Journal of Electrical Engineering & Technology
https://doi.org/10.1007/s42835-024-01870-3

ORIGINAL ARTICLE

Research on Development and Implementation of Integrated Energy Management System for Buildings

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Received: 10 January 2024 / Revised: 26 February 2024 / Accepted: 4 March 2024

Abstract

In response to the long-term instability of energy supply and demand and the challenges posed by climate change, there has been a recognition of the importance of utilizing renewable energy as a sustainable energy source to reduce primary energy consumption. Consequently, the building sector, a significant contributor to energy consumption, is currently exploring various energy-saving technologies that incorporate renewable energy. As the application of renewable energy sources becomes more widespread, there is a growing need for a Building Energy Management System (BEMS) capable of optimizing production and consumption through the efficient integration of operation and control. This paper presents the development and demonstration of a BEMS designed for the integrated operation and control of electrical energy and thermal energy in buildings. In addition, the developed BEMS was verified through empirical operation in two buildings to reduce the building's average power usage, peak power usage, and energy purchase costs.

Keywords Building energy management system · Renewable energy · Electricity energy · Thermal energy · Energy savings · Co-optimization

1 Introduction

Energy plays a pivotal role in economic development, and energy conservation stands as a crucial component of national policy. In a country like Korea, which imports over 97% of its energy, energy conservation has emerged as a pressing social concern. Developed nations exhibit higher building energy consumption compared to energy usage in industrial or transportation sectors. In the case of Korea, the energy consumption of buildings constitutes more than 25% of the total energy consumption across various economic sectors. In the densely populated city of Seoul, buildings' energy consumption alone contributes to 56% of the total energy consumption [1]. Therefore, to curtail the energy consumption of buildings and ensure a conducive indoor environment, it is imperative to assess the current state of buildings, establish energy-saving targets, and implement a Building Energy Management System (BEMS).

Moreover, numerous low-carbon energy-saving policies are being formulated in response to climate change agreements, leading to the development of various energy-saving technologies within the building sector. Currently, technical research aimed at energy conservation in buildings is progressing, encompassing passive saving technology to enhance the efficiency and eco-friendliness of building structures and materials, as well as active saving technology involving the replacement of low-power facilities and the optimization of building operations. Specifically, within the realm of active building energy-saving technology, there is a notable focus on BEMS technology designed for the efficient operation of buildings, with an emphasis on streamlining building functions distinct from traditional building automation and management technologies. Active research in this domain is being actively pursued [2].

However, in Korea, despite the government's sustained support for energy management in the building sector, its performance has been subpar, and there is a lack of actual commercialized technology for building energy

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management. Furthermore, although numerous companies and research institutes are developing BEMS and implementing them in real buildings to optimize energy consumption, questions persist about their effectiveness in energy saving, and the validation of objective outcomes remains insufficient. Consequently, the government is proposing several policies and countermeasures for energy management and reduction, emphasizing the introduction of core technologies capable of addressing challenges such as the expansion of buildings and the increase in quantity [3], along with the implementation of a systemized and integrated energy management operation system.

In this paper, a comprehensive Building Energy Management System (BEMS) has been developed and demonstrated. This system integrates and controls both electrical and thermal energy, expanding beyond the capabilities of BEMS systems that only manage electrical energy. As a result, the power consumption of the building under demonstration was identified, and the power-saving effect was analyzed to validate the system's performance and energy savings.

The rest of this paper is organized as follows. The role and function of a general BEMS are defined in Sect. 2. Section 3 details the development of a comprehensive BEMS designed for the operational control of electrical and thermal energy. To achieve energy savings, an operational control algorithm applicable to a comprehensive BEMS is proposed. Section 4 introduces cases that demonstrate the developed comprehensive BEMS in the field and analyzes its empirical effects. Finally, Sect. 5 summarizes the contents of this paper and discusses the conclusion.

2 Building Energy Management System

The Building Energy Management System (BEMS) is a system that achieves energy savings and provides optimal operating information for the facility and the operating devices related to building energy. An ideal management strategy is established by analyzing the energy use status and the operation history of the facility. Real-time monitoring of power consumption is emphasized, and it is grounded in the perspective of consumer-oriented power energy-related systems [4–6]. It is essentially an energy management system that offers real-time power consumption information to users and facilitates power demand prediction based on real-time observed data.

This BEMS optimizes commercial power consumption. Unlike home use, which employs a progressive rate system, the commercial electricity rate system necessitates the management of both a base rate associated with the maximum power demand throughout the year and power usage using differential rates based on the time of day [7]. Data measured through BEMS enables users to observe total energy usage and each facility usage. Building managers can analyze the energy usage patterns of the building, identifying and managing energy waste items for energy-saving purposes.

3 Development of a Building Energy Management System (BEMS) for the Operation Control of Electrical and Thermal Energy

3.1 BEMS Function and Structure

The architecture of the comprehensive BEMS engine, which integrates and controls electrical and thermal energy, as developed in this paper, is depicted in Fig. 1. The comprehensive BEMS engine comprises data communication and collection modules, message queues, data processing modules, and data access objects (DAOs). The data communication/collection module communicates with electrical and thermal source facilities to gather status information from each facility, responsible for transmitting and receiving data according to control commands.

The comprehensive BEMS engine, developed in this paper, can accommodate 48 types of new renewable energy distributed power electric facilities and 12 types of heat source facilities. A message queue is implemented to prevent missing data and facilitate distributed processing of large data when a substantial amount of real-time data, collected through the data communication/collection module, surpasses the processing capacity of the data processing module. It temporarily stores and transfers the collected data to the data processing module in a FIFO (First In, First Out) sequential manner. This implies that when the comprehensive BEMS accommodates a new facility, a data processing module for communication between the new facility and the system is added, and traffic may occur due to multiple paths caused by the addition of the data processing module. In such cases, utilizing a message queue offers the advantage of enhancing the system's reliability by consolidating all the traffic generated by the application of the message queue in one place to process data sequentially, ultimately preventing data loss.

