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# Development and Integration of a HEMS with an Advanced Smart Metering Infrastructure

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**Abstract**—Advanced metering infrastructures (AMI) are required for the future smart grid operation by providing useful information about users' behavior as well as grid performance such as the consumption and power quality. This paper is focused on the development of a LabVIEW application for user-interface and implementation of a Home Energy Management System (HEMS) based on AMI.

## I. INTRODUCTION

In order to achieve a full-renewable energy system, the reduction and optimization of the energy consumption is becoming as important as the energy generation itself.

Smart grids require precise information in order to manage the energy efficiently and enhance the energy supply, hence Advanced metering infrastructures play a main role for providing the data in future energy systems. They do not only allow monitoring the energy consumption or generation for billing purposes, but they also provide useful power quality information without the unaffordable cost for the end-user that a power quality meter usually means. Moreover, this network was initially conceived for the renovation of the electrical grid, nevertheless it might integrate nowadays water and gas measurements looking towards to a future of mixed energy systems [1]. For instance in Denmark, 83% of the energy consumed by the residential sector is used for heating [2],

therefore an AMI able to integrate different energy systems will bring significant impact on the aggregate energy savings. In addition, the information can be used to deploy HEMS or higher level control systems to achieve significant energy savings and resources optimization. For instance a simple In-Home display, for visualization of the users' consumption, can induce significant energy savings [3].

This paper presents an application which is currently being developed at Aalborg University, which integrates: i) data acquisition modules, to obtain data from an AMI and store it in a database system, ii) energy management algorithms with scheduling, optimization and forecasting capabilities, iii) a general user-interface to visualize the different variables of the systems.

## II. SYSTEM DESCRIPTION

The system is formed by several smart meters and data concentrators, provided by a well-known Danish manufacturer, a database system, and a GUI. An overview of the whole system is shown in Fig. 1.

Three-phase electricity smart meters were installed in the experimental setups in Microgrid Research Laboratory, whereas water, district heating, and single-phase electricity smart meters will be installed in the demonstration home [4].

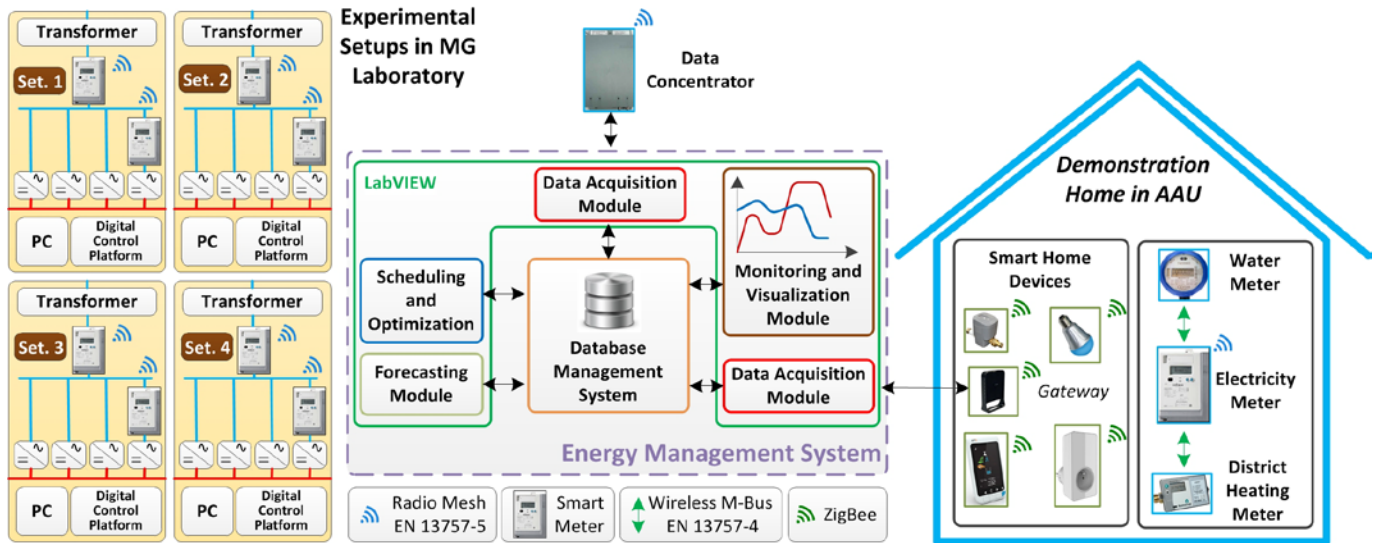


Fig. 1. Advanced Smart Metering Infrastructure and Energy Management System in Microgrid Research Laboratory at Aalborg University.

