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The Optimal Operation of Distributed Generation Possessed by Community Energy System Considering Low-Carbon Paradigm

Hun Shim, Sung-Yul Kim and Jin-O Kim

Abstract**-- By development of renewable energy and high-efficient facilities under the environment of deregulated electricity market, the operation cost of distributed generation(DG) becomes more competitive. Also, international environmental regulations of the leaking carbon become effective to keep pace with the global efforts for low-carbon paradigm. These contribute to spread out the business of DG. Therefore, the operator of DG is able to supply electric power to customers who are connected directly to DG as well as loads that are connected to entire network. In this situation, community energy system(CES) having DGs is recently a new participant in the energy market.**

DG's purchase price from the market is different from the DG's sales price to the market due to the transmission service charges and etc. Therefore, CES who owns DGs has to control the produced electric power per hourly period in order to maximize the profit. Considering the international environment regulation, CE newly will be an important element to decide the marginal cost of generators as well as the classified fuel unit cost and unit's efficiency.

This paper introduces the optimal operation of CES's DG connected to the distribution network considering CE. The purpose of optimization is to maximize the profit of CES and Particle Swarm Optimization (PSO) will be used to solve this problem. The optimal operation of DG represented in this paper would guide to CES and system operator for determining the decision making criteria.

Index Terms**—optimal operation, community energy system, carbon emission, particle swarm optimization.**

I. NOMENCLATURE

$G_{CES,DG}$	DG owned and operated by CES
$P_{CES,DG}(t)$	Active power provided for customers in CES's control area at time t
$Q_{CES,DG}(t)$	Reactive power provided for customers in CES's control area at time t
$H_{CES,DG}(t)$	Thermal energy provided for customers in CES's control area at time t
$G_{ind,DG}$	DG located in CES's control area and owned by an individual
$P_{ind,DG}(t)$	Active power supplied for customers by an individually owned DG
$Q_{ind,DG}(t)$	Reactive power supplied for customers by an individually owned DG
$P_i(t)$	Active power load of customer i
$Q_i(t)$	Reactive power load of customer i
$H_i(t)$	Thermal load of customer i
$P_n(t)$	Active power flowing in and out of network interconnected with CES's control area
$Q_n(t)$	Reactive power flowing in and out of network interconnected with CES's control area
$P_{PV}(t)$	The power production of photovoltaic generator at time t
$\eta_p(t)$	Energy conversion efficiency of PV at time t
A_p	Area of the PV array
K_p	Coefficient of correct
$G(t)$	Radiation intensity at time t
$\alpha_g, \beta_g, \gamma_g$	Coefficients of gas turbine cost function
$\alpha_b, \beta_b, \gamma_b$	Coefficients of boiler cost function
$\alpha_{c,p}, \beta_{c,p}, \gamma_{c,p}$	Coefficients of CHP cost function based on active power
$\alpha_{c,h}, \beta_{c,h}, \gamma_{c,h}$	Coefficients of CHP cost function based on heat
κ	Active/thermal rate
$\Xi_{CE,n}(t)$	The amount of CE at t [ton-CO_2]
$\xi_{CE,n}$	The average amount of CE according to 1[MW] power supply of entire network
$\Xi_{CE,CES}(t)$	The amount of CE according to generation of DGs in CES's control area at t [ton-CO_2]
$\Xi_{CE,CES,n}(t)$	The amount of CE for supplying energy demand in CES's control area at t [ton-CO_2]
CE_{CES,DG_i}	CE coefficient of CES's DG i by fuel type [ton-CO_2/MWh_f]

