NEIGHBORHOOD ENERGY MANAGEMENT SYSTEM

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ABSTRACT

Increasing building energy efficiency is an important topic when attempting to achieve national and European climate goals. Energy efficiency through energy management during operation is a key issue with high leverage potential, especially neighborhood management - control systems that are capable to optimize local generation and consumption while assuring the comfort and performance of several buildings is promising. Using the recent advancements in information and communication technology it is possible to build effective neighborhood energy management systems as well as information and decision support systems with user interfaces for different stakeholders that can take the advantage of variable tariffs and diversity of supply. Beside technological aspects, the stakeholders require motivation as well as better understanding of energy and how it should be consumed.

This paper explores the approach of the EEPOS project, how to establish neighborhood energy management and examines the advantages and challenges of such a system. Although the main focus is the technology being used, we also address stakeholder integration that support the technology and allow for better market penetration. A virtual demonstrator setup explores the technical preconditions and boundaries and supports the integration of the EEPOS IT platform.

Keywords: neighborhood energy management, OGEMA, load shifting, load balancing, demand side management

INTRODUCTION

Increasing building energy efficiency is an important topic when attempting to achieve national and European climate goals [1]. Instead of only addressing individual buildings, energy efficiency can be improved through energy management during operation on the neighborhood level. Recent advancements in information and communication technology (ICT) allow the development of information and decision support systems that can optimize local generation and consumption in energy positive neighborhoods.

This paper explores the approach of the EEPOS project [2]. After a review of the related work, the IT platform is presented, including its applications. To evaluate the potential for optimization, the operation data are analyised and a virtual demonstrator is described. Finaly, the paper is concluded and a plan for future work is presented.

RELATED WORK

There has been a progress regarding ICT-supported business models for neighborhood operators during the last years, but still a big potential for improvements exists [3]. New business models for district level energy services related to smart grids and distributed energy production are under development. Hence, there are plenty of business opportunities at the neighborhood level [4]. Prosumers (producer and consumer) are really newcomers who can in addition of consuming also generate energy and supply their extra energy it into the grid [5]. At the moment, there are no real markets for prosumers due to lack of motivation, incentives and information [6].

Most systems for energy management and building energy efficiency are designed to work with a limited set of communication technologies. Smart grid approaches for the integration of larger public sites aim at a direct control of large loads and generation capabilities. The advantage of this is clearly defined interfaces, but the disadvantage is limitations regarding intelligent control strategies.

On the building level solutions for analyzing and management of energy exist, especially for electricity, heating and water consumption. All basic routines of monitoring, analysis with reports related to buildings can be done over the internet. Functionality may include numerous reports e.g. alarm reports, monthly and yearly energy consumption, water consumptions etc. This offers a good ground, but development towards more easy access and user friendliness as well as support on the neighborhood levels is required.

In the near future buildings, building blocks and residential areas are going to be supplied by several energy sources. In many areas prosumers have begun to produce electricity and this tendency will continue but the energy gained is frequently lost due to lack of storage or demand at a given moment in time. Currently there are only very few such neighborhoods, but as the number of zero or positive energy buildings is increasing, so is the number of such neighborhoods.

Information models for energy and energy related building systems and components are currently being developed on several levels. On the one hand projects like SEMANCO [7] are creating standards for information models in the context of large levels (between neighborhood and city scale), while on the other hand e.g. the HESMOS [8] project tries the same on a building automation level.

For informing and involving end users and other relevant stakeholders an information and decision support system is required in order to take advantage of variable tariffs and diversity of supply in order to provide profound end-user motivation [9] ("personal drivers") and understanding of energy consumption [10].

