A MICROGRID MODEL FOR THE INTEGRATED OPERATION OF HEAT AND ELECTRICITY

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ABSTRACT

This paper presents a model to operate the microgrid combined heat and electricity in DongShin University (DSU) campus, Korea. Since a relatively large amount of heat energy has been consumed in DSU, MG system is designed containing not only general energy-producing facilities but also the thermal storage tank. The usefulness of the facility that produces both heat and electricity would be raised through the function of the balancing operation in the proposed EMS. The operating modes of EMS have been diversified to enhance operational accuracy and to respond to specific situations. The proposed EMS is based on the operational purpose of saving electric energy's demand charge and reducing electricity and thermal energy usage rate. It is expected that the proposed MG model would contribute greatly to activation of various similar sites.

INTRODUCTION

For lots years we have been focused on the design of Microgrid (MG) system with such electricity resources as Gas Turbine (GT), Photovoltaic (PV), Wind Turbine (WT) and Battery Energy Storage System (BESS). The optimal operation of these resources can enhance the overall power system performance, if managed and coordinated efficiently using Energy Management System (EMS). According to the previous studies, the ESS that reflects the scenarios based on the tariff is tested.[1], and the methodology is proposed by hierarchical structure in office building.[2]. However, it can be difficult for MG operation to compete on cost alone if based on only electricity. Some energy resources such as Fuel Cells (FC), Combined Heat and Power-plant (CHP) involve production of heat, and reduce fuel costs and consumption, since the same fuel that produces the electricity and the heat. In this regard, the optimal operation of system that integrated heat and electricity is studied [3-7]. However, they are described focused on the methodology not a model considering the various characteristics of sites.

This paper introduces a MG model combined heat and electricity in Dong-Shin University (DSU) campus, Korea. DSU has a small size campus with 30 buildings and 8000 students, and two-thirds of the about 190 universities in Korea is similar in size. The site used about 14[TJ] of thermal and electrical energy in 2016, of which electrical energy is about 7[GWh] and its annual electricity peak is about 2.7[MW]. Since most students live in dormitories, a relatively large amount of heat energy, which is produced by Liquefied Natural Gas (LNG), is consumed.

In order to develop the suitable model to this site, this paper addresses as follows.

- MG site information
  - The scheme of energy tariffs applied to the DSU
  - MG system configuration in DSU
- EMS operating modes
  - Day-ahead scheduled mode
  - Real-Time scheduled mode
  - Manual mode
- Integrated operation algorithm
  - To reduce the demand charge
  - To reduce the energy charge

MG SITE INFORMATION

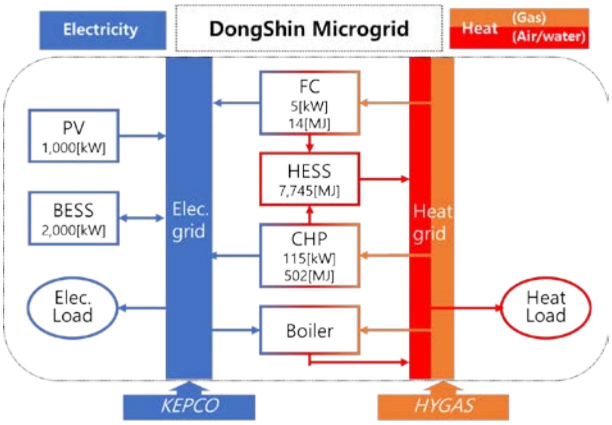
The scheme of energy tariffs applied to DSU site is as follows.

<Table. 1. Scheme of energy tariffs applied to DSU>

	Demand charge	Energy charge
LNG	-	Single (won/MJ)
Electricity	(won/kW)	TOU (won/kWh)

In Table 1, the cost for LNG is charged with the single rate [won/MJ] according to the energy consumption. On the other hand, the electricity bill is paid according to not only the energy usage [kWh] which is based on Time of Use (TOU) but also the peak demand [kW].

The MG system configuration that is integrated with the thermal and electrical elements for the DSU is shown in <Fig.1.>. This configuration and capacities for new facilities such as PV, BESS, FC, HESS and CHP were decided according to the feasibility study based on the historical energy-load data and <Table. 1.>.



