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Thermal and Electrical Energy Mix Optimization(EMO) Method for Real Large-scaled Residential Town Plan

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Abstract – Since Paris Climate Change Conference in 2015, many policies to reduce the emission of greenhouse gas have been accelerating, which are mainly related to renewable energy resources and micro-grid. Presently, the technology development and demonstration projects are mostly focused on diversifying the power resources by adding wind turbine, photo-voltaic and battery storage system in the island-type small micro-grid. It is expected that the large-scaled micro-grid projects based on the regional district and town/complex city, e.g. the block type micro-grid project in Daegu national industrial complex will proceed in the near future. In this case, the economic cost or the carbon emission can be optimized by the efficient operation of energy mix and the appropriate construction of electric and heat supplying facilities such as cogeneration, renewable energy resources, BESS, thermal storage and the existing heat and electricity supplying networks. However, when planning a large residential town or city, the concrete plan of the energy infrastructure has not been established until the construction plan stage and provided by the individual energy suppliers of water, heat, electricity and gas. So, it is difficult to build the efficient energy portfolio considering the characteristics of town or city. This paper introduces an energy mix optimization(EMO) method to determine the optimal capacity of thermal and electric resources which can be applied in the design stage of the real large-scaled residential town or city, and examines the feasibility of the proposed method by applying the real heat and electricity demand data of large-scale residential towns with thousands of households and by comparing the result of HOMER simulation developed by National Renewable Energy Laboratory(NREL).

Keywords: Energy utilization plan, Energy mix optimization, Energy portfolio, Thermal and electric energy, Large scale residential town

1. Introduction

Microgrid is a group of interconnected loads and distributed energy resources(DERs) in such a way that the energy supply meets the local energy demand in the energy network. And it can connect and disconnect from the main energy grid in both grid-connected and isolated modes.

Department of Energy(DOE) of USA categorizes the microgrid into utility model, landlord model, co-operation model, customer-generator model and district heating model according to the ownership of facilities[1-2]. Among them, district heating model is a microgrid system owned and managed by a company to meet the electric and heat energy demand using its own energy network which is very similar to Integrated Energy Supply(IES) business in Korea[3]. IES is a service for the district energy utility to supply and sell the heat and electricity made by the energy generation facilities like combined heat and power(CHP) stations, renewable energy sources(RES) to residential, industrial and commercial customers in the local district. Through IES, the district heat and electric energy can be used more efficiently, resulting on the reduction of customer's economic burden of heat and electric charges. Moreover, it can partially contribute the reduction of greenhouse gas emission [4-7]. However, it is difficult to design and install the energy supply facilities considering its own urban characteristics, because, in general, the construction plan of local energy facilities is not conducted in the step of district unit planning.

In paper [8-15], the researches to solve the above problem have been carried out these day. In the previous study [8], an optimal operating method of CHP and ESS based on Lagrangian was introduced and the chance of its real commercial operation was reviewed. Dynamic programming-based algorithm for IES operation was proposed by the reference [9]. And another optimal operating strategy of micro-CHP and electric vehicle(EV) based on the mixed integer linear programming to balance the supply and demand of power and heat energy was introduced in [10]. Heat and electric energy are supplied to fit the indoor temperature within the available range by using GAMS software and CPLEX solver in [11].

In this paper, we focus on an optimization algorithm for

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energy mix determining the optimal capacities of generators and storages in both electricity and heat which can be applied in the stage of energy utilization plan. CHP, Heat Only Boiler(HOB), Thermal Energy Storage(TES) and Energy Storage System(ESS) are considered as energy supplying utilities. And the simulation result of our algorithm on the real large-scale residential town will be compared with that of HOMER. Simulations are divided into 2 steps. At the first step, a local energy system without TES will be simulated and compared, because HOMER does not provide TES model of thermal network. From the simulation, we compare the results between HOMER and our optimization method in case of an energy network without TES only. At the next step, we conduct a simulation to determine the capacities of heat and electric generators and storages containing TES by using our optimization method.