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$\mathrm{CE}_{\mathrm{ind,DG}_i}$	CE coefficient of individual DG i by fuel type [ton-CO_2/MWh_f]
$\eta_{\mathrm{CES,DG}_i}$	Generation efficiency[GJ_e/GJ_f] of CES's DG i
$\eta_{\mathrm{ind,DG}_i}$	Generation efficiency[GJ_e/GJ_f] of individual DG i
EUA_p	CE cost based on European Union Allowance [\$/ton-CO_2]
$f(t)$	Total profit of CES at time t
$\mathrm{P}(t)$	Difference between total active power and total active load in CES's area
$\mathrm{Q}(t)$	Difference between total reactive power and total reactive load in CES's area
$\mathrm{C}_{\mathrm{P,customer}}$	Sales price of active power for CES's customer
$\mathrm{C}_{\mathrm{H,customer}}$	Sales price of thermal energy for CES's customer
$\mathrm{C}_{\mathrm{P,market}}$	Market price of active power to buy or sell
$\mathrm{C}_{\mathrm{Q,market}}$	Market price of reactive power to buy or sell
$\mathrm{C}_{\mathrm{CES,DG}_i}$	Generation cost of CES's DG i
$\mathrm{C}_{\mathrm{P,ind,DG}}(t)$	Price of active power from individual DGs to CES at time t
$\mathrm{C}_{\mathrm{Q,ind,DG}}(t)$	Price of reactive power from individual DGs to CES at time t
$\mathrm{C}_{\mathrm{CE}}(t)$	CE cost at time t
k	The dimension of the optimization problem
$iter$	Iteration number for optimization problem
$iter^{\max}$	Total iteration number for optimization problem
w_{iter}	The inertia weight at iteration $iter$
$w^{\max}$	The maximum inertia weight
$w^{\min}$	The minimum inertia weight
c_1, c_2	Acceleration coefficients
r_1, r_2	Uniformly distributed random numbers [0,1]
$\mathrm{V}^{j}_{iter,k}$	The kth element of the particle j's velocity vector at iteration $iter$
$\mathrm{X}^{j}_{iter,k}$	The kth element of the particle j's position vector at iteration $iter$
$\mathrm{Xbest}^{j}_{iter,k}$	The kth element of the particle j's best position vector until iteration $iter$
$\mathrm{Xbest}^{g}_{iter,k}$	The kth element of the swarm's best position until iteration $iter$

INTRODUCTION

Distributed Generation (DG) such as hydro, photovoltaic arrays, fuel cells, microturbines and battery storage, generally stands for small scale generator connected to distribution network. DG is useful for maintaining system stability, offering spinning reserve, reducing transmission cost and distribution cost[1]. It gives comfortability of energy supply and improvement in quality to electricity energy consumer[2,3]. From social ramification, renewable energy takes effect to reduce the greenhouse gas that is mainly caused by large power station. Also, electricity price is expected to drop due to the competition in generation, transmission and distribution which are divided by because of the deregulation. However, the price will be floating in the new competition organization. In this circumstance, DG is a good alternative for reducing transmission cost and electricity price.

Recently, DGs connected in distribution network are installing much more than before. Also, DG installed in distribution network is now spreading out around the world with keen interest because generally DG has the characteristics of low-carbon emission as the paradigm changing to environmental agenda internationally. In this situation, the operator of DG is able to supply electric power to customers who are connected directly to DG as well as loads that are connected to entire network. Recently, Community Energy System(CES) having DGs is a new participant in the energy market. CES can be regarded as an improved type of DGs like Virtual Power Plant(VPP) or microgrid[4]. CES supplies both electrical and thermal energy to customer who is in its control area. Because of the international environmental regulation, diffusion of high-efficiency generators as well as renewable energy sources is unavoidable and it contributes to spread out the business of CES. The studies for optimal operation of DGs possessed by CES are required and are going on now all over the world. This paper reflects dynamic market price of active and reactive power and proposes optimal operation of CES considering carbon emission (CE). Photovoltaic generator which is one of the renewable energy, gas turbine, combined heat and power(CHP) are applied to the case study as DGs. To optimize the amount of generation, Particle Swarm Optimization(PSO) algorithm is used because it is required to have fast and robust solutions for the operation of DGs.

II. COMMUNITY ENERGY SYSTEM DESCRIPTION

CESs who are recently new participants in power market supply active and reactive power and thermal energy to a control area with renewable energy and high-efficiency plant according to the demand of the control area.

A. Structure of Community Energy System

CES can participate in a power market when it has generally more than 50% (each nation has a different standard) of load demand in a control area. It can trade overs and shorts of energy through an interconnected network. So CES can join in a power market as both power generation operator and customer. This can be represented as Fig.1.

