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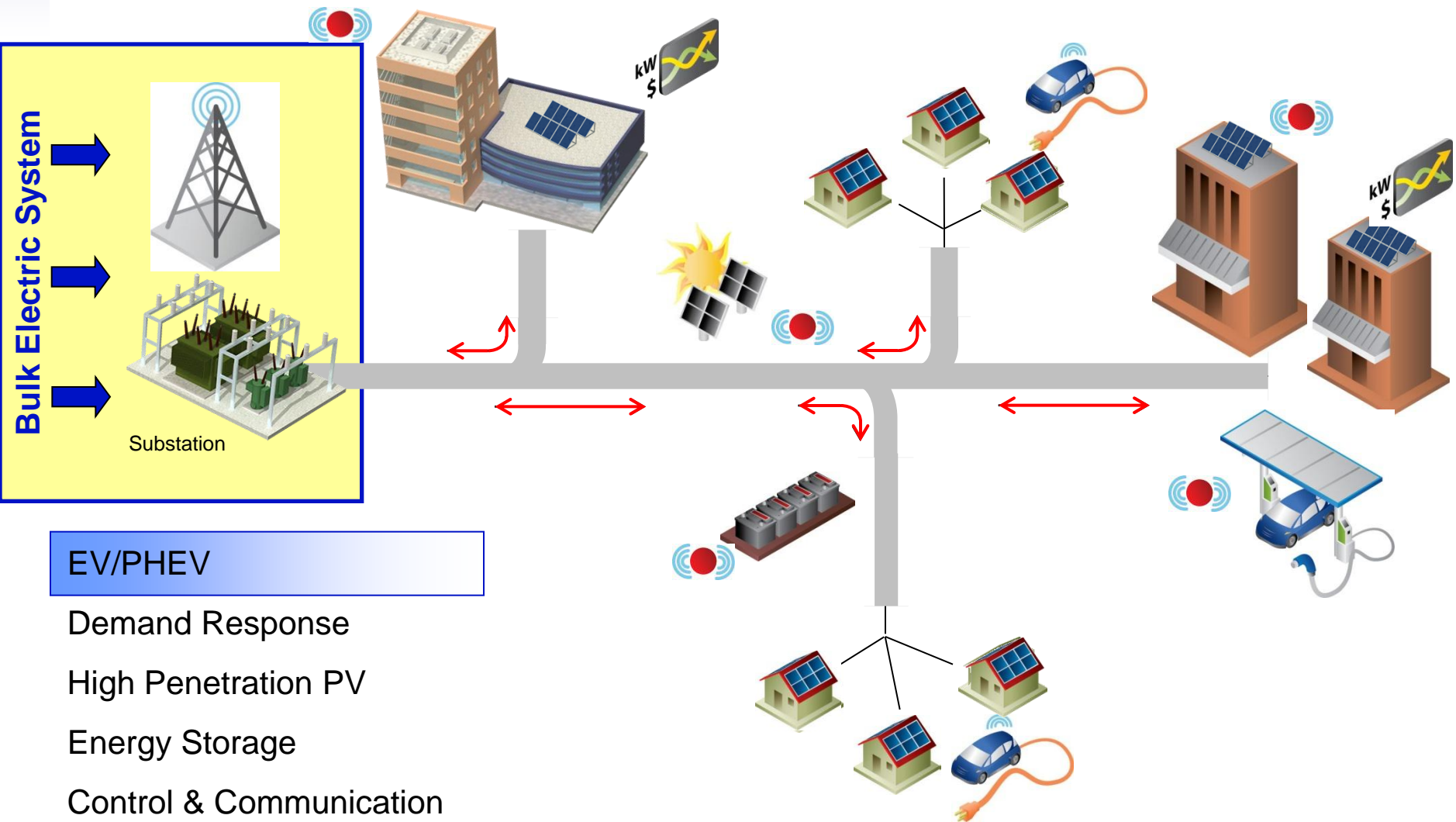
# Distribution Modeling for Integration of PV, PEV, and Storage

