GREEN AGH CAMPUS

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Abstract: Smart grid systems are the response for the growing global energy demand and the environment protection concerns. To obtain all profits from a smart grid solution, its development has to rely on technical issues but also on an active participation of a system end users. In this paper we present an overview of the Green AGH Campus project which is based on advanced technologies tested in other similar projects. Its innovation is combining the role of a fully functional smart grid solution with educational features and the potential of replicating obtained results in other environments. The intelligent lighting system is also discussed as the most developed part of the Green AGH Campus.

1 INTRODUCTION

The Green AGH Campus smart grid project was started by a consortium which initially consists of AGH University of Science and Technology, General Electric Energy and Marshal's Office of the Malopolska Region. Members of the consortium represent academia, research, development, industry and municipality.

AGH University of Science and Technology is the leading Polish technical university (Webometrics, 2012) with 38,000 students of nearly 200 specialties within 50 disciplines. Its graduates work in the electronics and telecommunications industry, companies designing and installing systems and computer networks, making equipment for large corporations, e.g. automatics and robotics systems or specialized measuring and medical equipment, also in firms offering new telecommunications services, such as multimedia communication systems. (AGH UST, 2012)

The profile of the University and careers of its graduates make us expect that starting the Green AGH Campus project for educational goals will propagate positive attitudes toward energy usage and management among professionals.

General Electric Energy being the part of GE company consists of the following divisions: Energy Services, GE Oil & Gas and GE Power & Water. It is active in such areas as energy production, distribution and management, renewable energy sources or the reutilization of water. The GE Energy, which participated in numerous smart grid projects, ensures technological background of the project.

The Marshal's Office of the Malopolska Region being the third partner of the project, represents municipal organizational units. Its experience will allow to migrate the Green AGH Campus as a scalable solution to other communities interested in achieving economic profits.

2 SMART GRID PROJECT EXAMPLES

Growing global energy demand and associated growth in energy prices but also planned reduction of CO_2 emission stimulate development of the range of methodologies and technologies related to energy production and distribution.

Smart grids which are oriented for those goals allow achieving them by reducing energy usage, obtaining energy from renewable sources, developing energy storage methods or linking small suppliers to the energy grid. The following proof of concepts regarding smart grid solutions should be presented here.

Amsterdam Smart City which includes multiple initiatives like West Orange (400 households with new energy management systems), Climate Street (smart meters and plugs, energy saving lighting) or ITO Tower (sensor-based lighting, heating, cooling, smart plugs).

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The GE smart grid demonstration project on **Maui Island**, Hawaii, based on the U.S. Clean Energy Technologies Action Plan. Key objectives of the project include effective management of renewable generation based on a distribution management system (DMS) platform, demand response and integration of energy storage.

BedZED in Hackbridge, London, England. The general assumption underlying this housing development was using renewable energy only, produced on site by solar panels or co-generation plant. Additionally the energy efficient materials and technologies were applied. All energy saving steps reduced the power usage by 25% compared to the average for United Kingdom.

3 GREEN AGH CAMPUS

In the Green AGH Campus project we would like to adopt best practices applied in developing existing smart grid projects. We will focus on developing methods that will promote effectively smart grid solutions in environments for cities or larger regions. Two barriers may be identified here:

1. the lack of professionals who can create such solutions,
2. the lack of a public demand for their implementation (mainly due to the weak awareness of potential benefits).

Localization of the project at the university campus solves both problems as it is explained later on.

Our basic goal is to prepare the environment which allows both researching (in terms of using modern energy technologies) and demonstrating it to students in the *real micro-world*.

So-called *control room* enables us to research modern solutions including integrated approaches to:

- energy efficiency and application of low emission technologies (e.g. renewable energy sources, electric vehicles, etc.),
- optimal management of an integrated system and technologies for creating *NegaWatt* zones,
- combining technical/economic value and the end user,
- transforming managed data into information applicable in an effective management of advanced *NegaWatt* functions and moving clients from the consumer role to the *prosumer* (*pro*ducer-con*sumer*) one,
- cooperation with DSO's for the active participation in the energy market,
- *knowledge exchange*, testing modern solutions and optimizing-operational processes,
- broadly defined intelligent networks (creating sand-boxes), and the work management and optimization,
- power grids with active (controllable) generation and customer load.

The overall architecture concept will be based on scalability, interoperability and availability through open-standard design and common information model (CIM) based integration.

