An Algorithm for Home Energy Management Using Environmental Conditions

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***Abstract*— Resent study of load management minimizes for electricity bill and peak load, but does not consider convenience about human experience. Just focused on saving energy management of the electricity price can't consider residential customers convenience. In this paper, we propose optimal load control strategy for human convenience as well as to minimize the electricity price. The strategy is to use some of the indoor environmental parameters, reflecting the various forms of patterns of energy management system, which controls the load within a range that can maintain human convenience.**

***Keywords*— EMS, Smart grid, IoT, RTP, Load Management**

I. INTRODUCTION

Recent power demand is increasing rapidly, as the growing interest in the environment, in the power industry, to bring the efficient use of energy has become a hot topic. The energy consumption on the part of home and commercial buildings as compared to other customers is showing a large increase rate. Recently, government to eliminate the instability of the power supply and demand repeated, in order to realize the electric tariff levels, have been lifted promote continuous electrical unit price. And, they, in order to increase the effect of the power demand control, consider to adopt real time electricity price (RTP). Unlike existing electrical charges environment, the real-time electricity rates environment, not only the total power consumption, the ratio of the time zone of the power usage is also an important factor in determining the electrical charges. Thus, the power consumers may react to changes electrical charges, it is necessary to coordinate the use of the load, monitor electrical unit price that most users varying total time, and accordingly the load to implement control. Therefore, in the real-time electricity rates environment, the need for automatically monitoring and energy management system that can be controlled by the load of the home Energy Management System (EMS) can be very large. However, in the case of residential, the ultimate purpose of load control, can have in savings electricity bill and peak power reduction, a person's comfort living in the house, that is considered very important also satisfaction with the residential environment. Therefore, in this study, is to propose the energy management method that takes into account to the indoor environment subject to the real-time electricity pricing. Sensors mounted on the indoor, detects the indoor environmental conditions, based on the values, to derive the result of the algorithm. Thus, reducing the power and controls the indoor unit to be used unnecessarily. Moreover, in consideration of the electricity price of the variable real time by using ESS, to be able to reduce the overall price and maximum load were prepared loading operation plan [2],[3],[4],[7].

This paper is structured as follows. First, in Section 2, we will introduce the research related to this article. in Section 3, a description will be given of the structure and the optimization algorithm of the energy management system proposed by the paper. In Section 4, evaluate the performance analysis of each algorithm scenario. In Section 5 is conclusion.

II. RELATED WORKS

This section summarized some of the issues related to the study.

A. Internet of Things

Internet of things, refers to the exchange environment with things and things or user information by attaching such as sensors to things. This technology, to collect information through the things. By using the collected information, provides the service to suit the user. Things are home appliances, a variety of devices such as smart equipment.

B. Smart Grid

Smart grid (Smart Grid) is that combines the IT and power system technology. This is evolved form of the power grid in order to optimize energy efficiency. By consumers and power supplier to exchange information in both directions, the smart grid, to optimize energy efficiency. This is composed of power plant, smart home, smart factory, smart building, micro-grid. Among them, the smart home combined with ubiquitous. Smart home user can easily reduce power consumption. Smart home can be expected efficiency of energy, energy saving such as the reduction of peak power.[5]

C. Energy Management System

The system is then reasonably available to define a functional business environment comfortable for efficient energy management. To establish the foundation for realizing various functions and management objectives, such as energy efficiency improvement, operation cost reduction, demand and supply balance, emission control, and utility maximization.[5]

D. The Real Time electricity Price

Currently, electricity fee structure of Korean housing to apply the progressive tax. This is a usage-based fee. Real-time electricity prices is not yet applied. In this study, we apply the method of calculating a separate fee to real-time three-stage. currently, This method is being tested applied in the Jeju smart grid demonstration park.

TABLE 1. THE REAL-TIME ELECTIRCITY PRICING FOR HOUSEHOD

In the color table means: Red is peak load time zones, yellow is middle load zones, Green is light load time zones. it is based on the SMP(SMP : System Marginal Price). And, it is the SMP of winter related expressions.

$$C_g(t) = C_{gp} \;,\; \forall t = 11,\, 12,\, 18\sim 20$$
$$C_g(t) = C_{gm} \;,\; \forall t = 10,\, 13\sim 17,\, 21\sim 23$$
$$C_g(t) = C_{gl} \;,\; \forall t = 1\sim 9,\, 24$$

$C_g(t)$: Hourly electricity rates(Won/Wh)

C_{gp} : Maximum Load Time Price(Won/kWh)

$= \Sigma(\mathrm{SMP}\ \ 1 \sim \mathrm{SMP}\ \ 5)/5$

C_{gm} : Medium Load time Price

$= \ \Sigma(\mathrm{SMP}\ \ 6 \sim \mathrm{SMP}\ \ 14)/9$

C_{gl} : Underload time price(Won/kwh)

