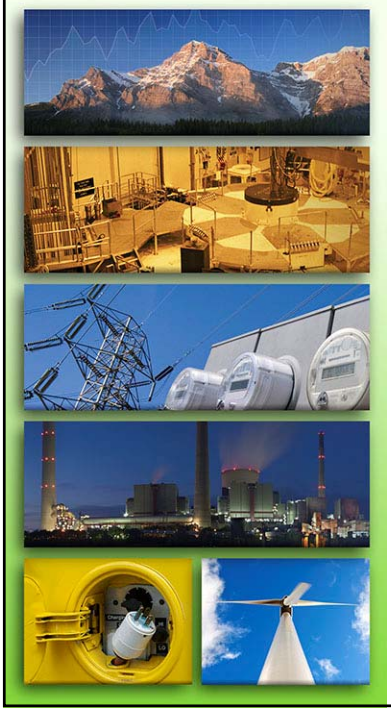

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AMERICAN ELECTRIC POWER

Virtual Power Plant Modeling & Simulation

Gale Horst

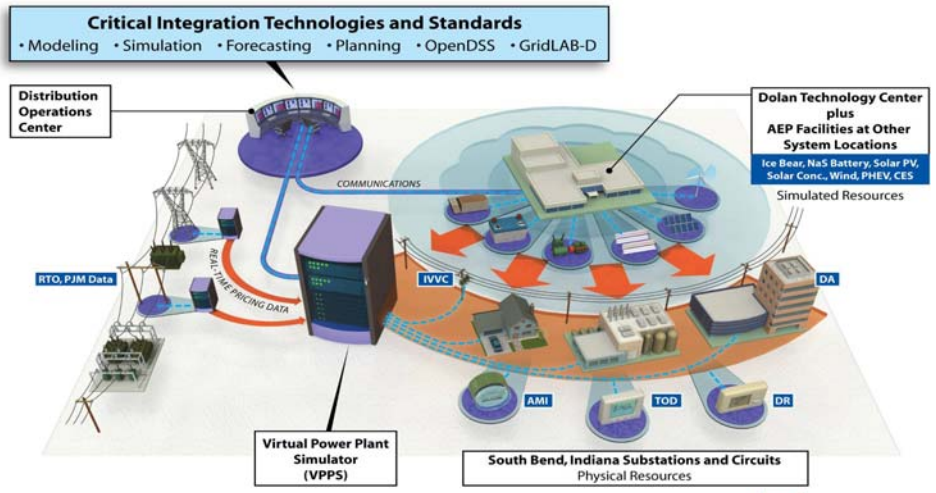
Project Manager, Smart Grid Demonstrations
Electric Power Research Institute (EPRI)

Roger Dugan

Sr. Technical Executive
Electric Power Research Institute (EPRI)

American Electric Power (AEP)

Virtual Power Plant Simulator (VPPS)



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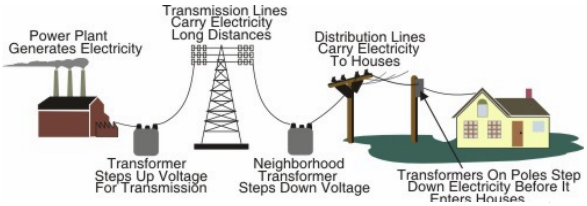
The Evolution of the Electric Utility System

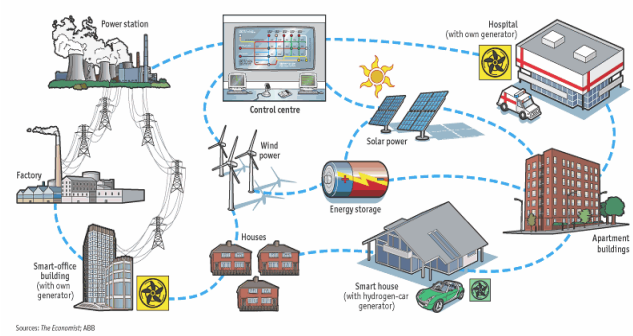
Before Smart Grid:

One-way power flow, simple interactions



After Smart Grid:

Two-way power flow, multi-stakeholder interactions



Adapted from EPRI Presentation by Joe Hughes
NIST Standards Workshop
April 28, 2008

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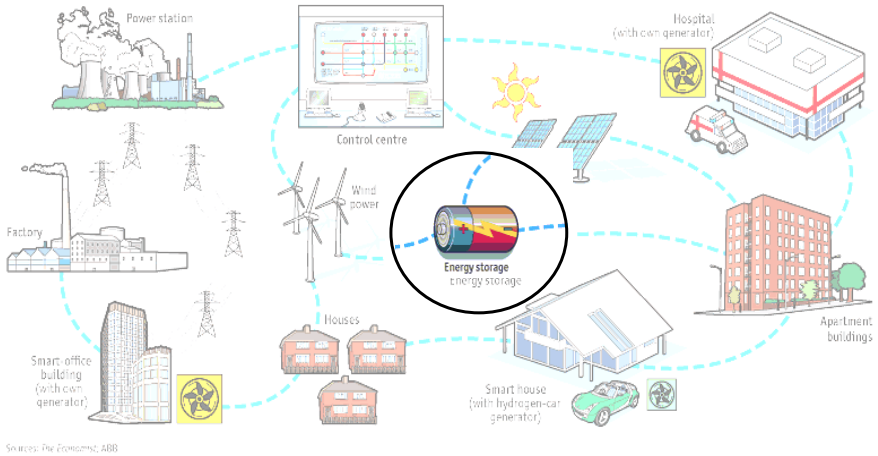
Smart Grid Enables Energy Storage

<u>But where is the best location/size for the storage</u> ?



