demand to arrive at that comfort level

- **Demand dispatch is built around the idea that many types of loads can be flexible in their power consumption while delivering the same quality of service to the consumer**
- **For example, consumers care about their water temperature, not instantaneous power consumption**
- **Maintaining water temperature within a desired range can be accomplished using many different power consumption trajectories**

COLLABORATORS

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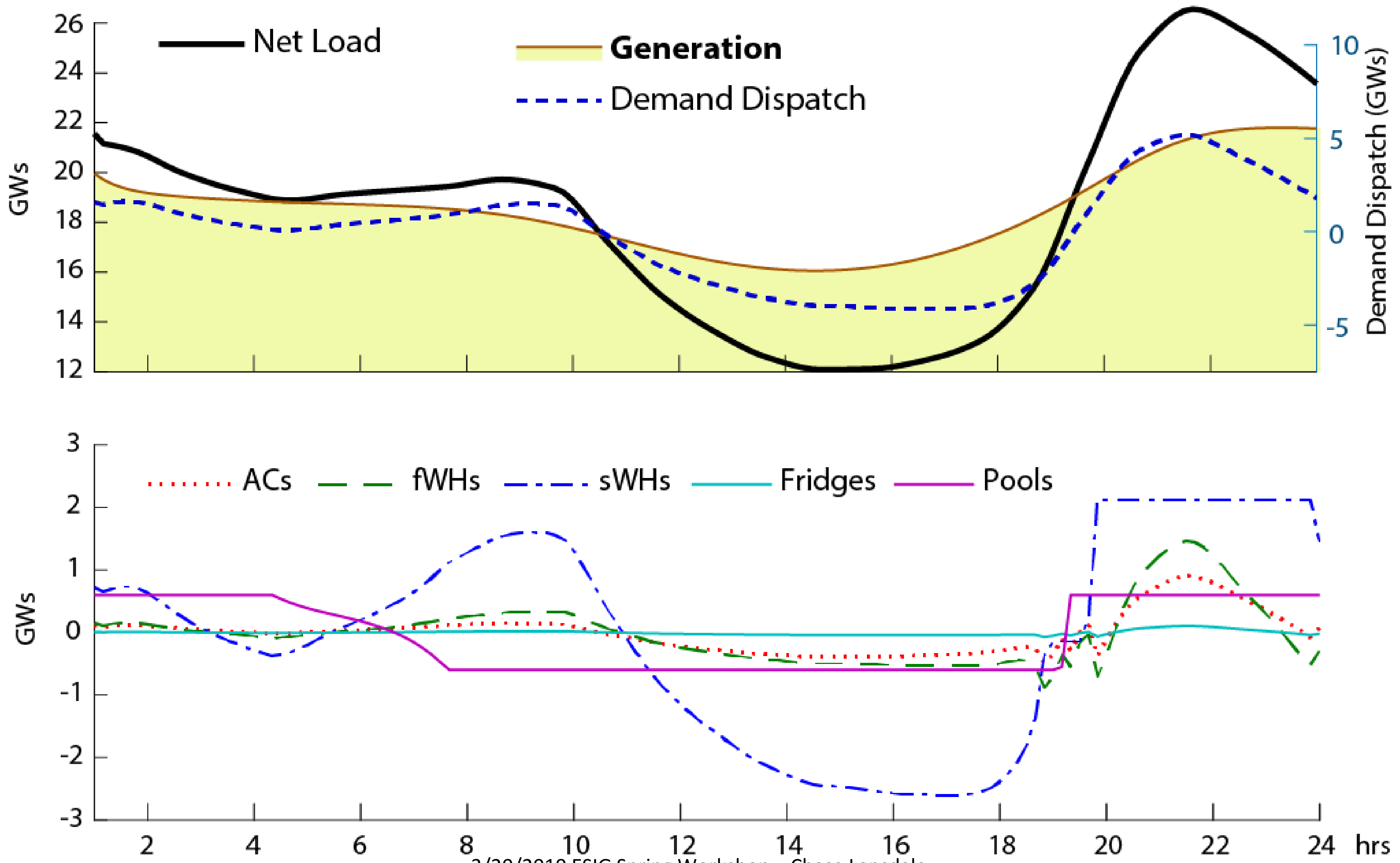
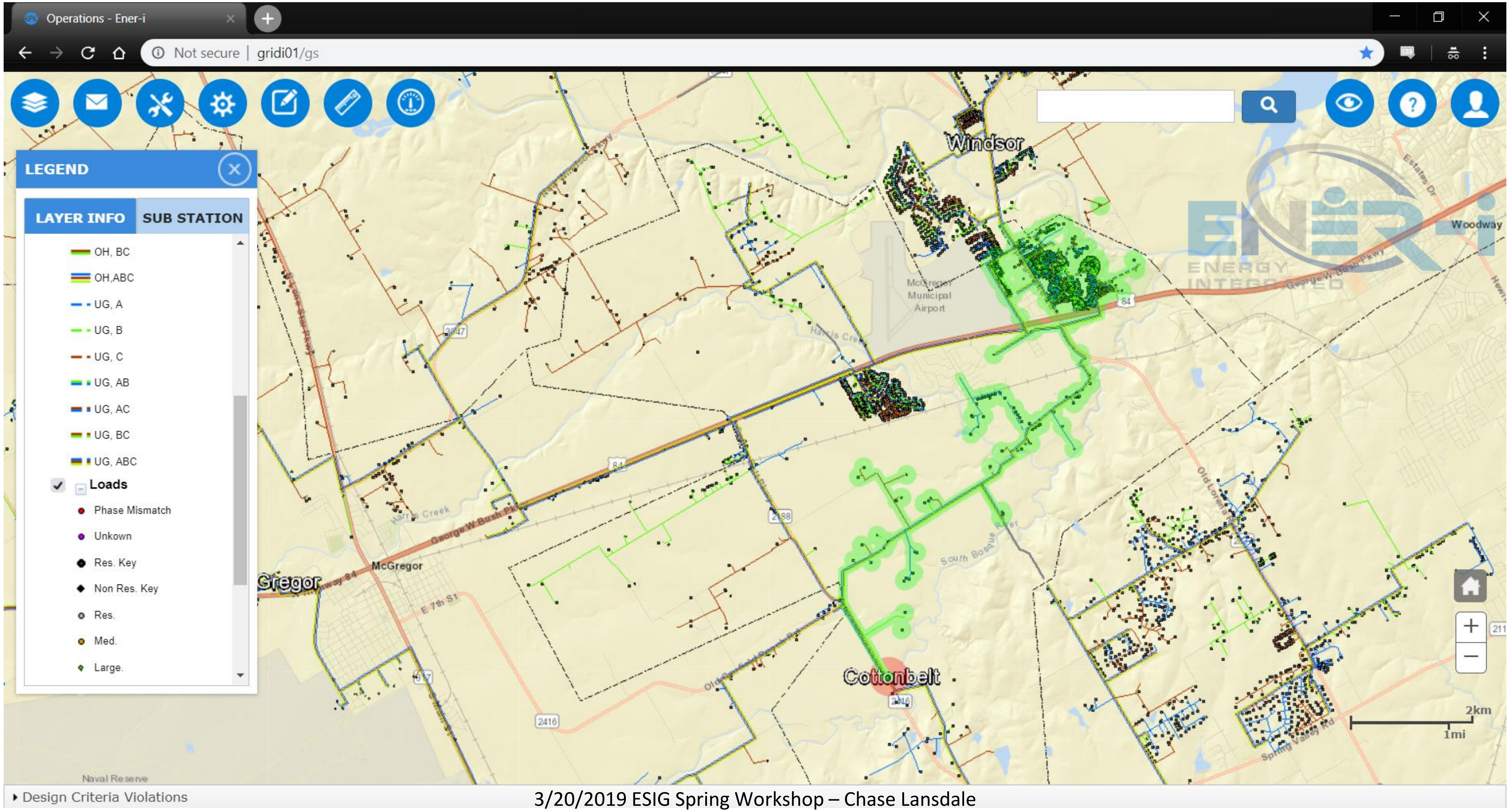
UNIVERSITY OF FLORIDA®

