ELEKTROTEHNIŠKI VESTNIK 80(5): 217-221, 2013
ORIGINAL SCIENTIFIC PAPER

A concept to optimize power consumption in smart homes based on demand-side management and using smart switches

Jure Močnik[1], Miha Gornik[1], Boštjan Murovec[2], Andrej Žemva[2]

[1]RC eNeM in Iskra Sistemi, Ljubljanska cesta 24a, Kranj
[2]Faculty of Electrical Engineering, Tržaška cesta 25, Ljubljana
E-mail: jure.mocnik@iskra-mis.si

Abstract. The paper proposes a concept of power-consumption optimization in smart homes based on demand-side management (DSM) and using smart able to control home electrical devices by a wireless connection. The advantages of the concept are lower power consumption without reducing the users living comfort and enabling the users to actively participate in the smart-grid load shedding.

Keywords: consumption optimization, demand-side management, load shedding, smart home, smart switches

Koncept optimizacije porabe električne energije v pametni hiši z vodenjem porabe in pametnimi stikali

Članek prikazuje koncept optimizacije porabe električne energije s pomočjo vodenja porabe in uporabo pametnih stikal za brezžično krmiljenje električnih naprav. Poudarek je na možnosti delovanja koncepta v načinu GPS, ki omogoča vodenje naprav glede na oddaljenost od pametne hiše. Prednosti koncepta so zmanjšanje porabe električne energije, brez zmanjšanja bivalnega ugodja uporabnika, aktivno sodelovanje v razbremenjevalni shemi distribucijskega omrežja in možnosti uporabe spletne oziroma android aplikacije.

1 INTRODUCTION

The overall economic growth and the consumer behavior increased the power consumption by some 1.7% per year over the period from 1997 to 2007, which made the power consumption to increase by 32.8%. This fact forces the world to improve the electric power grid, to increase power generation and to use electricity more efficiently.

The technique of managing the power distribution network called load shedding [1] recently appeared in the energy sector as part of the demand-side management [2]. This technique has been implemented in the power distribution network as an intentionally engineered power shutdown when the power demand exceeds the available power generation. Load shedding is usually used in two cases: when the power generation capacity is insufficient or the power transmission infrastructure is inadequate to deliver enough power for normal operation of the power distribution network.

As said above, load shedding is used when power demand is greater than power generation which is usually during the peak demand hours (e.g. in the middle of a hot summer day when people use their air conditioning).

It is up to the users to decide either to enjoy the comfort of unlimited power consumption or to reduce their electricity bills by 3-5%. Moreover, people must realize that power generation is unlimited and that their power consumption habits must be changed and economically managed.

Unfortunately, some electrical devices do not allow demand-side management/control since they require constant power supply (chest freezers, refrigerators, etc.), or are turned on permanently (TV sets, computers, water heaters, etc.). Power consumption of such devices can be reduced by turning them off when not used. How can this be done if, for example, we want water to be hot when we come home? To meet such challenges and to actively participate in the power-network control at the same time, a new concept of power-consumption optimization is presented below.

Received 10 June 2013
Accepted 12 September 2013

2 PROPOSAL OF A NEW CONCEPT OF POWER-CONSUMPTION OPTIMIZATION

In most of the existing load-shedding concepts [3] [4], the biggest power consumption devices are disconnected during the peak-demand hours. In the worst case this could mean that at noon of a hot summer day when power consumption is at its maximum, people are not be able to use their air conditioners. This would be unacceptable by users because of the very little discount offered by the power distribution utilities at the expense of reducing the users' comfort.

Our load-shedding-based concept is highly user-oriented. It consists of two differently oriented parts which share a common infrastructure.

The first part of the concept controls the network-voltage profile within the frame of demand-side management. This includes smart-home devices for which it is not important when they are connected (washing machines, dryers, dishwashers, etc.). These devices are connected to the home power network and are controlled by the power distributor.

Using the second part of the concept, the consumer's everyday life comfort is preserved and save electricity saved at the same time (water heaters, space heating, etc.). These devices are user-controllable.

One way of controlling these devices is by using GPS (global positioning system) [5] enabling the devices to be turned off or on at a set distance from the user's home. For instance, when a user is within a ten km zone from home, the water heater in a house will be turned on.

Home devices can be controlled also by an android or internet application with which operation of home devices can be monitored and their status manually changed.