The data processing module functions as a parsing unit, performing tasks such as consistency checking, classification, and interpretation of data received through the message queue. To load the processed data into the database through the data processing module, the DAO accesses the database and executes data input, inquiries, insertions, and modifications. This approach is employed because there are various data processing modules specialized for facilities corresponding to the variety of connected facilities. If all data directly accessed the database from the data processing module, excessive I/O traffic might be generated. Applying

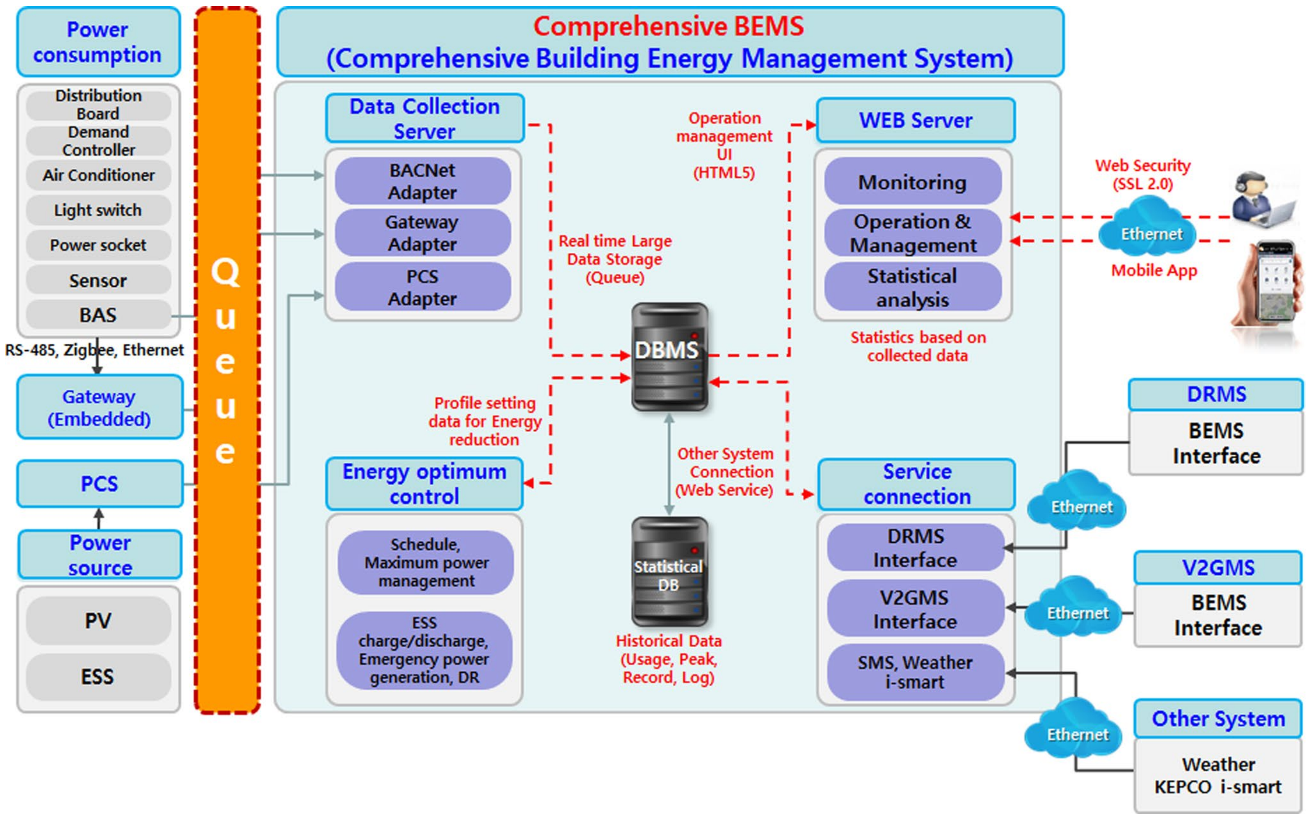


Fig. 1 The proposed BEMS architecture

DAO can prevent unnecessary traffic caused by frequent database access and termination. By concentrating only on write operations using the previously connected database connection, it offers the advantage of improving process speed and efficiency.

3.2 Development of a Comprehensive Building Energy Management System (BEMS) Energy Operation Control Algorithm

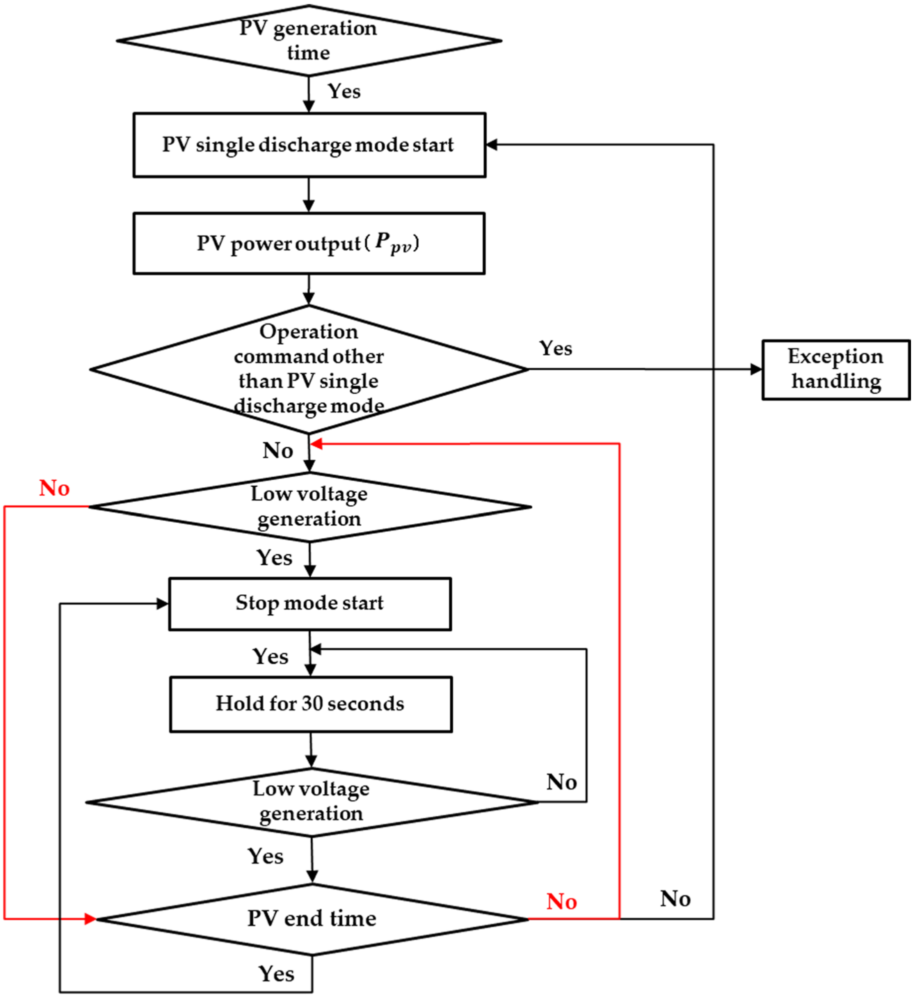
Accurate power demand prediction is essential for comprehensive Building Energy Management System (BEMS) energy control. However, the increased non-linear characteristics influenced by social, economic, day-of-day, and weather factors elevate the likelihood of prediction inaccuracies. Therefore, both an operation method based on real-time status information and an operation control method based on time series power demand prediction were applied in this paper for BEMS.