Adapted from EPRI Presentation by Joe Hughes
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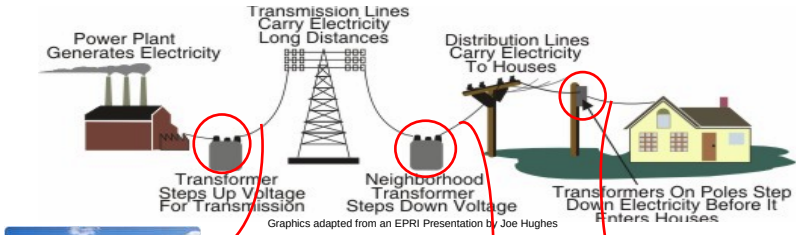
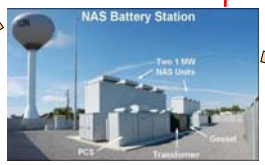
Migratory Path of Energy Storage – AEP



Graphics adapted from an EPRI Presentation by Joe Hughes

Large Central Units

MW x 100's



Substation Batteries

MW's

KW x 10's

Storage at Grid Edge

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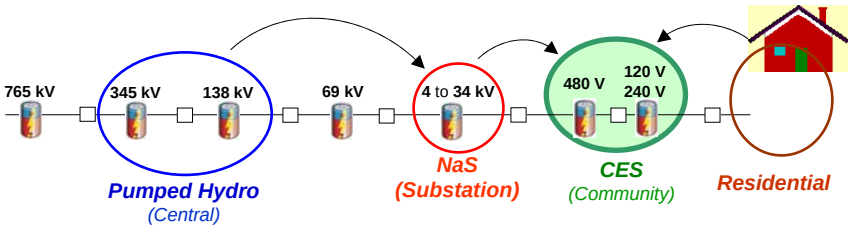
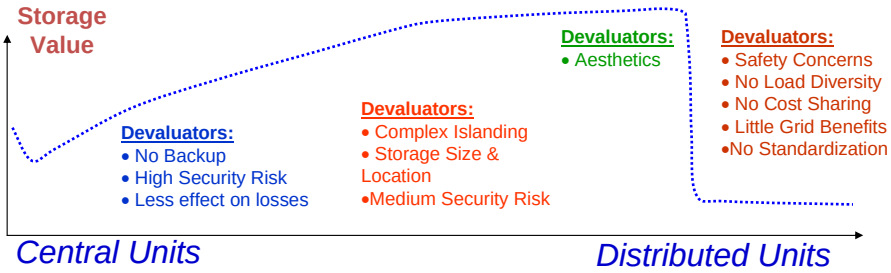
Locational Value of Electricity Storage





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To Optimize Storage

Need an energy storage system with the following FOUR key features:

1. Very Close to Customers
- Backup Power,
- Buffer Customer Renewables

2. Grid-Connected
- Load Leveling,
- Volt / VAR support

3. Utility-Operated
- Load Diversity (multiple customers on one storage)
- Improved Safety
- Optimizing Grid Performance

4. Utility-Owned
- Standardization & Commodity Pricing
- Socializing the Cost

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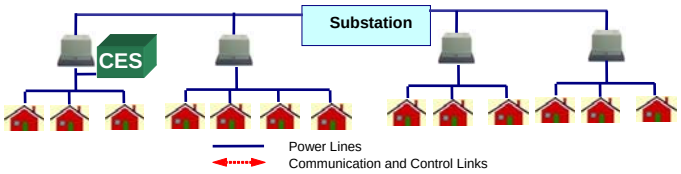
CES – A Virtual Substation Battery

CES is Operated as a Fleet offering a Multi-MW, Multi-hour Storage

Local Benefits:

1) **Backup power**
2) **Voltage correction**
3) **Renewable Integration**



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CES – A Virtual Substation Battery

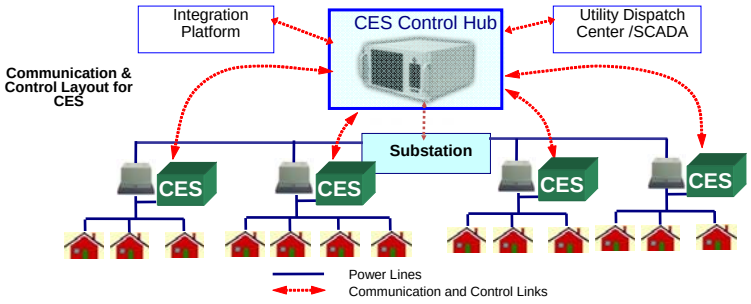
CES is Operated as a Fleet offering a Multi-MW, Multi-hour Storage

Local Benefits:

1) **Backup power**
2) **Voltage correction**
3) **Renewable Integration**

Grid Benefits:

4) Load Leveling at substation
5) Power Factor Correction
6) Ancillary services



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Benefits of Local Energy Storae

While Local Storage can function as a Multi-MW, Multi-hour Substation Battery, It has Inherent Advantages over Larger Batteries located in Substations:

- More **reliable** Backup Power to customers (closer)
- More **scalable**, flexible implementation (many small units)
- More **efficient** in buffering customer **renewable** sources
- More synergy with **Electric Vehicle** batteries
- Easier installation and **maintenance** (240 V)
- A **Unit outage is less critical** to the grid (smaller)

