

# Design and Implementation of Building Energy Management System with Quality of Experience Power Scheduling Model to Prevent the Blackout in Smart Grid Network

Delphine\*, Byeong Wook Jang\*, Yong Seop Shin\*, Seong Tae Kang\*, Jin Seek Choi\*

\* Department of Computer & Software Engineering, Hanyang University, 222, Wangsimni-ro, Seongdong-gu, Seoul  
tx100990@naver.com, jbus2580@naver.com, robot303@naver.com, stkang90@gmail.com, jinseek@hanyang.ac.kr

**Abstract**— Building energy management system (BEMS) has drawn public attention since it is not only help users to monitor and control their power consumption easily, but also reduce their electricity bill. Various scheduling models have been proposed to optimize power consumption. However, they are few solutions to prevent the blackout while optimizing power consumption. We design and implement a BEMS which can autonomously control the power consumption below a given threshold while negotiating electricity consumption with the smart grid system. By keeping the power consumption below a given threshold autonomously, the power demand will not excess the available supply, therefore can prevent the blackout. Since the threshold can be negotiated with the smart grid system, customers satisfaction can be increased.

**Keywords**— energy management system (EMS), building energy management system (BEMS), smart home, black out, quality of experience (QoE)

## I. INTRODUCTION

The development of technology causes a rapid increase of electricity consumption while power generator cannot provide as much power as the demand in a certain period of time because of some reasons[1][2]. Therefore, energy management system (EMS) including building energy management system (BEMS) and smart home has drawn much attention because of their advantages in monitoring and controlling power consumption effectively and conveniently. The EMS collects information of building power consumption, calculate and show it to users. It also able to control the on off state of appliances that are connected to the systems. By using the EMS, customers are not only easy to monitor and control their electricity power consumption but also reduce their monthly electricity bill and their electricity usage which can reduce carbon emissions[3]. However the EMS have not provide any solution to prevent the blackout when electricity demand is higher than the generated supply.

In this paper, we implement the BEMS with quality of experience (QoE) scheduling model which monitors and controls the power consumption to prevent the blackout while keep negotiating power consumption with the smart grid system.

In section II, the system architecture of will be presented, QoEn model will be described in section III, experiment testbed will be presented in section IV, followed by experiment schenario and result in section V and conclusion in section VI.

## II. SYSTEM ARCHITECTURE

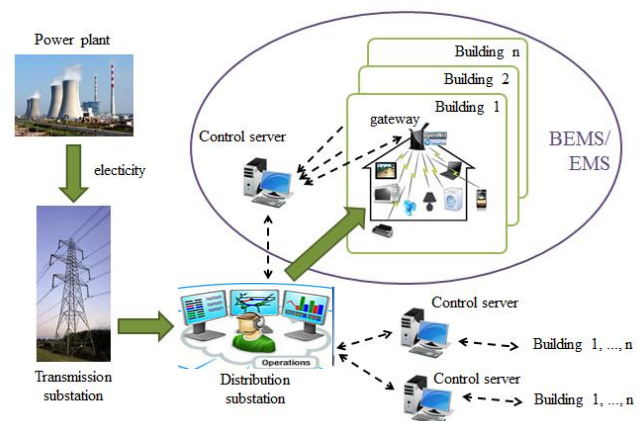


Figure 1. A classical smart grid architecture

Figure 1 shows a classical smart grid architecture. Generated power is transmit from a power plant to transmission substations. The transmission substations then redistribute the power to distribution substations. When a request comes from an appliances through a control server, the distribution substation then distribute power based on the requirement. In our system, we developed an implementation of the BEMS which is distributing requested amount of power

to appliances. Our system consists of a control server, gateways, and a set of appliances. The control server collects all information from the gateways, save and calculate the power consumption, then present it with table and graph. A gateway is connected with some controllable appliances; it receives the power consumption data from the appliances and send them to the server every 2 second. When the control server receive available power supply data, it sets a threshold for power consumption and send the threshold to the gateways. Considering the available power, a gateway then will optimizing the usage of available power through Quality of Experience (QoE)[4] scheduling for operating controllable appliances. The detail of scheduling mechanism will be presented in the next chapter.

### III. QUALITY OF EXPERIENCE (QOE) MODEL

QoE is a subjective measure of a customer's experiences with a service (web browsing, phone call, TV broadcast, call to a call center) by evaluating the customer's satisfaction through user experience which focuses on software interface and customer's experience[5]. In this model, appliances are divided into several priority levels according to the importance and a customer's requirement. In our current work, the priority level can be decided manually by users since each user may have different preferences. However, we will add a time based priority level which can help customers to manage their controllable appliances priority more conveniently.