Data observed at equal intervals over time are termed time series data. Power demand is also observed at regular time intervals, and it can be referred to as time series data. The purpose of time series analysis is to predict the future by analyzing present data under the assumption that certain patterns from the past persist in the future [8–10]. Various methods, such as trend models, moving average methods, exponential smoothing methods, factor decomposition, and autoregressive cumulative moving average (ARIMA) models [11, 12], can be employed to predict time series data. Time series data are characterized by long-term observations. If the system itself changes over time, a model that initially worked may no longer be suitable after the change. Additionally, if the time series fluctuates, it may not accurately reflect the trend. Therefore, when making predictions based on historical data, it is more reasonable to assign more weight to recently observed data than to treat all data equally.

The configuration of power demand changes over time and exhibits increased sensitivity to temperature in recent years. Consequently, predictions are made using the Exponential Smoothing Method, which prioritizes recent data. In the Exponential Smoothing Method, current data is believed to have a higher correlation with future information than past data, making it a means of prediction that places greater value on recent data and lesser value on older data.

The Exponential Smoothing Method allows new trends to be quickly tracked when changes occur by giving weight to recent data. During this process, setting the correct exponential smoothing constant becomes crucial. Increasing the exponential smoothing constant enables swift reflection

Fig. 2 Operation control algorithm of PV generation



of changes within a short period, while smaller constants contribute to stable predictions when the system experiences minimal fluctuations. Consequently, the selection of the exponential smoothing constant should align with the characteristics of power demand fluctuations when applying the Exponential Smoothing Method. In seasons with anticipated rapid power demand fluctuations, such as winter and summer, higher constants are chosen. Conversely, during milder seasons like spring and fall, where fluctuations are less severe, smaller constants are preferred.

Additionally, since the Time Series Prediction Method relies on historical data for predictions, its accuracy significantly diminishes when an abrupt system change occurs due to unpredictable factors not present in past occurrences. While power demand typically remains stable, sudden changes in temperature during winter or summer or abnormal climate variations can alter power demand. In such cases, prediction accuracy substantially decreases because, in the exponential smoothing method, predictions are made within the range of maximum and minimum values of input data.

3.2.1 Power Demand Forecasting Based on Exponential Smoothing Modeling

The exponential smoothing model is one of the simple yet effective model used in time series analysis to remove trends and seasonality patterns, enabling the prediction of future values. This model calculates an exponentially decreasing weighted average, giving greater weight to recent data and lower weight to older data. This ensures that the model reflects the latest information while retaining some influence from older data. The main steps of the exponential smoothing model are:

- Initialization: An initial estimate is established using the first few observations from the beginning of the time series data. The initial estimate can be set to the average, first value, etc.
- Smoothing: To predict the next observation, a weighted average is calculated between the current estimate and the most recent observation. The weights are adjusted according to a user-defined exponential smoothing coef-

Fig. 3 Optimal operation control algorithm for heat pump based on power demand forecast

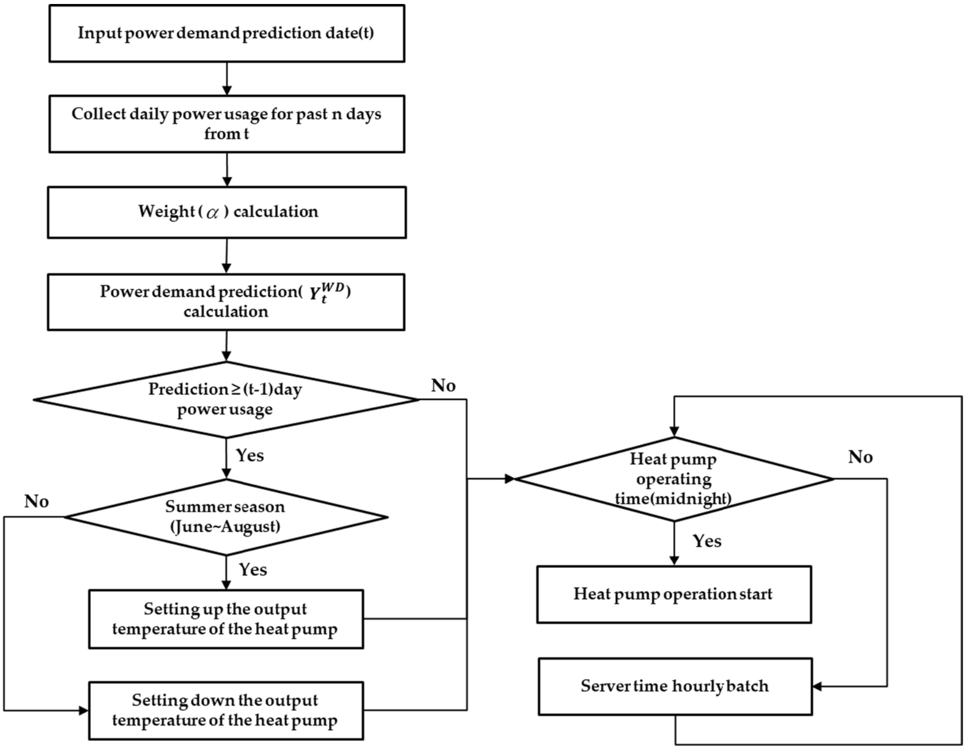
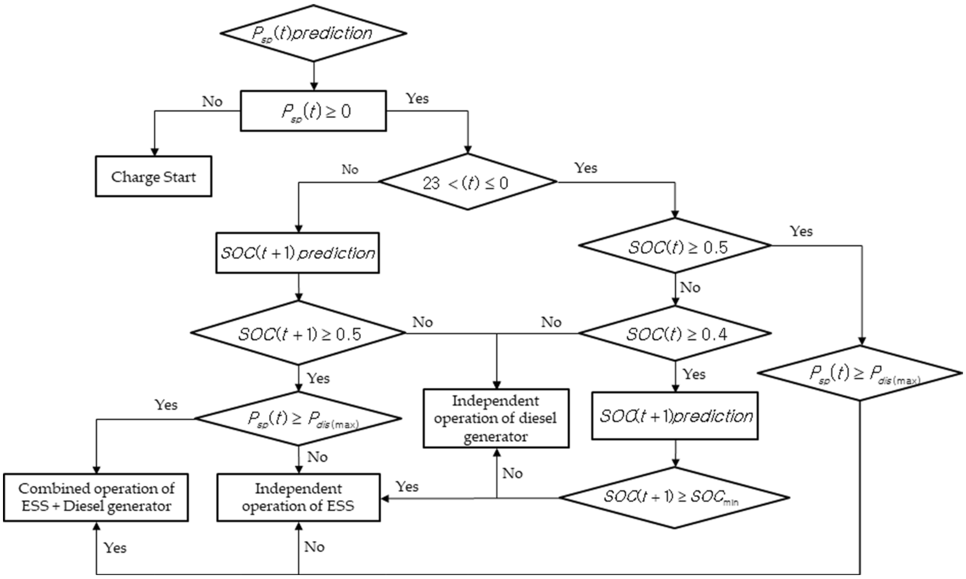