2. Conditions Analysis of Energy Mix Modeling

2.1 General status of IES

IES is an energy business that supplies and sells energy produced by one or more energy production facilities to a large number of users in the residential, commercial and industrial complex. The energy production facilities include cogeneration(Combined Heat and Power, CHP) plant, HOB, resource recovery facility, and so on. The heat produced is supplied to the customers and the power generated is returned to KEPCO. The business of IES is divided into the district heating and cooling(DHC) business, the industrial sector IES and the concurrent service. DHC is a business that supplies heat and hot water to the residential and commercial customers except for industrial buildings, and the industrial sector IES is a business that supplies the thermal energy to industries for the process use. The concurrent service is a combination of DHC and industrial sector IES.

2.2 District energy model

The simulation area is an actual residential town located near the metropolitan area in the urban planning stage. For the simulation town shown in Fig. 1., the maximum heat load, heat use and thermal density are expected as 290.57 Gcal/h, 743,550.2 Gcal/y and 42.8Gcal/km$^2 \cdot$h, respectively. Through this study, we determine the optimal capacity of each energy facility to meet heat and electricity demands in this region. The heat load is supplied by CHP, HOB and TES and the electric load is supplied by CHP, PV, ESS and main power system.

Fig. 1. Real residential town for the energy simulation

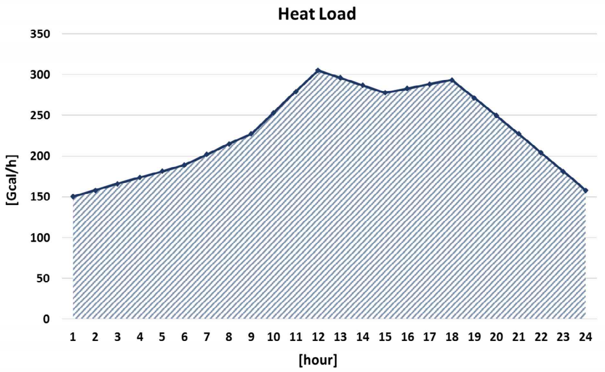

Fig. 2. Daily pattern of heat load in winter

The simulation is performed for a day of January in winter season when the maximum heat load occurs. And the thermal load of the district is based on the energy demand forecast data of the energy use plan. Generally, in the energy use plan, the modified bin method is used to divide total 8,760 hours of annual data into 3 hours and the thermal demand is estimated by using the average air temperature, the temperature differences between indoor and outdoor and the unit heat load. Deign outside temperature is based on the regulation on establishing and consulting procedure of energy use plan and energy conservation design criteria for buildings. The calculated heat demand and maximum thermal load is 832,916.4 Gcal/y and 305.15 Gcal/h, respectively, on the basis of the saturation year (2020). Saturation year means the year when 100% occupancy of residential, commercial, business and public facilities are achieved. Fig. 2. shows a daily pattern of heat load in winter season.

All electric loads in the area are supplied only by IES resources and the power demand forecast data is based on the energy use plan. In the energy use plan, the electric load is forecasted by the standard load method in (1), bases on loads per unit area and the motor load is forecasted by the linear regression analysis based on the motor load profile of residential building. F_C, L_U, A_O and L_A mean facility capacity, unit load, occupancy area and additional load, respectively.

$$FC\,[kVA] = L_U\,(VA/m^2) \times A_O\,(m^2) + L_A\,(VA/m^2) \qquad (1)$$

On the basis of 2020, Annual electric load is calculated

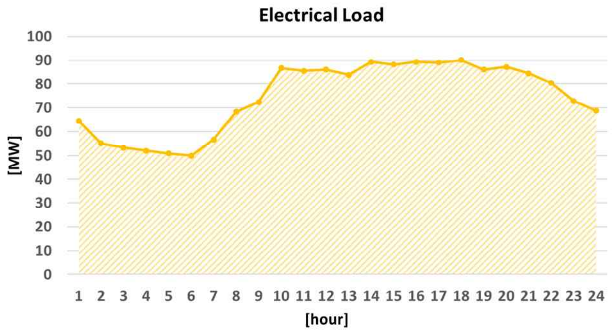

Fig. 3. Daily pattern of electric load in winter

as 719,229 MWh/y and the corresponding transformer capacity is 202,793kVA when considering a lagging power factor of 0.9 and a diversity factor of 1.3. Fig. 3. shows a daily pattern of electric load in winter season.