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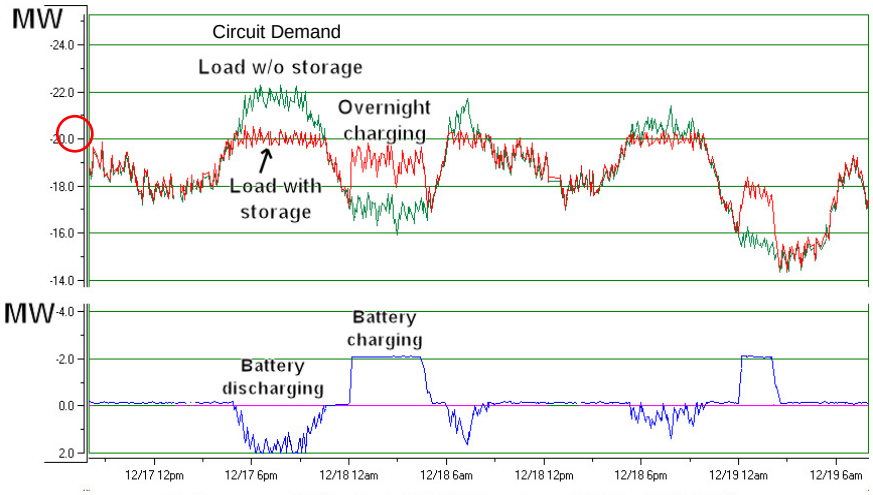
Load Following Peak Shaving



Performance of Balls Gap's 2MW Battery from 12/17 to 12/19/2008

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Community Energy Storage Simulations

In the

AEP Smart Grid Demonstration

Roger Dugan
Sr. Technical Executive
Electric Power Research Institute (EPRI)

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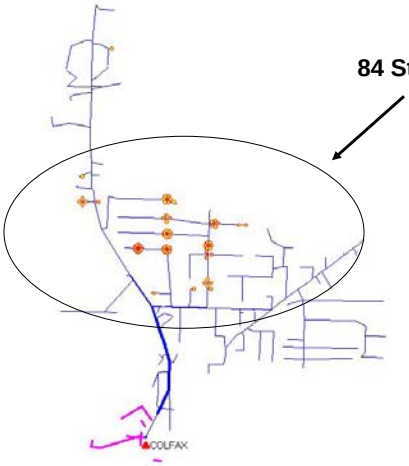
Circuit Diagram



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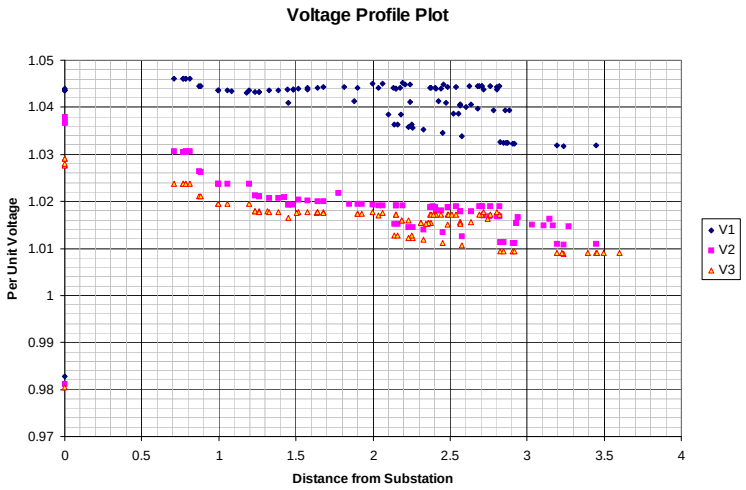
Voltage Profile



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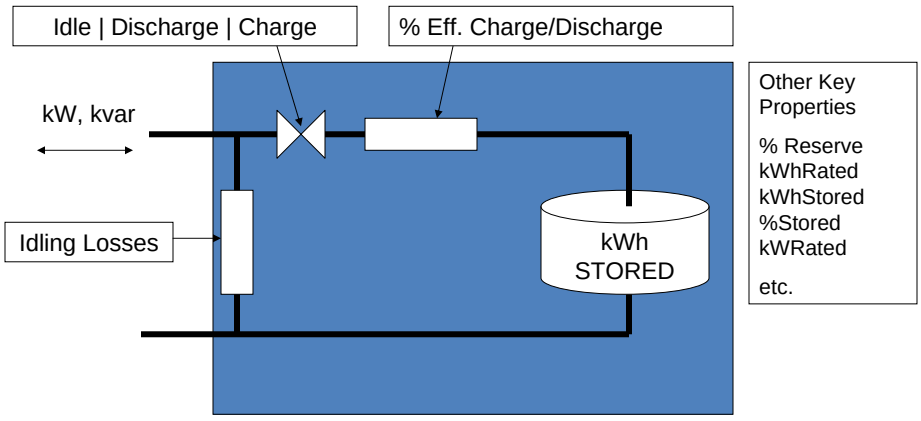
Storage Element Model in OpenDSS



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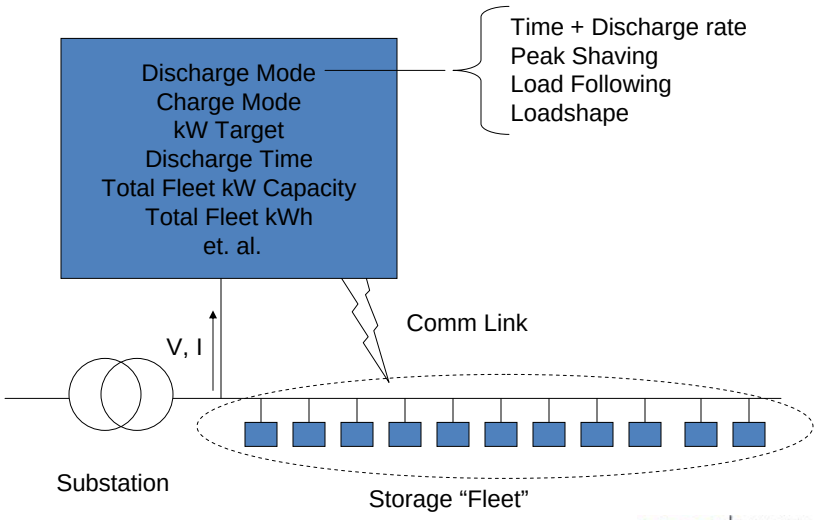
StorageController Element in OpenDSS



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Example Simulations

Investigating 25, 50, and 75 kWh storage options with various discharging schemes