IEEE PES Panel Session

Integrating Distributed Energy Resources  
with Smart Distribution Panel

Jason A. Taylor

# Distribution Smart Grid will Dramatically Alter System Behavior



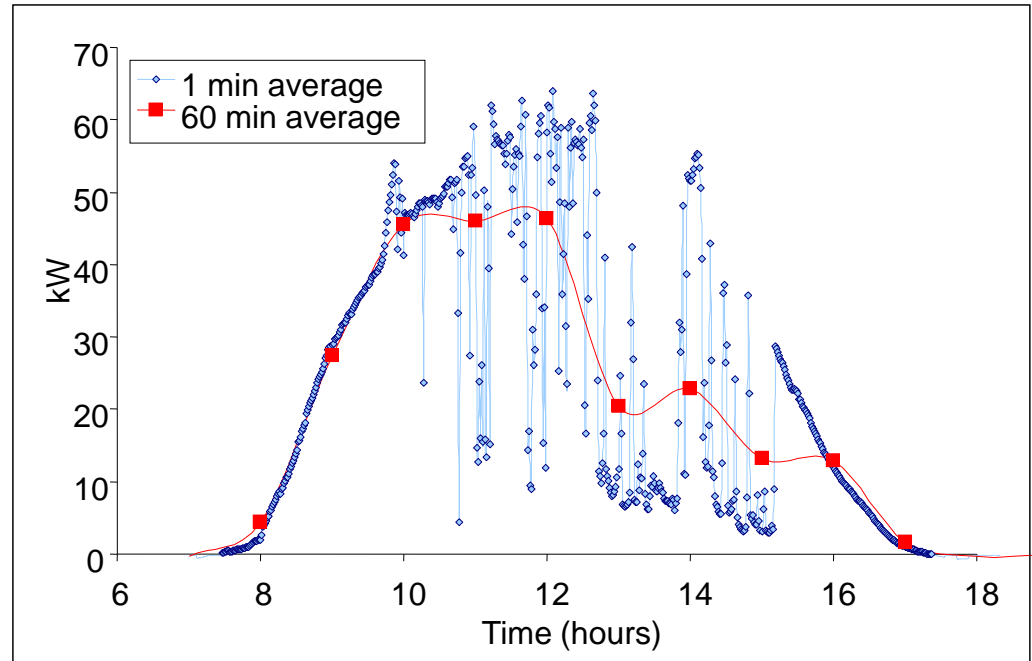
# Distributed Device Characteristics

- Spatial diversity
  - Model substation down to end-user
- Temporal diversity
  - Examine variations over time
- Examination of modeling/analysis requirements
  - OpenDSS
  - Sequential power flows (quasi-steady state)
  - Projected technology characteristics

# Solar Photovoltaic

## Key factors:

- Size of the solar resource
- Layout of the solar plant(s)
- Regional weather patterns
- Fixed vs tracking



Example 60 kW rooftop PV Output

Cloud passage may take 1-5 minutes across an entire feeder  
or  
Seconds to shade a centralized PV

