D7.2
LRSC Based Home Energy Management System Results

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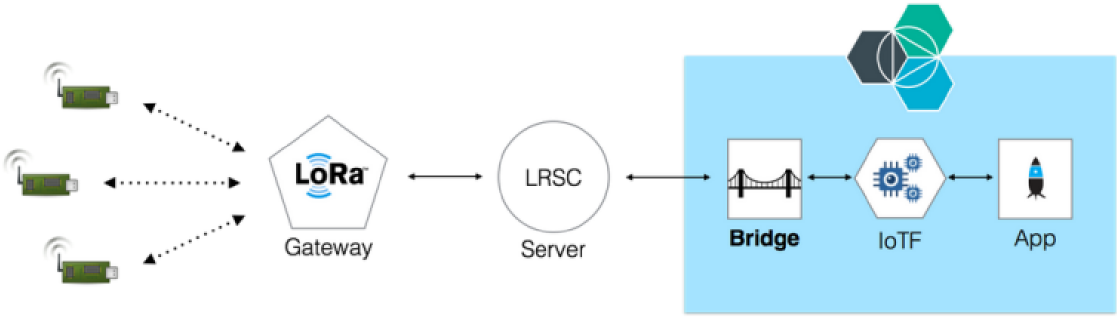
1 LoRaWAN Based Household Connectivity

One goal of the EcoGrid 2.0 project was to establish a prototype Internet of Things (IoT) long range communication network and to equip a number of participating households with Home Automation Devices communicating using this new communication infrastructure for monitoring and control. The IoT network was build based on the LoRaWAN communication standard maintained by the LoRa Alliance, see LoRaWAN Specification v1.1. The IBM Long Range Signaling and Control (LRSC) implementation of the LoRaWAN network infrastructure was used. The LRSC network infrastructure consists of several LRSC Gateways and a LRSC Network Server which perform wireless communication with IoT Devices as specified by the LoRaWAN protocol. The LoRaWAN standard supports long range communication which allows to cover a large geographic area using a small number of communication gateways. The figure below shows the infrastructure components of the LRSC network providing a new way to wirelessly connect IoT Devices in households to a remote management system.



IBM Long Range Signaling and Control (LRSC) infrastructure Components

For the EcoGrid 2.0 project two LRSC Gateways were deployed. The Gateways were managed by the LRSC Network Server software running in the BEOF IT system in Bornholm. The Gateways were installed in locations selected to cover the set of households equipped with Home Energy Management System (HEMS) devices developed for the project. The data from the HEMS devices which was sent using the LRSC network infrastructure was stored in the EcoGrid 2.0 Data Warehouse for further processing by the EcoGrid 2.0 system components.

2 LRSC Based Home Energy Management System

The IBM HEMS (*Home Energy Management System*) device box was developed and produced for the EcoGrid 2.0 project. It connects a heat pump of a household with the central management server via the LoRaWAN network. The box monitors the state of the connected heat-pump and reports it to the network server. The reported state includes the power consumption (three phases) as well as the inflow and the outflow temperatures of the heat-pump. Vice versa some components of the heat-pump can be controlled by the central management server. These components include four connected relay switches and one on-board digital-to-analog converter (DAC).

IBM Home Energy Management System – LRSC HEMS box

The figure above shows the IBM HEMS box which was installed in a number of EcoGrid 2.0 households to provide a new way to monitor and control their heat-pumps. The figure refers to several different components of the HEMS box: 1) Push Button, 2) LED Indicators (4x), 3) LCD Display, 4) Power Connector, 5) Relay Output Connectors (3x), 6) Input Switch Connectors (2x), 7) Temperature Sensor Connectors (2x), 8) Current Sensor Connectors (3x), 9) DAC Output Connector, 9) Firmware Loading Connector. The detailed description is given in the IBM HEMS Box User Guide.