APPLIED THEORY: CAISO MODEL

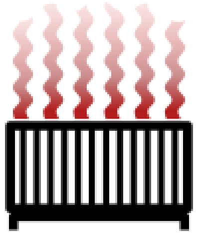


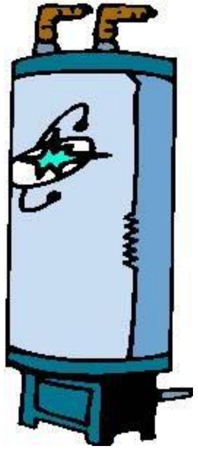
MODELING: PARTICIPANT SELECTION

Participant Selection [CIS + GIS + AMR]



RESIDENTIAL APPLIANCES



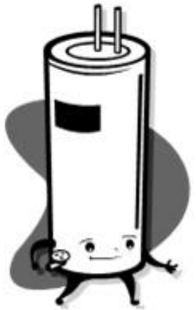


Space Heaters

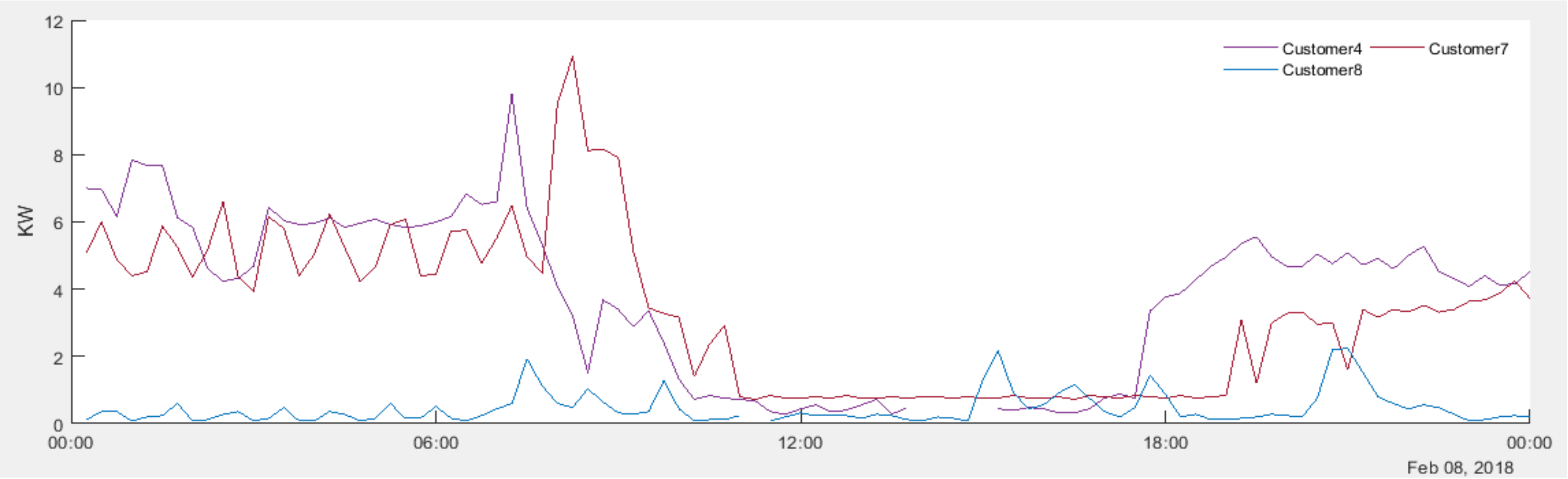
Fast & Slow Water Heaters

Refrigerators

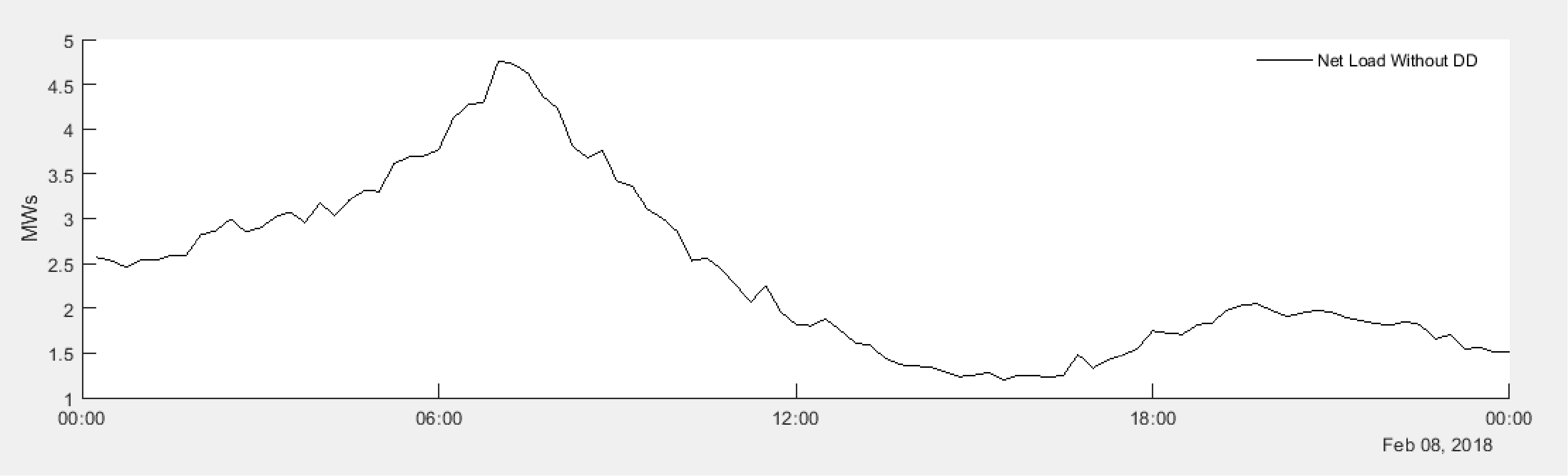
Pool Pumps



Member Usage Data [AMR / AMI]



Aggregate System Data [SCADA]



