Towards IT Solutions to Enable and Control Future Electric Energy Systems

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Center of IT-Intelligent Energy Systems (CITIES)
Scientific Objectives of CITIES

To establish methodologies and IT solutions for design and operation of integrated electrical, thermal, fuel pathways at all scales for the future electric energy system.
**The Danish Wind Power Case**

... balancing of the power system

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**In 2008** wind power did cover the entire demand of electricity in 200 hours (West DK).

**In December 2013 and January 2014** more than 55 percent of electricity load was covered by wind power. And for several days the wind power production was more than 120 percent of the power load.
Solar district heating in Denmark

Planned in 2014
197,855 M²
Total collector area: 574,023 m²

Ex: Future of Electric Utilities
Principles for DSM and Control
Principles for DSM and Control

- **Day Ahead:**
  - Stoch. Programming based on eg. Scenarios
  - Cost: Related to the market (one or two levels)

- **Direct Control:**
  - Actuator: **Power**
  - Two-way communication
  - Models for DERs are needed
  - Constraints for the DERs (calls for state est.)
  - Contracts are complicated

- **Indirect Control:**
  - Actuator: **Price**
  - Cost: E-MPC at low (DER) level, One-way communication
  - Models for DERs are not needed
  - Simple 'contracts'

*From a new Wiley Book: Control of Electric Loads in Future Electric Energy Systems, 2014*
Measures to activate flexibility

- 100% Renewables
- Multiple supply strings
- Dynamic tariffs
- Biomass
- Tax rules reflecting market price
- Intelligent consumption
  Demand response management
- Forecasting of Wind and Solar Power
Operational (grey-box) models, optimization and control

(Virtual) storage principles:
- Buildings provide storage up to, say, 10 hours ahead
- District heating systems lead provide storage up to 2-3 days ahead
- Gas systems provide seasonal storage
Case Study

Use of Smart Meter Data
## Results

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Perspectives for using data from Smart Meters

- Reliable Energy Signature.
- Energy Labelling
- Time Constants (e.g., for night setback)

Proposals for Energy Savings:
- Replace the windows?
- Put more insulation on the roof?
- Is the house too untight?
- ......

- Optimized Control
- Integration of Solar and Wind Power using DSM
Case study

Control of Power Consumption (DSM)
Olympic Peninsula project

- 27 houses during one year
- Flexible appliances: HVAC, cloth dryers and water boilers
- 5-min prices, 15-min consumption
- Objective: limit max consumption
Aggregation (over 20 houses)
Non-parametric Response on Price Step Change

Model inputs: price, minute of day, outside temperature/dewpoint, sun irradiance

Olympic Peninsula

![Graph showing consumption step response with 5 hours indicated](image_url)
Control of Energy Consumption

Model parameters

Consumption references

Price generator (controller)

Prices

Price-response estimator

Price-responsive consumption

Aggregated consumption

Exelon – IT and the Future of Electric Utilities

CITIES
Centre for IT Intelligent Energy Systems
Control performance

- Considerable reduction in peak consumption
- Mean daily consumption shift
Case study

Control of Heat Pumps
Grundfos Case Study
Schematic of the heating system
Modeling Heat Pump and Solar Collector

Simplified System
EMPC for heat pump with solar collector – savings: 35 pct
Our IT solutions for Smart Energy Systems

- Temperature control in houses (Samsung, ENFOR)
- HVAC systems (Grundfos, Samsung, ...)
- Supermarket cooling (Danfoss, ....)
- Electricity consumption in family houses (Saseco, ...)
- District heating/cooling networks (EMD International)
- Combined Heat and Power plants (Dong Energy, Cowi, ENFOR)
- Intelligent use of biomass (HOFOR, Dong Energy)
- Wastewater treatment plants (Kruger, Veolia)

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For more information ...

• See for instance

  www.henrikmadsen.org
  www.smart-cities-centre.org

• ...or contact

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