# Modeling Issues

## Typical meteorological year data

- Availability
- Resolution
- Units

## PV locations

- GIS Availability
- Customer adoption

## Inverter models

- Efficiencies
- Controls

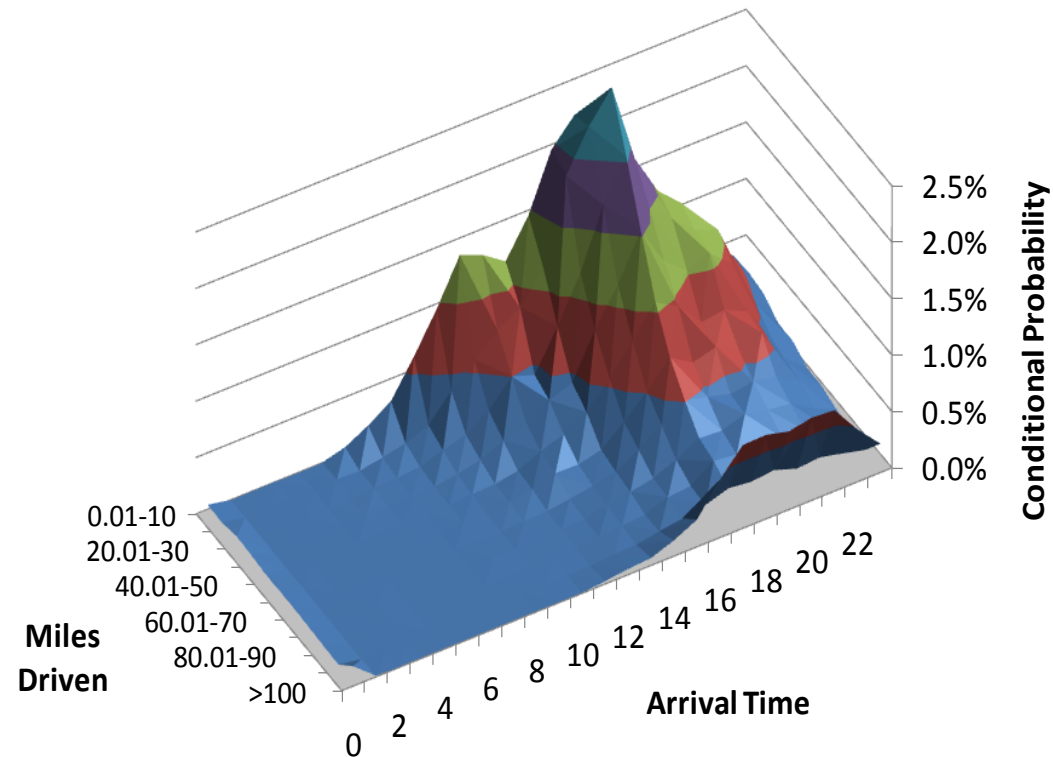
# Plug-in Electric Vehicles

## Spatial Variation

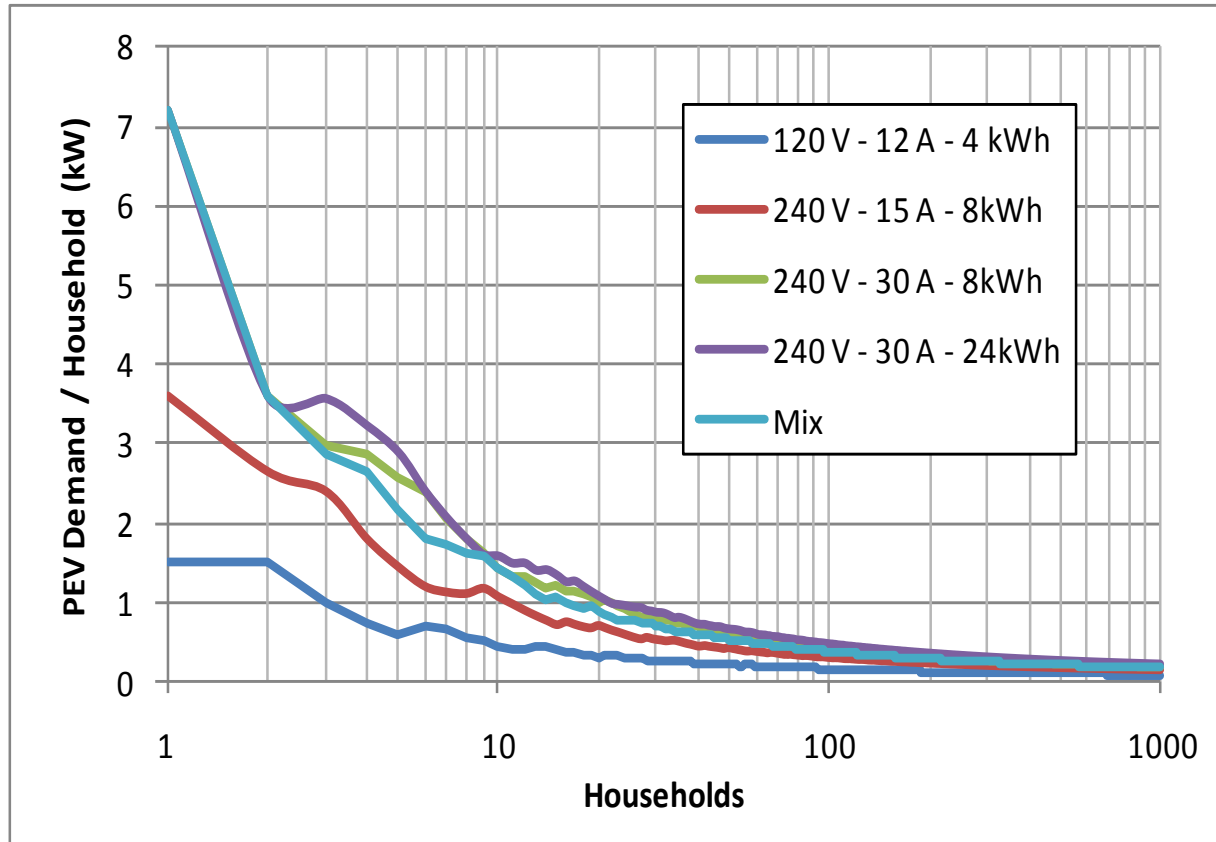
- Market penetration
- System configuration
- Socio-economics
- Connection availability