2.3 Simulation condition of CHP

According to the enforcement decree of Integrated Energy Supply Act, the amount of heat production in DHC should be more than 5Gcal/h except the self-consumption. And IES provider supplying both heat and electricity should have a thermal production capacity greater than the electricity production capacity, which means that the heat-electric power ratio(HER) must greater than 1.0. The maximum HER of CHP used in our study is calculated as 1.538 when considering a total CHP's efficiency of 75~90% and an electricity production efficiency of 30~ 40%. Although the LNG-fueled CHP is not constrained by HER criteria, we simulate it as a general CHP with HER of 1.867. Its capacity is determined by the maximum thermal load. We design the unit so that it can meet more than 60% of the maximum heat load, in order to operate CHP efficiently.

Main efficiency data of CHP are calculated by (2)-(5) [15].

Q_H, Q_E and Q_T mean heat production calorie(A), electricity production calorie(B) and fuel calorie(C), respectively. η_P, η_H, η_T mean electricity efficiency, heat efficiency and total efficiency of CHP, respectively.

$$\eta_P\,[\%] = \frac{Q_E\,(B)}{Q_T\,(C)} \tag{2}$$

$$\eta_H\,[\%] = \frac{Q_H\,(A)}{Q_T - Q_E\,(C-B)} \tag{3}$$

$$\eta_T\,[\%] = \frac{Q_E + Q_H\,(A+B)}{Q_T\,(C)} \tag{4}$$

$$HER[\%] = \frac{Q_H\,(A)}{Q_E\,(B)} \tag{5}$$

The operation mode of CHP can be divided into 2 modes according to the method of supplying heat and electricity from the power plant. One is heat load following mode and the other is electric load following mode. Heat load following mode is a method mainly used for district heating in winter. In this mode, it can supply the electricity generated by operating a back-pressure turbine by injecting the steam and also the heat energy with the exhaust steam. Electric load following mode concentrates mainly on electricity production in summer when the thermal load is little needed [16].

In this paper, the heat load following mode is used, because the simulation is performed for a day of January.

2.4 Simulation condition of ESS

The capacity of ESS is determined according to the guideline of ESS installation for public institute. The guideline requires that the PCS of ESS corresponding to 5% of the contract demand power should be installed for the public customers of which the contract demand is greater than 1,000kW.

Since the contract capacity of individual buildings are not known in the stage of energy supply plan, the capacity of ESS is estimated based on the transformer installation capacity of 202,793kVA so that we use ESS of 10.14MWh in this simulation.

2.5 Simulation condition of TES

TES is a hot water storage tank that can store the remaining heat after supplied to the customers. The fuel cost of TES changes according to the output changes of the cogeneration unit and HOB due to heat charging and discharging performance of TES. Therefore, the ramp rate setting is critical for the charging and discharging schedule and the capacity calculation of TES.

In this study, the heat flow is calculated and the unit conversion is performed, considering the pressure, piping diameter and flow rate when the energy is transferred from the constant-pressure regulation station to the district pressure regulators. As a result, the ramp rate of TES is set to about 105 Gcal/h.

2.6 Setting for economic analysis

To estimate the optimum capacity of the heat supply System Preferences facilities, the fuel cost shown in Table 1 and the electricity cost of each supply facility are used.

Each rate is calculated considering information on the wholesale rates and the supply capacity of CHP and HOB

Table 1. Parameters for economic analysis

Parameter	Value	Units
Supply calorie	10,141	kcal/Nm^2
CHP fuel cost	570.81	₩/m^3
Boiler fuel cost	646.9	₩/m^3

facilities provided by KOGAS on March 1, 2017. Nominal discount rate, real discount rate, inflation rate and project life for HOMER simulation are set as 3%, 2.28%, 0.75% and 25 years, respectively.

