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*Published in:*

Proceedings of the 5th IEEE International Conference on Consumer Electronics

*DOI (link to publication from Publisher):*

[10.1109/ICCE-Berlin.2015.7391260](https://doi.org/10.1109/ICCE-Berlin.2015.7391260)

*Publication date:*

2015

*Document Version*

Peer reviewed version

[Link to publication from Aalborg University](#)

*Citation for published version (APA):*

Diaz, E. R., Palacios-Garcia, E., Firoozabadi, M. S., Quintero, J. C. V., Guerrero, J. M., & Moreno-Munoz, A. (2015). Advanced Smart Metering Infrastructure for Future Smart Homes. In Proceedings of the 5th IEEE International Conference on Consumer Electronics (pp. 29 - 31). [7391260] IEEE Press. DOI: 10.1109/ICCE-Berlin.2015.7391260

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# Advanced Smart Metering Infrastructure for Future Smart Homes

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**Abstract**—Smart buildings and homes are becoming a key player in the future green and sustainable energy grid, due to the integration of distributed energy sources and the demand control capabilities. Advanced smart metering systems are required for the operation of the future smart grid. Smart metering systems allow to monitor the energy consumption of end-users, while provides useful information regarding power quality. The information provided by these systems is used by the system operator to enhance the energy supply, and several techniques, as load scheduling, demand side management, non-intrusive load monitoring, can be applied for this purpose. This paper shows an advanced smart metering infrastructure for integration in future smart homes, where not only the electrical consumption is monitored, but also the gas, water, and heating. Therefore, by monitoring all energy systems in the building, the users could be aware of their whole energy consumption, and advanced control techniques can be achieved by the Energy Management Systems (EMS).

**Index Terms**—Smart homes, Energy management, meter reading.

## I. INTRODUCTION

Inside de global energy consumption in the European Countries, the residential sector represents and average 30% being this demand the combination of different energy end-uses that conform a complex energy mix. In the particular case of Denmark this percentage is divided in main two groups with different purposes. The amount of energy used for heating represent 83% of the consumed in the residential sector, whereas 17% is electrical demand [1].

In order to reduce these figures, new energy policies and measures are being studied by researches and government to achieved a significant impact on the aggregate energy saving and meet the environmental requirements for CO<sub>2</sub> reductions [2]. However, all these measures need detailed data about the different demand profiles in households.

In this context, the advanced metering infrastructures (AMI) play a main role, where the manual data collection has been substituted by a complex communication chain composed of data concentrators, hubs, and different control and central units [3]. This network was initially conceived for the renovation of the Electrical Grid, nevertheless it might integrates nowadays

This work was supported by the Technology Development and Demonstration Program (EUDP) through the Sino-Danish Project Microgrid Technology Research and Demonstration (meter.et.aau.dk).

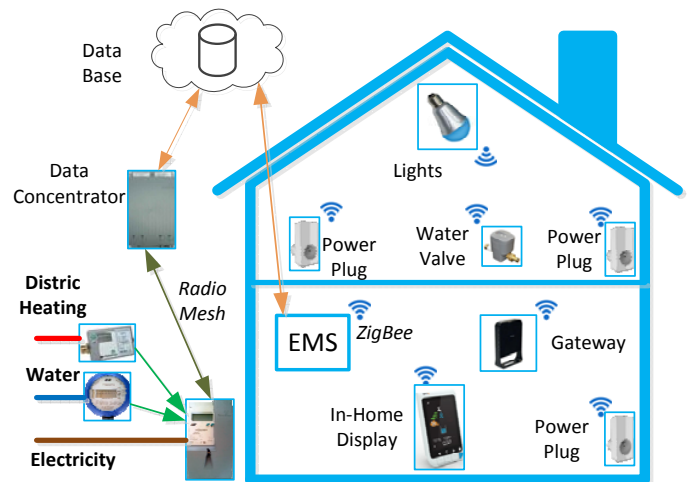


Fig. 1. Schematic of Smart Metering Infrastructure, Energy Management System and Smart Devices Integration.

gas and water measurements looking towards to a future of mixed energy systems [4].

In addition, this new concept not only gives the suppliers access to accurate data for billing, but it also provides a way to collect information of the end users, and establishing a two-ways communication. Therefore, the Smart Meters can be regarded as a costless way of obtaining detailed consumption profiles that can be used in higher level applications [5].

