POWER MANAGEMENT OF INTELLIGENT BUILDINGS IN SMART GRID

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Abstract: The paper presents an intelligent building project, located in Dunaujvaros, Hungary, which is intended to be connected to a locally set-up experimental Smart Grid. The intelligent buildings are considered as cells in neural network where the different cells are connected to each other, establishing a real information and power grid. Here, a unique theoretical solution has been proposed.

1 INTRODUCTION

Recent years the reduction of global energy consumption and role of the renewable and waste energy sources in power electric production have been extensively investigated as island or local grid connected power generation units. In distributed power generation the power consumption and generation can be more precisely synchronized and balanced, resulting lower power generation units that can be achieved by intelligent control systems. In general the power is produced by centralised power plants that are not suitable for significantly changing power level. The renewable energy sources offer promising solutions for small and medium scale power generation, producing "green" energy. In last decades a significant effort has been carried out to increase the role of renewable and waste energy sources in electric power generation. The renewable energy sources like solar, wind, geothermal or tidal energies can be harvested directly of indirectly by applying generator units. One of the most popular is the solar and wind energy due to the decreasing investment costs and relatively high efficiency. In Europe and globally more and more power stations utilizing the renewable energy sources are installed that means the number of power generation units has been increasing. Generally, these units are only connected to power grid, supply power for the consumers but the actual and total produced power is monitored only locally. Depending on the size of the power plant, the system should report the produced power to the local power supplier daily, weekly or monthly. In many cases the small scale (micro) power stations are not fully integrated into power grid, considering the actual state of produced power. There are numerous projects that investigate the Distributed Power Generation or Smart Grid (SG) (Kurohane 2010, KyungGyu 2011) but most of these projects are only focused on the design and construction aspects. Generally, the power production and consumption are considered as a two different operation that is usually separated in space and time. A very significant part of the produced electric power is utilized in buildings, like households, offices…etc. In lot of cases this power can be produced locally by micro power stations where the energy demand for buildings or tools installed can be provided partly or totally by utilizing renewable and alternative energy sources. The buildings equipped with control system is usually named as intelligent buildings are capable for controlling and monitoring HVAC, audio, security and other systems inside and outside the building. The Intelligent Buildings (IB) can also be applicable for power management that could be the solution to interconnect the different IBs and power sources. So it is desirable to integrate IBs into Smart Grid because of the following reasons that are discussed in paper. Due to the enormous amount of cost required for the structural change of the actual power generation and transmission systems the development of intelligent buildings and renewable energy systems can offer a promising, economical

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solution for more safety, comfortable and energy saving power grid.

2 POWER MANAGEMENT SYSTEMS

The informatics and power electronics in generation and distribution of electric power has became dominant in decades and its presence can be discovered from small power supplies to High Voltage Direct Current converters (HVDC). Due to the rapidly growing number of micro- or small power plants the requirements of power quality conditioning should be matched to standards, producing acceptable power quality for consumers. Because of the large number of nonlinear consumers and switch mode power supplies the additional losses in network, harmonics, voltage deviations and flickers should be taken into consideration and decreased as low as possible. The high-switching modern IGBT converters and high speed controllers provides outstanding possibility to minimize switching and conduction losses. Due to numerous advantageous features the converters are applied in wide range, like DC/DC; AC/AC - DC link converters and etc. In many cases large number of converters is used in buildings as well for different purposes. The converters and all devices related to them can be applied from mW to MW that means in power grid they have significant role. According to the novel green IT solutions the power management in power grid, a new controlling and monitoring solutions are proposed to reduce and balance the power consumption and adapt to changing power grid. The existing power generation and distribution system has some problems. First, it has centralized system architecture. Existing system utilizes centralized schemes when gathering and analyzing contexts to operate the power system intelligently, which causes long service response time. Second, it delivers electricity and control appliance based on fixed and predefined values. The Smart Grid and power management system applied in Smart Grid offers a viable solution to eliminate or significantly decrease the discussed disadvantageous features. The communication between the present and newly installed elements is one of the key-point of the whole structure. Globally, the Smart Grid can be regarded as an organic structure with millions and millions of participants (cells) and where a definite controlling and regulation processes are executed. Here, a special approach of power management is introduced where the basis of the Smart Grid is the intelligent building. Naturally, the renewable energy source are also organic part of the system where the energy demand is forecasted and monitored in buildings and grid as well and the whole system is semi self-autonomous system where the information is automatically produced and only the information is processed by different power management modules, organized into regions as shown later in Fig. 2.