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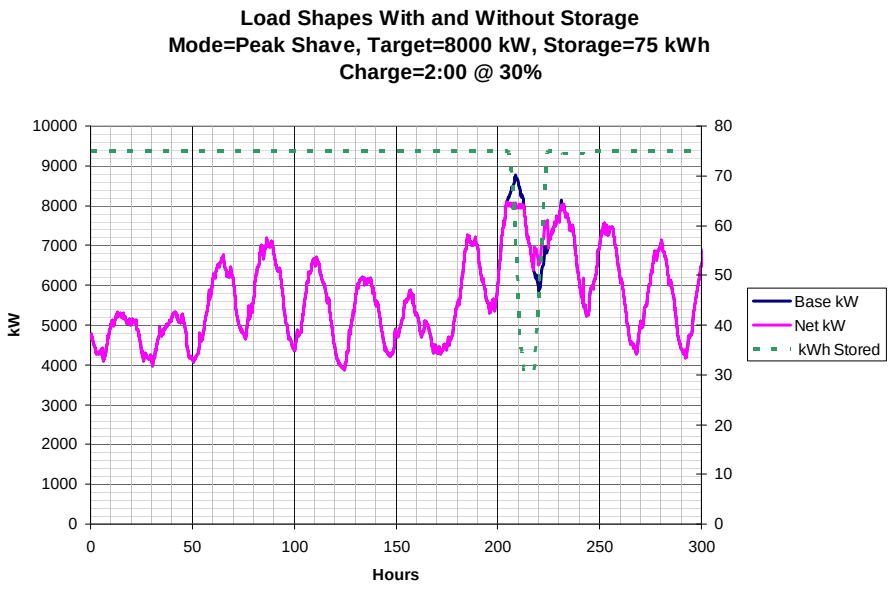

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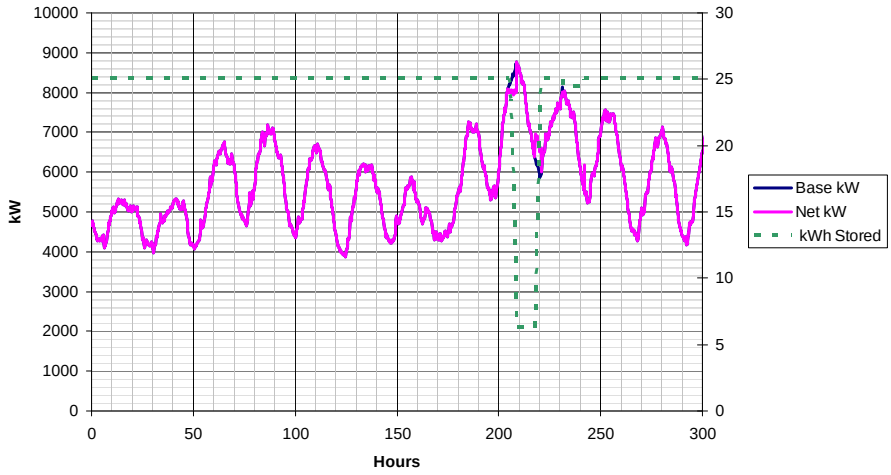
Load Shapes With and Without Storage
Mode=Peak Shave, Target=8000 kW, Storage=25 kWh
Charge=2:00 @ 30%



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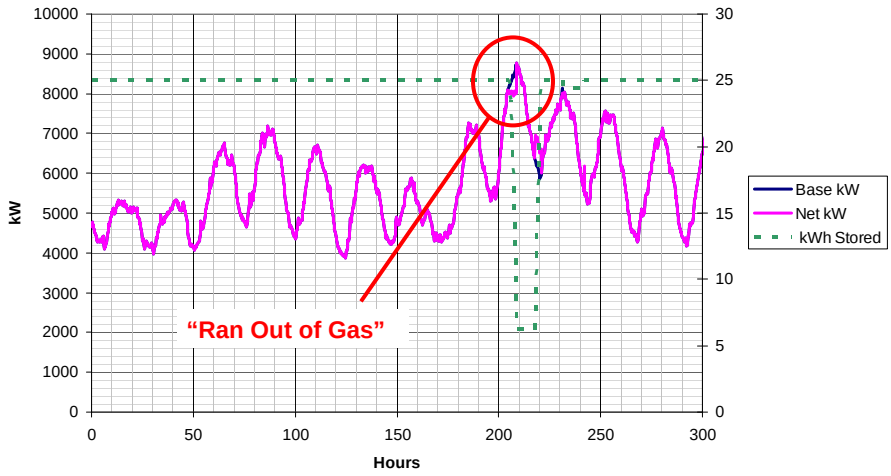
Load Shapes With and Without Storage
Mode=Peak Shave, Target=8000 kW, Storage=25 kWh
Charge=2:00 @ 30%



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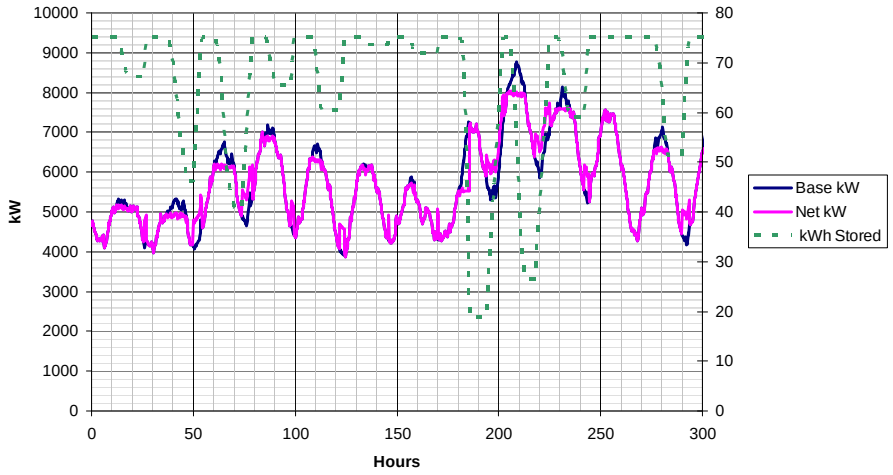
Load Shapes With and Without Storage
Mode=Load Follow, Time=12:00, Storage=75 kWh
Charge=2:00 @ 30%