## Temporal Variation

- Driving patterns
- Electrical connection
- Battery size
- Controls



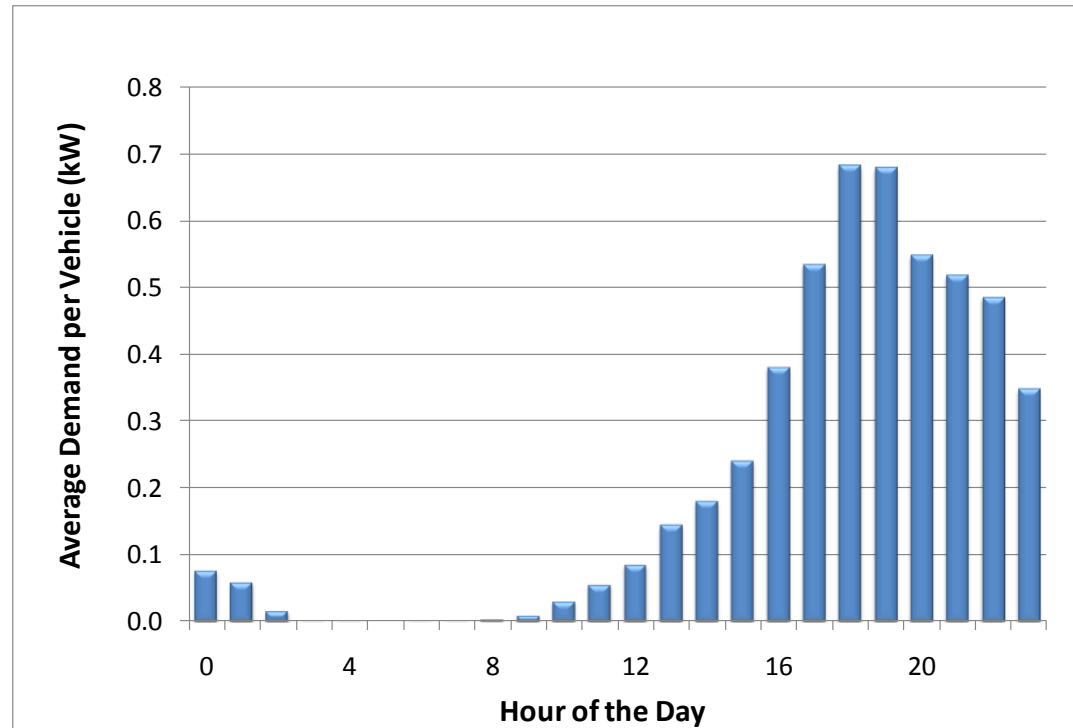
# PEV Load Diversity



**Assets classes will see different demands**

# Aggregate Demand

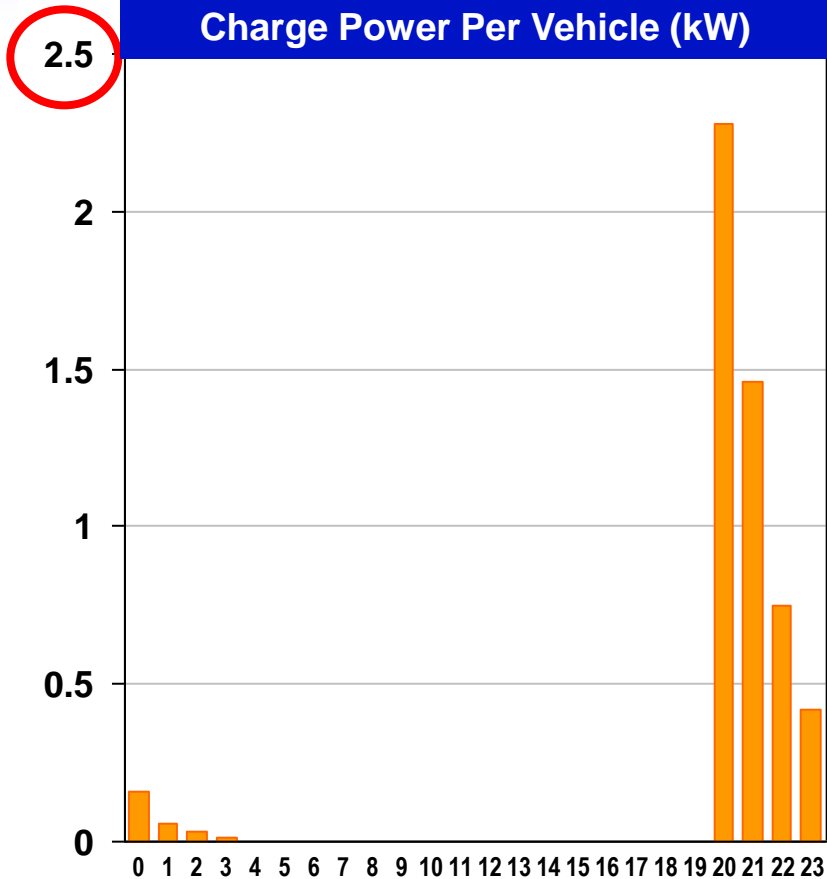
- Uncontrolled models
  - Time varying loads
  - Constant pf
  - Constant power/current
- Potential model states for controlled operation
  - kWh stored
  - kW rated
  - kWh rated
  - Interconnection time