The *control room* is an essential element of the teaching process at our university. The idea of this system is based on two optimization subsystems. The first one, incorporating the concept of DMS-based *shadow environment* (Fig.1), will optimize costs of energy consumed while keeping the maximum level of the energy reliability and security. The second subsystem is focused on the optimization of the energy consumption by local entities like student dormitories, didactic buildings or outdoor lighting.

The data gathered from the system will be used as an input for simulations which, will allow students who explore smart grid solutions, to discover consequences of control decisions made by them.

The solution development will rely on intelligent management systems (DMS), monitoring (smart meters) and automatics which cover smart buildings, intelligent lighting systems, energy storage, controllable energy receivers and so on. Besides the conventional energy sources, combined heat and power (CHP) and photovoltaic (PV) technologies will be used. Green AGH Campus components will be integrated using electrical grid and computer network (HAN/LAN) which enable remote monitoring, control, securing and other tasks.

Initially six buildings are designed to be covered by the project: four dormitories, one smart grid compliant university building and the swimming pool complex. Additionally the outdoor lighting is assumed to be the component of the smart grid as well.

Each dormitory will be equipped with a building management system (BMS) supporting both energy service and detailed accounting of energy consumers. The new idea is to develop the dedicated customer relations management (CRM) system that will teach users how to save the energy and/or decrease a housing fee. Learning the economic energy management generates not only temporary effects (i.e. current savings), but also long term ones. Let us notice that dormitory residents leave it after a few years, and next they may become natural ambassadors of the smart grid technology. This perspective gives the hope to break the mentioned second barrier of the smart grid technology development.

It should be remarked that the swimming pool may play yet another role in the project besides being the next building incorporated into the Green AGH Campus, namely it may be used as an energy storage.

The lighting system of Green AGH Campus will be designed to meet the following two requirements: improving public safety and decrease the operational costs. This part of the project as the most matured part of the solution will be discussed in more detail in the next section.

In this project we have paid the special attention to computer systems which are used to both intelligently control system's behavior and gather data concerning processes being performed. Obtained information will be stored in data repositories which allow data mining. That will help improving quality of the smart grid system control. Selected parts of those data will be distributed to third parties which can simulate and verify the possibility of applying some smart grid sub-solutions in their environments. Thus the second goal of the Green AGH Campus project, i.e. establishing scalable, interoperable platform enabling energy suppliers integration, will be achieved. The system scalability allows future Green AGH Campus growth and, on the other side, adapting it to other environments. The important feature is the system accessibility which will be accomplished by minimizing investment costs, making the solution be within reach of potential investors. It is planned to replicate the solutions tested in the project in other local government units. The main objective is to optimize energy management.

Expected added values of the Green AGH Campus solution are:

- improved safety of the system and the people, achieved by implementing intelligent, reactive systems of control and monitoring,
- effectiveness and lower exploitation costs achieved by intelligent power control, energy saving technologies but also by changing users attitudes,
- environmental protection achieved by using environment friendly technologies (e.g. LED lamps) and renewable energy sources and by decreasing the power consumption.

4 LIGHTING

The intelligent lighting system (ILS) is the important element of the Green AGH Campus. The ILS aim is twofold: increasing the quality of public spaces in particular by improving the personal safety and decreasing exploitation costs related to the illumination.

The first goal may be accomplished by analysis of a behavior of inhabitants e.g. using models describing the dynamics of pedestrians (Wąs, 2010). Results of such an analysis allow for correlating ILS performance with expected behaviors of pedestrians and preparing predefined lighting profiles suited for various environment states. Decreased illumination costs, being the second objective, is achieved by using energy saving technologies (e.g. light emitting diode - LED) and intelligent control adapting the system performance to actual needs.

The LED technology creates possibility for preparing lighting solutions satisfying design requirements and standards (Institution of Lighting Engineers, 2005) and on the other side capable of adapting to changing conditions of an environment. Taking the advantage of the second property may impact an energy consumption and related costs.

Managing the intelligent lighting system includes two aspects: 1) preparing a suitable distribution of lamps and 2) providing an intelligent control of a system. Both questions addressed below.

A primary objective of a light designer is securing the illumination of public spaces at the night time as well as preserving the energy efficiency and economy of solutions so that staying and moving in these spaces could be safe and comfortable. The basic goal of an artificial illumination in the urban area is to guarantee its safe usage and supporting the space orientation.

