Format 2

Preparation of Abstract for
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"Energy at home"

PowerFlexhouse research laboratory for smart energy management

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Abstract

The electricity consumption of Danish households in 2010 was 10.2 TWh [13], which is 31.8% of the overall national consumption. A part of the residential consumption is assumed to be flexible, therefore the demand can be controlled or shifted in time, for example because energy can be stored in thermal masses. Assessing the flexibility of household consumption is one of the most important topics in the Demand Side Management (DSM).

Many researchers and engineers design and verify their ideas through simulation with verified models. The next step of the development of energy management strategy is a laboratory test. Smart house laboratories allow researchers and engineers to gather an experimental data, get an experience with unreliable hardware and real environmental conditions. An experiment in a smart house usually records a large amount of time series from many sensors and actuators. This amount of data allows detailed analysis of tested algorithm and can reveal assumptions and simplifications that were undetected in the simulation. Once the algorithm or a new technology is successfully tested in the smart house laboratory, the next step is to deploy it in demonstration sites or in real houses.

PowerLab [18] is a set of state-of-the art experimental facilities for technology development, testing, training and demonstration of electric power and energy technology. PowerLab facilities are situated across Denmark and consist of high voltage and power labs, electric vehicles laboratory, demonstration site on the island of Bornholm, experimental distribution grid SYSLAB and Power FlexHouses facility for energy management in smart buildings.

Figure 1: Three PowerFlexHouses in SYSLAB

PowerFlexHouse laboratory of Technical University of Denmark is part of SYSLAB experimental distribution grid laboratory. It consists of an office building and two family houses as shown in Figure 1 connected to the SYSLAB power grid. The buildings have been converted into smart, remotely controlled lab facilities. The technology that is subject of the research in the PowerFlexHouses includes HVAC, energy storage in thermal mass, lighting, control of appliances, modeling, HEMS and impact of a smart house on the power system. Research activities including PowerFlexHouses are as follows:

1) Home Energy Management System (HEMS):
   a) model predictive control including electricity price and user preferences [6];
   b) on-line scheduling of appliance operation matching a bid from a negotiation based local energy market [10];
   c) distributed load scheduling based on a negotiation between appliances [8];
   d) distributed control of a house heating by modifying the behavior of individual heaters [12].
2) Mathematical modeling and identification: PowerFlexhouse [13], fridge [3,4,11], water boiler [5,7].
3) Information and Communications Technology:
   a) flexible home automation platform,
   b) ICT for testing home automation algorithms and controller deployment,
   c) service based RMI interface to smart house,
   d) OPC UA interface to smart house.
4) Development of smart devices and appliances: fridge control with use of smart plug and additional sensors [8,4], smart freezer
5) Smart grid experiments: hierarchical voltage control [9], house self-consumption of a local PV production [5,7], aggregation of demand side flexibility [12,14], participation in commercial aggregator run by DONG Energy as part of PowerHub project [14].
6) Hardware in the loop: PowerFlexhouse physical behavior applied to a population of houses in simulation [2].
7) Demand Side Management projects using PowerFlexHouse as demonstration of test site: INCAP [15], iPower [16], PowerHub [17].

PowerFlexhouse laboratory at Technical University of Denmark is a platform for education, experiments, demonstration, commercial and scientific tests.

References:

[1] Danish Energy Agency. Energy Statistics 2010, 2011.
[2] F. Sossan and H. Bindner, “A comparison of algorithms for controlling DSRs in a control by price context using hardware-in-the-loop simulation," in Power and Energy Society General Meeting, 2012 IEEE, 2012.

[3] F. Sossan, V. Lakshmanan, G. Costanzo, M. Marinelli, P. Douglas, and H. Bindner, “Thermal modelling of a household refrigeration unit for smart grids applications" in review for Smart Grid, IEEE Transactions on, 2013.
[4] V. Lakshmanan, M. Marinelli, A. Kosek, F. Sossan, and P. Nørgård, “Domestic Refrigerators Temperature Prediction Strategy for the Evaluation of the Expected Power Consumption” in 4th European Innovative Smart Grid Technologies (ISGT 2013), 2013.
[5] F. Sossan, A. M. Kosek, S. Martinenas, M. Marinelli, and H. W. Bindner, “Scheduling of domestic water heater power demand for maximizing PV self-consumption using model predictive control" in 4th European Innovative Smart Grid Technologies (ISGT 2013), 2013.
[6] Y. Zong, D. Kullmann, A. Thavlov, O. Gehrke, and H. Bindner, “Application of model predictive control for active load management in a distributed power system with high wind penetration", in IEEE Transactions on Smart Grid, vol. 3, no. 2, pp. 1055-1062, 2012.
[7] Y. Zong, L. Mihet-Popa, D. Kullmann, A. Thavlov, O. Gehrke, and H. Bindner, “Model Predictive Controller for Active Demand Side Management with PV Self-consumption in an Intelligent Building”. 3rd IEEE PES International Conference on Innovative Smart Grid Technologies (ISGT Europe), 2012
[8] A. Kosek and O. Gehrke, “A Distributed Multi-agent Control System for Power Consumption in Buildings, Communicating Process Architectures (CPA2012),2012.
[9] X. Han, A. Kosek, O. Gehrke, H. Bindner, and D. Kullmann, "Hierarchical Control Architecture to Activate Distributed Energy Resources Services: Voltage Control as an Application," in 2014 IEEE PES Transmission & Distribution Conference & Exposition, 2014.
[10] G. Costanzo, A. Kosek, G. Zhu, L. Ferrarini, M. Anjos, and G. Savard, “An experimental study on load-peak shaving in smart homes by means of online admission control" in Innovative Smart Grid Technologies (ISGT Europe), 2012 3rd IEEE PES International Conference and Exhibition on, Oct 2012, pp. 1{8.
[11] G. Costanzo, F. Sossan, M. Marinelli, P. Bacher, and H. Madsen, “Grey-box modeling for system identification of household refrigerators: A step toward smart appliances," in Energy (IYCE), 2013 4th International Youth Conference on, June 2013.
[12] D. Kullmann, O. Gehrke, and H. Bindner, “Implementation and test of demand response using behaviour descriptions," in Intelligent System Application to Power Systems (ISAP), 2011 16th International Conference on, Sept 2011.
[13] A. Thavlov and H. W. Bindner, “Thermal models for intelligent heating of buildings," in International Conference on Applied Energy (ICAE 2012), 2012.
[14] A. Thavlov and H. W. Bindner, “An aggregation model for households connected in the low-voltage grid using a VPP interface," in IEEE Innovative Smart Grid Technologies Europe (ISGT Europe), 2013.
[15] www.cee.elektro.dtu.dk/research/projects/38_INCAP
[16] ipower-net.dk/
[17] www.powerhub.dk/
[18] www.powerlab.dk

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