<Fig. 1. MG system configuration for the DSU >

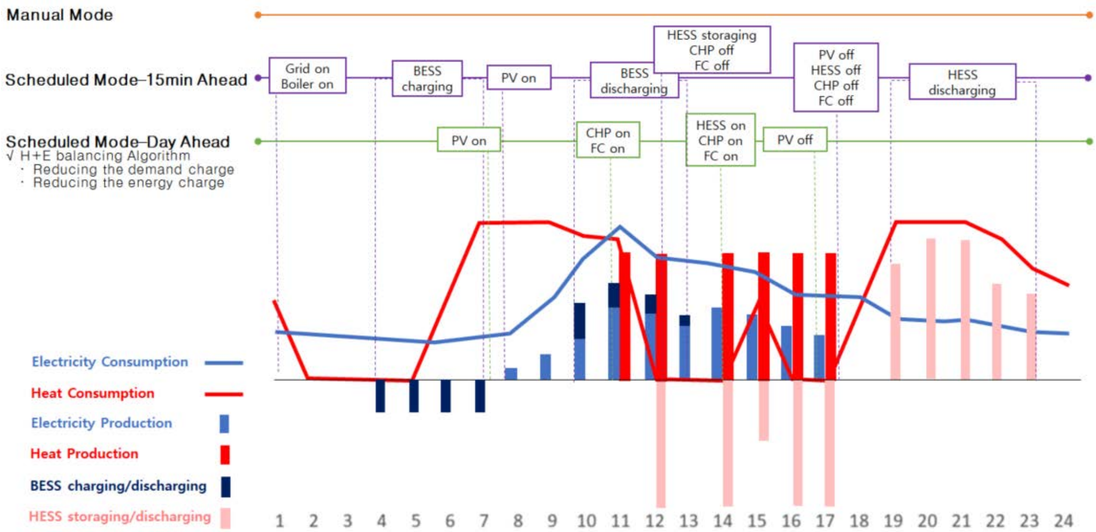
The electricity is supplied to the electrical load (every building) by PV, CHP, FC and KEPCO (Korea Electric Power Cooperation) and stored in BESS through the electricity grid. The heat grid includes both LNG pipes for heat production and air or water pipes for heat transfer, which is connected CHP, FC and HYGAS (HeaYang city Gas co.). The heat energy could be supplied to heat loads(some dormitories and office buildings) by FC, CHP and the heat grid, and stored in the thermal storage tank(Heat ESS; HESS). To more effectively operate with integrating heat and electricity, the DSU MG has BESS and HESS with adequate capacities. According to the feasibility study, the propose MG model could save 23% of heat and electric energy, and decrease the 20% of electrical peak demand, and achieve the 10% reduction of CO2 emission.

Since the system has an interdependence of heat and electricity facilities, the optimal operation of MG is a complex optimization problem that needs the elaborate functions of EMS.

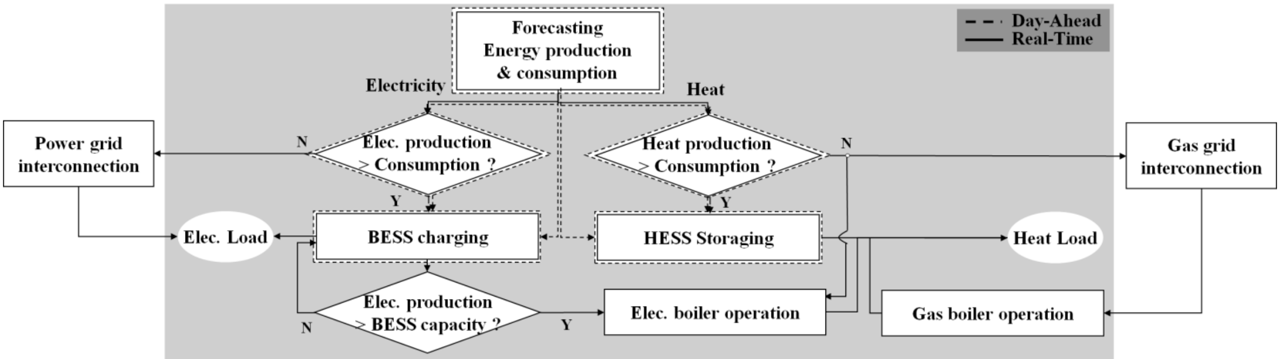
EMS OPERATING MODES

The operation concept of EMS for the DSU MG system that needed the integrated operation of heat and electricity is shown in <Fig.2.>. To solve the complex optimization problem effectively, EMS operating mode is divided into Day-Ahead Scheduled (DAS), Real-Time Scheduled (RTS), and Manual (M) mode.