3. Method for Optimal Energy Mix

3.1 Energy Mix Optimization(EMO) process

Object function and constraints for energy mix optimization (EMO) method are as follows.

- Objective function:

$$\min\left\{\sum_{h=1}^{24}\left(C_{CHP}\times\frac{P_{CHP,h}}{\eta_{CHP}}+C_{Boil}\times\frac{P_{Boil,h}}{\eta_{Boil}}+C_{Elec,h}\times P_{Grid,h}\right)\right\} \tag{6}$$

- Common Constraints:

$$\begin{aligned} &CHP_{\min}\le P_{CHP,h}\le CHP_{\max}\\ &SOC_{\min}\le ESS_{SOC,h}\le SOC_{\max}\\ &0\le P_{ESS,h}^{char},\ P_{ESS,h}^{dischar}\le ESS_{PCS} \end{aligned} \tag{7}$$

- Constraints for Electricity load following mode:

$$\begin{aligned} &L_{elec,h}=\frac{P_{CHP,h}}{HER}+P_{Grid,h}+P_{ESS}^{dischar}\\ &L_{heat,h}\le P_{CHP,h}+P_{Boil,h} \end{aligned} \tag{8}$$

- Constraints for Heat load following mode:

$$\begin{aligned} &L_{heat,h}=P_{CHP,h}+P_{Boil,h}\\ &L_{elec,h}\le\frac{P_{CHP,h}}{HER}+P_{Grid,h}+P_{ESS}^{dischar} \end{aligned} \tag{9}$$

- Other Constraints including TES:

$$\begin{aligned} &\sum_{h=1}^{24}\left(P_{CHP,h}+P_{Boil,h}+P_{TES}^{dischar}-L_{heat,h}\right)=0\\ &L_{elec,h}\le\frac{P_{CHP,h}}{HER}+P_{Grid,h}+P_{ESS}^{dischar} \end{aligned} \tag{10}$$

The objective function of EMO is to minimize the sum of fuel costs of CHP, boiler and electricity supplied from the main grid. $P_{CHP,h}$, $P_{Boil,h}$ and $P_{Grid,h}$ mean the outputs [Gcal] of CHP, boiler and the grid power supply[MW] at time h, respectively. η_{CHP} and η_{Boil} mean the total efficiency of CHP and Boiler. C_{CHP} and C_{Boil} are the fuel cost [₩/Mcal] of CHP and HOB. $C_{elec,h}$ is an electricity charge called TOU (Time of Use) at winter season in this study.

The operating range of CHP is set to 60 ~ 90% of its installation capacity at the maximum load status. State of Charge(SoC) and the charge/discharge efficiency of ESS is set to 0 ~ 100% and 90%, respectively. Maximum charge and discharge capacity of ESS, P_{ESS}^{char} and $P_{ESS}^{dischar}$, are limited by the rated power of PCS(ESS_{PCS}). $L_{heat,h}$ and $L_{elec,h}$ mean heat and electric loads at time h. In the electricity load following mode, the sum of electric outputs should be equal to the quantity of electric loads and the heat generation by CHP and boiler should be greater than the heat load quantity. In the heat load following mode, the sum of heat outputs should be equal to the quantity of heat loads and the electric generation by CHP, grid and ESS should be greater than the electric load quantity. In case of the heat load following mode including TES, the different constraint should be applied, which makes the sum of hourly heat generations by CHP, boiler and TES equal to the hourly heat load.

3.2 HOMER Simulation

HOMER(Hybrid Optimization model for Multiple Energy Resources) is an economic analysis program developed by NREL of DOE. It can evaluate economics of a microgrid by comparing the hourly energy flow of resources with initial investment cost, substitution cost, maintenance cost, etc.

In this study, we compose an electricity-heat hybrid system in HOMER as shown in Fig. 4.