$= \ \Sigma(\mathrm{SMP}\ \ 15 \sim \mathrm{SMP}\ \ 24)/10$

$\mathrm{SMP}_1 \sim \mathrm{SMP}_{24}$: Daily maximum – minimum SMP (Won/kWh)

The average of the SMP of the highest 5 hours is a maximum load. Next, the average of the SMP is 9 hours and 10 hours. Therefore unit price rates, which change from time to time, depending on the SMP. Interval time period is applied as well as the existing revelation star price.[3]

III. PROPOSAL

A. *CONCEPTUAL PROPOSAL*

Indoor energy management concept proposed in this paper, we propose as (Figure 1). Indoor appliance is controlled via an optimization algorithm of energy management or the user's request. energy management Optimization Algorithm collects the indoor environment information via the environmental sensors. By using the collected information, and controls the indoor appliance. In addition, to implement the power load management through the ESS.

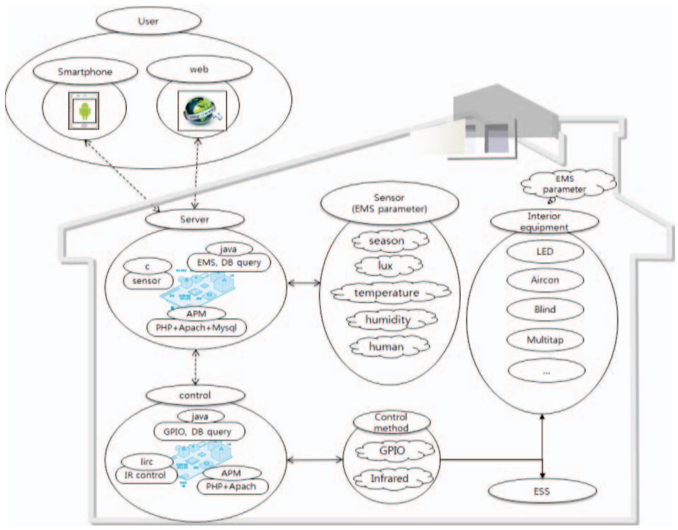

FIGURE 1. CONCEPTUAL

B. *ENERGY MANAGEMENT OPTIMIZATION ALGORITHM*

In this paper, we propose the Energy management optimization algorithm. Parameters of the algorithm are collected via the sensor. The value of illumination (Lux) for use. In the algorithm is 900 ~ 1,000. (Table 2), it was the illuminance criteria specified in the ANSI (American National Standard Institute) as a reference[5].

Light	Lux
Full moon, night light	0.25
candel light	1
Sunrise	400
Midsummer midday sun	100,000
Artificial lighting, excellent lighting of office	1,000

Livingroom	100
Street lighting	5~30

TABLE 2. LUX STANDARD[5]

Table 3 is a proper temperature and humidity seasons. This is the Korean Energy Management Corporation data[6].

Type (temperature, humidity)	scope
Comfortable indoor temperature	21.2 ~ 25.5 ℃
Winter indoor temperature	18~20 ℃
Summer indoor temperature	26~28 ℃
Comfortable indoor humidity	28 ~ 40 %

TABLE 3. TEMPERATURE, HUMIDITY STANDARD[2],[6]

We propose which two kinds of configurations. Configuration has the EMS and the Battery. Configuration information of the algorithm is defined as shown in Table 4,5.

Sensor	The algorithm parameters	Purpose
Motion Sensor (humen)	P_{Human}	The presence or absence of the use of indoor
Light sensor	P_{Lux1}(outdoor) P_{Lux2}(indoot)	Illuminance sensing
Temperature and humidity sensors	$P_{Temperature}$	Temperature sensing
	$P_{Humidity}$	Humidity sensing

TABLE 4. EMS PARAMETER

The algorithm parameters	Purpose
C_t	Charging time
P_{peak}	A defined peak
Light Load($s_{t,low}$) Middle Load($s_{t,middle}$) Over Load($s_{t,high}$)	Time load of season