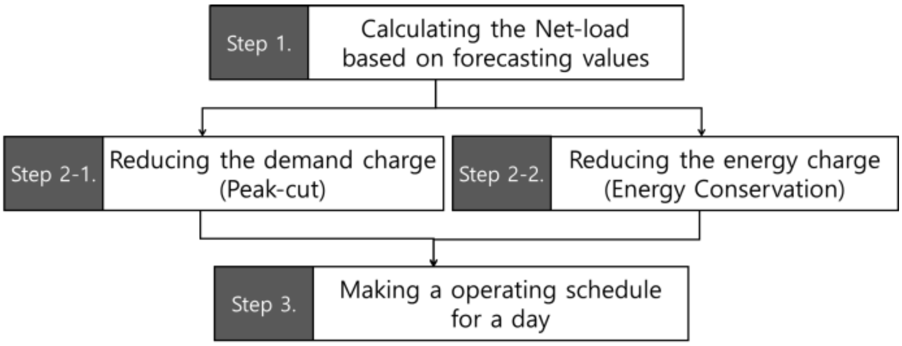
The operation schedule of EMS should be estimated considering the balancing heat and electricity. In other words, they are not managed separately. <Fig 3.> shows



<Fig. 2. Operating modes of EMS >



<Fig. 3. The flow chart for the scheduled modes>



<Fig. 4. The scheduling process of DAS mode >

the flow chart for in the scheduled (DAS and RTS) modes.

EMS estimates the operation schedule of facilities in DAS mode, and then corrects it in RTS mode to improve the accuracy of the schedule. It is similar to the economic dispatch process of Independent System Operator (ISO).

In DAS mode the energy amounts of facilities including BESS charging and HESS storaging are decided using the forecasting values, in order to secure the needed energy for operating goal. In RTS mode, based on the results of DAS mode, the operating values of facilities including the boiler of electricity and gas are determined, and the needed electricity could be supplied from KEPCO.

On the other hand, M mode has the function that the operator could control the EMS using manual command with the first priority. It is necessary to operate for the special situations such as the system emergency, the functional test, system maintenance and so on.

INTEGRATED OPERATION ALGORITHM

This paper addresses optimal day-ahead scheduling algorithm for DAS mode in the proposed EMS considering the integrated operation of heat and electricity. The process could be summarized as shown in <Fig 4.>.

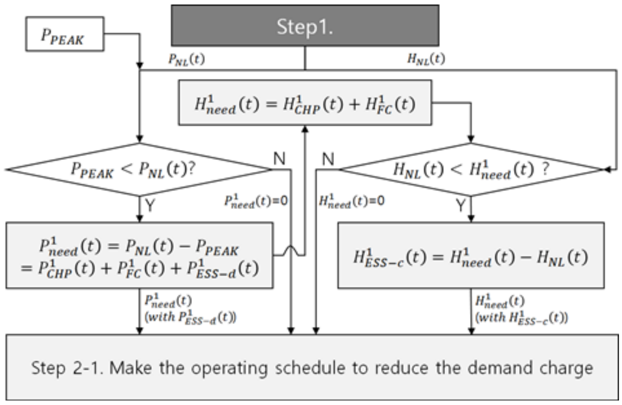
In this figure, Step1 could calculate the net loads (P_{NL}, H_{NL}) using the heat load (H_{Load}), the electricity load(P_{Load}) and non-controllable facilities(P_{NC}, H_{NC}) as follows.

$$P_{NL}(t) = P_{Load}(t) - P_{NC}(t) \tag{1}$$
$$H_{NL}(t) = H_{Load}(t) - H_{NC}(t) \tag{2}$$

Where, DSU MG only has the PV(P_{PV}) that is a non-controllable facility.

DAS mode takes into account the amount and cost of electricity required and tracks the production-consumption of heat. This is because it enables efficient utilization of CHP and FC, which generate heat at the same time when producing electricity, and also could operate the electricity and gas boiler.

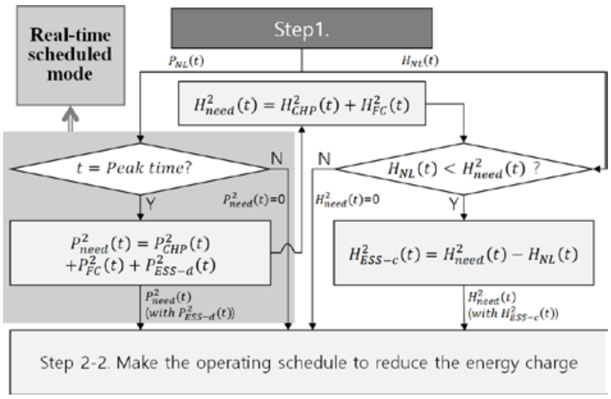
The flow chart of Step 2-1 for peak-cut is as follows.