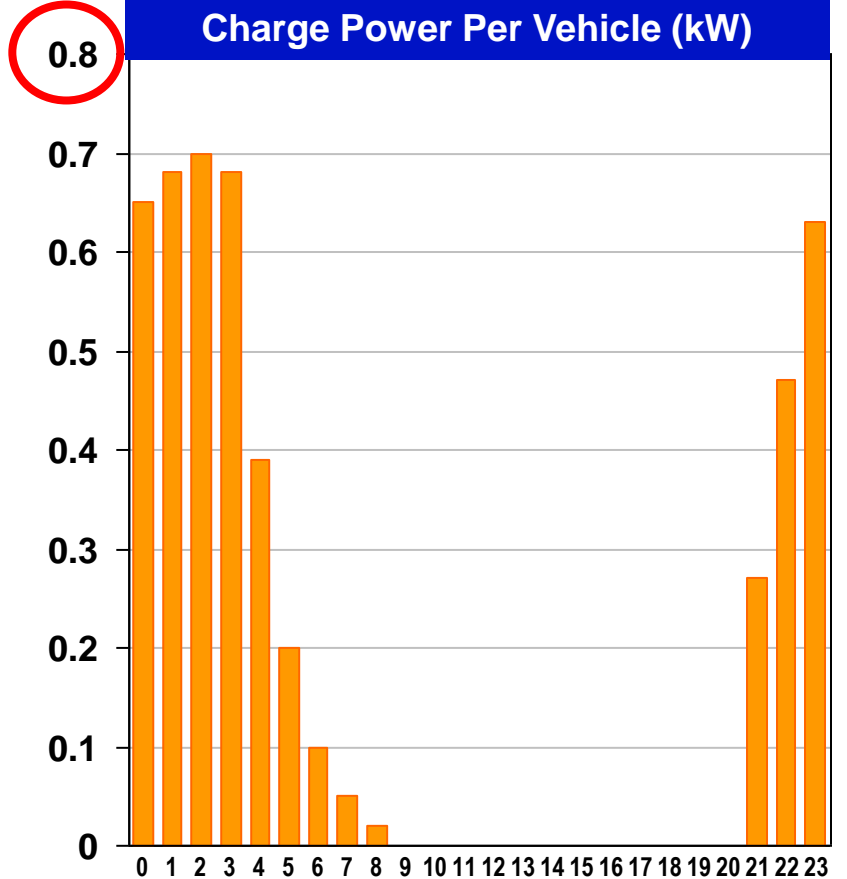
**Uncontrolled peak correlates w/  
peak residential demand**