2.1 Power Management in Intelligent Buildings

Emerging green IT and Smart Grid technologies that has been changing the electric power infrastructure more efficiently, these technologies enable the power system operator and a consumer to improve energy efficiency and reduce greenhouse gas emission by optimizing energy distribution and management. There are many studies of these topics with the trend of green IT and smart grid technology. However, existing systems are still not effectively implemented in home or building because of their limitations and its complexity. One of our main goal is to set-up a local microgrid that has flexible and programmable structure. The Smart Grid is a next generation power network utilizing IT technology as in case of intelligent buildings. Power management system should be capable to control and deliver power from suppliers to consumers using two-way communication reducing the response time, which leads to energy efficiency and grid reliability enhancement. The PM system has basically the capability to sense internal and external consumption and power generation within a given unit, cell, domain or region, and grid conditions, measure power, and control appliances with two-way communication to electricity generation, transmission, and distribution and consumer parts of power grid. Applying intelligent power management in smart grid, it is possible for the consumer to dynamically respond to changes in energy consumption, demand and grid conditions. E.g.: when the power is low-cost or there is additional “free” power, the user can allow the smart grid to turn on certain home appliances that can run at arbitrary hours. The power managing is a multi-layer process having large number of connections with other units resulting high flexibility system. At lowest layer, these are the cells that are the smallest measurement and data analysis units, the control system is implemented in microcontrollers as today in system of intelligent buildings.

2.2 Organic Structural System and Smart Grid

In many cases there are similarities between natural phenomena and engineering problems. Eg.: the relationship between the aerodynamics of airplanes and flying birds is very deep and strong. As it was discussed earlier the management systems of smart grid, smart metering, intelligent buildings, and renewable energy sources and so on are quite complex where extremely large number of participants are involved in information and power flow. Here and (Varga, 2011) a new idea is proposed where the intelligent buildings in Smart Grid are considered as a cell, the "smallest" and not divisible further, as the nerve-cell in nervous system. The human brain is one of most complex system, containing billions and billions of nerve-cells that are formed into regions and connected to each other.

When a specific region of the human brain has damaged, other parts can partly or entirely take over the role of the damaged part. There is large redundancy in the system as it is desirable in Smart Grid as well. The connection between the nerve-cells and its spurs are shown in Fig. 1. The nerve-cells can vary in size and shape and central nervous system have different types of nerve-cells as the elements connected to Smart Grid may also vary in size and function. The following similarities can be discovered during the analysis of nervous system and application of intelligent buildings in SG:

- The intelligent building can be considered as a nerve-cell and the basis of the smart metering unit in smart grid
- The dentrites of nerves cells are responsible for sensing the incoming pulses of human body as the measurement of power, current, voltage, time... in engineering practice. The measurement of physical and electrical parameters in intelligent buildings are also forwarded to the central unit using different communication protocols such as WiFi, Bluetooth and so on. The information from other buildings is also accepted by communication ports as other fibres are connected to dentrites of nerves cells. According to the number of axons of nerve cells several types of nerves cells are differentiated, like multi-polar, pseudo-unipolar, bipolar or pyramid types.

  The connection between other intelligent buildings is very similar to the structure of nerve cells as the information (electric pulse) is transmitted to other nerve-cells.

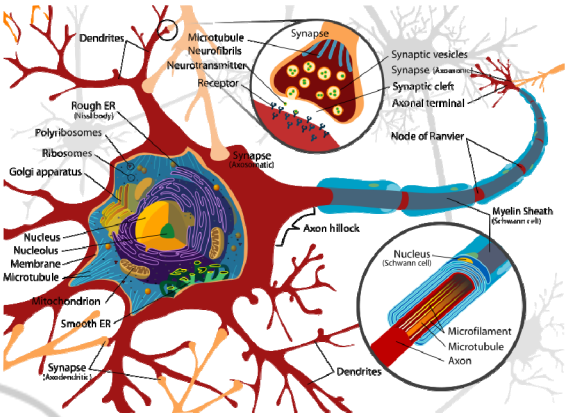

Figure 1: Schematic layout of a nerve cell [wikipedia].