Fig. 4 Peak Shaving-based ESS algorithm



ficient (usually a value between 0 and 1). The predicted value ($\hat{y}_t$) at time t is calculated as follows:

$$\hat{y}_t = \alpha \times y_{t-1} + (1-\alpha) \times \hat{y}_{t-1} \tag{1}$$

where α is the exponential smoothing coefficient; smaller values assign more weight to the forecast value at time $t-1$.

- Iteration: The new forecasts are used to predict the next observation, and this process is repeated iteratively. As the model continues to predict future values, it learns patterns in the data.

The exponential smoothing model is effective, suitable for real-time data or data with large fluctuations. However, depending on the characteristics of time series data, finding the optimal alpha value is important, and the model must be periodically updated to reflect the latest data when predictions are needed.

3.2.2 Development of Operation Control Algorithm for PV Generation

The building energy management system (BEMS) proposed in this paper is based on real-time status information for efficient control of solar power generation. This is because it is difficult to predict the output of solar power generation due to weather conditions such as the position of the sun and the amount of clouds [11]. This process is shown in Fig. 2.

- PV power generation starts measuring in batches by checking the server time every 10 min. Measurement is set to start at 07:00 in summer (June–August), at 08:00 in spring (March–May) and fall (September–October), and at 08:30 in winter (November–February).
- Most buildings consume PV power in real time, and the energy generated through PV-only discharge mode is used by the building in real time. The PV output produced at this time is as in Eq. (2).

$$P_{pv} = \tau_{pv} \times N_{pv} \times A_m \times G_t \times \left[1 - \sigma(T_c - 25)\right] \tag{2}$$

where τ_{pv} is the efficiency of solar panels, N_{pv} is the number of PV modules, A_m is the area of single PV panel (m^2), G_t is insolation, σ is the maximum power temperature coefficient ($-0.47\%/^{\circ}\mathrm{C}$), T_c is the Cell temperature.

- If low voltage occurs due to external conditions such as bad weather, stop operation and check the voltage every 30 s to protect the solar power generation system.
- If low voltage does not occur, discharge operation mode is executed to maintain PV power generation.
- PV power generation termination is carried out in batches in server time and is confirmed at 10-min intervals. PV power generation ends at 20:00 in summer (June–August), 19:00 in spring (March–May) and fall (September–October), and 17:00 in winter (November–February).

3.2.3 Development of Heat Pump Operation Algorithm Based on Power Demand Forecast

In general, heat pumps are operated during the middle of the night when the electricity rate is at its lowest. The water