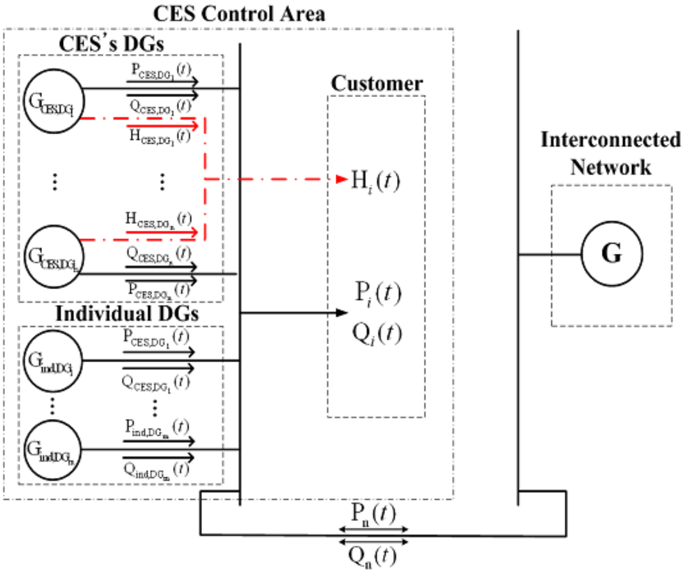

Fig. 1. Configuration of Community Energy System

CES firstly supplies thermal energy to the CES's control area and then generates active and reactive power for the customer's demand. Generally, thermal energy is provided by boiler and CHP. If active and reactive power generated by CES's DGs and, at the same time, bought from individual DGs, is not sufficient for its own customer's demand, it should be supplied from the neighbor network connected to CES's control area.

B. Operation Cost by Distributed Generator Types

There are various forms of DGs, such as hydro, photovoltaic arrays, fuel cells, microturbines and so on. This paper discusses about an optimal generation of each generator type for the maximum operation profits when CES provides a customer with active and reactive power and thermal energy through photovoltaic, gas turbine, boiler, CHP and SVC.

1) *Photovoltaic Generator*

The production power and operation cost of photovoltaic generator (PV) are represented by insolation around solar battery and the efficiency of energy conversion as follows:

$$P_{PV}(t) = \eta_p(t) \cdot A_p \cdot K_p \cdot G(t) \tag{1}$$

$$C_{PV}\left(P_{PV}(t)\right) = 0 \tag{2}$$

where the operation cost in order to produce power of PV can be ignored because PV uses rays of the sun as the origin of energy.

2) *Gas Turbine*

If a gas turbine produces regular power for an hour, the cost function per hour is commonly given as the form of a quadratic equation as follows.

$$C_{GT}(t) = \alpha_g + \beta_g \cdot P(t) + \gamma_g \cdot P(t)^2 \tag{3}$$

3) *Boiler*

Boiler produces heat energy instead of electric energy, and other features are similar to gas turbine.

$$C_{Boiler}(t) = \alpha_b + \beta_b \cdot H(t) + \gamma_b \cdot H(t)^2 \tag{4}$$

4) *Combined Heat and Power*

CHP produces heat and electric energy at the same time. This paper uses thermal ratio due to the amount of active power generated.

$$\begin{aligned} C_{CHP}(t) &= \alpha_{c,p} + \beta_{c,p} \cdot P(t) + \gamma_{c,p} \cdot P(t)^2 \\ &= \alpha_{c,h} + \beta_{c,h} \cdot H(t) + \gamma_{c,h} \cdot H(t)^2 \end{aligned} \tag{5}$$

$$P(t) = \kappa \cdot H(t) \tag{6}$$

III. CARBON EMISSION

Conventionally, the generators with competitive price will hold a prominent position in the market without regulation for CE, however, if considering the international environment regulation, CE newly will be important elements to decide marginal costs of generators as well as the fuel cost and generators efficiency. [6,7]

Only fossil fuels give off carbon and the amount of carbon differs from each other so that CE coefficient for each fuel needs to be decided separately[5]. This paper refers to IPCC(Intergovernmental Panel on Climate Change)'s CE coefficient for each fuel[kg-CO_2/GJ_f].