3 KEY ELEMENTS OF THE CONCEPT

Figure 1 shows the key elements of the proposed concept. They are divided into the execution elements (main receivers, smart switches) and service elements (GPS trackers, internet and android applications). The smart-house execution elements are responsible for proper execution of the commands sent by the service elements.

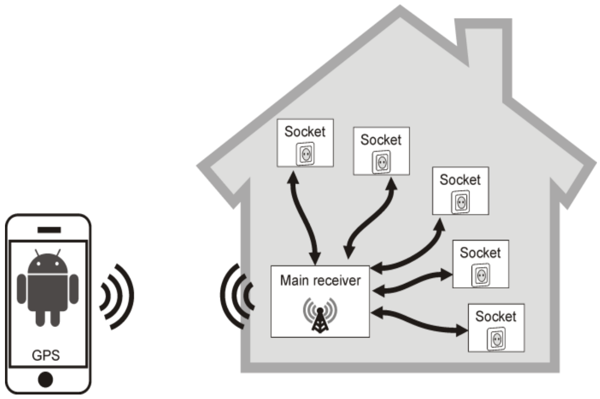

Figure 1. Key elements of the concept.

3.1 Smart receiver

The most important, execution element is the main receiver (Figure 2). It manages the obtained requests and sends them to the smart switches through RF communication. The requests are stored to the disk in case of power failure and are reused when the process is restarted.

The main receiver receives requests or data sent either by demand-side management through the power-line communication (PLC) receiver, internet or android application or GPS receiver. Internet is used to transfer requests or data to the main receiver. Using internet is preferred for being the most widely used and the most economical medium.

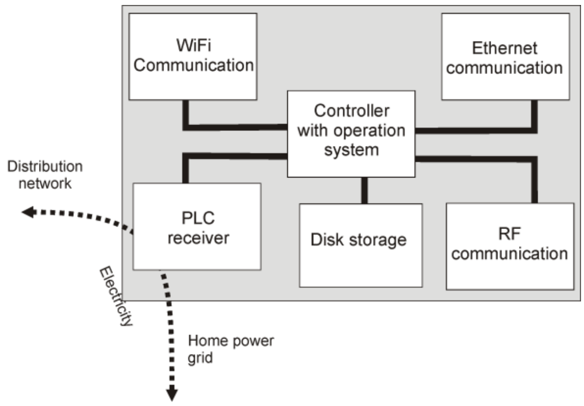

Figure 2. Receiver platform structure.

3.2 Smart switch

The smart switch (Figure 3) is the second component of the execution elements with the requests sent by the main receiver it directly operates the power devices connected to it. This is done by using power sockets or relay output (RO) modules.

There are many types of the smart switches. They vary in terms of the number of sockets (one, two or three) and the number of ROs. One of them having a minimized structure is designed for lights (it has no DSM button, no ROs and only one bistable relay).

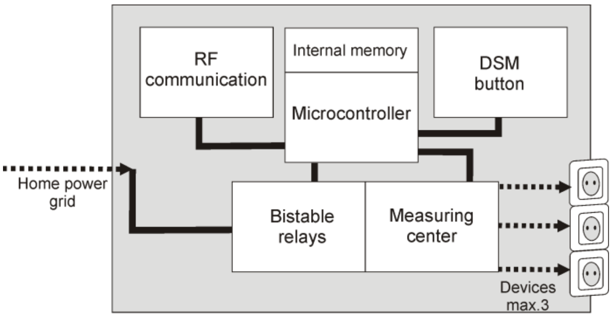

Figure 3. Switch platform structure.

The important part of the smart switch is the microcontroller, which communicates with the main receiver through RF communication. A unique communication address is assigned to every switch. The microcontroller task is to control the bistable relays and to receive the measured data from the measuring system. The measured data and statuses of the bistable relays are transmitted to the internet or android application where the user can verify and modify them.

One of the features of the smart switch is the DSM button which turns the smart switch into the DSM mode in which a certain number of sockets is assigned to work through DMS.

The smart switch contains a power-measuring system with an internal memory where the measured data are stored. They are used to create a power-consumption model to monitor the energy consumption of each connected socket, thus enabling the user to further optimize power consumption.

3.3 Android and internet application

The most important service elements are the internet and android application that both communicate with the main receiver.