The system is divided into 2 parts: electricity and heat. Electric part consists of grid, ESS, PV, ESS and CHP.

For electricity from a grid, TOU is applied and the contract capacity is used as the maximum incoming power. PV is used as much as the scheduled amount at the energy supply plan. With the PV capacity, hourly PV generation is calculated by considering the temperature and environmental conditions in the district and the final hourly electric demand is determined by subtracting it from the total hourly electric demand. Therefore, ESS, power grid and some parts of CHP generation will cover the rest of the electricity demand excluding the local PV output.

In HOMER, the heat load is provided only by CHP and HOB with the electricity load following mode, regardless of the season. Based on the electric load, the output of

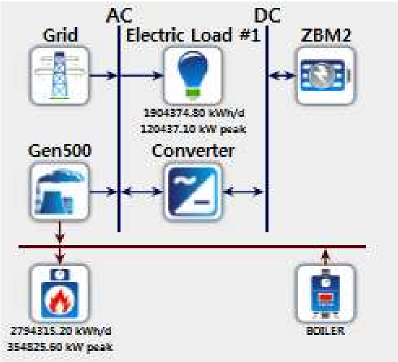

Fig. 4. Electricity-heat hybrid system for HOMER simulation

CHP is determined preferentially and the rest of output is supplied to the heat load according to the heat recovery rate. HOB is simply driven to cover the rest of heat load by CHP. Furthermore, HOMER does not provide TES models. So, we cannot directly compare our optimization result applying the heat load following mode and TES with the HOMER's simulation.

In the case study, we will assume the energy mix optimization(EMO) process of the electricity load following mode without TES at first. And it will be compared with HOMER simulation. Then the EMO model will be applied to the real case of the large-scale residential town with TES and electricity load following mode.

4. Simulation Results

4.1 Comparison with HOMER simulation for electricity load following mode

Table 2 and 3 show the hourly operation schedule and optimal capacity of each energy facility which are obtained from the result of HOMER, respectively. And fig. 5. describes the hourly status of them. As mentioned earlier, this is simulated with the electricity load following mode.

Table 4, 5 and Fig. 6. show the hourly operation schedule and optimal capacity of each energy facility by using EMO model simulated with MATLAB, respectively.

In the case of HOMER, the optimal capacity of CHP and HOB is 190 Gcal/h and 142 Gcal/h, respectively, so that the electricity generation by CHP and the discharge amount of ESS can meet the electric demands. And the optimal capacity of CHP and HOB is determined as 188 Gcal/h and 143 Gcal/h by EMO model. As with HOMER, the total

Table 2. HOMER simulation results on hourly scheduling and total energy cost

hr	Grid	CHP		HOB	ESS		
		elec	heat		char	disch	SOC
	MW	MW	Gcal	Gcal	MW	MW	MWh
1	0.00	65.39	127.90	22.28	1.02	0.00	0.91
2	0.00	65.39	127.90	30.09	2.78	0.00	3.41
3	0.00	65.39	127.90	37.89	2.78	0.00	5.91
4	0.00	65.39	127.90	45.70	2.78	0.00	8.41
5	0.00	65.39	127.90	53.51	1.64	0.00	9.89
6	0.00	65.39	127.90	61.31	0.36	0.00	10.21
7	0.00	65.39	127.90	74.01	0.08	0.00	10.28
8	0.00	68.31	132.99	81.61	0.00	0.00	10.28
9	0.00	72.34	140.02	87.27	0.00	0.00	10.28
10	0.00	86.73	165.10	88.14	0.00	0.00	10.28
11	0.00	85.56	163.07	116.13	0.00	0.00	10.28
12	0.00	86.09	164.00	141.15	0.00	0.00	10.28
13	0.00	83.86	160.10	135.96	0.00	0.00	10.28
14	0.00	89.35	169.67	117.30	0.00	0.00	10.28
15	0.00	88.24	167.74	110.14	0.00	0.00	10.28
16	0.00	89.38	169.72	113.35	0.00	0.00	10.28
17	0.00	89.00	169.06	119.19	0.00	0.00	10.28
18	0.00	90.11	170.99	122.44	0.00	0.00	10.28
19	0.00	86.11	164.02	107.40	0.00	0.00	10.28
20	0.00	87.26	166.03	83.38	0.00	0.00	10.28
21	0.00	84.48	161.18	66.22	0.00	0.00	10.28
22	0.00	75.99	146.38	57.85	0.00	4.50	5.28
23	0.00	72.79	140.81	40.27	0.00	0.00	5.28
24	0.00	68.75	133.76	24.15	0.00	0.00	5.28
				Elec Purchase		₩ 0	
				Fuel Cost		₩371,813,379	
				Total Cost		₩371,813,379	

