

Modelling a detached house in a smart grid environment: Improving energy efficiency through home automation

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Introduction

Smart energy networks (SENs) aim at increasing the energy efficiency, flexibility, safety and reliability of energy networks. SENs facilitate the transition to a more sustainable energy system. Energy consumption in Finland doubled since the 1970's and, at the same time, peak power levels (Figure 1) have increased by 330% (Statistic Finland, 2011), showing a tremendous opportunity for deploying SENs. In parallel, the EU legislation for building performances is targeting nearly-zero energy buildings (NZE) for new construction by 2020 (2010/31/EU, 2010). Achieving this target will require the deployment small-scale renewable energy as well as energy efficient technologies for balancing the energy used in the different sectors: heating/cooling, ventilation, lighting, domestic hot water and appliances. Both of these can be handled by the use of SEN. Gellings (2009, p.83) described the perfect electric network as a multi-layer system where the smart house defines the bottom level and the top level is the smart grid, surrounded by a set of technology that will enhance the smart energy network.

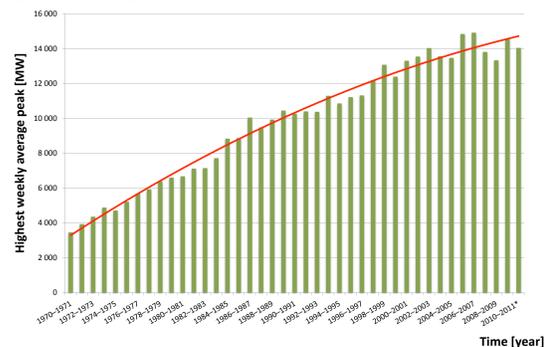


Figure 1 - Peak power level in Finland from 1970 to 2010

Objectives

As a multi-layer system, the different levels have to be modelled. This research has been based on a bottom-up approach where the detached house represents the lowest level.

Thus, similar objectives than those set for a smart grid were given and represent the first part of the objectives set for this research:

- Improve the energy efficiency of the building,
- Assess the potential redistribution of energy at the house level.

The second part of the objectives is building-related, and aims at:

- Modelling user response
 - In everyday life
 - Regarding the control system of the building
- Creating A link between the bottom layer of the SEN with the top layer (the smart grid)

Methods

Climate data from the Oulu region (Figure 3) on an half hourly base was used to enable the calculation of energy production and natural luminosity.

A MatLab/Simulink model (Figure 2) was developed in order to simulate the detached house. It integrates 21 appliances with different power ratings and the lighting system. Three energy production units can also be installed:

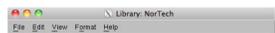


Figure 2 - MatLab/Simulink Interface built for the simulation

- Wind Turbine
- PV-Panels (3 technologies)
- Fuel Cell (+ electrolyser)

The user's behaviours were based on the EuP (Energy using Product directive) reports that highlighted mean weekly use for different appliances. Combined with daily distribution for energy use, it gave random scenarios for a given detached house.

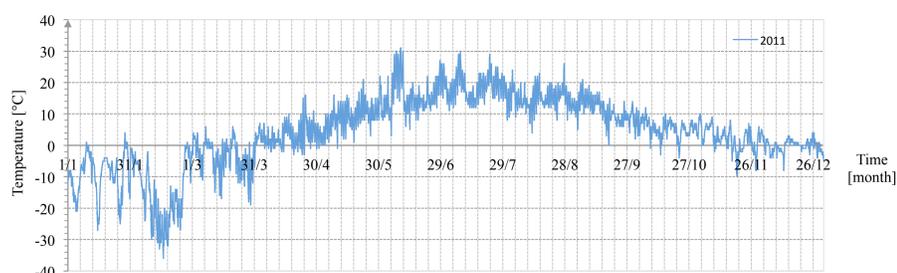


Figure 3 - Hourly outside temperature variation for Oulu, 2011. A set of 12 years climatic data (Temperature, solar radiation, wind speed, wind direction, relative humidity) has been extracted and processed on an half hourly basis.

Results

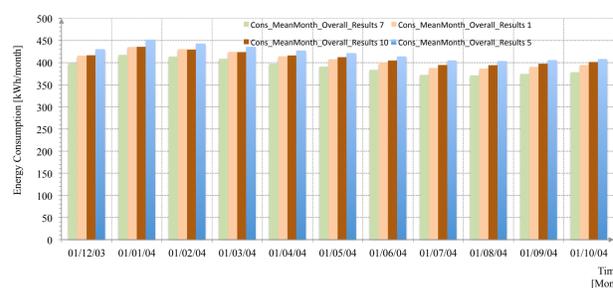


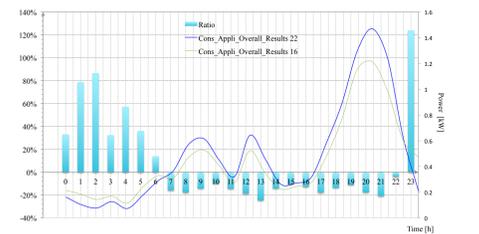
Figure 4 - User response model. From no control (blue) to full automation with "Green" user with high response (green).

The model integrates 3 types of user named "Brown", "Orange", and "Green". Each of them react differently regarding the feedback given by the smart meter.

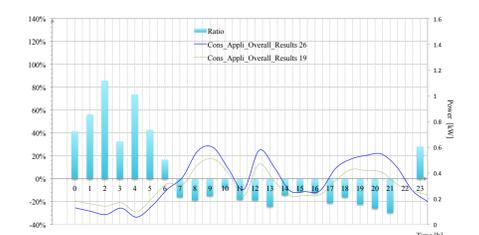
Green users have a positive response of 70 %, while Brown users have a positive response of 30 % to the recommendations

given by the smart meter. A higher positive response reduced the energy consumption by 8 % while a low positive response would reduce the energy consumption by 2.5 % (Figure 4). At the same time, the model showed a redistribution of the energy used at the house level, intending to reduce the peak load hours (morning, mid-day and evening peaks). The redistribution varied from an increase of +83 % of the energy consumption over the night and a decrease of -35 % of the energy consumption over the day (Figure 5).

The presence of an electric sauna at home (Figure 5a) drastically disturbs the mean daily energy profile in the evening, compare to the same house that does not have these high peaks of consumption (Figure 5b).



(a)



(b)

Figure 5 - Mean daily energy profile in the dwelling including all appliances and lighting, with sauna (a) and without sauna (b)

A full control of some white goods allowed decreasing the energy consumption by 2 %. The automation system was taking a decision based on the price and the flattening of the curve, thus, it tried to flatten the curve of energy consumption and having the lowest price taking into account that all cleaning should have been ready by morning.

Conclusion

The MatLab model of the detached house allowed surveying the energy flux within the building and the possible interaction with the SEN. Electric energy at a single house level can be managed and a reduction in energy use of up to 10-15 % can be achieved. The study showed that having the end-users active in the reduction of their energy consumption is of primary importance, meaning that educative and interactive feedbacks should be used. Finally, it is expected that having multiple houses integrated in a smart grid will flatten the energy consumption profile at the grid level.

This study will be followed by a 4 years studies in the frame of the Thule doctoral programme where a bigger and more complete model will be developed base on the "game theory" and the sustainability assessment of the SEN developed will be studied. This study will consider SEN in the north.

References

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