IT PLATFORM ARCHITECTURE

The goal is to design and implement an energy management system capable to optimize the local energy generation and consumption considering all energy systems (mainly heating, but also HVAC, lighting and others) in buildings and in the neighborhood. This would ideally advance the transition towards energy positive neighborhoods. The system shall also be capable to analyze consumption and use this information (as a decision support system) to integrate use of energy storages such as water tanks and intrinsic thermal storage in building structures. Neighborhood energy information and weather forecasts also contribute to the knowledge base necessary to perform energy matching with the low voltage electricity distribution grid. The architecture of the system is shown in Figure 1 (left).

The core of the NEMS is the OGEMA Framework (Open Gateway Energy Management) [11], an open-source software system developed as universal framework for energy management. To standardize energy management, OGEMA has a large range of data models which describe elements used in energy management. These can represent devices that need to be controlled (such as washing machines, cooling or heating systems), sensory information (such as temperature, brightness, local electricity consumption etc.), and external data which is needed for management (such as weather forecasts, variable electricity prices). The full range of data models can be found at [12]. Devices represented by a particular data model can be connected to OGEMA via one of several communication driver standards (such as ZigBee, KNX, or EEBus) or via custom, model-specific hardware drivers. Application based on the OGEMA framework (OGEMA apps) are making use of both the standard data models and (where applicable) the communication drivers, and represent all aspects of energy management and monitoring. Depending on the particular access rights of the app, they can access any sensor and device connected to the running OGEMA installation and make use of persistently stored data (so-called “resources”), as well as share app-generated data with other running apps. The currently running apps as well as the status of the currently used resources can be reviewed via the administrative web interface (Figure 1, right).

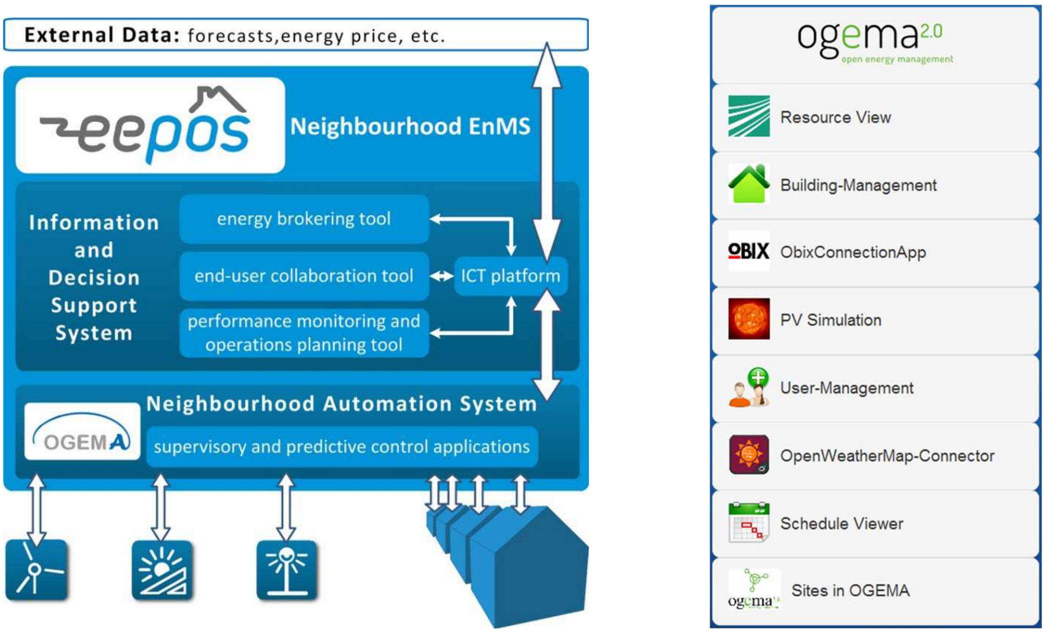

Figure 1: IT architecture of the platform (left) and OGEMA user interface (right).