A gateway uses the determined priority level to manage the operation of controllable appliances based on a given threshold value. When there is not enough power, the gateway will ask the control server to increase the given threshold and the control server will resend the request to the distribution substation to change the power configuration to fulfill the request. If there is a possibility to increase the threshold value, the control server will send the new threshold value to the gateway that may meet the power requirement. This dynamic threshold may increase the customer satisfaction since the system mostly provides a solution when a user needs to use power more than the given threshold value. However, when the power reconfiguration is not possible, the gateway will reduce the power usage by turning off or postponing an operating appliance which has the lowest priority level. If two or more appliances have a same priority level, an appliance which uses least power will be selected. This threshold negotiation and power reconfiguration process will be used too when the a power shortage or the blackout is estimated. By scheduling the operation of appliances below a threshold, the blackout can be prevented. Moreover, since customers make a bid for the residual power depending on their requirements, customers increase their satisfaction while optimizing the available power consumption.

### IV. EXPERIMENT TESTBED

The control server dynamically negotiates power consumption threshold based on the power requirements from gateways and lists them in the tables, then calculate the total power consumption and update the total power consumption

graph every two seconds. Gateways are optimizing the operation of controllable appliances usage under a given threshold. When the power supply is not enough and the power reconfiguration is not possible, server will lower the threshold and send a message to the gateways to reduce the power consumption under the given threshold. In our system, we currently change the threshold manually from the room setting tab by inserting the new threshold and broadcast it.

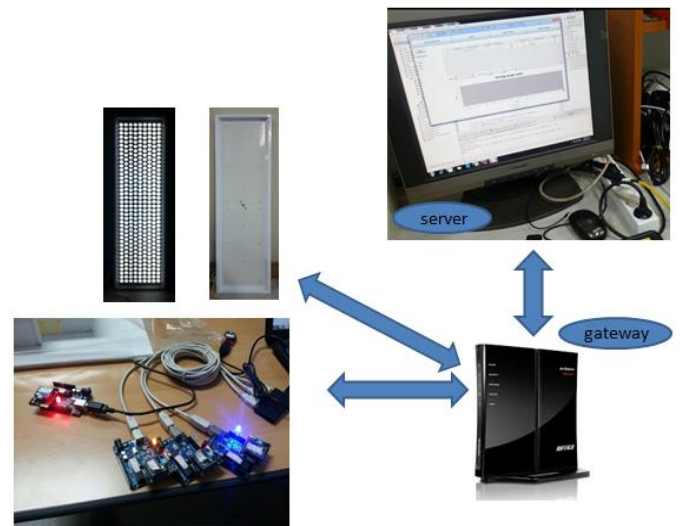


Figure 2. Experimental testbed

Figure 2 shows the testbed of our experiment. The gateway periodically receives current electricity usage information from the LED lights. The gateway then parsing the received message and send it to the server every 2 second. After received the messages, server presented all information in the tables and calculate the total electricity consumption of all appliances then present it through the graph at the bottom of the frame. In our experiment, we gave priority level for each LED and a threshold value for power consumption.

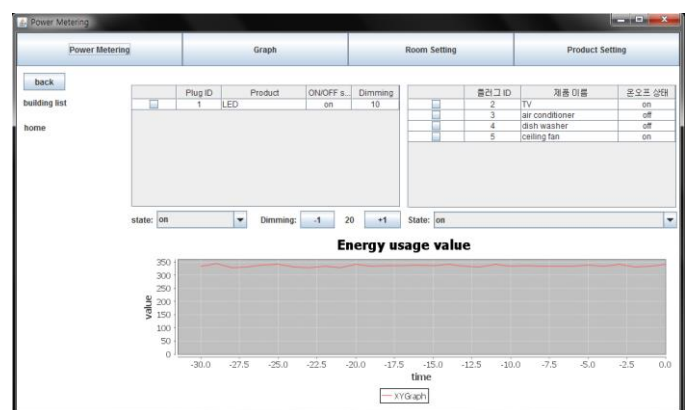


Figure 3. Power monitoring and controlling frame

Power monitoring and controlling frame in the server can be seen in the figure 3. Server received appliances power consumption information from gateways and lists them in the tables, calculate the total power consumption and update the

total power consumption graph every two seconds. When the power supply is not enough, server will reduce the threshold and send a message to the gateways to reduce the power consumption. In our system, we currently change the threshold manually from the room setting tab by inserting the new threshold and broadcast it. The dynamic negotiation procedure will be remained at further implementation topic.

In case of the power requirement was higher than the threshold but the threshold value could be increase, the control server sent a new threshold value which meet the power requirement. However, when the power requirement was higher than the threshold and the threshold value could not be increased, the control server sent the rejection message to the gateway and the gateway changed the power configuration by turning off appliances from the lowest priority level until the power usage became lower than the threshold value. This automatically rearrangement of appliances operation also happens when generated power is reduced due to some reasons such as system faults.