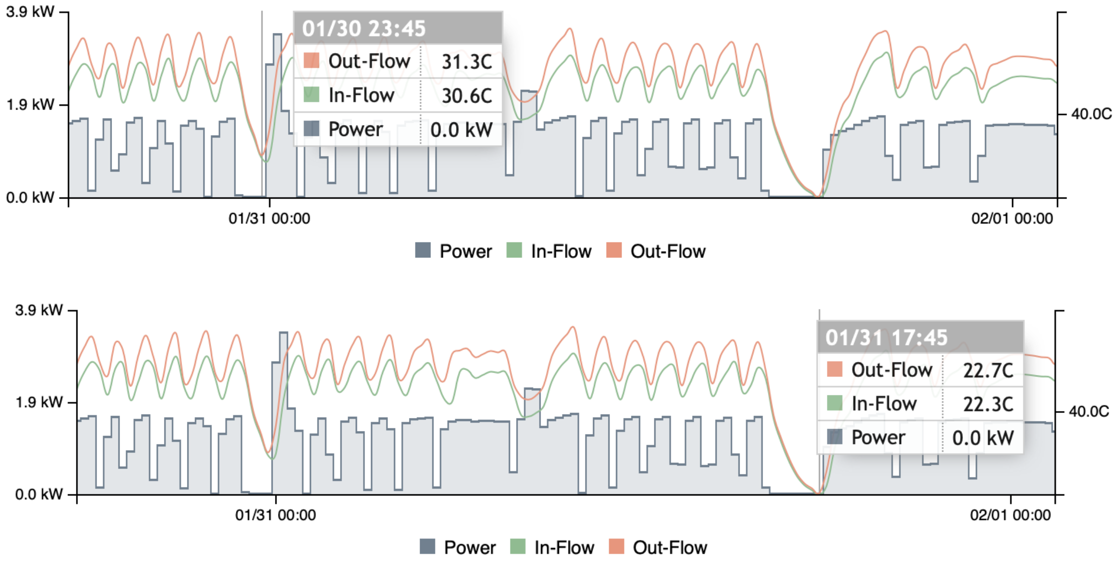
The HEMS box is processing the sensor information from the connected heat-pump and uses the established EcoGrid 2,0 LRSC communication network to transmit the collected data to the central management system. To optimize the network bandwidth usage, the LoRaWAN messages containing sensor values are sent in adaptive intervals based on the changing data dynamics. Messages are sent in frequently when the sensor values are changing quickly, and in larger intervals when the values are stationary.

The sensor data collected by the HEMS box consisting of power consumption and inflow/outflow water temperature allows to obtain real-time view on the heat-pump operation and to better understand the changing household conditions. Using this data, the flexibility model of a household can be further refined and adapted according to the changing behavior of a household. Though the box provides functionality to directly control the heat-pump operations, this functionality was not used in the demonstration period of the project. The focus was on the evaluation of the additional real-time heat-pump information obtained from the installed HEMS box devices.

3 Evaluation of the LRSC HEMS Sensor Data

The HEMS box collects information on the heat-pump power consumption (three phases) as well as the inflow and the outflow temperatures of the heat-pump. This information is sent to the LRSC data management application which stores it in the EcoGrid 2.0 data warehouse. The database table *eg_lrsc_data* contains all the data received from the installed HEMS devices. This database table is updated as soon as a new data record is received through the LRSC communication network and thus contains the information describing the current state of the heat-pumps. The availability of this data allows to perform high-quality estimation of the flexibility of a household. Furthermore, it allows to directly assess the impact of the control operations switching off/on the heat-pump. Through monitoring of the inflow and outflow water temperature of the heat-pump the implications on the current indoor temperature of the household can be assessed in close to real-time.

The charts below show the HEMS box data from a household of around 150 m^2 equipped with an air/water geothermic heat-pump collected between 30/01/2019 and 01/02/2019 with resolution of 15 minutes. This household was managed by the IBM aggregator using the Basic product. The gray filled area shows the power used by the heat-pump in kW, the green line shows the inflow water temperature of the heat-pump and the red line the outflow water temperature. As one can see from the charts, during the normal operation the heat-pump uses around 1.6 kW when active. The normal range for the outflow temperature is between 46°C and 57°C. The normal range for the inflow temperature is between 43°C and 52°C. The heat-pump is automatically activated when the inflow temperature goes under 43°C.



Home Energy Management System (HEMS) data – Example 1

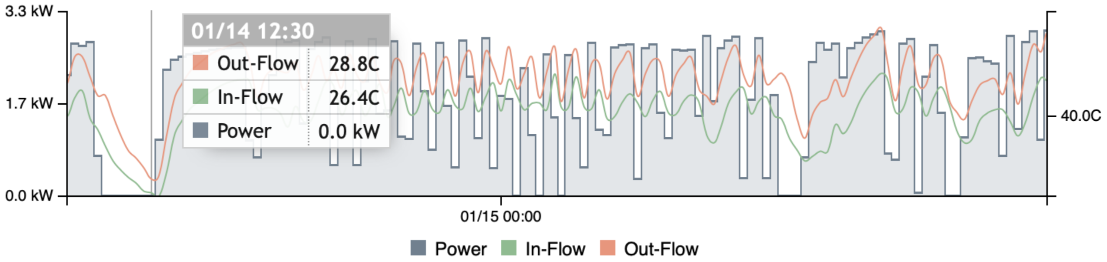
In the time period shown, two flexibility activations were performed. The first activation started January 30 at 23:00 and lasted for one hour. At the end of this one-hour activation the inflow temperature (30.6°C) and the outflow temperature (31.3°C) were very close and significantly lower than the temperatures during the normal heat-pump operation. The radiators of this household got slightly cold with 30.6°C inflow temperature after switching off the heat-pump for one hour.