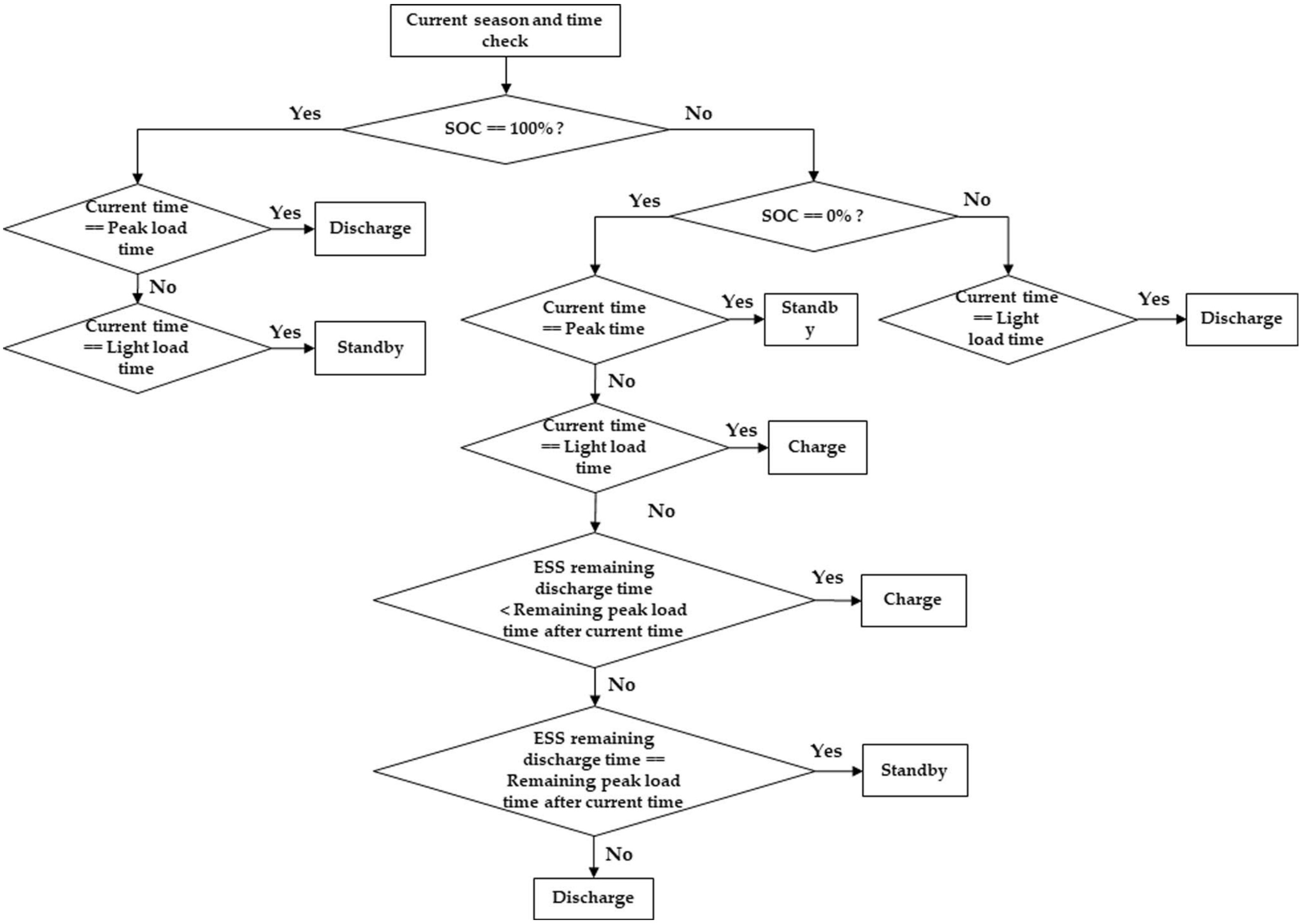
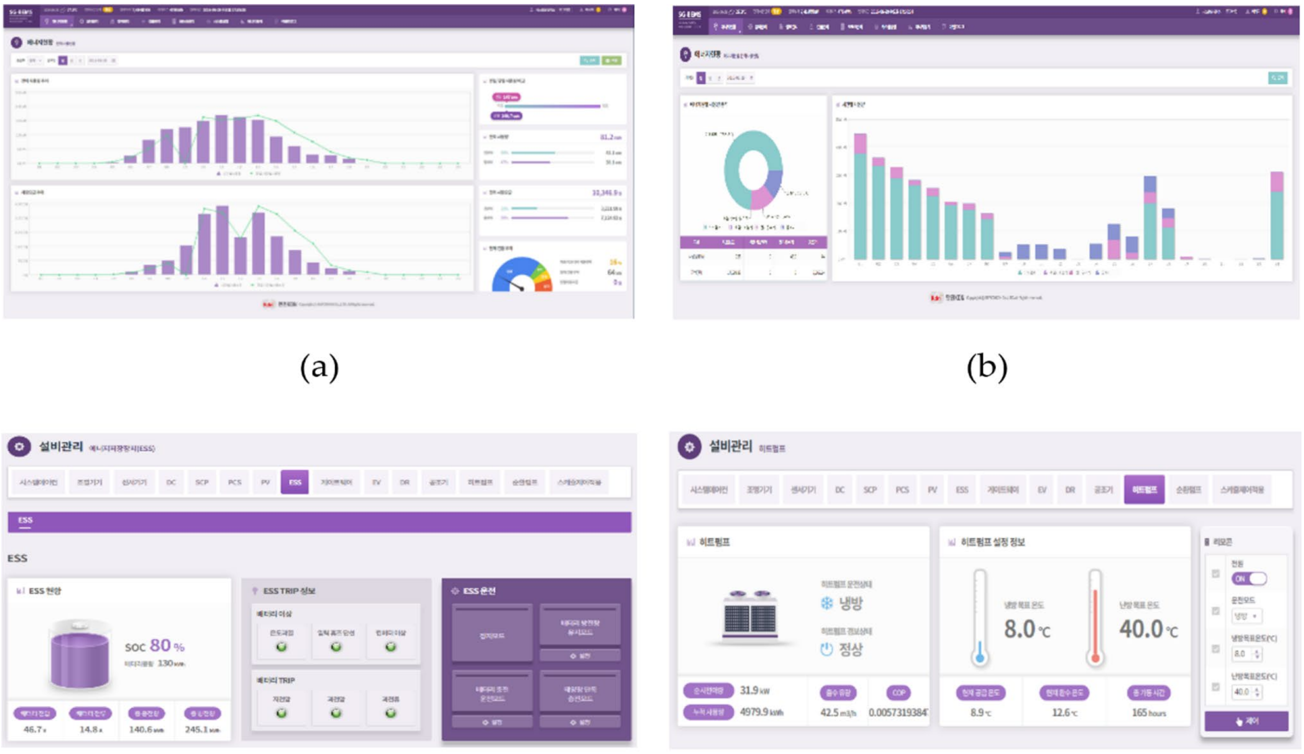


Fig. 5 Price-based ESS operation algorithm



(a)

(b)

(c)

(d)

Fig. 6 Comprehensive BEMS web-based HMI screen, **a** Energy use status; **b** Electricity usage status by energy source; **c** ESS management/control; **d** Heat pump management/control

is cooled or heated and stored in a condensation tank to be utilized for cooling and cold water in summer, and for heating and hot water in winter. The algorithm developed and applied to operate and control the heat pump in Building Energy Management System (BEMS) is illustrated in Fig. 3.

The power demand forecast value is calculated through the equation every day. In the summer, if real-time power demand exceeds the forecast value, set the heat pump temperature 3 °C higher. If the above conditions are not met, the outlet temperature of the heat pump is set 3 °C lower. The BEMS server time is organized into batches and checked every hour. When the time reaches 24:00 h, the heat pump operation is executed under the above-described conditions.

3.2.4 ESS Operation Algorithm Development

ESS operation varies based on installation purpose and surrounding equipment characteristics. Generally, in the case of ESS integrated with renewable energy, the dynamic output characteristics of the renewable energy source influence charge and discharge power supply. Additionally, optimizing ESS power charging and discharging according to different load conditions—light, heavy, and maximum

Table 1 Comprehensive BEMS web-based HMI provision function

Function	Detailed operation control content
Energy status	Real time power usage, power usage by energy source, maximum peak, PV generation, ESS charging and discharging
Facility management and control	Heat Pump, AHU, FCU, Water Heater, Boiler, Inverter, Circulation Pump, System Air Conditioner, Lighting, Outlet, Distribution Board, PV, PCS, ESS, etc
Energy operation policy	Maximum Peak Control, Target Reduction, etc
Energy performance analysis	Hourly/Daily/Monthly/Yearly Electricity Usage, Energy Source Usage, Maximum Peak Power, Period Comparison Fee, Distribution of Electricity Usage