## V. EXPERIMENT SCENARIO AND RESULT

**TABLE 1.** APPLIANCES WITH THEIR POWER USAGE AND PRIORITY LEVEL

| node ID | appliance name  | power usage (Wh) | priority |
|---------|-----------------|------------------|----------|
| 1       | LED light       | 55-60            | 1        |
| 2       | TV              | 200-210          | 3        |
| 3       | air conditioner | 3500-4200        | 2        |
| 4       | dish washer     | 190-200          | 3        |
| 5       | ceiling fan     | 75               | 4        |

Table 1 shows the power usage of each appliances with their priority level. In our experiment, LED light and ceiling fan was operating and the current threshold value is 300wH. When a user wanted to turn on the TV which increased the total real time electricity requirement from 130-135 to 330-345. In this case there are two possibilities to satisfy the request: increase the threshold value or change the power configuration. When it was possible to increase the threshold value as we can see in figure 4a, the control server sent a new threshold value to the gateway to meet the power requirement. Figure 4b shows a state where the threshold value cannot be increased that forced the gateway to change the power configuration by turning off appliances from the lowest priority level; in this case the ceiling fan was turned off. After turning off the ceiling fan, the margin between the total power consumption was 240-245 which means there was enough power to turn on the TV.

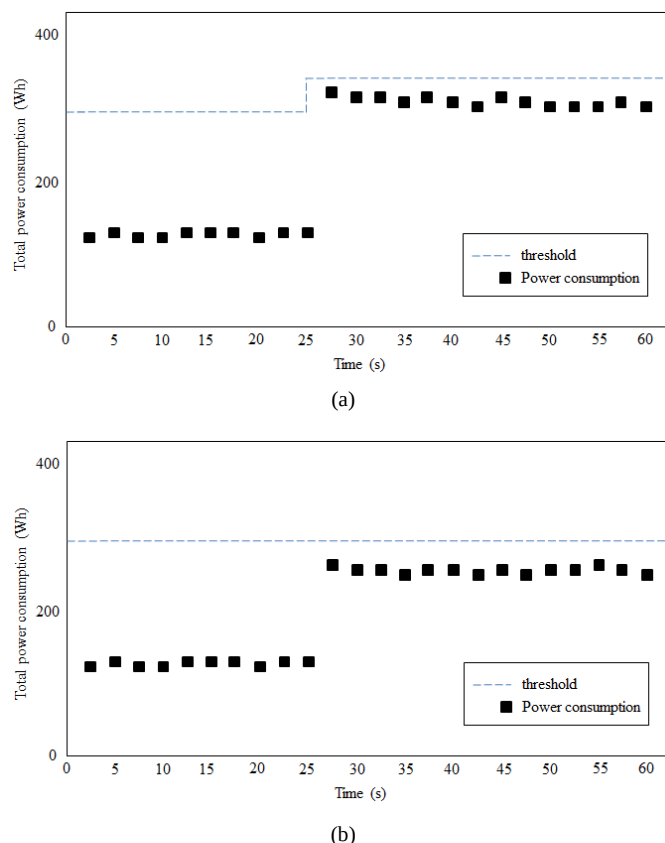


**Figure 4.** (a) Increase of threshold value (b) power reconfiguration considering electricity requirement and available power supply

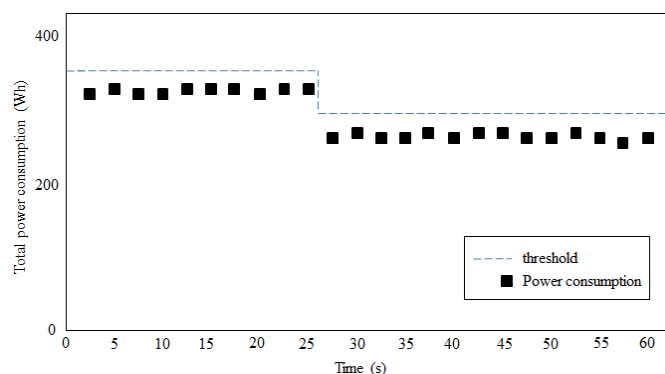


**Figure 5.** Power reconfiguration due to reduction of the threshold value

Another experiment schenario is when the control server send a new lower threshold value to the gateway due to some grid fault. In figure 5, the current threshold value is 350 but it was lowered to 300. At first, the total real time electricity usage of LED light, TV and ceiling fan is around 330-345. Since the threshold was reduced to 300, the gateway change the power configuration by turned off the ceiling fan since it has the lowest priority level among the operating appliances.

## VI. CONCLUSIONS

An implementation of BEMS with QoE scheduling model has been proposed to prevent blackout while optimizing the

available power consumption. Threshold negotiation depending on user requirement provides a solution to fulfill the power requirement when there is not enough energy, therefore can maximizing the customer satisfaction. By keeping the power usage below the threshold line, the system can prevent the blackout while optimizing the usage of the available power.

#### ACKNOWLEDGMENT

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