Table 3. HOMER simulation results on Optimal capacity of energy resources

	Heat		Electricity	
	CHP [Gcal/h]	HOB [Gcal/h]	ESS [MWh]	Grid [MW]
Optimal Capacity	190	142	10.28	0
Energy Supply ratio	57%	43%	100%	0%

Table 4. EMO model results on hourly scheduling and total energy cost

hr	Grid	CHP		HOB	ESS		
		elec	heat		char	disch	SOC
	MW	MW	Gcal	Gcal	MW	MW	MWh
1	0.00	65.39	122.06	28.12	1.02	0.00	0.91
2	0.00	65.39	122.06	35.92	2.78	0.00	3.41
3	0.00	65.39	122.06	43.73	2.78	0.00	5.91
4	0.00	65.39	122.06	51.54	2.78	0.00	8.41
5	0.00	65.39	122.06	59.34	1.76	0.00	10.00
6	0.00	65.39	122.06	67.15	0.00	0.00	10.00
7	0.00	65.39	122.06	79.84	0.00	0.00	10.00
8	0.00	69.31	129.38	85.22	0.00	0.00	10.00
9	0.00	73.34	136.91	90.38	0.00	0.00	10.00
10	0.00	87.73	163.76	89.48	0.00	0.00	10.00
11	0.00	83.31	155.52	123.68	0.00	2.50	7.50
12	0.00	87.09	162.57	142.58	0.00	0.00	7.50
13	0.00	84.86	158.41	137.65	0.00	0.00	7.50
14	0.00	90.35	168.65	118.32	0.00	0.00	7.50
15	0.00	89.24	166.59	111.29	0.00	0.00	7.50
16	0.00	90.38	168.70	114.36	0.00	0.00	7.50
17	0.00	86.75	161.93	126.32	0.00	2.25	5.00
18	0.00	87.86	164.00	129.43	0.00	2.25	2.50
19	0.00	83.86	156.53	114.89	0.00	2.25	0.00
20	0.00	88.26	164.76	84.65	0.00	0.00	0.00
21	0.00	85.48	159.56	67.84	0.00	0.00	0.00
22	0.00	81.49	152.12	52.12	0.00	0.00	0.00
23	0.00	72.79	135.88	45.19	0.00	0.00	0.00
24	0.00	68.75	128.33	29.58	0.00	0.00	0.00
				Elec Purchase		₩ 0	
				Fuel Cost		₩372,312,489	
				Total Cost		₩372,312,489	

Table 5. EMO model results on optimal capacity of energy resources

	Heat		Electricity	
	CHP [Gcal/h]	HOB [Gcal/h]	ESS [MWh]	Grid [MW]
Optimal Capacity	188	143	10	0
Energy Supply ratio	57%	43%	100%	0%

cost is same as the fuel cost since no power is supplied through the main power system.

The HOMER and EMO operation schedules are very similar as shown in Fig. 4. and Fig. 5. The biggest difference between the two results is the operation schedule of ESS. In HOMER, the maximum charge and discharge of ESS is effected by some constraints of maximum charge current, kinetic storage model and maximum chargeable capacity, which are the battery's own characteristics. It is expected that this will not cause a critical issue even if they are not included in EMO model because these parameters are not set in the energy supply planning stage.