Constrained optimization computes net load *with* demand dispatch

- **Costs are placed on:**

Quadratic program over time-period $[t, \mathcal{T}]$:

$$
\begin{aligned}
\underset{g,\,x}{\text{minimize}} \quad & \int_t^{\mathcal{T}} \Big\{ c_0(g(t) - \bar{l}) + \varrho_0(\tfrac{d}{dt} g(t)) \\
& \quad + \sum_{i=1}^{M} \Big(c_i(x_i(t)) + \varrho_i(u_i(t)) \Big) \\
\text{subject to} \quad & l(t) = g(t) + \sum_i u_i(t), \\
& \tfrac{d}{dt} x_i(t) = -\alpha_i x_i(t) - u_i(t), \\
& -\eta_{i-} \le u_i(t) \le \eta_{i+}, \\
& |x_i(t)| \le C_i \\
& 0 = \int_t^{\mathcal{T}} u_i(\tau)\, d\tau
\end{aligned}
$$

Constrained optimization computes net load *with* demand dispatch

- **Costs are placed on:**
  - **Generation ($ / Traditional >> $ / Demand Response)**

Quadratic program over time-period $[t, \mathcal{T}]$:

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Constrained optimization computes net load *with* demand dispatch

- **Costs are placed on:**
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  - **Ramping**

Quadratic program over time-period $[t, \mathcal{T}]$:

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Constrained optimization computes net load *with* demand dispatch

- **Costs are placed on:**
  - **Generation ($ / Traditional >> $ / Demand Response)**
  - **Ramping**
  - **Deviation from nominal energy demand (change in energy behavior)**

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Constrained optimization computes net load *with* demand dispatch

- **Costs are placed on:**
  - **Generation ($ / Traditional >> $ / Demand Response)**
  - **Ramping**
  - **Deviation from nominal energy demand (change in energy behavior)**
  - **Deviation from nominal power demand (Utility Control Signal)**

Quadratic program over time-period $[t, \mathcal{T}]$:

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OPTIMIZATION: COSTS & CONSTRAINTS

Constrained optimization computes net load *with* demand dispatch

- **Costs are placed on:**
  - **Generation ($ / Traditional >> $ / Demand Response)**
  - **Ramping**
  - **Deviation from nominal energy demand (change in energy behavior)**
  - **Deviation from nominal power demand (Utility Control Signal)**

- **Constraints *guarantee*:**
  - **Quality of service to the consumer (temp, etc.)**

Quadratic program over time-period $[t, \mathcal{T}]$:

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  - **Generation ($ / Traditional >> $ / Demand Response)**
  - **Ramping**
  - **Deviation from nominal energy demand (change in energy behavior)**
  - **Deviation from nominal power demand (Utility Control Signal)**

- **Constraints *guarantee*:**
  - **Quality of service to the consumer (temp, etc.)**
  - **Same net daily energy consumption**

Quadratic program over time-period $[t, \mathcal{T}]$:

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\begin{aligned}
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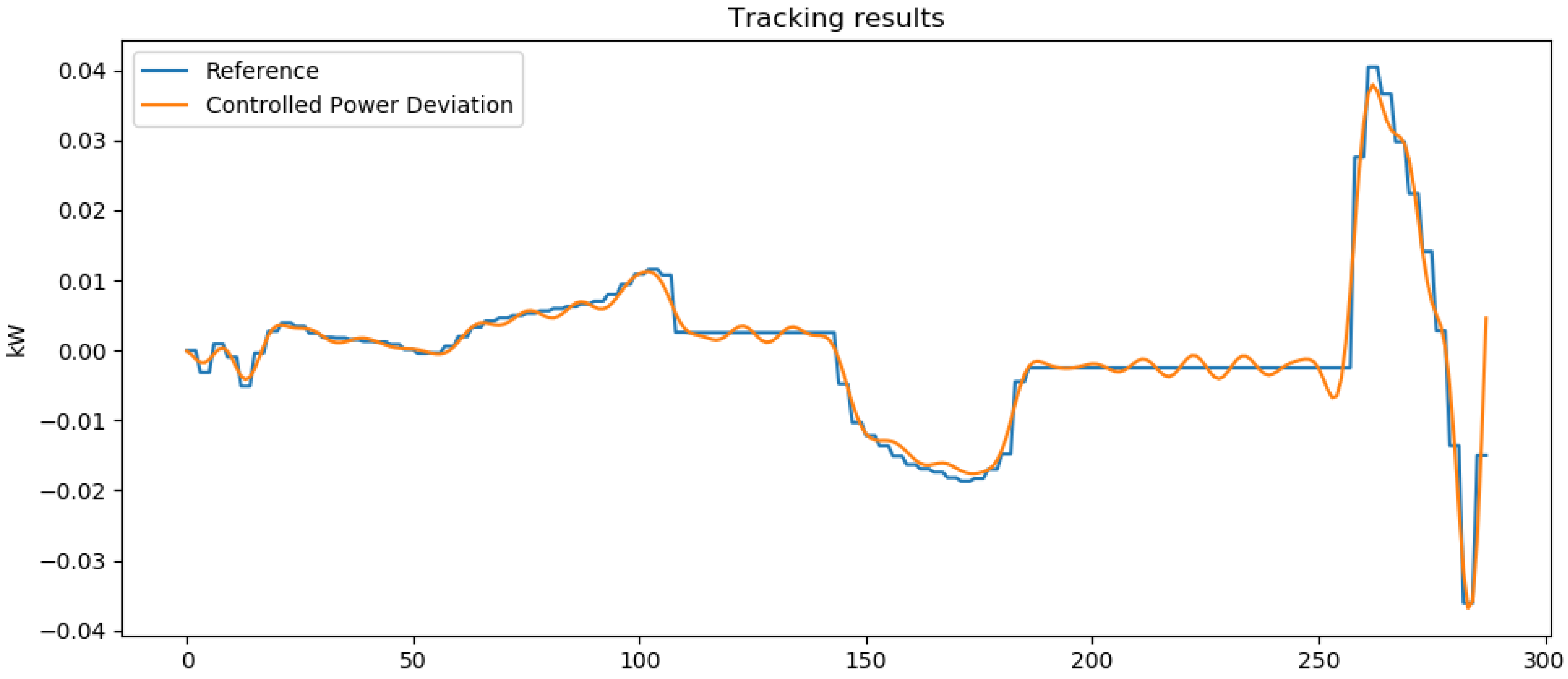
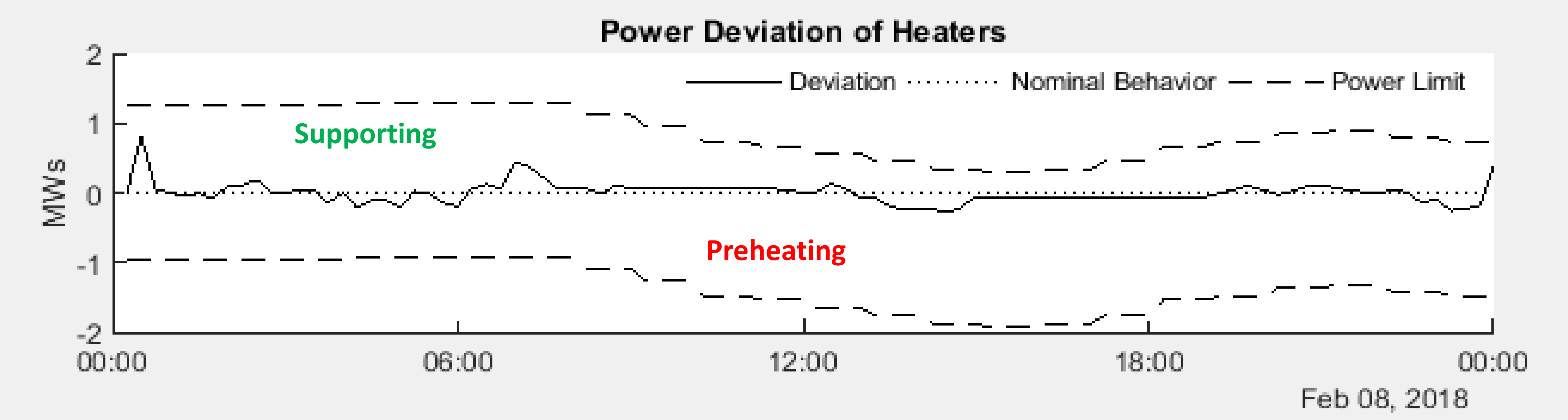
$$

