Effects of Home Energy Management Systems on Distribution Utilities and Feeders Under Various Market Structures

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Retail Tariffs are Evolving

- Net metering is unsustainable at high penetrations of distributed generation
- Ramp rates are increasing
- Transactive pricing results in volatility
- Customers need incentives to schedule

Credit: EPRI “The Integrated Grid: Realizing the Full Value of Central and Distributed Energy Resources” (October 2007)

Integrated Energy System Model (IESM)

- Simulation tool
- Physics-based performance of technologies and buildings
- Multiple retail markets and tariff structures
- Provide market layer input to market-to-device HIL testing
IESM is a Co-Simulation Tool

Enterprise Message Bus (asynchronous)

Scenario Repository

Component Repository

Discrete Event Simulation coordinator

Power System Simulator (e.g., GridLab-D, EnergyPlus)

Load (Virtual / Hardware-in-the-Loop)

Optimization Engine (e.g., GAMS, Pyomo)

Consumer Agents

Market Policy Rule Engine

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Home Energy Management System (HEMS)

- Minimizing cost for air conditioning
- Using predicted weather conditions and energy prices
- Setpoint kept at or below desired temperature
- Can be 5°F (2.8°C) below the desired temperature
20 Identical Houses with Varied Schedules

- Daytime temperatures: 72.0 - 77.0°F (22.2 - 25.0°C)
- Start time: 4:00 and 8:00 AM
- Nighttime mode after 16 hours – temperature increased by 3°F (1.7°C)
Time of Use (TOU) Pricing

- TOU pricing from Duke Energy*
- Mid-day price peaks with shoulders

* Residential Service Time-of-Use Schedule R-TOU-31

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HEMS Minimizes Cost by Precooling Houses

- Precool by about 2°F (1.1°C) before peak pricing
Average Residence Saves 5% on Electric Bill

- Estimated energy bills for July 7-17, 2012
- Two market structures and three HEMS penetrations
- Bills under uniform rate are higher during other seasons
But Loads are Shifted Earlier

- Increased peak load
- Potentially increasing infrastructure requirements
- Potentially decreasing the transformer lifetimes

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Next Steps and Future Work

- Larger feeders with many homes
- Rooftop photovoltaic solar
- HEMS with cost-comfort tradeoffs
- Additional controllable loads (water heating and electric vehicles)
- Hardware-in-the-loop testing
- Integration with bulk power system models
Conclusions

- HEMS and controllable loads can be beneficial
- But markets / tariffs need to evolve and supporting equipment is necessary
- Potential unintended consequence of TOU rates are identified and quantified
- Larger systems should be analyzed to better understand issues and opportunities
- HIL testing is underway to verify performance
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