The internet application is mostly designed to easily build the virtual structure of a home using a smart receiver and smart switches and to allow controlling the devices, through it is rather impractical to use it anywhere.

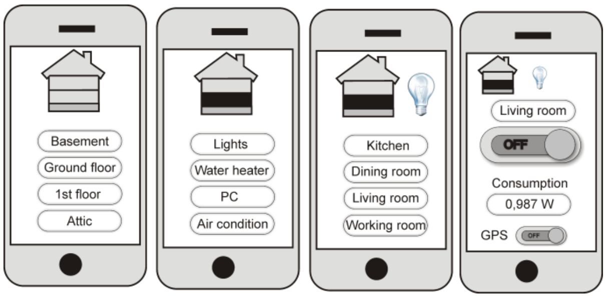

Figure 4. Android application.

The service component more practical to use is the android application shown in Figure 4. This application is always at hand and allows for an easy access to the home network to which all the devices are connected. The fourth mobile phone presented in Figure 4 shows how easy it is to manage the light in the living room on the ground floor with the on/off button. The application also comprises a consumer monitor displaying the power consumed by the devices.

A special feature of this application is the GPS mode which activates the devices automatically at a set user distance from home.

4 OPERATION OF THE CONCEPT

The first step in optimizing the power consumption is to run the internet application and create a virtual house with all the lights and sockets with the assigned operation modes (DSM mode, smart mode or permanently energized mode). Through this process is quite complex and time-consuming, it simplifies the further procedure greatly. To make the service more portable, it is recommended to use it on an android device.

The smart receiver and smart switches can work simultaneously in three operational modes.

The DSM mode is used to connect devices which are part of load shedding (the user has no control of when they are activated). This mode can be easily selected in the application or by pressing the DSM button on the smart switch. The devices are activated when the main receiver receives the distributor's command. This mode is suitable for dishwashers, tumble dryers and similar devices.

The second mode is the permanently energized mode in which the sockets are under a constant voltage. This mode is designed for devices which must always be active (freezers, chest freezers, etc.).

The smart mode is the most dynamic of all since it can work in different ways. It can operate fully automated guided by a time table and/or a GPS device. If a time table is used, the operations are guided by a schedule.

The schedule is generated on the internet or android application and sent to the main receiver where it is saved. If the GPS mode is used, the operations are guided by GPS tracker. Each socket and RO of the smart switch has the GSM mode in which it can be controlled by the GPS location. In this case, GSM submits the location to the main receiver that contains the list of the sockets operated by GPS and the radius of which the sockets are activated or deactivated.

The receiver can also work in the manual mode, this means that every command is sent from the internet or android application.

However, for some devices a full shut down is not the best choice for maintaining optimal power consumption. One of such devices is the main water heater which consumes less power if its temperature does not fall below a certain limit. In this case, the device is operated by RO. RO operates differently than the socket because it does not control the charge of the electrical device but only its mode of operation (normal or sleep). An electrical device connected to RO supports such operation. Such device is connected to a permanently energized socket and has an additional connection with RO in order to control it. When RO is turned on, the device receives the request to put into the sleep mode.

5 SIMULATION RESULTS

Operation of our concept was simulated by using a 100-liter water heater with of power of 2000 W. A mechanism to control two temperature states was used. One state was in execution when the user was at home and the water-heater temperature set to 60°C. The other state was in execution when the user was not at home and the water heater set so as to decrease the temperature down to 50°C. In our simulation we used a he scheduled time table with which the water-heater temperature was set between the two states.

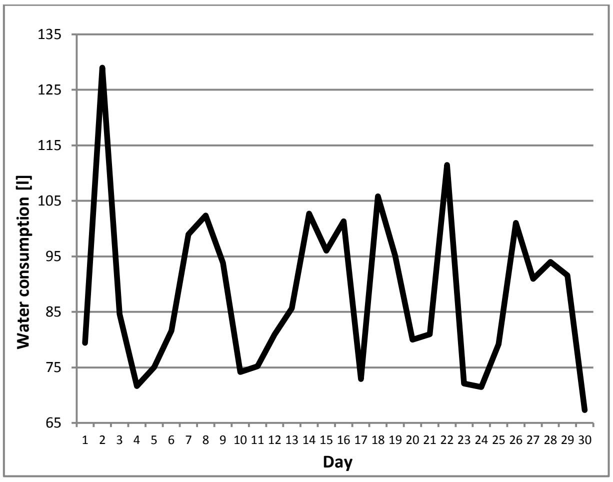

Figure 5. Water consumption in a home.