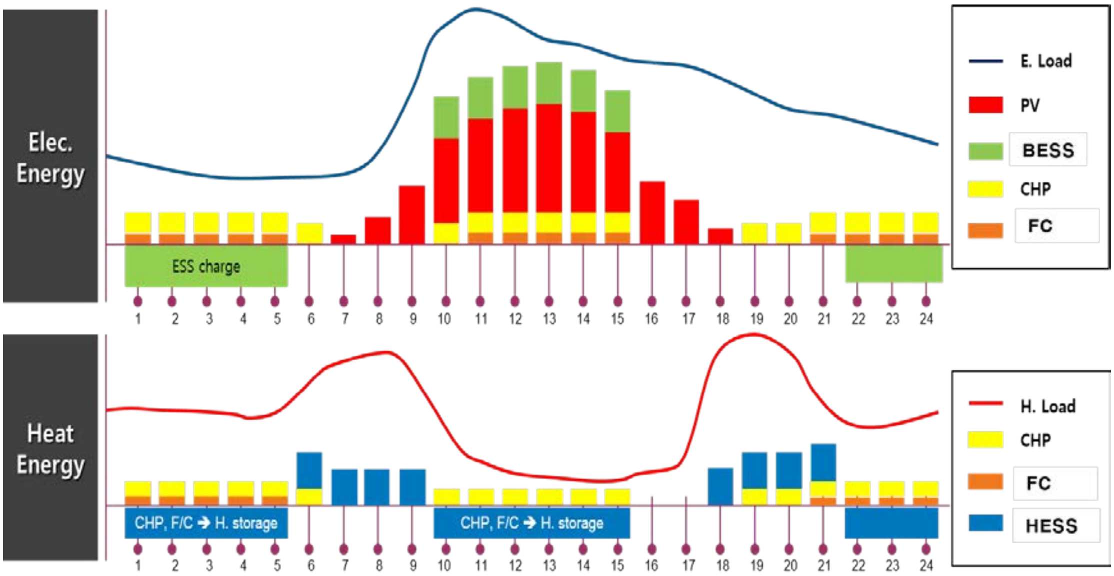
<Fig. 5. Flow chart of Step2-1 for peak-cut >

In <Fig 5.>, the amount of electricity production ($P^1_{CHP}(t)$, $P^1_{FC}(t)$, $P^1_{ESS-d}(t)$) is decided by comparing the net load($P_{NL}(t)$) and peak demand(P_{PEAK}), which could be variously set considering methods of demand forecasting and capacity of facilities in the site. HESS storaging energy($H^1_{ESS-c}(t)$) is decided by comparing the net load($H_{NL}(t)$) and the heat energy($H^1_{CHP}(t)$, $H^1_{FC}(t)$) produced by the CHP and FC. This is efficient method for reducing the demand charge as well as energy charge of heat.

The flow chart of Step2-2 for energy-conservation is as follows.



<Fig. 6. Flow chart of Step2-1 for energy conservation>



<Fig. 7. An example of the heat and electricity integrated operation in DAS mode of EMS for 24 hours >

In <Fig 6.>, the amount of electricity production ($P^2_{CHP}(t)$, $P^2_{FC}(t)$, $P^2_{ESS-d}(t)$) could be estimated using the value at the peak time in TOU tariff with the largest variation of electrical energy charge. This is the operating method of the DAS mode, and its value is corrected by RTS mode according to the electricity and heat tariff.

These Schedules made by Step 2-1 and Step 2-2 could be utilize the integrated operating schedule, through the Step 3. The final schedule in DAS mode could be set as follows by selecting the maximum value.

$$P^{sch.}_{need}(t) = \text{Max.}\ (P^1_{need}(t), P^2_{need}(t)) \quad (3)$$

$$H^{sch.}_{need}(t) = \text{Max.}\ (H^1_{need}(t), H^2_{need}(t)) \quad (4)$$

<Fig.7.> shows an example of balancing the two different energy resources using the HESS and BESS. The results were performed with the proposed algorithm in DAS mode.

CONCLUSION

This paper is described a MG model for DSU campus which has various energy load types. The model includes the general generation facilities with BESS as well as CHP, FC, and HESS which is operated with heat and electricity, simultaneously. The proposed EMS was configured to operate based on day-ahead and real-time scheduled modes for the integrated operation of heat and electricity. Also, the method of reducing the demand charge through peak reduction and the energy charge reduction method considering the characteristics of the TOU scheme are presented for the day-ahead scheduling. Finally, an example of the heat and electricity integrated operation in DAS mode of EMS for 24 hours is illustrated numerically.

Potential future works may include developing the algorithm for RTS mode, and then modifying the model using the operational track records in DSU MG.

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