# Smart Charging Control

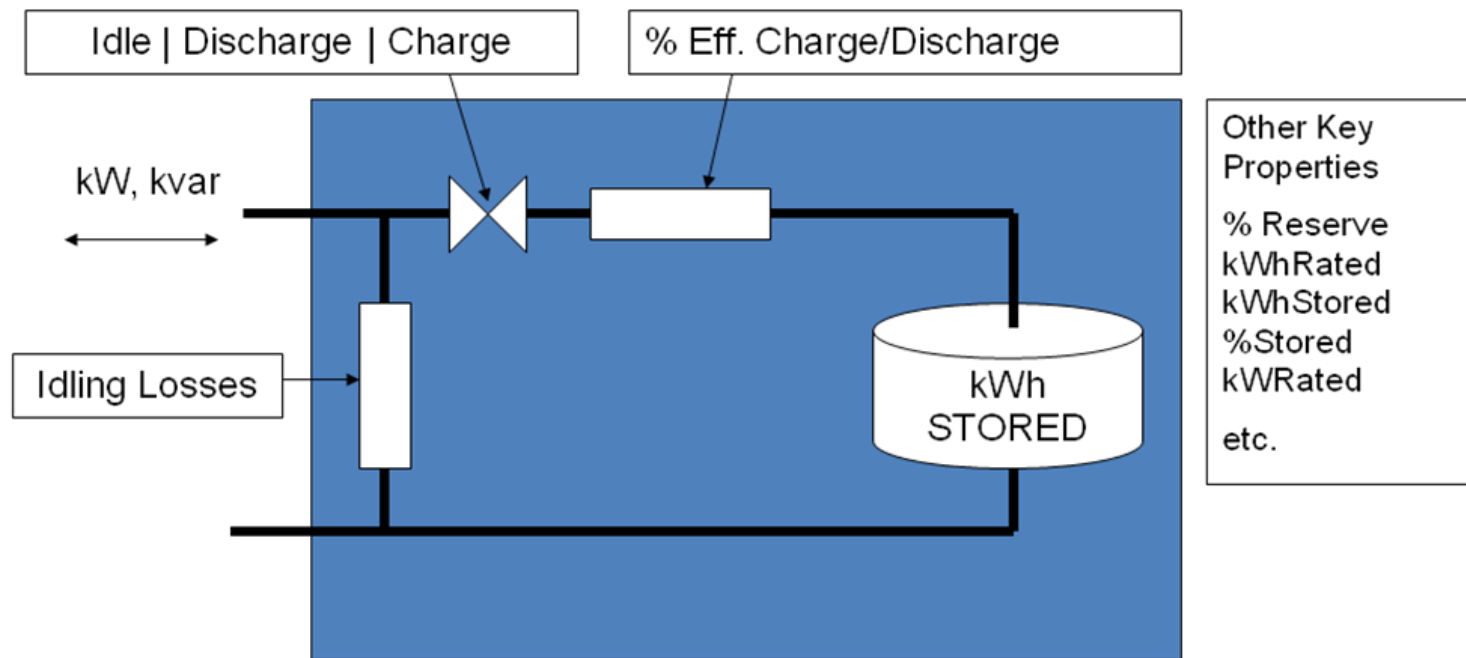


**Simple delay of charge**

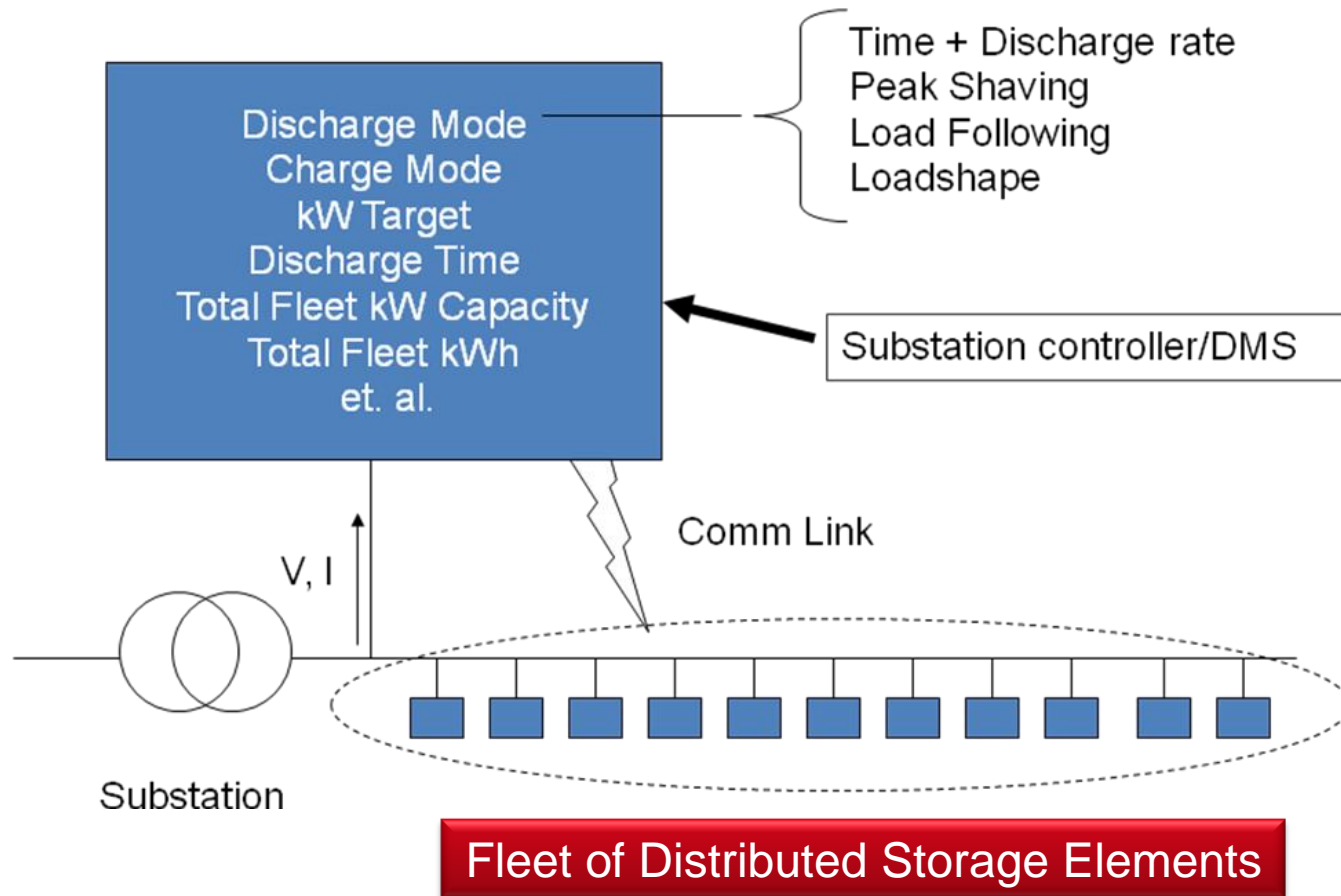


**Diversified control**

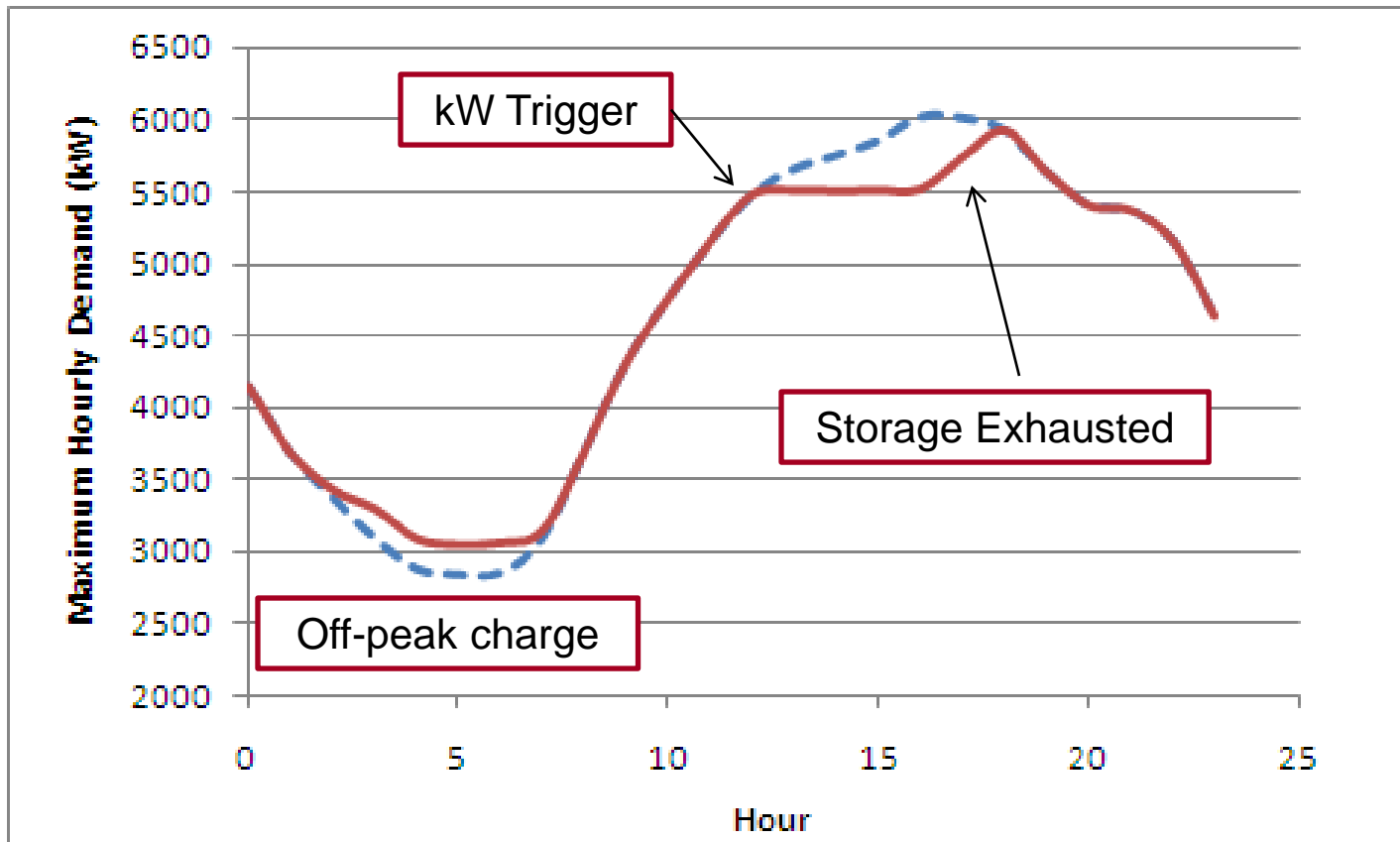
# Generic Energy Storage Element



# Storage Control as a DMS Function



# Peak Shave Control Example



# Distribution System Models

- Time step

Electric vehicle charging	(minutes, hours)
Solar and wind generation	(seconds)
Storage simulations	(minutes to hours)
Energy Efficiency	(minutes to hours)
End use load models	(minutes to hours)
End use thermal models	(minutes to hours)

- Existing distribution controls including load tap-changers, feeder regulators, capacitor banks and associated set-points and time delays.
- System unbalance