The first approach could be a simple energy consumption visualization using In-Home displays [6]. This measure do not directly influence the end-users' consumption. Nevertheless, if the user is aware of the energy demanded and the economical cost, some energy saving can be induced [7].

Further improvement could be achieved by means of an Energy Management system (EMS) [8]. Thus, the combination of advanced control algorithms, detailed measurements from the SMs, and Smart Devices which can be connected, disconnected or regulated, will drive to significant savings. All of these thanks to the development of low cost Personal Area Networks (PAN) like Zigbee or Bluetooth that allow the interconnection of the different home appliances [9].

The aim of this paper is to present a real application which is

being development in the Aalborg University, Denmark, where a whole AMI system from a well-know danish manufacturer would be integrated inside a Smart Home, equipped with controllable Smart Devices, energy displays and an EMS.

## II. SYSTEM DESCRIPTION

The information provided by the AMI system can be used either for billing purposes by the utility company or consumption analysis and energy optimisation by the energy management system. The conceptual integration of the AMI system, EMS and Smart Home Devices is shown in Fig. 1.

The AMI system is formed by the smart meters, a data collector, and a database system. Three smart meters are installed in order to obtained the consumption profiles of electricity, water and district heating. The water smart meter is a static ultrasonic flow measurement meter, which also provides information of the water an ambient temperature. The ambient temperature is used as a warning about freezing or unintended high temperatures, while the water temperature can be used as a quality indicator. The district heating smart meter provides the heating energy consumption by measuring the temperature and water consumed. The device calculates the energy based on the formula in EN 1434-1:2004.

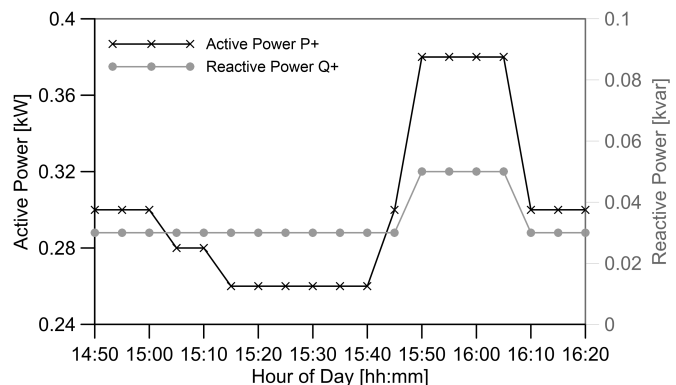
The water and district heating smart meters collect and send the data to the electricity meter by a wireless M-bus radio communication (EN 13757-4). The data are sent to the electricity meter every 16 or 96 seconds depending on the format selected for the packets. In addition, all this information exchange is encrypted and protected against unauthorized monitoring using AES-128.

Regarding the electricity meter, it is designed to measure bidirectional power flows, as well as several power quality features, as the total harmonics distortion (THD), power factor, voltage unbalance, voltage variations, sags and swells. Another Additional feature of this system is the possibility of remotely cut or enable the power supply according to demand thresholds or prepaid tariffs.

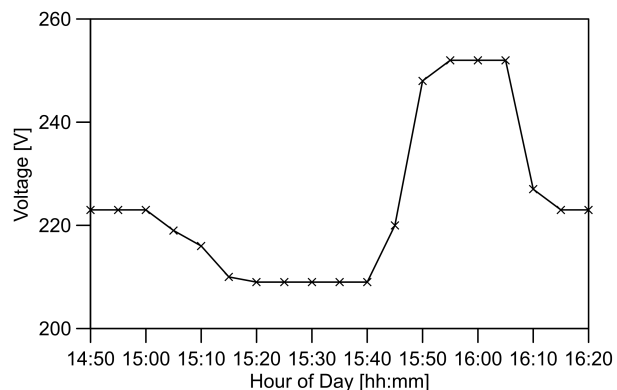
All the data collected from the Smart Metering system are sent to a data concentrator system using a wireless communication. In this case, a radio mesh topology is used, based on the standard EN 13757-5. This data concentrator is able to manage up to 500 Smart Meter and is equipped with two working modes, automatic meter reading (AMR) and on demand reading.