APPLICATIONS

In EEPOS, OGEMA is used as the base for a Neighborhood Automation System (NAS), which monitors electricity consumption and production at the neighborhood level and attempts to shift consumption to more favorable times. The following apps are primarily used:

- **Load Prediction**: Predicts the load within a neighborhood based on past behavior.
- **PV Forecast**: Generates a forecast schedule of the PV (photovoltaic) electricity production of a particular plant, based on its location, technical specifications, geometric alignment, time of the day, and weather forecast.
- **Adaption Requester**: Based on information from the Load Prediction and PV Forecast apps as well as electricity price information, the Adaption Requester can identify time periods when electricity production exceeds demand and vice versa. To maximize the efficiency and stability of the local grid and minimize losses, this app attempts to shift the consumption of the individual households by producing a schedule of adaption requests – numeric values ranging from -2 (strongly shift electricity consumption away from this time) to +2 (strongly shift electricity consumption to this time). This information can then be sent to the individual households where the adaption requests can either be used to automatically control electricity-consuming devices or are used by the inhabitants to manually alter their consumption behavior.

Additional apps, such as **Simulated PV Plant** or **OpenWeatherMap-Connector** can be used to simulate a "virtual" PV plant or to provide additional data such as weather forecast from publicly available services [13].

THERMAL DEMAND AND SUPPLY

As a first result, the system has been used to collect baseline data for electric energy and heat consumption from a demo-site. These are used to assess the impact of the energy management measures. The main components of interest in the demo site in Langenfeld (North-Rhine-Westphalia, Germany) are a small district heating grid supplying hot water for about 70 multifamily dwellings, as well as the local heating plant providing the thermal energy. The plant is equipped with a biomass boiler (840 KW), a natural gas powered CHP (100KW thermal, 50KW electric), a natural gas boiler (1300 KW) and as a backup a boiler using marine fuel oil (also 1300KW), as well as a 24.000l hot water storage used as a buffer.

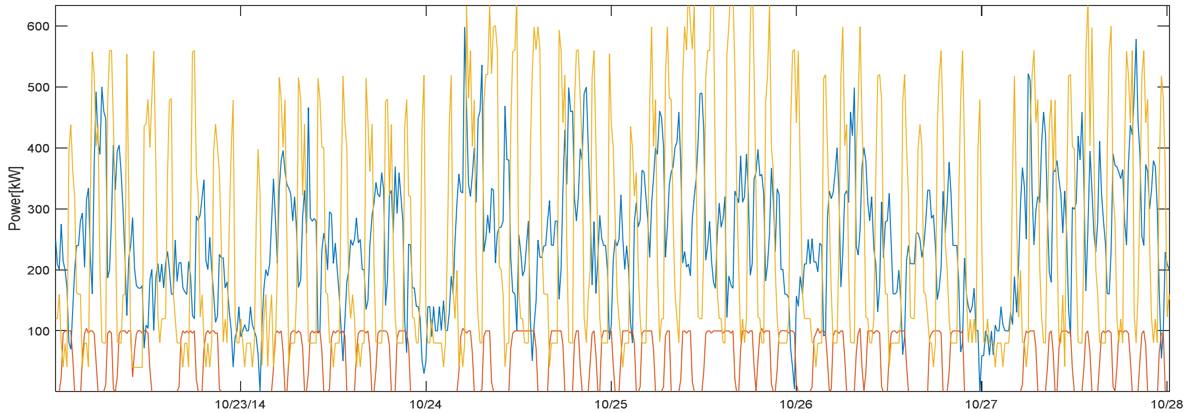

Figure 2: Thermal energy provided by the plant with biomass (yellow), gas boiler (blue) and gas powered CHP (red)

As shown in Figure 2, the CHP, the most efficient of the plants, is not operating continuously. At the same time, the gas boiler is running at power which could be actually covered by the CHP. Furthermore, when the power is combined, the CHP is running at its optimal point, with nearly the full 50KW of electrical power which, due to the fact that it is heat driven, drops to 30 KW or below in some situations. As this is clearly a problem on the demand side, proper demand side management, e.g. by ending the night set back earlier so that the energy used for this increased heating demand coincides with the domestic hot water peak in the morning, could lead to a longer operation of the CHP in the morning while decreasing the amount of thermal energy provided by the gas boiler. As the first peak in the electric grid coincides with the morning peak in thermal energy, the power produce could thus be used locally, therefore putting no strain on the grid.