Stochastic, distributed control techniques enable tracking of the desired power deviation

- Power deviation is computed centrally, but decisions are made locally
  - Local control reduces computation and communication requirements
  - Local control maintains privacy and guarantees QoS

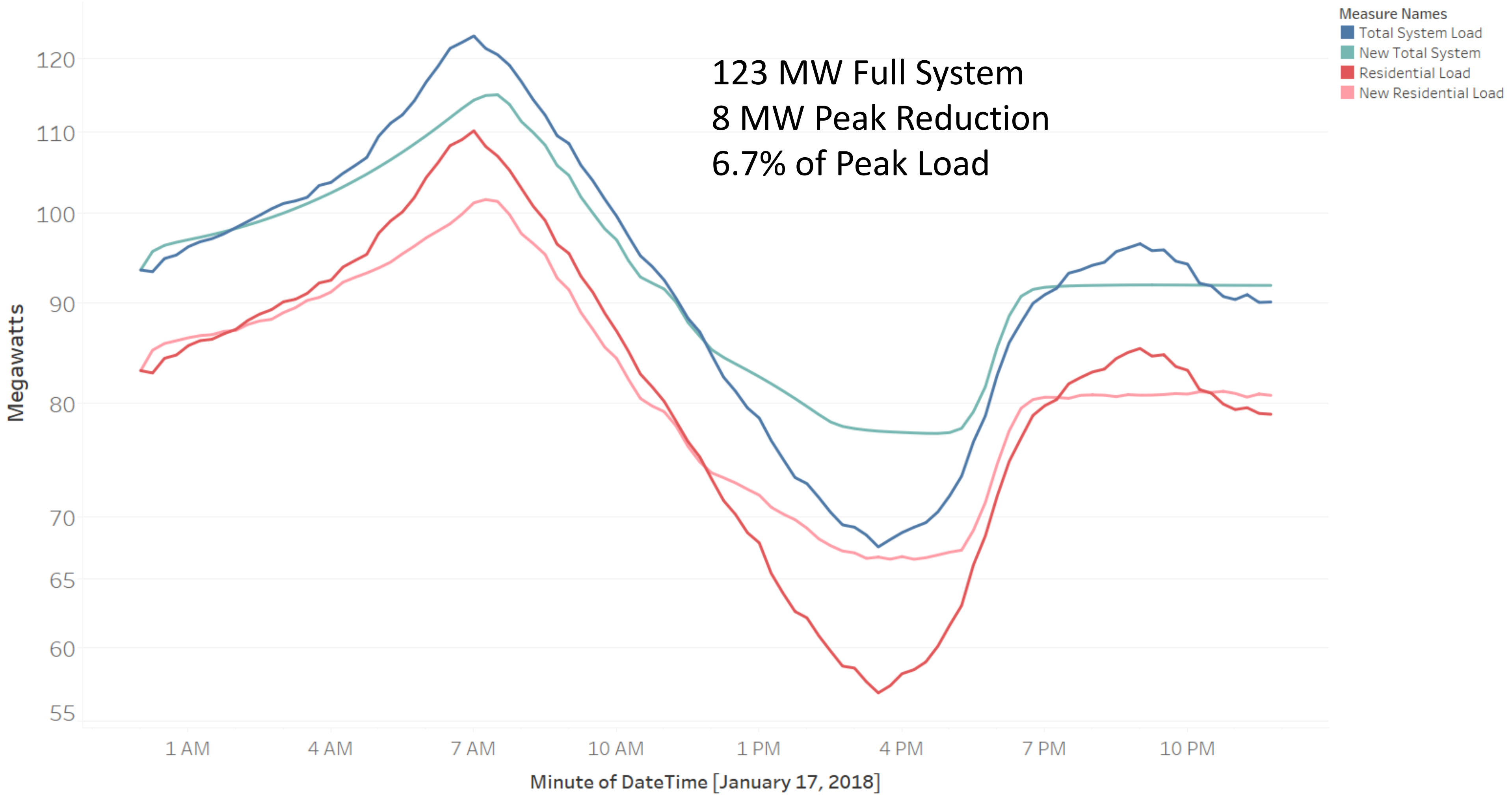


OPTIMIZATION: SIMULATED BEHAVIOR



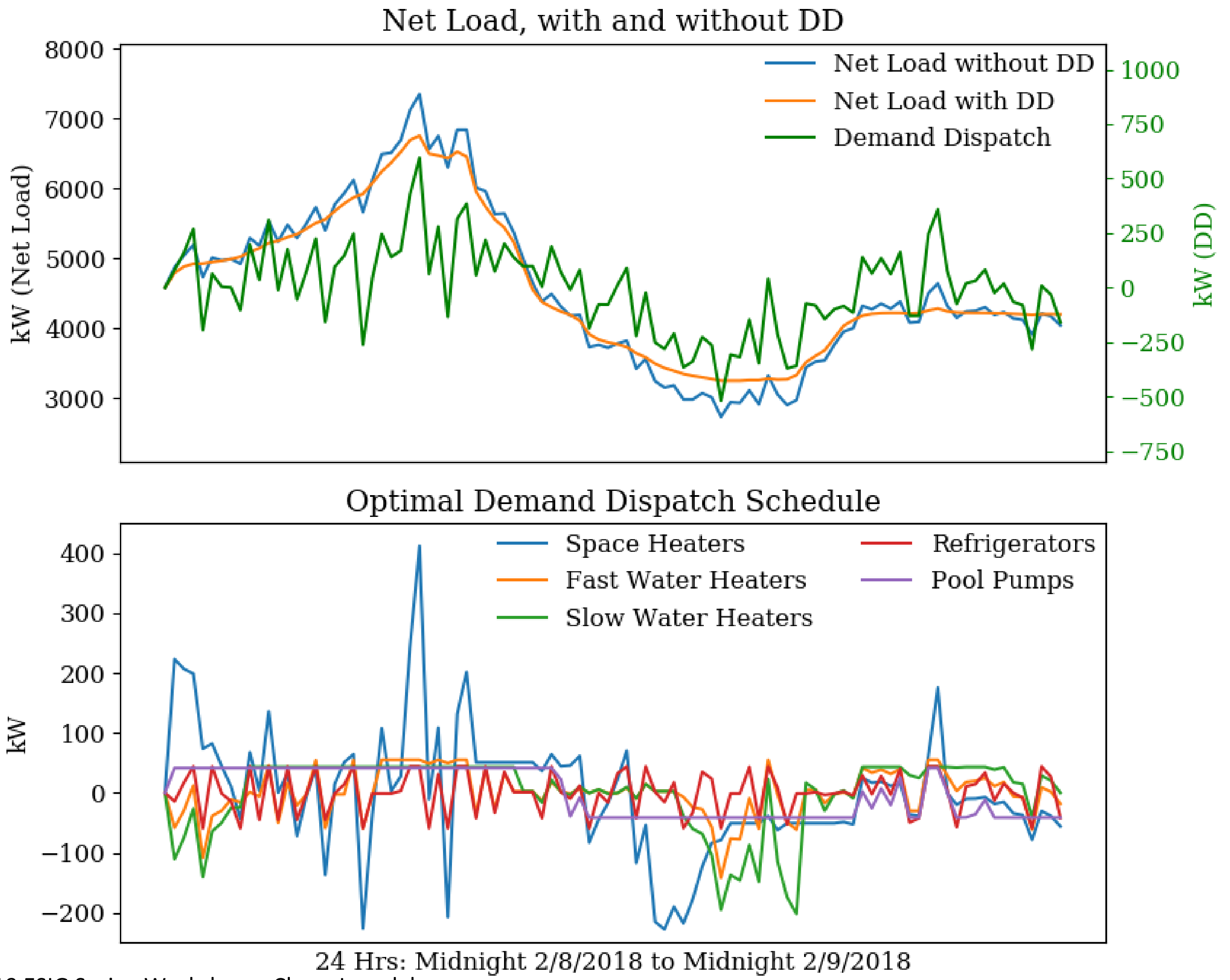
RESULTS: LOAD SHAPING

TimeSeries



The trends of Total System Load, New Total System, Residential Load and New Residential Load for DateTime Minute. Color shows details about Total System Load, New Total System, Residential Load and New Residential Load.