Finally, the data packets are transferred from the data concentrator to two levels database system using the DLMS/COSEM standard over Ethernet, GPRS or 3G. The storage system is composed of a short-term database for the on demand readings, system events and wireless network optimization purposes, whereas a long-term database is used for indefinitely store the consumption profiles with a maximum of 5 minutes resolution.

Inside the Smart Home, the EMS accesses the information stored in the AMI database using user defined privileges, so only the personal data can be read, as well as a SSL connection. These data together with smart home devices, are employed in order to apply the advanced control algorithms



(a) Active and Reactive Power Profiles



(b) Voltage Profile

Fig. 2. Scenario 3. Voltage and Reactive Power during a load disturbance, using droop control.

developed at Aalborg University. Therefore, through the smart devices the EMS control and regulation capabilities over the home appliances are achieved.

In the future Smart Home, a wide range of Smart Home Devices are integrated in the system such as power plugs with metering and switching capability, lighting control equipment, in-home displays, smart switches/dimmers, air monitoring devices, and water valves. Every single smart home device will send and receive information, through a low-power ZigBee PAN, to a central coordinator device. This device has two parallel tasks. In the one hand, it works as a gateway providing data to the EMS. In the other hand, it is responsible of receiving the commands, when actions need to be taken on the system, according to the advanced control algorithms.

## III. TEST AND RESULTS

The smart meters, and the communication systems with the EMS and within the AMI has been tested. The smart meters have been connected to their respective systems, in order to obtain the measurements. Then the data provided by the smart meters have been obtained through the data collection system, using a basic API service. The data provided by the electricity smart meter is shown in Fig. 2. The voltage, and active and reactive power, consumed by the experimental setup where the smart meter is installed, have been monitored for 90 minutes. It provided measurements of the variables every 5 minutes.

#### IV. CONCLUSION AND FUTURE WORK

This paper has shown the possibilities that can be obtained from the integration of the advanced metering infrastructure with the concept of Smart Home. A whole real AMI system has been described, showing the information flow, the communication structure and the different variables that can be monitored in the system.

Likewise, the in-home system composed of a wide range of Smart Devices and a central EMS has been illustrated, being the cornerstone to achieve substantial energy savings and showing the benefits of low-cost wireless PAN for the integration of appliances at home, leading to the future Internet of Things (IoT).

Current works are focused on the development of an information interchange system between the central database and the individual users' EMS, these results will be presented in the following papers.

#### REFERENCES

- [1] Danish Technological Institute, "IEA HPP Annex 42 : Heat Pumps in Smart Grids Task 1 ( i ): Market Overview," vol. 1, no. September, pp. 1–38, 2014.
- [2] UNFCCC, "Kyoto Protocol To the United Nations Framework Kyoto Protocol To the United Nations Framework," *Review of European Community and International Environmental Law*, vol. 7, pp. 214–217, 1998.
- [3] K. D. Craemer and G. Deconinck, "Analysis of State-of-the-art Smart Metering Communication Standards," *Proceedings of the 5th Young Researchers Symposium*, pp. 1–6, 2010.
- [4] H. Lund, S. Werner, R. Wiltshire, S. Svendsen, J. E. Thorsen, F. Hvelplund, and B. V. Mathiesen, "4th Generation District Heating (4GDH)," *Energy*, vol. 68, pp. 1–11, Apr. 2014.
- [5] J. Zheng, D. W. Gao, and L. Lin, "Smart meters in smart grid: An overview," in *IEEE Green Technologies Conference*, 2013, pp. 57–64.
- [6] Dong Sik Kim, Beom Jin Chung, Sung-Yong Son, and Jeongjoon Lee, "Developments of the in-home display systems for residential energy monitoring," in *2013 IEEE International Conference on Consumer Electronics (ICCE)*. IEEE, Jan. 2013, pp. 108–109.
- [7] K. Ehrhardt-Martinez, "Changing Habits , Lifestyles and Choices : The Behaviours that Drive Feedback-Induced Energy Savings," *Energy*, pp. 202–507, 2010.
- [8] F. Staff, "Assessment of Demand Response and Advanced Metering," *Federal Energy Regulatory Commission*, p. 139, 2008.
- [9] F. Bellido-Outeirino, J. Flores-Arias, M. Linan-Reyes, E. Palacios-garcia, and J. Luna-rodriguez, "Wireless sensor network and stochastic models for household power management," *IEEE Transactions on Consumer Electronics*, vol. 59, no. 3, pp. 483–491, Aug. 2013.