In the case which active power and thermal energy are supplied in CES's control area through entire network, CE is calculated as follows:

$$\Xi_{CE,n}(t) = \left[\sum_{i \in CES,Load} P_i(t) + \sum_{i \in CES,Load} H_i(t) \right] \cdot \xi_{CE,n} \tag{7}$$

The amount of CE at time t is analyzed by the average amount of CE according to 1[MW] power supply of entire network for supplying electricity energy from entire network without CES to customers in CES's control area.

In the case that CES operates DGs having various characteristics of fuel types, the expected amount of CE as generation of CES' DGs and individual DGs and as supplying electricity energy according to power and thermal load in CES's control area are represented, respectively, as follows:

$$\Xi_{CE,CES}(t) = \sum_{i \in CES,DG} P_{CES,DG_i}(t) \cdot \frac{CE_{CES,DG_i}}{\eta_{CES,DG_i}} + \sum_{i \in ind,DG} P_{ind,DG_i}(t) \cdot \frac{CE_{ind,DG_i}}{\eta_{ind,DG_i}} \tag{8}$$

$$\begin{aligned} \Xi_{CE,CES,n}(t) = &\begin{bmatrix} \displaystyle\sum_{i \in CES,Load} P_i(t) - \sum_{i \in CES,DG} P_{CES,DG_i}(t) - \sum_{i \in ind,DG} P_{ind,DG_i}(t) + \\ \displaystyle\sum_{i \in CES,Load} H_i(t) - \sum_{i \in CES,DG} H_{CES,DG_i}(t) \end{bmatrix} \cdot \xi_{CE,n} \\ &+ \left[\sum_{i \in CES,DG} P_{CES,DG_i}(t) \cdot \frac{CE_{CES,DG_i}}{\eta_{CES,DG_i}} + \sum_{i \in ind,DG} P_{ind,DG_i}(t) \cdot \frac{CE_{ind,DG_i}}{\eta_{ind,DG_i}} \right] \end{aligned} \tag{9}$$

CES should supply thermal energy preferentially in needs of customers in CES's control area. This paper assumes that individual DGs can't produce thermal energy. The amount of CE can be calculated by equations (8) and (9) suggested in this paper according to CE coefficient by fuel type and generation efficiency by DG.

A. The Cost By Carbon Emission

In practice, considering European Union Allowance(EUA), the additional generation cost by CE can be obtained according to CO_2 emission based on 1[ton] as follows:

$$\mathrm{C}_{\mathrm{CE}}(t) = \mathrm{EUA}_{\mathrm{p}} \cdot \Xi_{\mathrm{CE}}(t) \tag{10}$$

This paper compares CES's operation cost with/without CE cost in the case studies.

IV. OBJECTIVE FUNCTION OF COMMUNITY ENERGY SYSTEM

The objective function in this paper is to maximize the total benefit of CES, benefit from transaction, cost of active/reactive power, generation cost of CES's DG and extra cost for CE. As an additional expenses, CE cost is estimated by using equations (8) and (10). The objective function can be formulated as follows:

$$\begin{aligned} f(t) = {} & \mathrm{C}_{\mathrm{P,cutomer}} \cdot \sum_{i\in\mathrm{CES,Load}} \mathrm{P}_i(t) + \mathrm{C}_{\mathrm{H,customer}} \cdot \sum_{i\in\mathrm{CES,Load}} \mathrm{H}_i(t) \\ & + \mathrm{C}_{\mathrm{P,market}}(\mathrm{P}(t)) + \mathrm{C}_{\mathrm{Q,market}}(\mathrm{Q}(t)) \\ & - \sum_{i\in\mathrm{CES,DG}} \mathrm{C}_{\mathrm{CES,DG}_i}(\mathrm{P}_{\mathrm{CES,DG}_i}(t)) - \sum_{i\in\mathrm{CES,DG}} \mathrm{C}_{\mathrm{CES,DG}_i}(\mathrm{H}_{\mathrm{CES,DG}_i}(t)) \\ & - \sum_{i\in\mathrm{ind,DG}} \mathrm{C}_{\mathrm{P,ind,DG}}(t) \cdot \mathrm{P}_{\mathrm{ind,DG}_i}(t) - \sum_{i\in\mathrm{ind,DG}} \mathrm{C}_{\mathrm{Q,ind,DG}}(t) \cdot \mathrm{Q}_{\mathrm{ind,DG}_i}(t) \\ & - \mathrm{C}_{\mathrm{CE}}(t) \end{aligned} \tag{11}$$