TABLE 5. BATTERY PARAMETER

EMS part confirms the necessary parameter values to the algorithm via a sensor mounted in the interior. Illuminance (P_{Lux1}, P_{Lux2}) is confirmed through the illuminance sensor. It will be involved in the LED control in the illumination parameters of the algorithm. Temperature and humidity ($P_{Temperature}$, $P_{Humidity}$) are confirmed through the temperature and humidity sensor. The temperature and humidity of the parameters of the algorithm, is involved in air conditioner (heater) control. Table 6 is a representation of the algorithm in the form of codes.

```
READ : P_Human , P_Lux1, P_Lux2, season, P_Temperature , P_Humidity , C_t,
s_t,low, s_t,middle , s_t,high, P_peak
Thead(EMS){
  if(someone in the room(P_Human==1)){
    if(P_Lux1, P_Lux2 over 1000 lux)
      LED off
    switch(season case: spring ~ winter)
      if(Humidity, Temperature standard)
          Heater on, Aircon on
      else
          Heater off, Aircon off
}

Thread(Battery){
  if(t= s_t,low){
    Charging priority1 : charging during s_t,low
    Priority power use3 : power-peak
  else if(t=s_t,middle)
    Charging priority2 :charging during s_t,low - s_t,middle
    Priority power use2 : power-peak
  else if(t=s_t,high)
    Charging priority3 :charging during s_t,middle - , s_t,high
    Priority power use1 : power-peak
}
```

TABLE 6. PROPOSED EMS ALGORITHM

Next, describing the operation of the algorithm. When the algorithm to work, check the parameters(P_{Human} , $P_{Lux1,}$ $P_{Lux2,}$ $P_{Temperature}$, $P_{Humidity}$, Season). The algorithm calculates the seasonal cycle, it is divided into summer and winter. Illuminance reference value, to use 1000 lux. Indoor (P_{Lux2}) confirms if the outdoor (P_{Lux1}) corresponds to the reference value. If when it reaches the reference value, turn off the light. Temperature ($P_{Temperature}$) and humidity ($P_{Humidity}$) The reference value is determined through the season. In the case of a summer day, the temperature is 26 to 28 degrees and the humidity has as a reference value of 20 to 40. Interior of appliance that the indoor environment is the same as the reference value (airaon, heater) operate. It brings a parameter that changes the optimization algorithm of energy management on an ongoing basis. And dynamically reflect on the operation of the indoor unit. battery parts, it operates using load conditions. Charging time, the price order is I operate preferentially a low time. Peak management Price order to work preferentially high time. peak to reduce the consumption in the order of high power use.

IV. PERFORMANCE ANALYSIS

In this chapter, we will confirm the performance analysis results of the optimization algorithm of energy management. Scenarios were tested to target winter, weekday home. Table 7 is a consumer electronics requirements under the scenario.

name	user preference and power requirement
1. Hob 2. heater	Operating period: 7pm-8pm(Hob/oven) 9pm-10pm, 3am-5am(heater) hourly consumption: 1kWh
3.Fridge and freezer	Operating 24hrs hourly consumption: 0.12kWh
4.Water boiler	Hourly consumption: 0-1.5kWh daily requirement: 3kWh
5.Electric vehicle	Preferred charging period: 8pm-8am charging power: 0.1kW-3kW daily requirement: 5kWh
6.Washing machine	Operating 2hrs, once per day 1kWh for the 1st hr 0.5kWh for the 2nd hr
7.Dish washer	power: 0.8kWh for 1 hour daily requirement: 0.8kWh
8.LED	About 10% of the total consumption
9.battery	hour charging : 1.5kwh charging time(origin) : 11-17 charging time(cost) : 1,2,6,7,8,23,24

TABLE 7. CONSUMER ELECTRONICS REQUIREMENTS[1],[4],[8],[9]

Figure 2 is a graph of charging cost the battery.

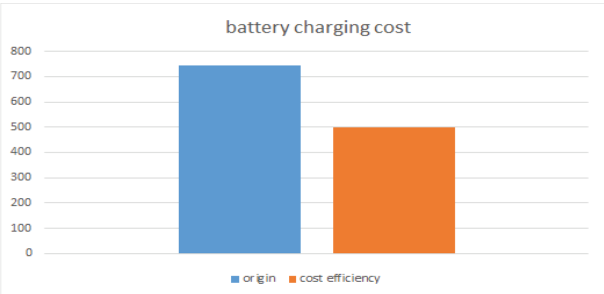

FIGURE 2. BATTERY CHARGING COST

The reason for use in this way is to reduce the price for the time of charging the same energy. Efficiency is about 32%. Using the table 7 scenario to measure the energy consumption in the room.

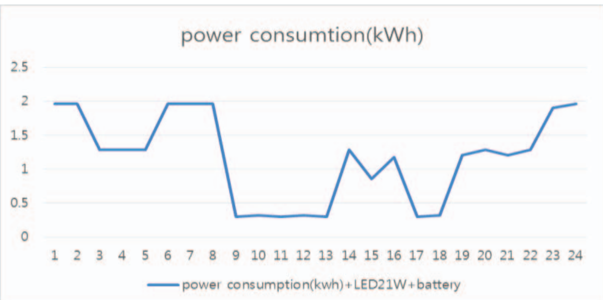

FIGURE 3. POWER CONSUMPTION

Figure 3 is obtained by considering the charging time of the battery usage time of the household appliance. The excess time 1.5 kilowatts is high power consumption. because that contains the power to charge the battery.