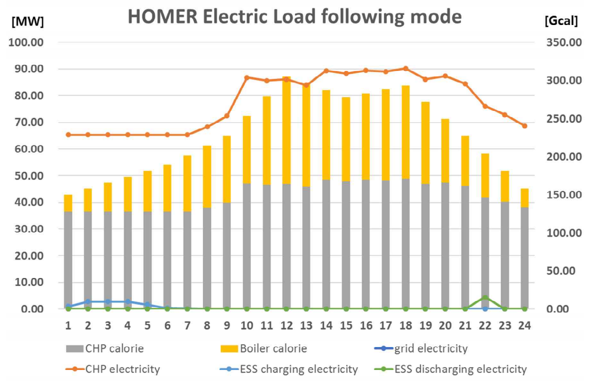

Fig. 5. Hourly status of energy facilities from HOMER simulation by electricity load following mode

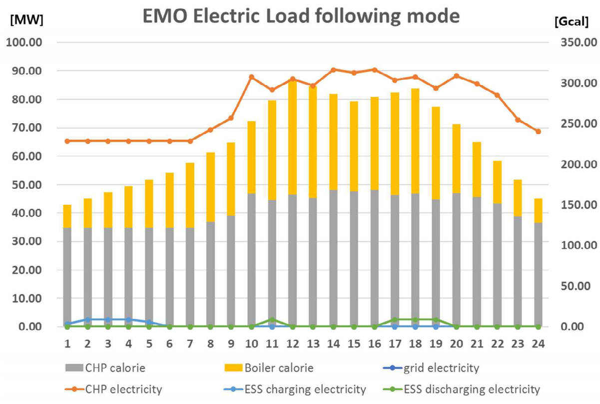

Fig. 6. Hourly status of energy facilities from EMO model by electricity load following mode

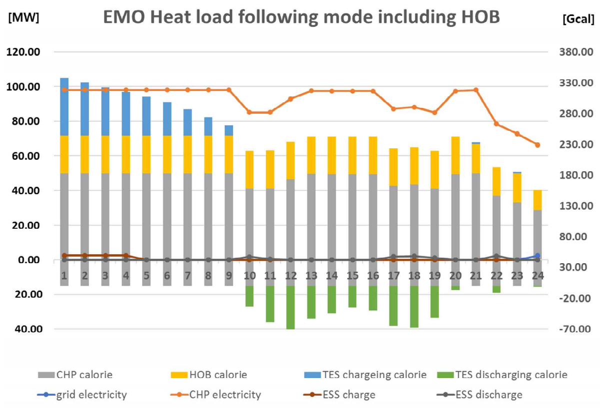

Fig. 7. Hourly status of energy facilities from EMO model by heat load following mode including TES

4.2 EMO simulation for real residential town

Table 6 and 7 show the simulation result by EMO model for the heat load following mode including TES.

From EMO model simulation, the capacity of CHP, HOB, TES is determined as 204 Gcal/h, 61 Gcal/h and 523 Gcal/h, respectively. And the electric power is supplied from a main power during only 1hour when the power stored in ESS is depleted. From the schedule graph shown in Fig. 7., the surplus heat output of CHP and HOB is

Table 6. EMO model results on hourly scheduling and total energy cost for the heat load following mode with TES