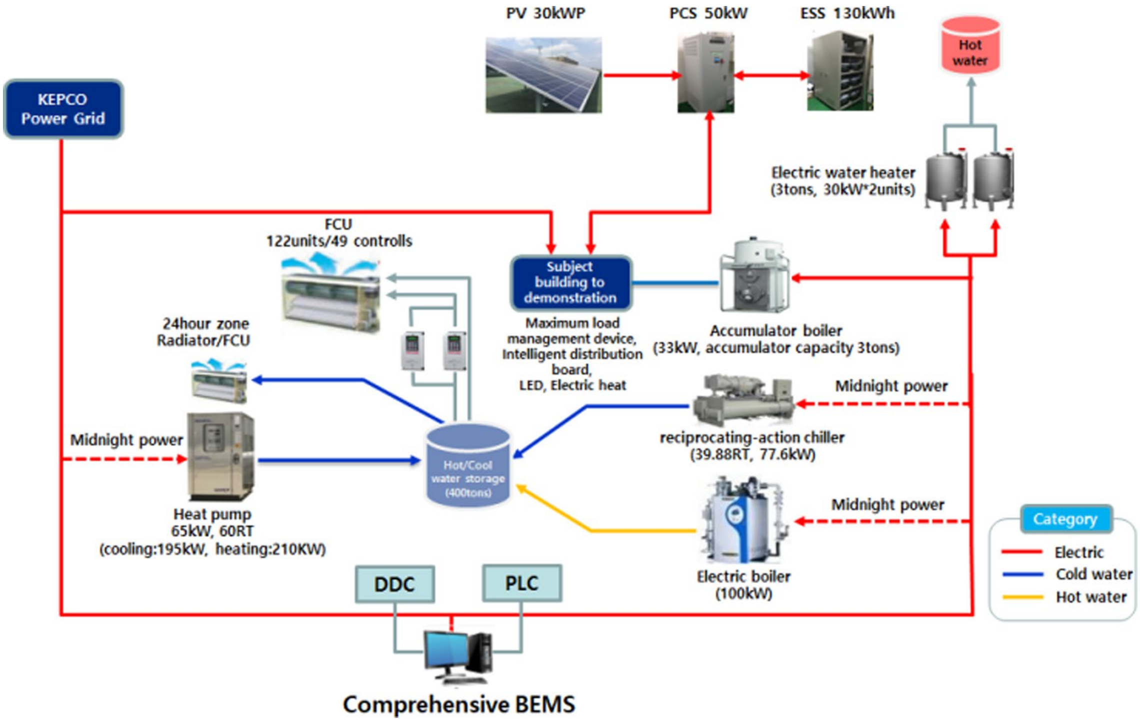


Fig. 7 Structure of the BEMS at site #1

load—can significantly enhance the efficiency of renewable energy power supply.

In this paper, an ESS charging/discharging operation algorithm was developed and applied for both the single operation mode of ESS and the combined operation mode with a diesel generator serving as backup power in emergencies. Figure 4 shows the flowchart of the proposed ESS operation algorithm, and the details are explained in detail below the flowchart.

The electricity amount at time (t) is predicted based on the output of the renewable energy generation and the load to be supplied at time (t). Equations (3) and (4) are utilized to calculate the predicted value.

$$P_{sp}(t) = P_{load}(t) - P_{res}(t) \tag{3}$$

where $P_{sp}(t)$ represents the amount of power to be supplied to the load at time t; $P_{load}(t)$ and $P_{res}(t)$ are the load and the total output of PV generation at time t.

$$P_{res}(t) = P_{pv}(t) \times \eta_{inv} \tag{4}$$

where η_{inv} represents the efficiency of the inverter.

If the output of renewable energy does not meet the load, power can be supplied only if the load can be sufficiently met based on the state of charge (SOC) of the ESS. During light load periods, when operating in the single operation mode, SOC (t + 1) is estimated and if it is over 50%, the power charged in the load is discharged. During heavy load periods, discharge is initiated when the State of Charge (SOC) at time (t) is 50% or more. If it remains within the range of 40–50%, the SOC at time (t + 1) is estimated to determine


(a)
(b)
(c)
(d)

Fig. 8 On-site photograph of comprehensive BEMS construction/demonstration facility at site #1, **a** Air heat pump; **b** Electric boiler; **c** Cold and hot water circulation pump; **d** inverter

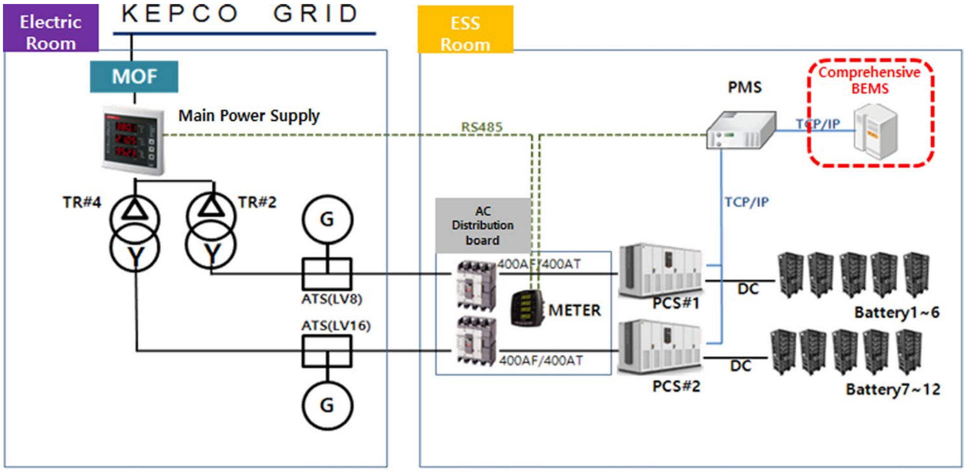


Fig. 9 Schematic diagram of the BEMS at site #2

the discharge. The discharged SOC (t + 1) must satisfy a specific SOC value at this time.

Under light load conditions, if the estimated State of Charge (SOC) at time (t + 1) is 50% or less, and the load to be covered exceeds the maximum dischargeable capacity of the Energy Storage System (ESS), supplementation with a diesel generator is implemented. This becomes necessary when the load rises rapidly, or the total output of renewable energy inadequately meets the load, making it impossible to fulfill the required electricity amount solely through ESS single operation. In case of heavy load, SOC (t) can be sufficiently discharged to more than 50%, but if the load exceeds the maximum discharge capacity of the ESS, power is controlled to be supplied to the diesel generator. Otherwise, it will only be discharged by the ESS.


(a) (b)

Fig. 10 Demonstration PCS and ESS at site #2, **a** Lithium-ion ESS (571.8kWh); **b** PCS (500 kW)

Moreover, if a Time-of-Use (TOU) rate system, wherein electricity rates vary depending on the time of day, is applicable, the control algorithm for the Energy Storage System (ESS) must consider this aspect. For instance, a control algorithm is employed that charges electricity to the ESS during late-night hours when electricity rates are low and discharges it during the day when electricity rates are high. Figure 5 depicts a flowchart illustrating the electricity rate-based ESS operation algorithm within the proposed Building Energy Management System (BEMS) in this paper.