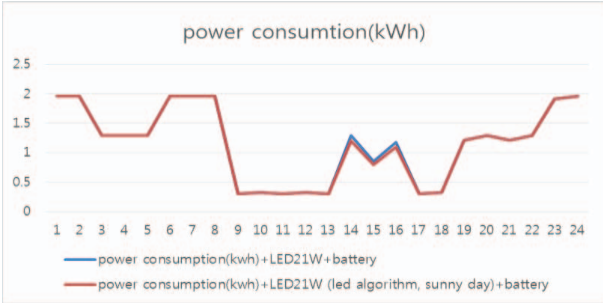

FIGURE 4. POWER CONSUMPTION(LED)

Figure 4 is a graph showing efficiency by utilizing the illumination algorithm. The result, a sunny day is the reference. Energy efficiency is increased by about 1 percent to show the efficiency of the daytime time. The reason for significant efficiency has not increased, because the proportion of lighting power is low.

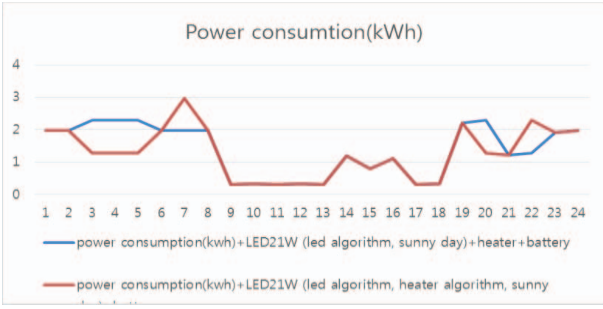

FIGURE 5. POWER CONSUMPTION(LED,HEATER)

Figure 5 is when it is applied including humidity and temperature. It can be seen that the shape of the graph of when it is applied to the heater is changed much. The reason for the result comes out in this way, because the operation time is different. Existing heater operation request time pm9-10, am3-5. However, operation request time when applying the algorithm is changed pm19, pm22, am7. This is because the operating mainly human activity time in the algorithm. At this time, the efficiency of energy use will rise about 10%. The following is a Figure 6 to reduce the high load. Reducing the load is obtained by using the battery.

In addition it will be the efficiency is increased by about 6.2%. Table 8 is a table showing the efficiency of each stage charges. Calculation was referring to the power tariff of kepco. It has a policy that price will be formulated in 100kWh unit. And it is to formulate the weight of the price is different in step. In the case of three it was calculated[8]

Case 1 : Using EMS algorithm(LED)
Case 2 : Using EMS algorithm(LED, Heater)
Case 3 : Using EMS, Battery algorithm(LED, Hater)

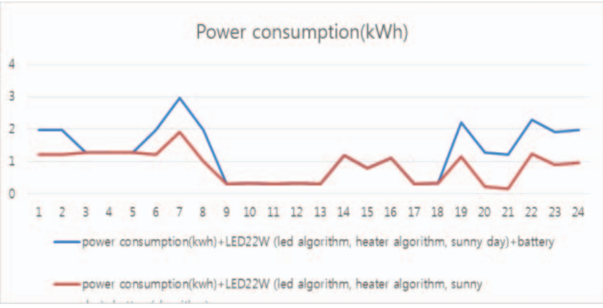

FIGURE 6. POWER CONSUMPTION(LED,HEATER,BATTERY)

	Case1	Case2	Case3
day(kwh)	32.82316263	30.82316263	20.32316263
month(kwh)	984.6948788	924.6948788	609.6948788
cost1 (weight : 60.7)	6070	6070	6070
cost2 (weight : 125.9)	12590	12590	12590
cost3 (weight : 187.9)	18790	18790	18790
cost4 (weight : 280.6)	28060	28060	28060
cost5 (weight : 417.7)	41770	41770	41770
cost6 (weight : 709.7)	343891.0165	301321.0165	77828.51647
cost sum(won)	451171.0165	408601.0165	185108.5165

TABLE 8. EFFICIENCY OF EACH STAGE CHARGES[8]

It is possible to save power of 12.5kW per day. 1 month between 266062.5 (won) and can be saved as much cost.

V. CONCLUSION

In the power industry, according to a recent power demand is soaring environment are important for saving energy. In this study, it is intended to propose an energy management method that takes into account to the indoor environment subject to the real-time electricity rates. It designed an optimization algorithm to control the dynamic devices in accordance with the indoor environment. Rather than merely to control the appliance, it is proposed in view of the functions that can be controlled as needed with changes in the environment. Electrical efficiency is increased by about 10%. Here we added a ESS. Finally, 1 month between 266062.5 (won) and can be saved as much cost.

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