hr	Grid	CHP		HOB	TES			ESS		
		elec	heat		CH	DC	SOC	CH	DC	SOC
	MW	MW	Gcal	Gcal	Gcal	Gcal	Gcal	MW	MW	MWh
1	0.00	98.08	183.09	61.13	94.04	0.00	94.04	2.78	0.00	2.50
2	0.00	98.08	183.09	61.13	86.23	0.00	180.27	2.78	0.00	5.00
3	0.00	98.08	183.09	61.13	78.43	0.00	258.70	2.78	0.00	7.50
4	0.00	98.08	183.09	61.12	70.62	0.00	329.32	2.78	0.00	10.00
5	0.00	98.08	183.09	61.20	62.88	0.00	392.20	0.00	0.00	10.00
6	0.00	98.08	183.09	61.12	55.00	0.00	447.20	0.00	0.00	10.00
7	0.00	98.08	183.09	61.20	42.38	0.00	489.58	0.00	0.00	10.00
8	0.00	98.08	183.09	61.13	29.62	0.00	519.21	0.00	0.00	10.00
9	0.00	98.08	183.09	61.09	16.89	0.00	536.09	0.00	0.00	10.00
10	0.00	85.08	158.82	60.82	0.00	33.60	502.49	0.00	1.65	8.17
11	0.00	85.14	158.93	60.84	0.00	59.43	443.06	0.00	0.42	7.70
12	0.00	92.86	173.34	60.82	0.00	70.99	372.08	0.00	0.00	7.70
13	0.00	97.61	182.21	60.84	0.00	53.02	319.06	0.00	0.00	7.70
14	0.00	97.46	181.93	60.84	0.00	44.19	274.87	0.00	0.00	7.70
15	0.00	97.46	181.93	60.82	0.00	35.12	239.74	0.00	0.00	7.70
16	0.00	97.46	181.93	60.82	0.00	40.31	199.43	0.00	0.00	7.70
17	0.00	87.21	162.79	60.82	0.00	64.63	134.80	0.00	1.79	5.72
18	0.00	88.12	164.48	60.82	0.00	68.13	66.67	0.00	1.99	3.50
19	0.00	85.00	158.67	60.82	0.00	51.93	14.74	0.00	1.1	2.28
20	0.00	97.46	181.93	60.81	0.00	6.66	8.07	0.00	0.00	2.28
21	0.00	98.08	183.09	47.31	3.00	0.00	11.07	0.00	0.00	2.28
22	0.00	78.44	146.42	46.74	0.00	11.07	0.00	0.00	2.05	0
23	0.00	72.79	135.88	47.00	1.81	0.00	1.81	0.00	0.00	0
24	2.39	66.36	123.87	32.24	0.00	1.81	0.00	0.00	0.00	0
					Electricity Purchase			₩ 145,982		
					Fuel Cost			₩ 368,838,486		
					Total Cost			₩ 368,984,468		

Table 7. EMO model results on Optimal capacity of energy resources for the heat load following mode with TES

	Heat			Electricity	
	CHP [Gcal/h]	HOB [Gcal/h]	TES [Gcal/h]	ESS [MWh]	Grid [MW]
Optimal Capacity	204	61	523	10	3
Energy Supply ratio	26%	8%	66%	77%	23%

stored at TES while the heat load is relatively small. And the TES discharges the stored thermal energy when the heat load increases, which makes the energy supply efficiency high.

In the electricity load following mode, the output of HOB fluctuates a lot from 24 to 142 Gcal/h. On the other hand, it changes less from 32 to 60 Gcal/h and the capacity of HOB also decreases in the heat load following mode.

The heat load following mode has lower fuel and total energy cost than the electric load following mode, and the HOB capacity is reduced.

5. Conclusion

As the interest in greenhouse gas reduction and eco-friendly energy resource increases, a hybrid microgrid which can provide both electric and heat energies is also getting the spotlight. Now, IES is an energy supplying service for the district energy utility to supply and sell the heat and electricity made by the energy generation facilities like CHP and RES to residential, industrial and commercial customers in the local district. For the actual construction of the energy saving district, it is necessary to design the efficient energy supply plan coping with the expected energy demands. Therefore, this paper is written to suggest an energy mix optimization(EMO) method to determining the optimum capacity of the energy supply facilities by using CHP, HOB, TES, ESS and grid power, based on the real case of large-scaled residential town. And the result is compared with the HOMER simulation. The EMO model can be efficiently and simply used in the initial stage of energy supply planning. More sophisticated and concrete methods of energy implementation appropriate for each construction stage should be devised through the next studies. Also, it is necessary to be supplemented with the advanced research to set up the regular planning process applicable for an optimal energy mix by using the actual energy operation data.

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