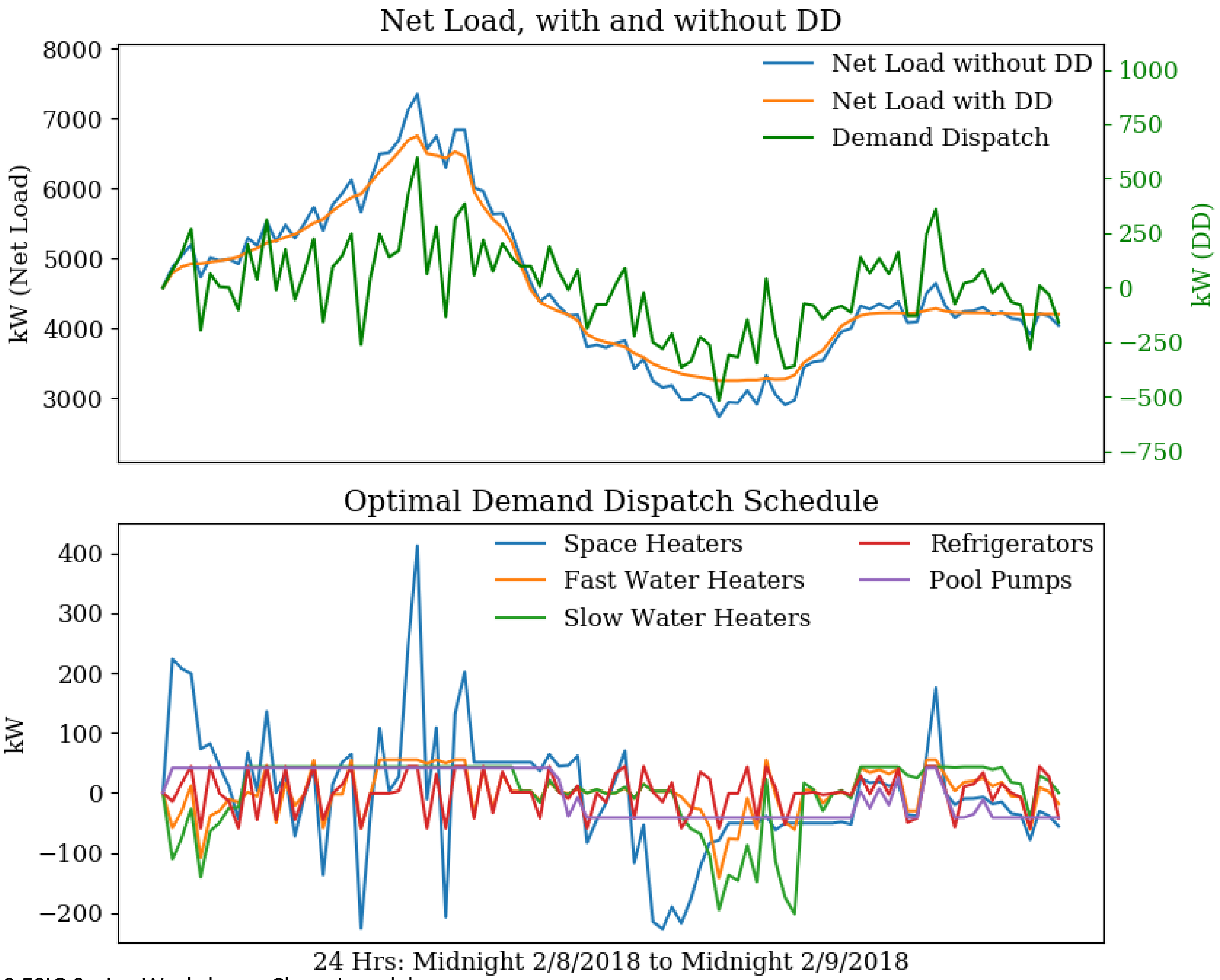
RESULTS: LOAD SHAPING



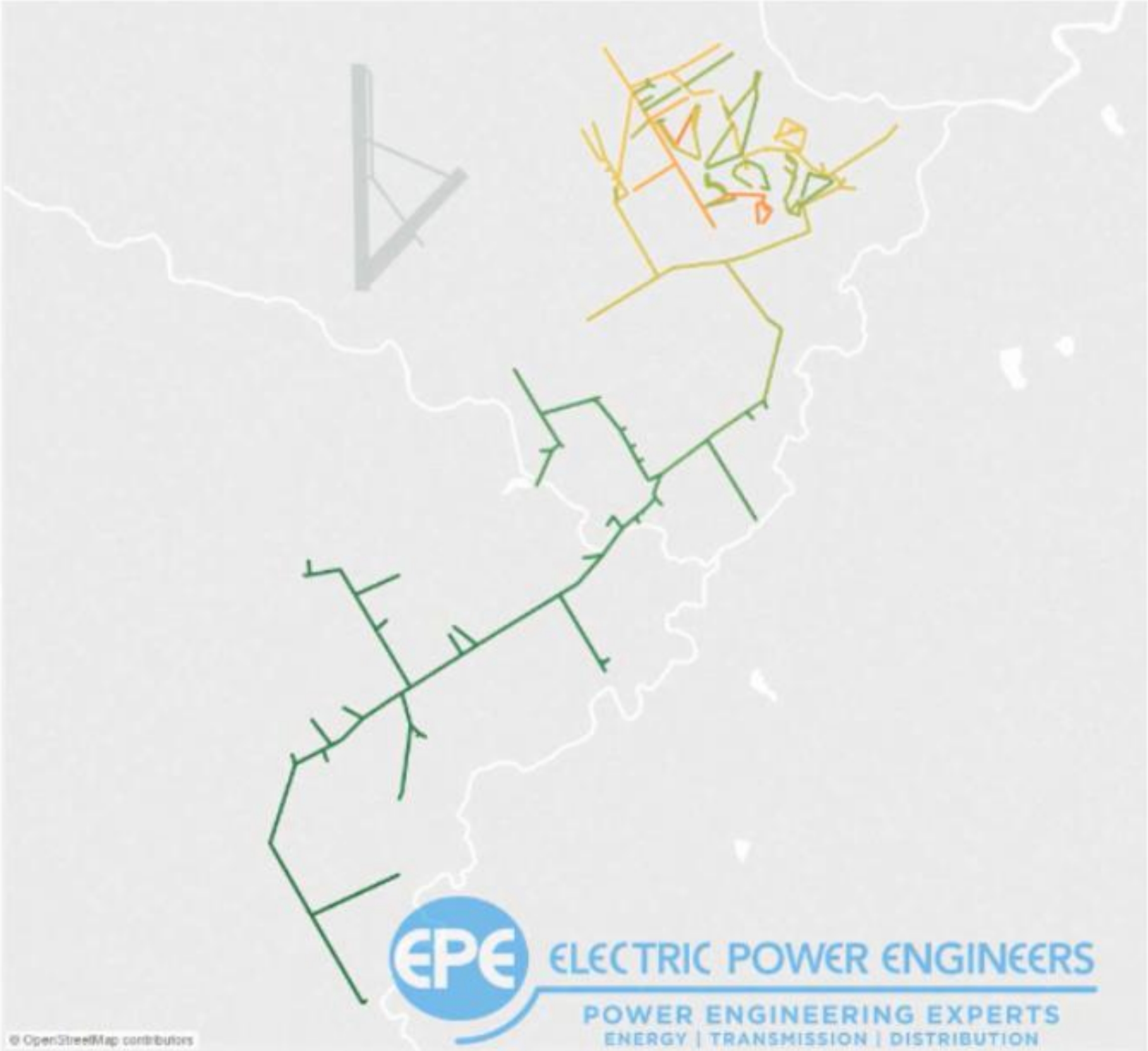
RESULTS: LOAD SHAPING

- 8% reduction in peak kW
- Significantly lower ramp rates
- Significantly smoother net load trajectory

10-year Economic Analysis 1 Feeder with 1,400 participating appliances	
Peak charge savings	$448,540
Line loss savings	$82,641
CapEx Deferral savings	N/A
Cost of implementing DD	$104,850
Net savings	$426,331