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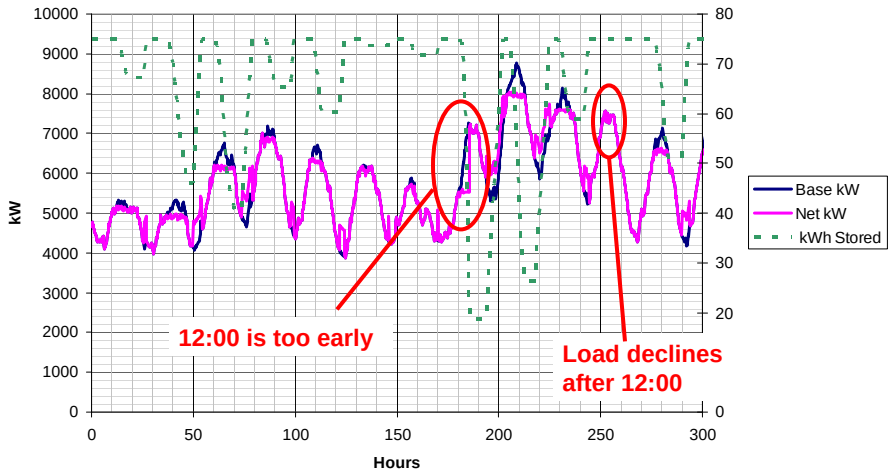
Load Shapes With and Without Storage
Mode=Load Follow, Time=12:00, Storage=75 kWh
Charge=2:00 @ 30%



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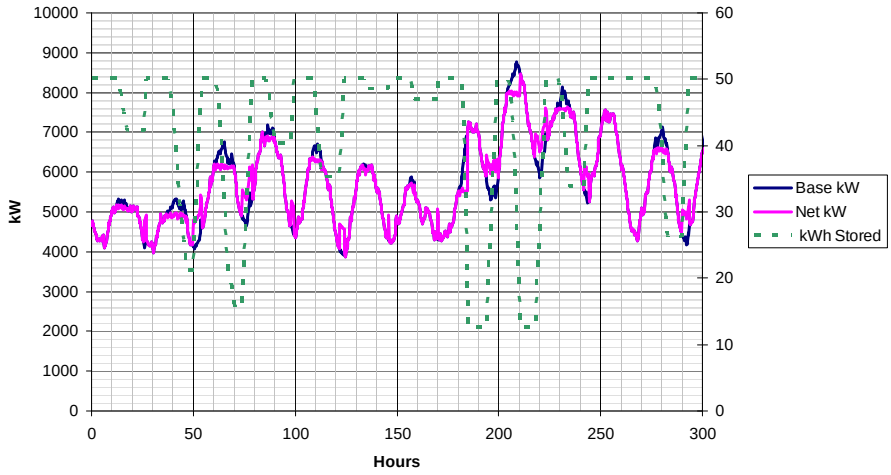
Load Shapes With and Without Storage
Mode=Load Follow, Time=12:00, Storage=50 kWh
Charge=2:00 @ 30%



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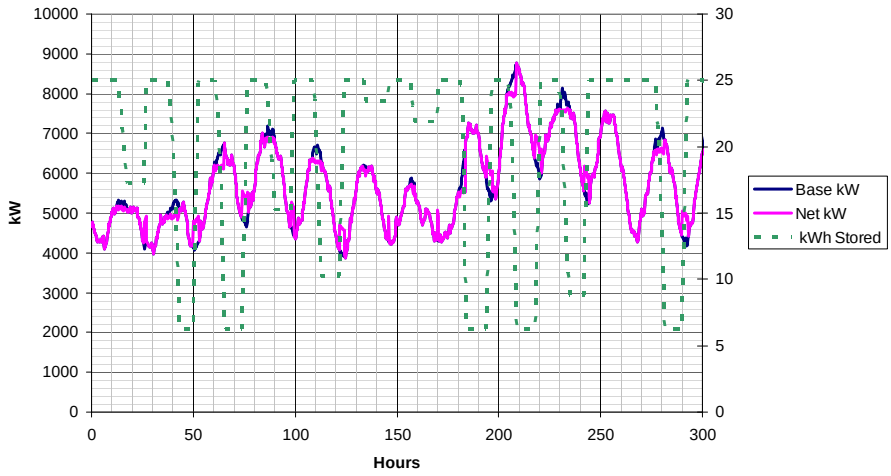
Load Shapes With and Without Storage
Mode=Load Follow, Time=12:00, Storage=25 kWh
Charge=2:00 @ 30%



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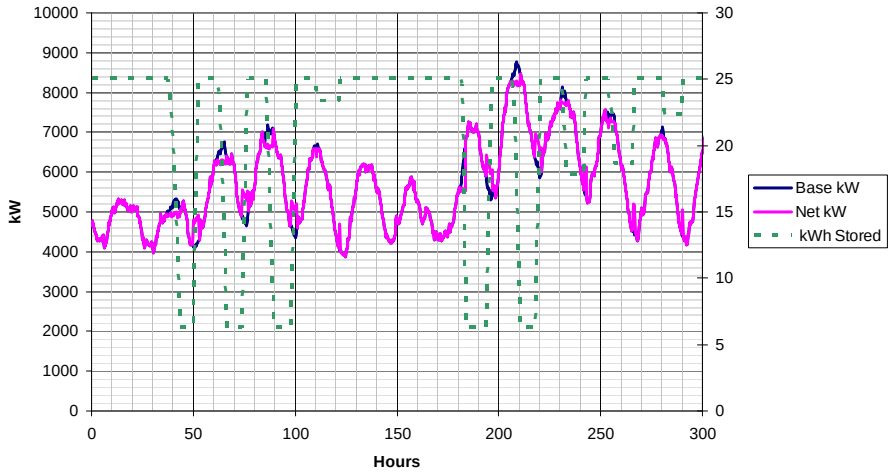
Load Shapes With and Without Storage
Mode=Load Follow, Time=13:00, Storage=25 kWh
Charge=2:00 @ 30%