The analysis showed potential for some of the dwellings that will be the focus of the demonstrator. In order to ensure scalability of the approach it was proven that the tenants are representative for average energy consumption both in quantitative and qualitative behavior.

DEMONSTRATOR

Based on the specifications of the dwellings in Langenfeld, a virtual demonstrator is created that allows to experiment with the available demand response potentials. This demonstrator uses dynamic thermal simulation tools that are used for providing qualitative information on the thermal performance of energy systems and buildings. However, the tools are not designed to cooperate with an external controller as it is established in the Demand-Response app of EEPOS. Because the buildings at the demo site do not have significant thermal-electric coupling, it would not allow for dedicated electric load management without significant effort in instrumentation. Therefore, a building has been added virtually to the dwelling that allows executing electric demand response management. All buildings are represented in a simulation environment and backed up by real-world monitoring data.

The goals of the virtual demonstrator are to prove the methodology and show replicability of the solution. For that purpose, thermal simulation for 30 buildings in Langenfeld is performed. Thermal 3D models are created using TRNSYS or EnergyPlus. Additionally, models of CHP (combined heat and power) unit with CoP (Coefficient of Performance) 100 kW thermal, 50kW electric, gas heating unit (1300 kW) and biomass heating unit (840 kW) are created.

The simulation can deliver the following:

1. Heat demand for the next 24 hours for each building (in 10 min resolution)
2. CO2 profile for the next 24 hours (based on operation of CHP, biomass and gas)
3. Electricity production profile for the next 24 hours (based on CHP production)

The simulation does not regard duty cycles of e.g. gas heating unit and the impact on efficiency as well as losses in local distribution grid.

For the load management control, the goal is to change temperature setpoints in the apartments. For this it is necessary to provide the heat consumption for the next 24h for each apartment as well as difference in thermal consumption in 10 min resolution as reply to the adaptation requests. The heat unit control strategy is designed to minimize CO2 emissions during its operation (Table 1).

Condition	**Action**		
	CHP	**Biomass**	**Gas**
demand > 0 kW	ON	OFF	OFF
demand > 100 kW	ON	ON	OFF
demand > 940 kW	ON	ON	ON
demand <= 0 kW	OFF	OFF	OFF

Table 1: Heat unit control strategy.

The OGEMA Load Shifting App uses an algorithm with the following steps:

1. Collect all thermal load profiles of all buildings
2. Use the static “heat unit control strategy” to calculate the overall CO2 consumption
3. Issue adaptation requests to all buildings
4. Collect replies of buildings: difference in thermal consumption in 10 min resolution
5. Optimize for minimum CO2 using the “heat unit control strategy”
6. Inform building to execute the adaptation request (commit change)

A VirtualBEMS (virtual building energy management system) component waits for OGEMA adaptation requests and triggers the thermal simulation to create a response to OGEMA. This configures the simulation tool, runs the simulation and collects the simulation results. The

OGEMA Simulated Weather app is used in the VirtualBEMS simulation to get the weather forecast for the next 24 hours.

CONCLUSION AND OUTLOOK

We have presented the approach of the EEPOS IT Platform that is used for establishing neighborhood energy management by interacting with energy consumers and producers and providing services for better management of energy. The different apps are available on the OGEMA platform, while the virtual demonstrator uses existing simulation tools and links them to the communication interfaces used by the apps. The virtual demonstrator uses a real world dwelling as a foundation and the analysis of the operation data shows clear potential to optimize neighborhood energy management, which can be exploited using the EEPOS IT Platform. The next steps are the commercial exploitation of various available functions in order to advance energy efficiency on neighborhood level.

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