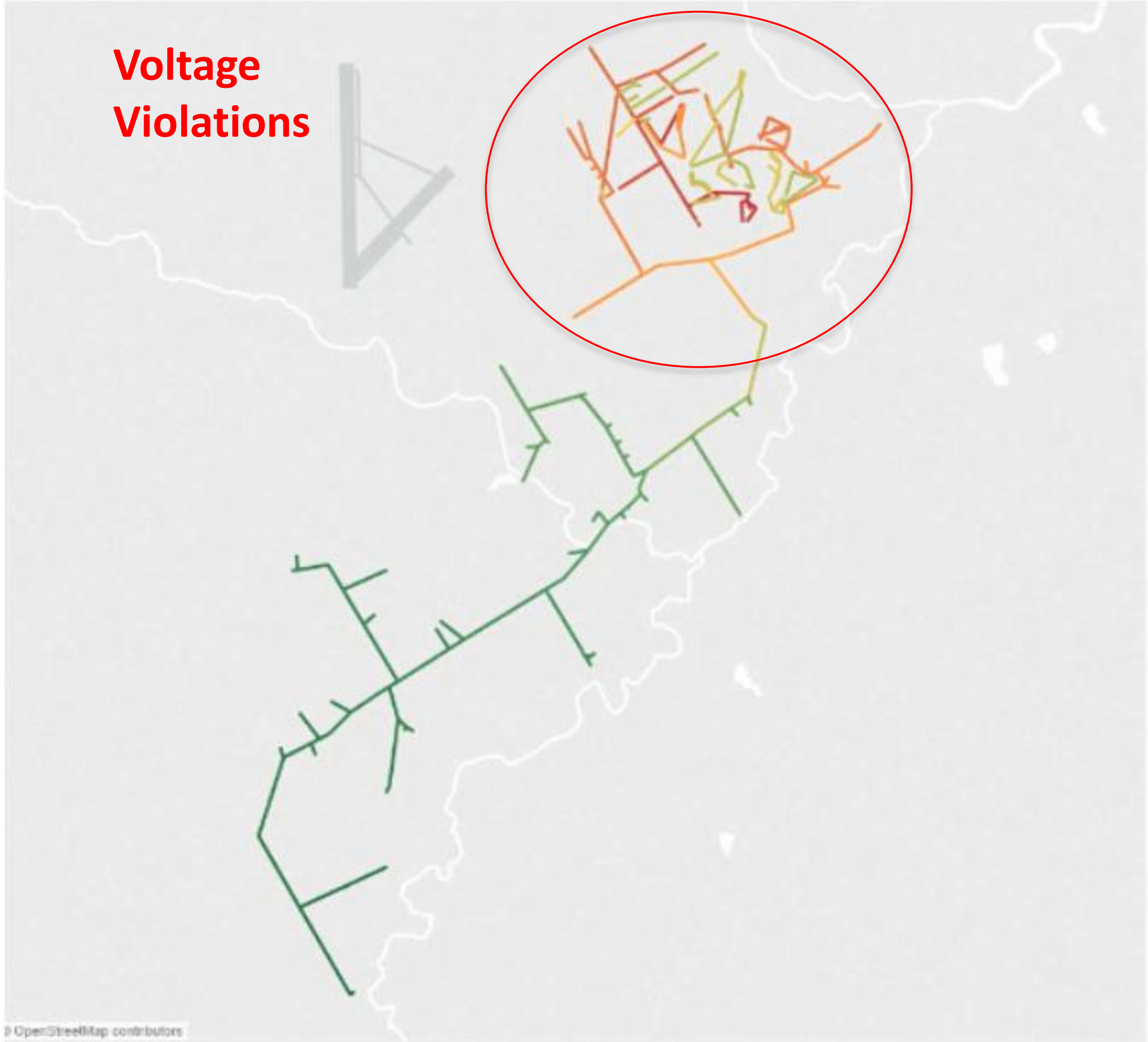


RESULTS: RELIABILITY

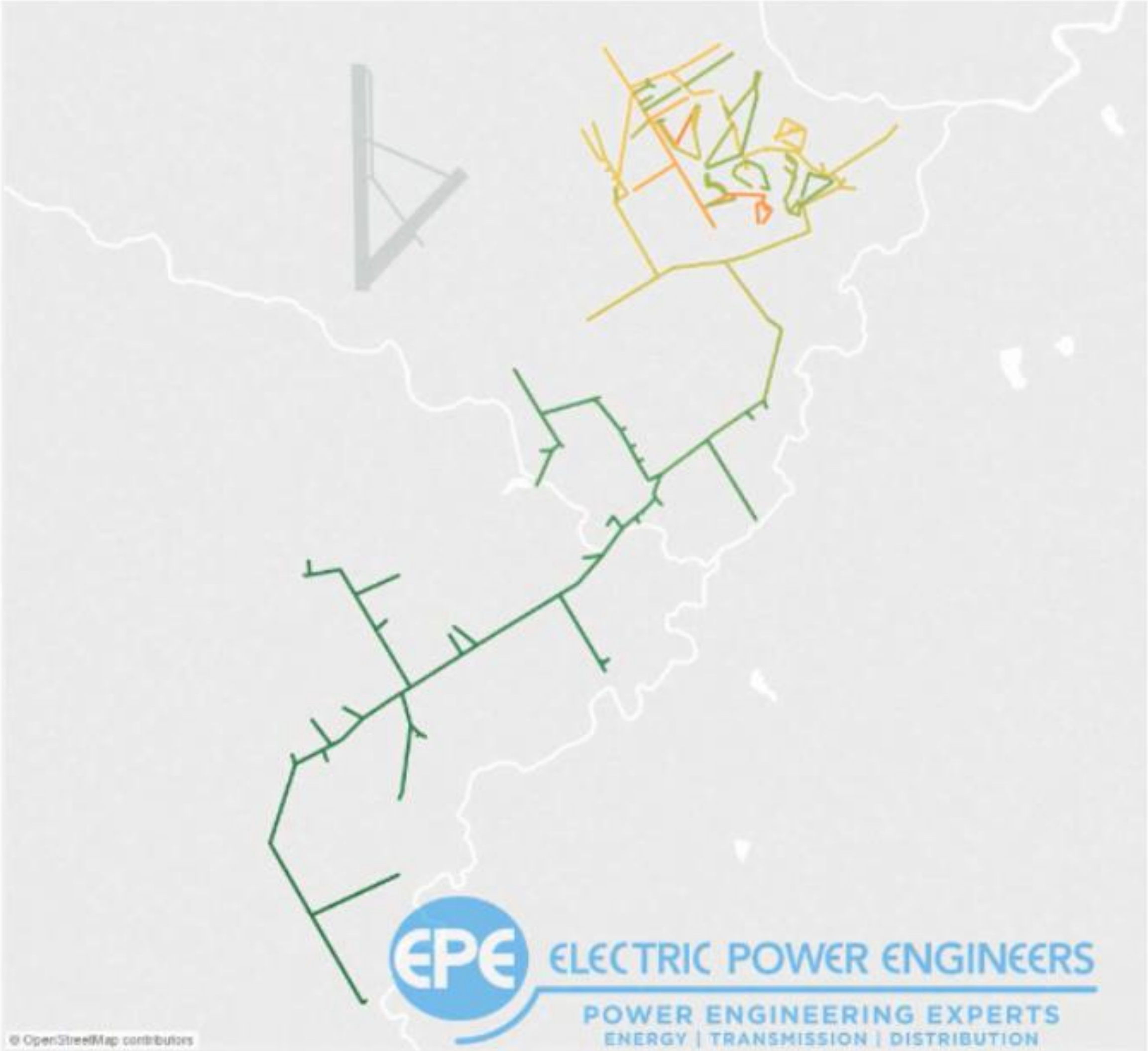
BASE CASE	DEMAND DISPATCH
	

RESULTS: RELIABILITY

BASE CASE

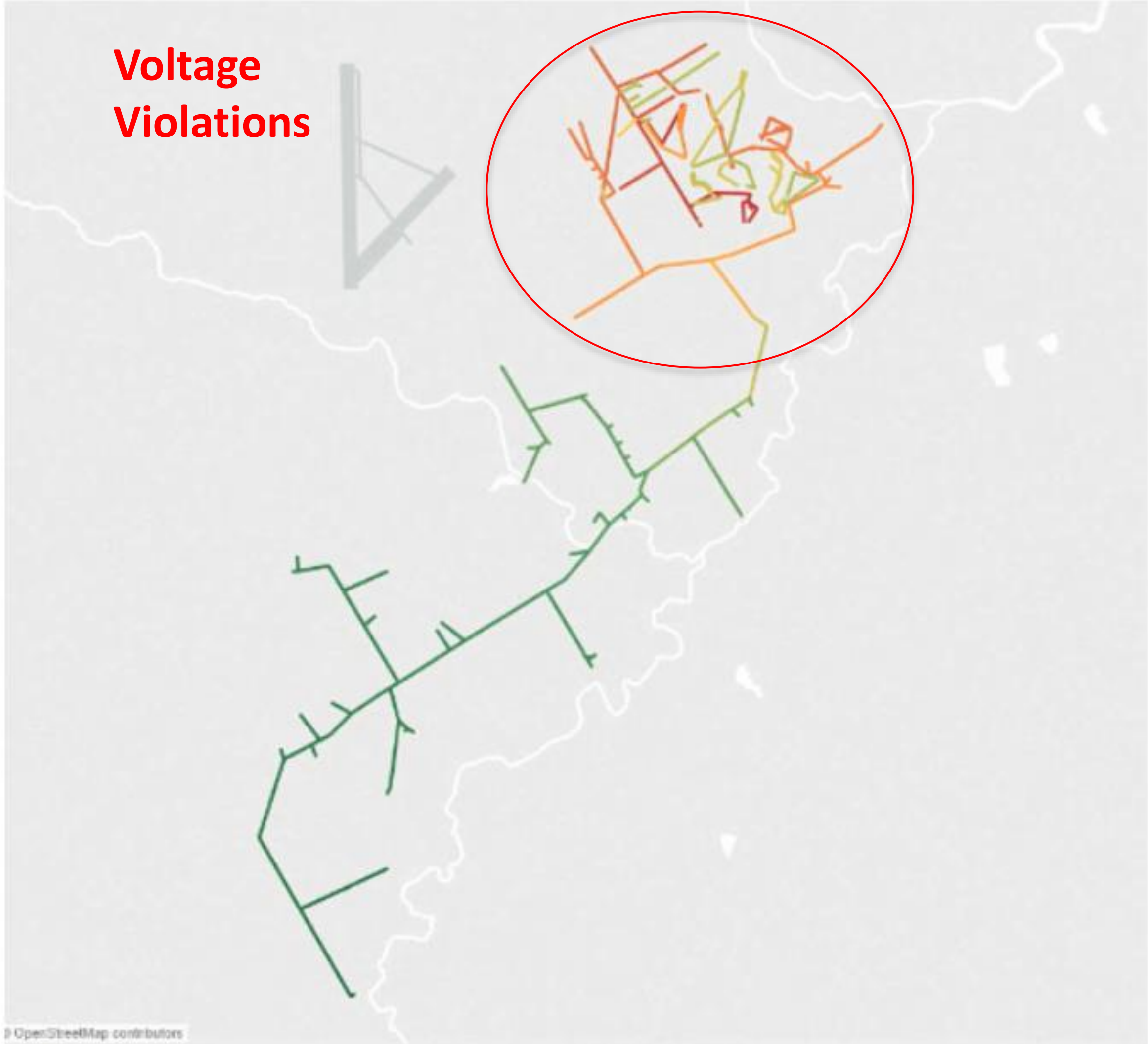


DEMAND DISPATCH

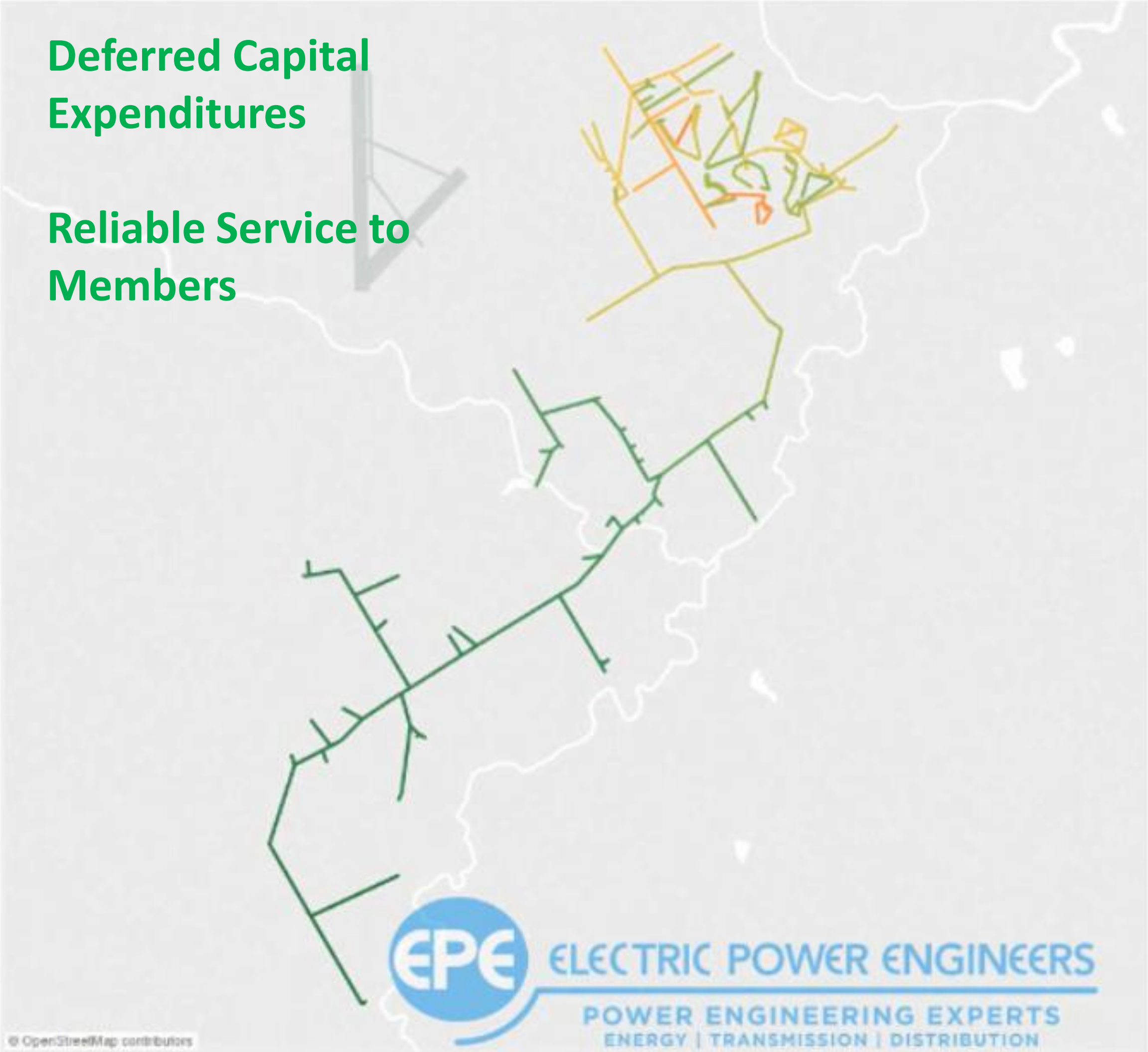