3.3 Web-Based BEMS HMI Development

In this paper, a web-based Human Machine Interface (HMI) capable of remotely operating and controlling an integrated BEMS for electric and heat energy was developed. This led to the enhancement of the energy-saving effect by diversifying the detailed energy information monitoring for each load source and implementing optimal operation control for various consumption patterns. The HMI comprises an energy status monitoring screen that displays detailed real-time operation and status information for electricity, heat source, renewable energy, and an efficiency analysis screen

Table 2 ESS communication interface and protocol

Connection	Item	Communication method	Protocol	Communication period
PMS	PCS	TCP/IP	Modbus	Within 1 s
PMS	BMS	TCP/IP	Modbus	Within 1 s
PMS	AC distribution board (Meter)	TCP/IP	Modbus	Within 1 s
PMS	Maine Power Board	RS485	Modbus	500 ms
ESS BMS	Rack BMS	CAN	CAN	Within 3 s
PMS	Comprehensive BEMS	TCP/IP	Modbus	measurement: 30 s Control: Real time

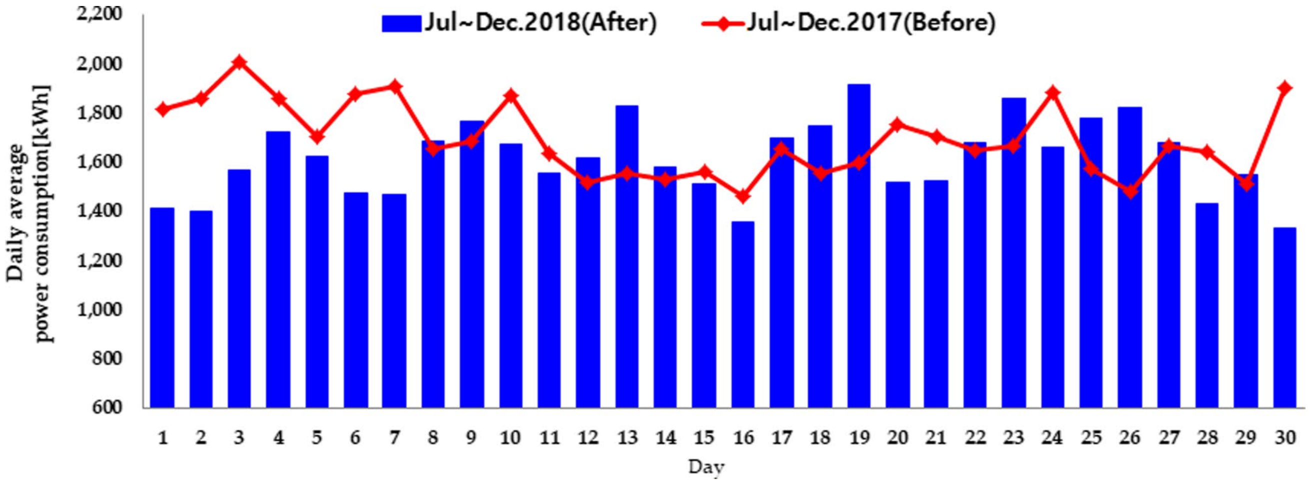


Fig. 11 Comparison of power consumption before and after BEMS application at site #1

Table 3 Comparison of average power consumption at site #1

	Before ('17.7.1–12.30)	After ('18.7.1–12.30)
Monthly	57,641 kWh	48,476 kWh
Daily	1921 kWh	1615 kWh

Table 4 Information of seasonal power tariffs

Power rate (KRW/kWh)				
Basic rate	Load level	Jun.–Aug.	Mar.–May., Sep.–Oct.	Nov.–Feb.
8320	Light	56.1	56.1	63.1
	Medium	109.0	78.6	109.2
	Maximum	191.1	109.3	166.7

Table 5 Information of ToU (Time of Use) tariffs

Load Level	Other seasons	Winter
Light	23:00–09:00	23:00–09:00
Medium	09:00–10:00	09:00–10:00
	12:00–13:00	12:00–17:00
	17:00–23:00	20:00–22:00
Maximum	10:00–12:00	10:00–12:00
	13:00–17:00	17:00–20:00
		22:00–23:00

for building energy and facilities. Additionally, it offers various statistical analysis information to improve efficiency based on real-time collected energy and equipment data. This energy statistical analysis facilitates control for efficient operation. The inclusion of a setting function for energy management operation policy through HMI enables flexible adjustment of optimal operation control for changing building environments and energy consumption patterns, thereby increasing the energy-saving effect. The detailed functions provided by the web-based BEMS HMI are outlined in Table 1, and some screens are presented in Fig. 6.

4 BEMS Construction and Demonstration Case

The first demonstration building implementing the developed BEMS is a public building in Seoul with 4 floors above ground and 1 floor underground, can accommodate approximately 190 people, and has a contracted power of 450 kW. The building was completed in 1990 and needed remodeling for convenience and energy conservation.

Before remodeling, the buildings faced inconveniences as managers had to manually monitor and control electricity and heat source facilities. Moreover, there was no capability to collect, store, and analyze data on energy usage by facility. Energy wastage occurred due to variations in each manager's facility operation experience. The installation of BEMS aimed to address these administrative inconveniences and actively promote energy savings.

The structure of the BEMS, as installed in this paper, is depicted in Fig. 7. The heat pump operates during late-night hours, utilizing off-peak power to produce cold water in the summer and hot water in the winter, which is stored in a heat storage tank. The stored cold and hot water is then supplied to the Fan Coil Units (FCU) located in the building's offices for cooling and heating. Similarly, electric boilers, freezers,

Fig. 12 Comparison of monthly electricity purchase costs at site #1

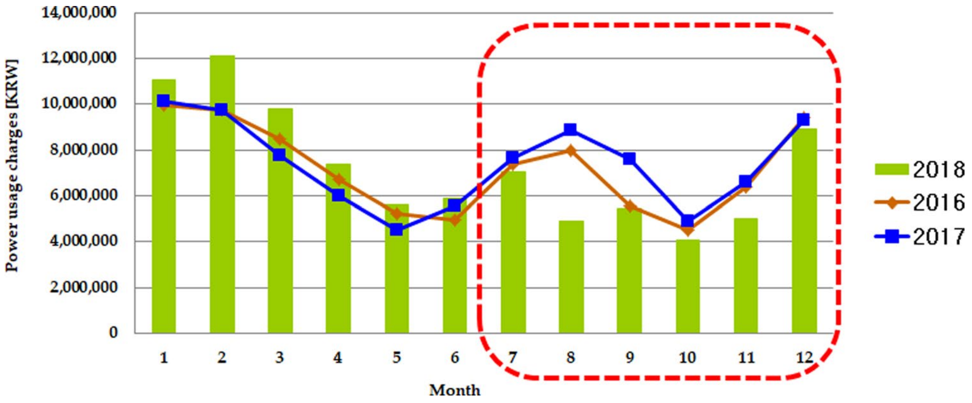


Table 6 Comparison of electricity purchase costs throughout the demonstration period at site #1

Period		Average monthly payment electricity bill (KRW)
Before	‘16.7–12	6,865,485
	‘17.7–12	7,490,812
After	‘18.7–12	5,760,435

Table 7 Comparison of power consumption before and after BEMS installation at site #1

	Before (‘17.7.–12.)	After (‘18.7.–12.)
Average monthly power consumption	57,641 kWh	48,476 kWh
Peak power	322 kW	252 kW

thermal storage boilers, and electric water heaters also operate during the night. BEMS collects real-time status information from these facilities and executes controls to reduce energy usage based on the current status and external environment.