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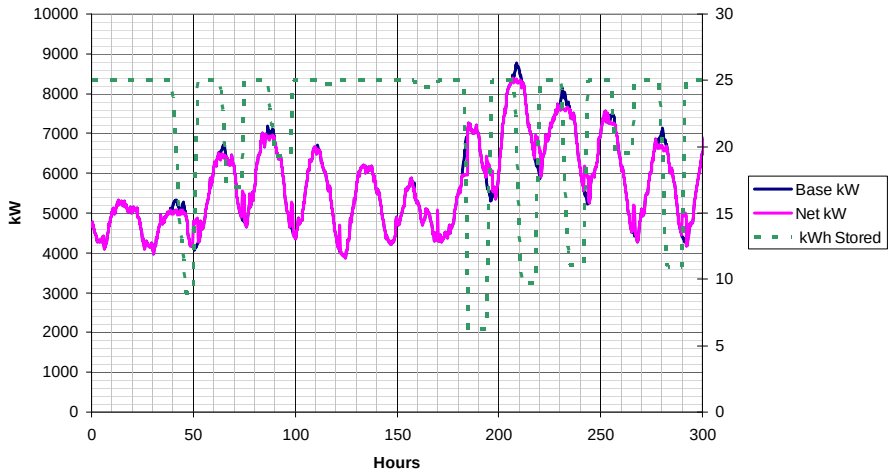
Load Shapes With and Without Storage
Mode=Load Follow, Time=14:00, Storage=25 kWh
Charge=2:00 @ 30%



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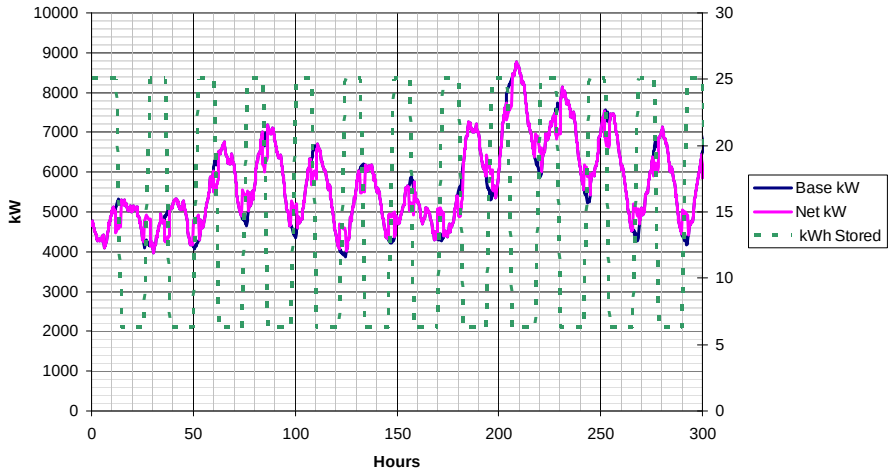
Load Shapes With and Without Storage
Mode=Time + fixed rate, Time=12:00 @ 30%, Storage=25 kWh
Charge=2:00 @ 30%



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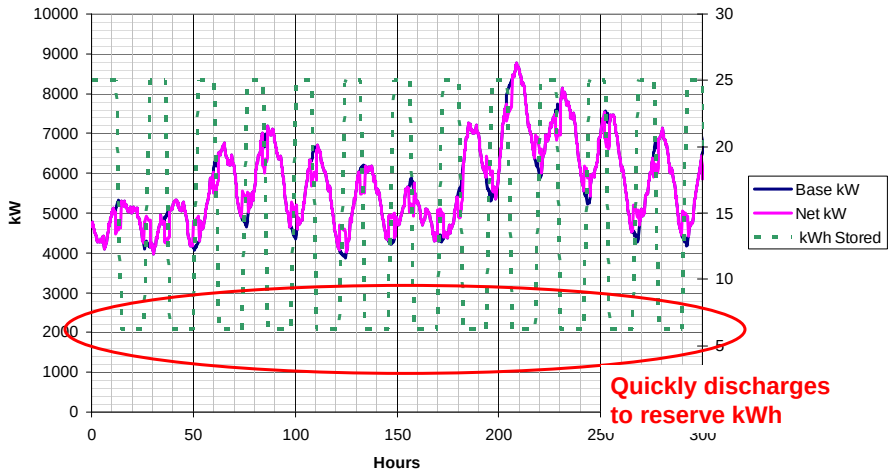
Load Shapes With and Without Storage
Mode=Time + fixed rate, Time=12:00 @ 30%, Storage=25 kWh
Charge=2:00 @ 30%