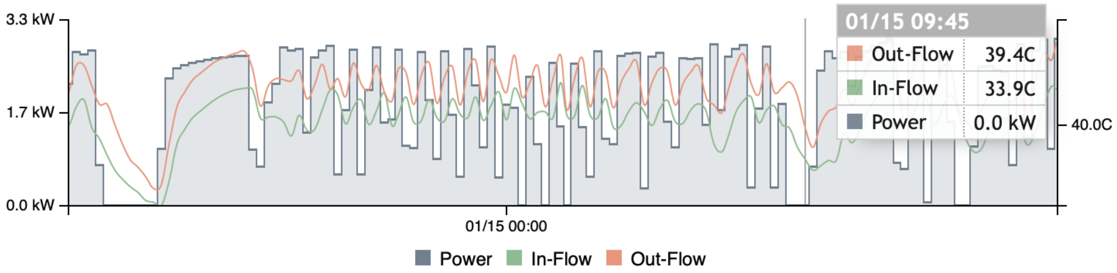
The second flexibility activation is related to the execution on a long-duration test lasting two hours. It started January 31 at 16:00 and ended at 18:00. At the end of this test the inflow temperature was 22.3°C and the outflow temperature 22.7°C. The radiators of the household got cold with 22.3°C inflow temperature after switching off the heat-pump for two hours. That surely had implications on the indoor temperature of the household.

The data from this household shows that even switching off the heat-pump for one hour brings the radiator temperature significantly down and outside of the typical range, the radiators start to feel cold. So even though the indoor temperature is probably not changing so much after one hour, the colder radiators need to be understood and accepted by the members of the participating households.

Another interesting observation is related to the heat-pump behavior directly after a flexibility activation period where the rebound occurs. After the first one-hour flexibility activation ending January 31 at 00:00 we see a very strong rebound effect, the power used by the heat-pump doubles and goes up to 3.4 kW during the next 30 minutes. The behavior after the long duration test shown here, however, is different. The power consumption of the heat-pump goes to the average volume, it does not significantly increase, however the heat-pump works constantly at this level for a longer time period, without automatically switching off, in order to recover. The heat-pump has two ways to get back to normal operating conditions after being stopped for a while, which leads to two different rebound shapes.

The figure below shows the behavior of another household, also of around 150 m^2, equipped with an air/water heat-pump of a different model than in the first example. This household was managed by the Insero aggregator and selected the Economy product. It shows the data collected between 14/01/2019 and 15/01/2019 with resolution of 15 minutes.





Home Energy Management System (HEMS) data – Example 2

As one can see from the charts, during the normal operation this heat-pump uses around 2.8 kW when active. The normal range for the outflow temperature is between 42°C and 52°C. The normal range for the inflow temperature is between 40°C and 45°C. The heat-pump is automatically activated when the inflow temperature goes under 40°C.

In the time period shown, two flexibility activations were performed as well. Here, the first activation was initiated by a long duration test. It started January 14 at 11:00 and lasted for two hours. At the end of this two-hours activation the inflow temperature (26.4°C) and the outflow temperature (28.8°C) were significantly lower than the temperatures during the normal heat-pump operation. The radiators of this household got feelingly cold with 26.4°C inflow temperature after switching off the heat-pump for two hours.

The second activation started January 15 at 09:00 and lasted for one hour. At the end of this one-hour flexibility activation the inflow temperature (33.9°C) and the outflow temperature (39.4°C) were lower than the temperatures during the normal heat-pump operation, but not as much as in the first example. The radiators of this household got slightly colder than normal with 33.9°C inflow temperature after switching off the heat-pump for one hour. The household in the second example is newer than in the first case and might be better insulated, which would explain its slightly different behavior.

In the second example, the heat-pump behavior directly after a flexibility activation period, which is responsible for the rebound volume and shape, is always of the same kind. The power consumption of the heat-pump goes to the average volume, it does not significantly increase, however the heat-pump works constantly at this level for a longer time period, without automatically switching off, in order to recover.

The data evaluation shows that the sensor data collected by the HEMS devices provides a very good basis to accurately understand the behavior of a household heating system. Based on this data an aggregator can forecast the power consumption of a heat-pump and estimate the effect of switching off the heating system for a particular time period. The rebound characteristics can be directly evaluated and taken into account. Getting direct connection to the heat-pump sensor data allows for good forecast quality and planning. Furthermore, as the sensor data is updated close to real-time, the actual effect of flexibility activations can be directly verified, and appropriate correcting measures can be taken by the management system.

4 References

LoRaWAN Specification v1.1: https://lora-alliance.org/resource-hub/lorawanr-specification-v11

IBM HEMS Box User Guide-V4

Read more at www.ecogrid.dk