- If one cell is dropped out, the system can be operated further
- Different cell types are grouped into regions as different units (e.g.: power generation, buildings, data centres...etc.) can also grouped into "regions", having different communication and purposes

This way of approach of intelligent buildings in Smart Grid can be regarded as a new way of thinking about SG. In next chapter, basics of the novel system structure are introduced based on this topology. In future, this topology will be investigated in detail and a local smart grid will be developed for further investigations where a smart energy distribution and power management system will be implemented.

3 SYSTEM ARCHITECTURE

In this chapter, the basic topology of the system architecture of Intelligent Power Management System (IPM) for energy distribution and management service in buildings is discussed.

3.1 Intelligent Buildings

The basic unit of the system is the smart buildings equipped with a microcontroller unit that is able to communicate with other units, buildings and receive and transmit data to centres. According to the size of the building, the complexity of the implemented system can vary in wide range. In household applications where own heat and/or electric power sources are installed the power management system is able to autonomously regulate the power consumption of appliances utilizing the locally

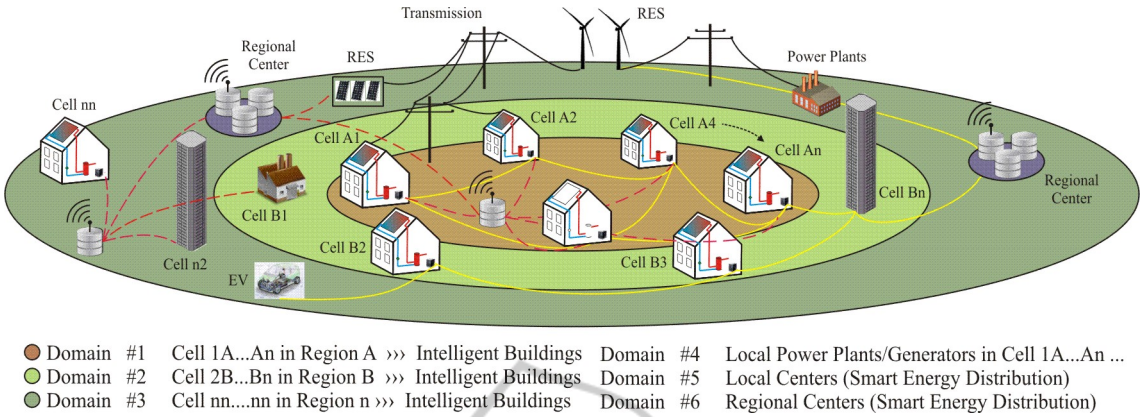

Figure 2: Overview of the smart energy distribution and power management with intelligent buildings.

produced power. In case of insufficient power level, the system send a request to local centres that this unit requires additional power. Due to the controllable appliances the power production and consumption can be balanced according to the information provided by IBs, local and regional centres. Inside the building, depending on the size of building, there is one or more microcontroller control unit equipped with intelligent sensing wired/wireless units. This unit is able to monitor the actual state of the internal and external processes and the management system. The information should be evaluated and stored that can be accessible for other units if it is requested. In buildings large number of devices can be found that are usually not controllable, only connected to the AC network and can be manually operated.

Applying small, inexpensive measurement and control units theses devices can be apparent for other units that are the first step to set-up a local smart grid. Both wired and wireless communication is important because in buildings where the wiring between the control unit and device is not solvable wireless communication should be applied. Fig. 2 shows a possible configuration for a smart measurement unit and a control unit where the intelligent power management module should be implemented in IBs transmitting data to local/regional centres. Beside the AC network that can be also used for communication, the local DC networks can be a new way of power distribution where the losses can be reduced. In many household or office devices requires DC power supply, like laptop, PC, cell phones, LED lamps and so on. Here, a so called multi-agent based DC-DC converters can be applied in DC network that balance the power consumption and offers high efficiency and reliability. The larger devices like motors, transformers, fridge, heating units requires AC supply. The system should handle both DC and AC measurement and control units that can be connected as plug-and-play devices as a pendrive to PC. If a new device is installed and plugged to the power supply, it is automatically recognized. The IPM should be able to communicate with certain centres, gathering information about the environment (weather-forecasting, grid conditions...) and should transmit actual state and load patterns determined by power management system based on load forecasting with user patterns. In our project two intelligent buildings have been built and local smart grid is under development by applying intelligent sensor and control units and developing a local power management system. The overview of smart energy distribution and power management is shown in Fig. 2. Main goal of our project is to develop and construct such a local microgrid, containing several IBs, that is flexible and enlargeable.