RESULTS: RELIABILITY

BASE CASE



DEMAND DISPATCH



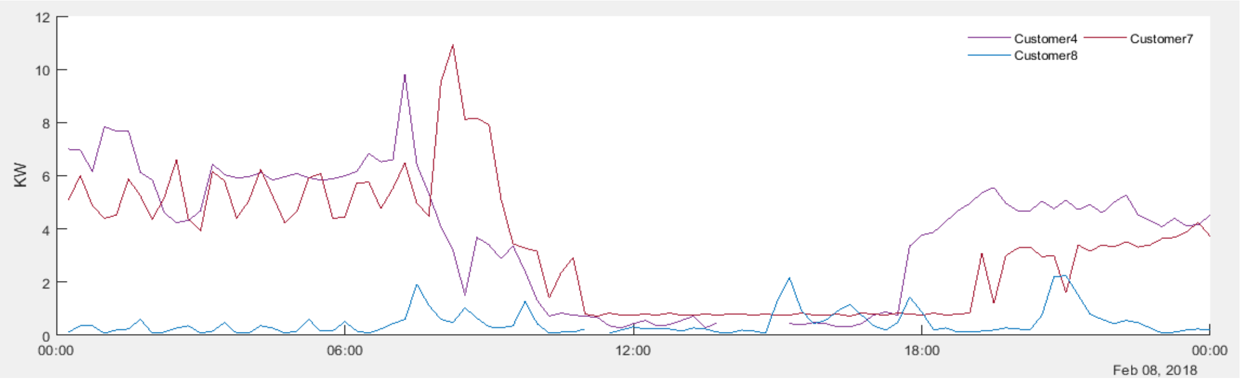
WHAT'S NEXT

Load Disaggregation

- Determine what appliances are being used and their traditional behavior

Localized Control Modeling

- Model each load's controller individually to better simulate real-world application



Field Testing + Pilot Project

- Implement controllers on real life systems
- Test different control signals and analyze load response in relation to traditional behavior

THANK YOU

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