The target equipment that collects and controls the real-time data from the BEMS is electric energy equipment, which includes PV, ESS, PCS, smart distribution panel, lighting, and outlet. Thermal energy equipment encompasses a heat pump, fan coil unit (FCU), cold/hot water circulation pump, inverter, heat storage boiler, electric water heater, electric boiler, digital electricity meter, flow meter, thermometer, and supply/exhaust fan. Figure 8 displays an actual image of the main facilities of the tested building, operated and controlled by this comprehensive BEMS.

The second demonstration building that has implemented the developed BEMS is a commercial public building established in 2014. This 18-floor building with a basement

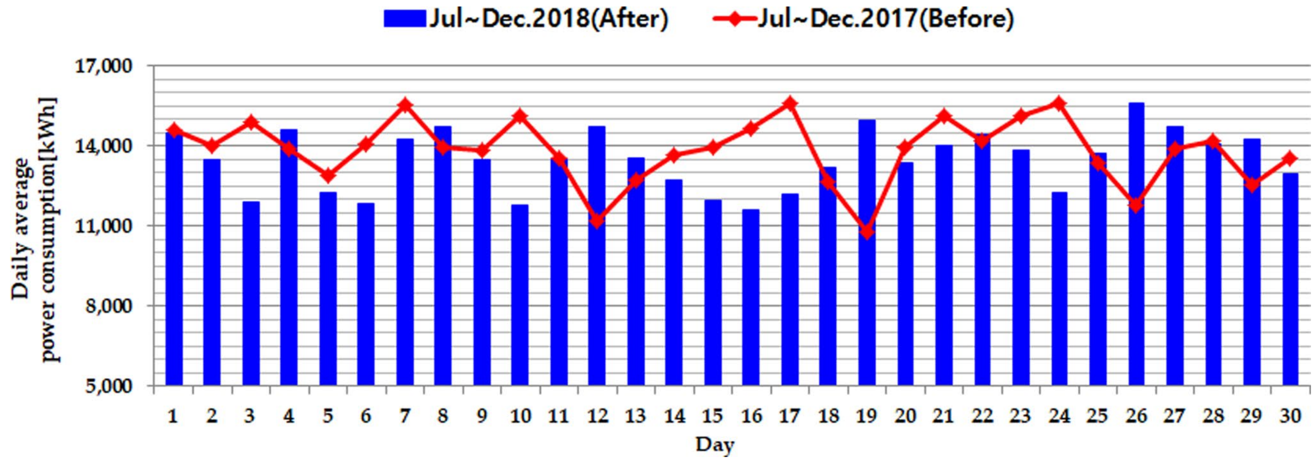


Fig. 13 Comparison of power consumption before and after BEMS application at site #2

Table 8 Comparison of power consumption before and after BEMS installation at site #2

	Total	Daily average
Before ('17.7.1–12.31)	414,775 kWh	13,825 kWh
After ('18.7.1–12.31)	404,131 kWh	13,471 kWh

is designed to control the Li-ion ESS operation for approximately 1000 people with a contracted power capacity of 6000 kW. Figure 9 illustrates the schematic diagram of a Li-ion ESS and the BEMS linking system. The Power Conversion System (PCS) has a rated capacity of 500 kW (250 kW × 2 types), and the ESS rated capacity is 571.8kWh, consisting of Bank 2 types, 12 racks, totaling 192 cells. The BEMS collects and controls the status information of these components.

The picture of the equipment actually connected is shown in Fig. 10. In the BEMS, communication and control functions were implemented in connection with PMS (PCS Management System). And the optimal condition of operational control in accordance with the run of PCS and ESS was derived, and the operation control algorithm was developed and applied according to the analysis of power consumption pattern of the building to be tested and the setting of power reduction target. At this time, management items such as bank/rack/tray/cell status information, SOC, SOH, power measurement information, and main power reception information are monitored. Also ESS charge/discharge operation control, charge/discharge amount setting, etc. can be controlled.

As shown in Table 2, the communication between BMS and PMS applied ModbusRTU protocol over RS485. And the communication between PMS and comprehensive BEMS server sends and receives data using TCP / IP communication method through Ethernet.

4.1 Effectiveness and Economic Analysis of the BEMS

Building Energy Management Systems (BEMS) were implemented in July 2018. To assess their impact, energy consumption data from July to December 2017 was compared to data from the same period in 2018. As shown in Fig. 11 and Table 3, average power consumption decreased by 15.9% after six months of BEMS operation.

In order to evaluate the economic savings effect of application of the BEMS, electricity cost was analyzed. As shown in Tables 4 and 5, the power rates for this case study are based on the ToU (Time of Use) tariff.

Electricity bills also saw a significant drop after BEMS installation in 2018, as illustrated in Fig. 12. For the July-December period, average electricity bills were 6,865,485 won and 7,490,812 won in 2016 and 2017, respectively. However, after BEMS implementation, the average bill dropped to 5,760,435 won, representing a 23.1% reduction (Table 6). Similarly, the maximum peak power decreased by 22%, from 322 to 252 kW (Table 7).

The second demonstration building also experienced a reduction in power consumption, as shown in Fig. 13 and Table 8. Figure 13 depicts a clear downward trend in average daily power usage after BEMS installation. Compared to the pre-BEMS period, total power consumption and average daily power consumption decreased by 2.6% (Table 8). However, unlike the first building, obtaining hourly power data before BEMS installation was challenging for the second building, preventing a comparison of maximum peak power changes.

5 Conclusion

In this paper, an integrated BEMS that monitors and controls electrical and thermal energy was developed and installed in a building to verify its performance. The proposed BEMS minimizes power consumption and increases use efficiency through the operation of ICT-based energy facilities. In addition, real-time energy use monitoring and remote services were provided by applying a web-based HMI, thereby increasing user convenience and operating efficiency of energy facilities. In the previous BEMS research paper, a complex energy optimization algorithm such as machine learning was applied to improve energy use efficiency. However, it is difficult to be commercialized because it costs too much to apply the existing methods. The proposed BEMS verified that it has an energy saving effect by applying a simple algorithm and a web-based HMI without applying a complex algorithm. These results indicate that the proposed method can be a practical solution for commercialization and universalization of BEMS.

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