3.2 Domains and Regions

In a city large number of different types of buildings can be found as cells in a network that are connected to each other by the power grid. In Fig. 2 the IBs are grouped according to their size and type and different domains are formed. In Domain #1 buildings named between Cell 1A and An are situated within the inner circle. These buildings belong to a certain district or a type and all of them are connected to directly each other or indirectly through a local centre. The information provided by IBs are forwarded to local centres where the information is further processed and forwarded to regional centrals that are in direct connection with central control. Doman #2 and #3 are different domains that are connected to each other by local or regional centres. All other participants of smart grid can also connect to local or regional centres e.g.

local power plants. Local centres transmits data to regional centres.

4 CONCLUSIONS

The paper presents a new approach of application of intelligent buildings and renewable energy sources in smart grid. The proposed Intelligent Power Management (IPM) units provide information about the operation of smart homes and grid conditions, collecting and analyzing the measurement results, load patterns and other request that are sent and received to/from different units. The intelligent buildings can be considered as organic cells in an organic structure. The IPM has several numbers of layers according to the size of buildings and its complexity also different but in all layer the information is forwarded to upper layers and other cells/centres, like weather forecasting centres, other smart buildings centres where information provided by IPMs is further processed.

According to the incoming data from IPMs the control of all elements is performed by controller units, located in intelligent buildings. A modern power grid needs to become smarter in order to provide an affordable, reliable and sustainable supply of electricity. For these reasons, considerable activity should have been carried to formulate and promote a vision for the development of future smart power grids. Here, a specially designed laboratory set-up has been presented, providing experimental verification of future results. The buildings and laboratories are currently under construction as shown in Fig. 3. Beside the College of Dunaujvaros some industrial partner are desirable to involve in our project to extend the our microgrid and local Smart Grid and Metering system.

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Figure 3: Intelligent Buildings (laboratories) in Dunaujvaros.

REFERENCES

Varga Z., Szabo I., 2011. Intelligent Buildings in Smart Grid, In *8th International Conference on the European Energy Market*. 25-27 May 2011, Zagreb, Croatia

Kurohane K., Senjyu T., Yona A., Urasaki N., Goya T., Funabashi T., 2010. A Hybrid Smart AC/DC Power System, In *IEEE Trans. on Smart Grid*. Vol. 1 No. 2, September 2010, pp. 199-204

Katiraei F., Iravani M.R., 2006. Power Management Strategies for a Microgrid with Multiple Distributed Generation Units. In *IEEE Trans. on Power Systems*. Vol. 21 No. 4, November 2006, pp. 1821-1831

Gamauf T., Leber T., Pollhammer K., Kupzog F. 2011. A Generalized Load Management Gateway Coupling Smart Buildings to the grid. In *AFRICON'11*. 11-13 September 2011, Zambia, pp. 1-5

KyungGyu P., Yoonkee K., SeonMi K., KwangHo K., WookHyun L. HwaChoon P. 2011. Building Energy Management System based on Smart Grid. In *33rd Telecommunications Energy Conference (INTELEC)* . 9-13 October 2011, Amsterdam, Netherland, pp. 1-4

Gassman, H. Meixner. 2002 Sensors in Intelligent Buildings, Wiley & Son Vol. 2., ISBN: 978-3-527295579, May 2002

Tanaka K., Uchida K., Oshiro M., Goya T., Senjyu, T., Yona A. 2010. Optimal operation for DC smart-houses considering forecasted error. In *Conf. Proc. of IPEC 2010*, 27-29 October 2010, Singapore, pp. 722-727

Dae-Man H., Jae-Hyun L., 2010. Design and Implementation of Smart Home Energy Management systems based on Zigbee, In *IEEE Trans. on Consumer Electronics*. Vol. 56 No. 3, September 2010, pp. 1417-1425