A lighting design process is constrained by architectural assumptions related either to aesthetic or functional demands, compulsory standards like EN 13201 or CIE 115:2008 and implied energy consumption (e.g. see (Institution of Lighting Engineers, 2005)). The first constraint takes into account such issues as the safety of the people or enhancing the orientation ability in an urban space. The second one defines requested properties of an illuminated area. It should be remarked that such a characteristic is given by a set of *lighting profiles* corresponding to variant validations of predefined configurations of such parameters as daylight level, actual traffic intensity, weather conditions and so on (Fig. 2).

The ILS control acts based on data received from sensors and on a selected lighting profile.

The common issue related to both the design and the control of the ILS is their high computational complexity. The simple example illustrating the problem's order of magnitude is the number of possible

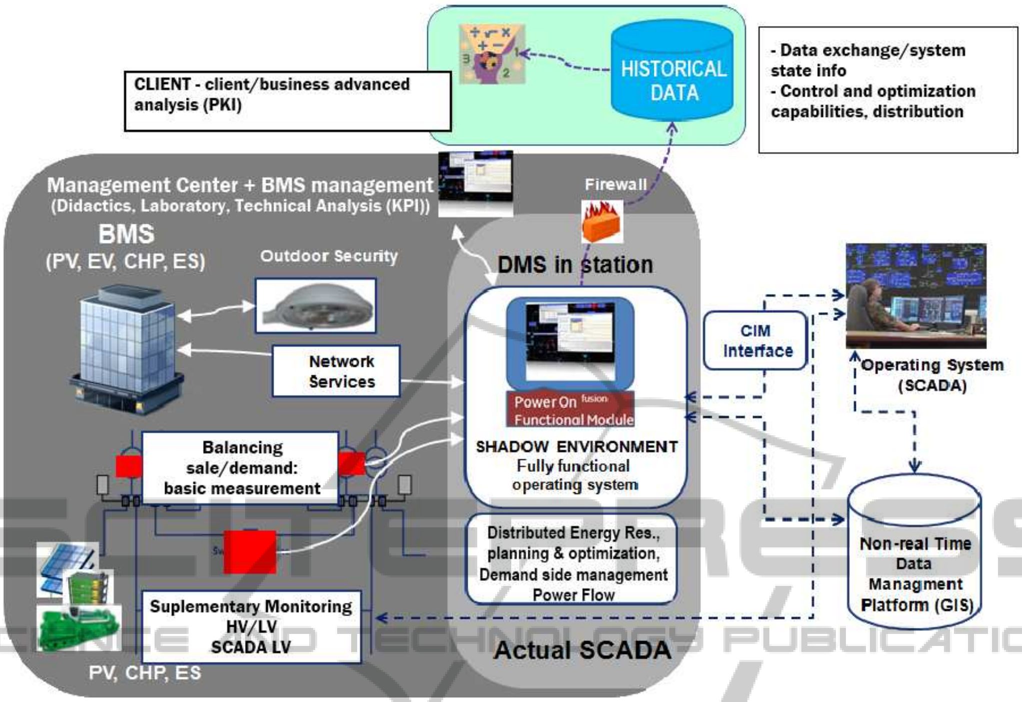

Figure 1: Example of localized control system ”Shadow Environment”.

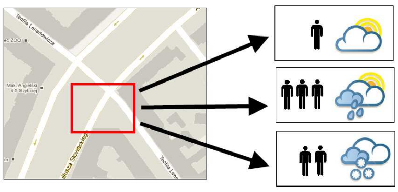

Figure 2: Exemplary city area with corresponding lighting profiles.

states for a row of ten LED luminaries when each lamp may work at ten luminosity levels. Such a system may take 10^{10} states.

To overcome the computational complexity related problems a formal representation of a system has to be introduced. A graph model of an urban space coupled with distributed, agent-based computations paradigm are applied (see (Sędziwy and Kotulski, 2011)). The control system is supported by distributed rule based Artificial Intelligence systems.

5 CONCLUSIONS

The Green AGH Campus combines the most innovative smart grid solutions tested in other existing implementations with the educational features of the university. The preliminary analysis of the first phase of the project (in particular development of the lighting system) shows that the system complexity forces using advanced computer science technology based on Artificial Intelligence. On the other side these AI-based methods support scalability of the system. Scalability and open-standard design of the solution will enable its replication to other environments.

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