On top of this, an HEMS is being deployed to perform energy optimization tasks by using the information provided by the AMI. Likewise different smart home devices will be employed to perform the control actions. Those devices include smart plugs, dimmable lights, in-home displays and water flow regulator to name a few.

Each setup has two smart meters, which allow the Microgrid Research Group to use the laboratory as a simulated smart grid platform. Several features are measured by the electricity meters such as active positive and active negative, reactive positive and reactive negative energy, Total Harmonic Distortion (THD), power factor, voltages unbalances, registration of over-voltages and under-voltages, and detection of sags and swells.

Different communication protocols are used to transfer the information between devices. Electricity meters communicate with the data concentrator by means of a radio mesh topology, based on the standard EN 13757-5. Regarding the security of the transferred information, all the AMI communication is encrypted and protected against unauthorized monitoring by using AES-128. Furthermore, the district heating and water meter transfer the data to the electricity meter by a wireless M-Bus radio communications (EN 13757-4).

The data concentrator receives all the information, and it transfers the data packets to the acquisition system, using Ethernet, although, GPRS or 3G communications are also available. The data concentrator has two different working modes, one for automatic meter readings (AMR), and a second one for on-demand readings.

The HEMS is formed by a database system and several modules with different functions as acquiring and storing the data, monitoring, optimizing and forecasting, which are being implemented in LabVIEW. The database system is developed in MySQL and contains separate tables that implement the relational structure. Several variables can be measured by the smart meters, so each record includes the type of measure and the units. In addition, the data can be obtained by the two different working modes of the data concentrator, so they are stored separately. That is due to the different time interval between the readings, which is 5, 15 or 60 minutes, depending on the configuration settings, when the AMR working mode is used, or as soon as it is available when requesting on-demand variables. Nevertheless a time stamp is always assigned to the measured variable by the smart meter, so it is always possible to precisely identify when the measure was performed.

### III. RESULTS

Initial results are shown in Fig. 2, where the active power consumption and the voltages, of one experimental setup, were monitored. In order to obtain a finer interval between the readings, on-demand readings mode was used. The setup's activity was monitored for 17 minutes, obtaining 30 seconds time interval between readings. The time interval between readings depends on the strength of the communication link, and the number of requested readings. For this case, 30

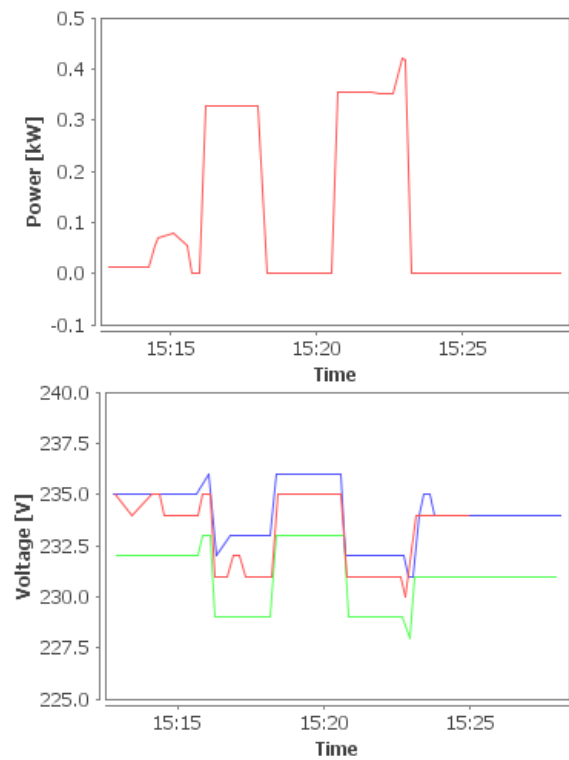


Fig. 2. Monitored Active Power and Three-Phase Voltages Profiles

seconds definition was obtained when requesting 8 variables (three-phase voltages, three-phase currents, active power, and frequency) with good signal strength, a frequency high enough to apply demand response strategies in the domestic environment.

### IV. CONCLUSIONS

The current work has presented the integration possibilities of smart metering systems into HEMS providing the necessary information for taking the suitable control actions and allowing the end users to be aware of their consumption by means of the GUI being developed.

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