To measure power consumption of the water heater, the MC350 measurement recorder made of the Iskra Sistemi manufacture was used. It was set to measure and record the current and voltage of five-minute intervals. The measurements of one month were used to calculate the water-heater power consumption.

Power consumption without using our concept was not measured but was calculated by using the data of water consumption and the time when the water heater was turned on during the measurement conditions. The power consumption without using our concept was not measured because the water monthly consumption cannot be easily replicated, therefore as approximate calculation was made.

As shown by our experiment, 2646.05 liters of water flew through the water heater in the observed month. The average power consumption per day without using our concept was 4.517 kWh, whereas, by using it the average measured power consumption that was measured reduced by 0.506 kW, thus making the average power consumption to be 4.011 kWh per day. So we can see, that the average water-heater power consumption dropped by 11.2%.

Our simulation proves that the concept works in practice and that it can be used also with other electrical devices for the purpose of minimizing power consumption.

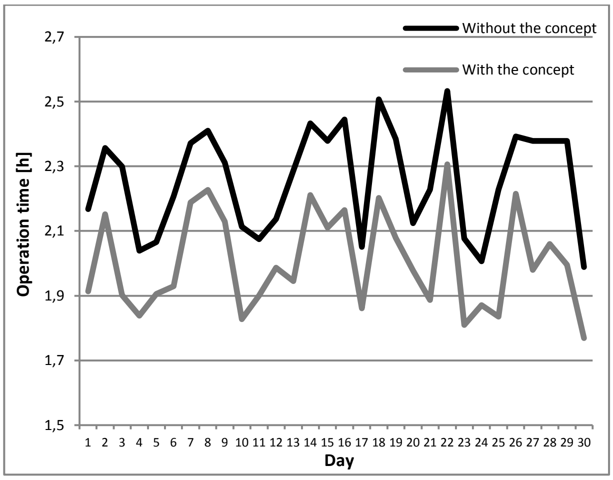

Figure 6. Comparison of water-heater operation by using or not the purposed concept

6 CONCLUSION

The world power consumption importantly increases during the day for which reason new power plants either distributed or concentrated, should be build. To avoid constructing new power plant which is a long lasting process and but not a long-term solution for providing enough energy, changing the user habits to optimize domestic power consumption should be promoted.

In general, people prefer their comfort assumed to them by using electricity to saving money. Therefore, the concept of power-consumption optimization proposed in this paper is an optimal solution. The concept is based on load shedding guided by demand-side management and smart home structure that can be automatically or manually guided by a GPS or an android phone.

The paper presents a concept of power-consumption optimization by using corresponding electronic devices and applications. The focus of our future work will be on transferring the concept and electronic devices and associated applications from the prototype to the commercial product.

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Jure Močnik is a post-graduate student at the Faculty of Electrical Engineering, University of Ljubljana, from which he graduated in 2010. Since then he has been employed as a researcher with Iskra Sistemi and RC eNeM. His research interests include power-quality control, distributed power production and new concepts of the smart distribution network.

Miha Gornik is a post-graduate student at the Faculty of Electrical Engineering, University of Ljubljana, from which he graduated in 2008. Since then he has been employed as a developer with Iskra Sistemi. His work and research includes power-quality control, process automation and programming of user-friendly interfaces.

Boštjan Murovec received his B.Sc., M.Sc. and Ph.D. degrees in electrical engineering from the University of Ljubljana in 1996, 1999 and 2002, respectively. He is currently an assistant professor at the Machine Vision Laboratory at the Faculty of Electrical Engineering of Ljubljana. His current interests lie in image processing, pattern recognition, embedded design, combinatorial optimization and sequence analysis.

Andrej Žemva received his B.Sc., M.Sc. and Ph.D. degrees in electrical engineering from the University of Ljubljana in 1989, 1993 and 1996, respectively. He is Professor at the Faculty of Electrical Engineering of Ljubljana. His current research interests include digital-signal processing, HW/SW co-design, ECG signal analysis, logic synthesis and optimization, test-pattern generation and fault modeling.