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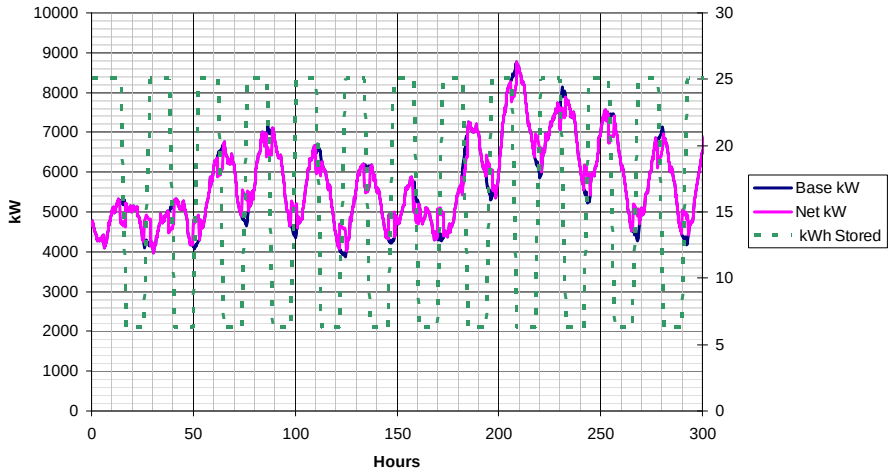
Load Shapes With and Without Storage
Mode=Time + fixed rate, Time=14:00 @ 25% Storage=25 kWh
Charge=2:00 @ 30%



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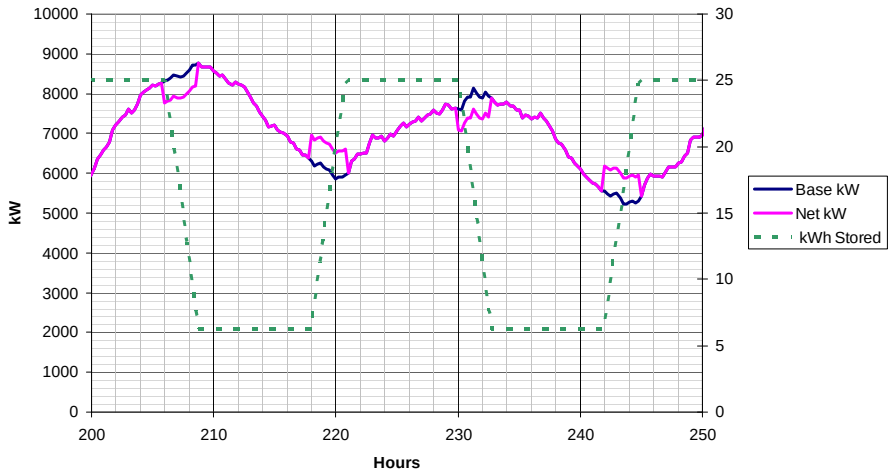
Load Shapes With and Without Storage
Mode=Time + fixed rate, Time=14:00 @ 25% Storage=25 kWh
Charge=2:00 @ 30%



(Expanded Scale)

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Conclusions

- 25 kWh storage is quickly depleted when used for day-to-day peak shaving
  - Have to be very careful with discharge strategy
- Load following with a later time trigger is likely more useful than a fixed discharge rate or an early time trigger
- 75 kWh would be “nice to have”
  - Costs are a factor

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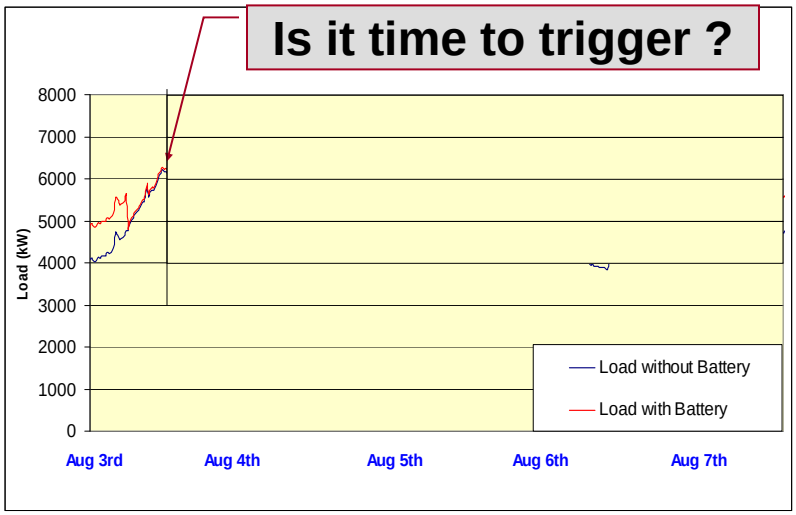
Discharge Algorithm Development



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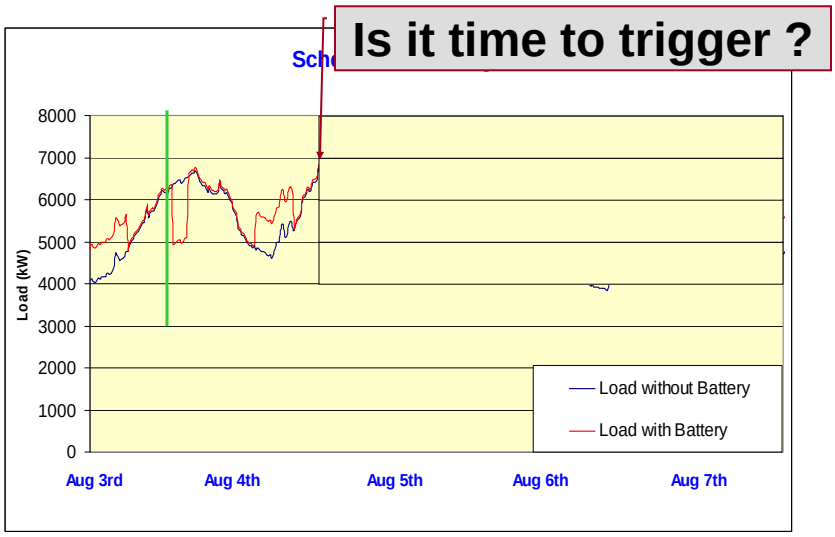
Discharge Algorithm Development