# Customer Load Models

## Allocation Transformer kVA

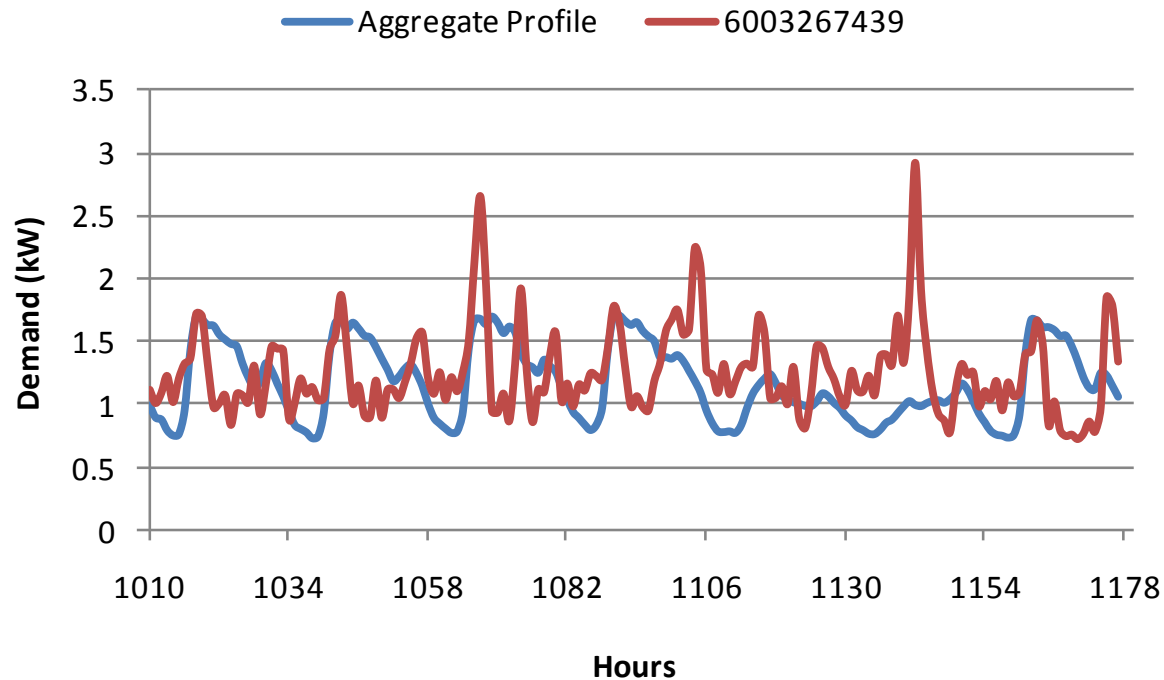
- Limited diversity

## Allocation Billing data (kWh)

- Better diversity

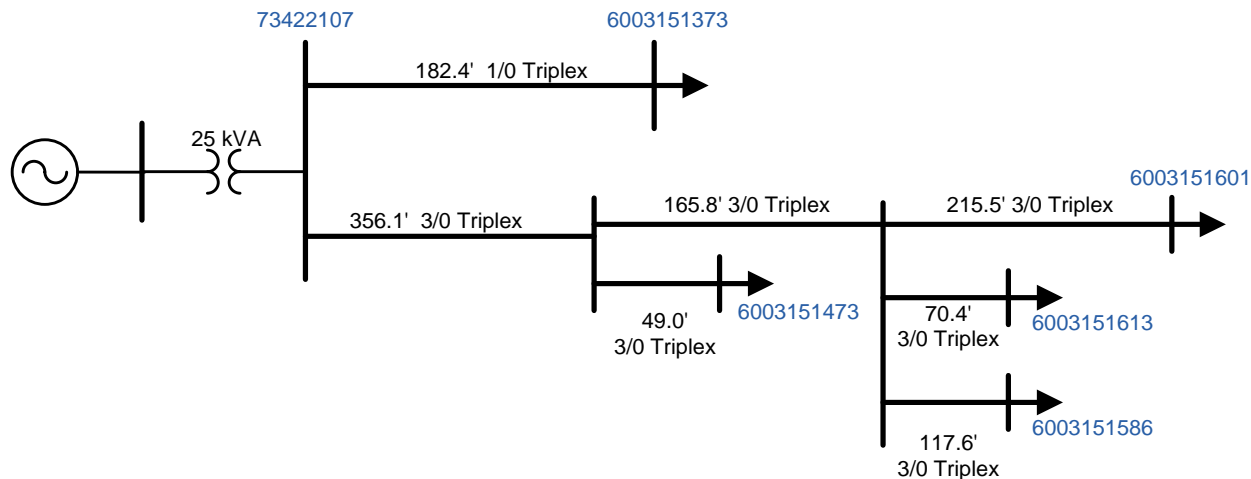
## AMI

- Best diversity
- Data challenges



# Secondary Models

- Secondary circuit data is typically not collected by most North American utilities
- Customer level impacts from end-use DR may not be represented



# General Modeling Requirements

- Capture technology temporal and spatial characteristics
- Identify aggregate control model requirements and functionalities
  - Device / control interactions
  - Optimal control design
- Identify circuit model requirements based on ***technology characteristics*** and ***study goals***
- Develop new analysis methods were needed