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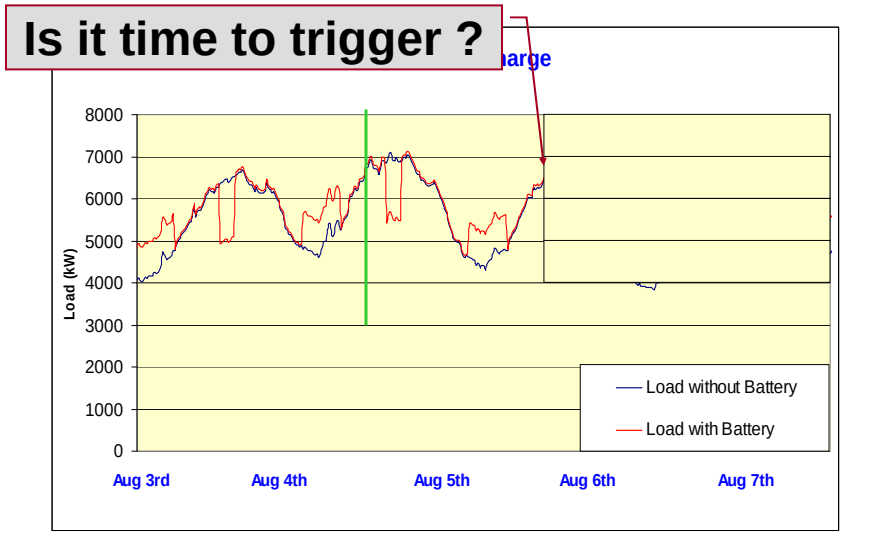
Discharge Algorithm Development



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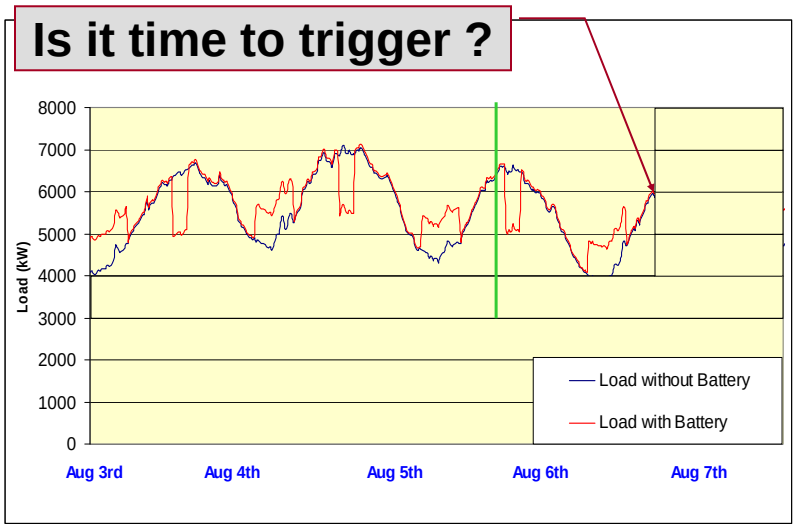
Discharge Algorithm Development



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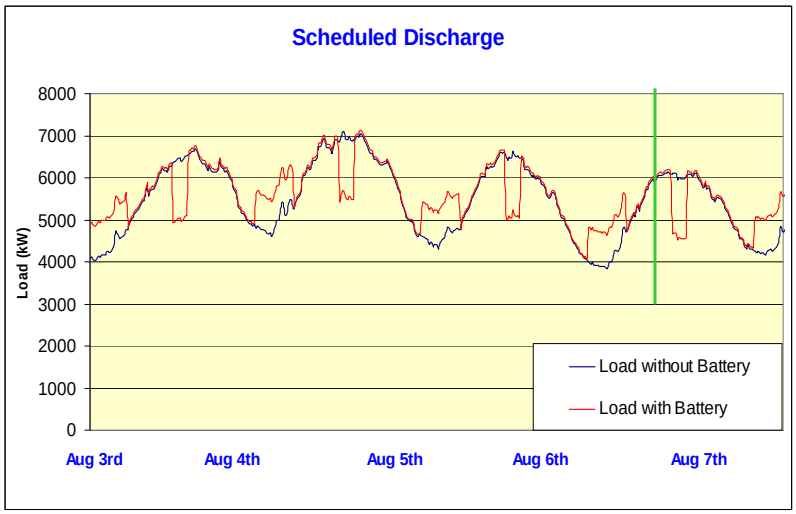
Discharge Algorithm Development



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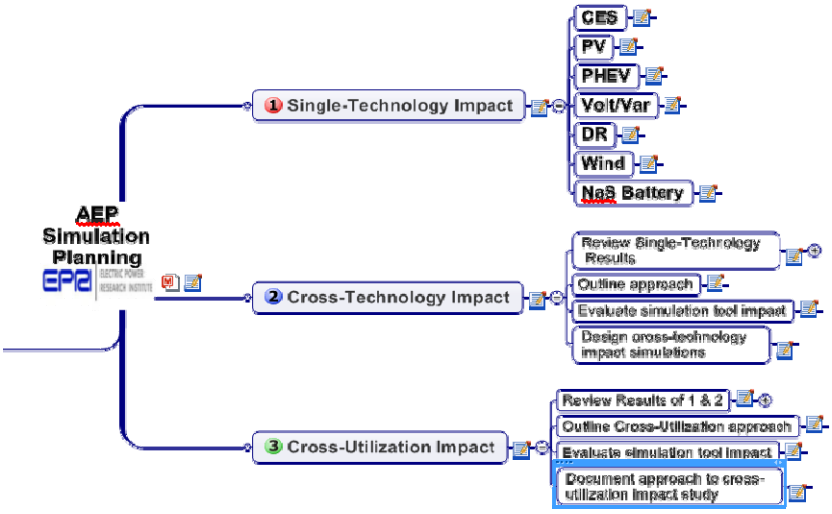
AEP Approach to Smart Grid Technology Simulations



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