CES makes hourly generation plan of active and reactive power and thermal energy. However, CES should supply thermal energy preferentially. Overs and shorts of active and reactive power will be traded through individual DGs and interconnected network. It is assumed that the supplying price of active power and thermal energy is constant because this paper focuses on the operation technique of DGs according to the low-carbon paradigm. On the contrary, it is assumed that the hourly prices of active/reactive power transacted through interconnected network and individual DGs are flexible.

Each DG's capacity is limited:

$$\begin{cases} \mathrm{P}_{\mathrm{CES,DG}_i,\min}(t) \le \mathrm{P}_{\mathrm{CES,DG}_i}(t) \le \mathrm{P}_{\mathrm{CES,DG}_i,\max}(t) \\ \mathrm{Q}_{\mathrm{CES,DG}_i,\min}(t) \le \mathrm{Q}_{\mathrm{CES,DG}_i}(t) \le \mathrm{Q}_{\mathrm{CES,DG}_i,\max}(t) \\ \mathrm{H}_{\mathrm{CES,DG}_i,\min}(t) \le \mathrm{H}_{\mathrm{CES,DG}_i}(t) \le \mathrm{H}_{\mathrm{CES,DG}_i,\max}(t) \end{cases} \tag{12}$$

The constraints between load and generation are given by:

$$\begin{cases} \sum_{i\in\mathrm{CES,Load}} \mathrm{P}_i(t) \le \sum_{i\in\mathrm{CES,DG}} \mathrm{P}_{\mathrm{CES,DG}_i}(t) + \sum_{i\in\mathrm{ind,DG}} \mathrm{P}_{\mathrm{ind,DG}_i}(t) + \mathrm{P}(t) \\ \sum_{i\in\mathrm{CES,Load}} \mathrm{Q}_i(t) \le \sum_{i\in\mathrm{CES,DG}} \mathrm{Q}_{\mathrm{CES,DG}_i}(t) + \sum_{i\in\mathrm{ind,DG}} \mathrm{Q}_{\mathrm{ind,DG}_i}(t) + \mathrm{Q}(t) \\ \sum_{i\in\mathrm{CES,Load}} \mathrm{H}_i(t) \le \sum_{i\in\mathrm{CES,DG}} \mathrm{H}_{\mathrm{CES,DG}_i}(t) \end{cases} \tag{13}$$

When CES purchases or sells the electricity in interconnected networks, power factor(PF) should be kept up considering system stability. The following shows the constraint of PF.

$$\left|\tan\theta\right| \ge \left|\frac{\mathrm{Q}(t)}{\mathrm{P}(t)}\right| \tag{14}$$

V. PARTICLE SWARM OPTIMIZATION

The PSO algorithm is a population-based stochastic optimization technique[8,9]. The potential solutions, called the particles, fly through the search space by following the current optimal particle. Objective function values are used as the fitness values of particles to guide the search process. Each particle records its best individual fitness and position (*pbest*) for iteration. Moreover, each particle knows the best fitness and position for iteration in the group (*gbest*) among all individuals. The velocity of a particle is influenced by three components inertial, cognitive, and social. the mathematical model for PSO is as follows:

$$\begin{aligned} \mathrm{V}^{j}_{iter,k} = {} & w_{iter} \times \mathrm{V}^{j}_{iter-1,k} + c_1 \times r_1 \times (\mathrm{Xbest}^{j}_{iter-1,k} - \mathrm{X}^{j}_{iter-1,k}) \\ & + c_2 \times r_2 \times (\mathrm{Xbest}^{g}_{iter-1,k} - \mathrm{X}^{j}_{iter-1,k}) \end{aligned} \tag{15}$$

$$w_{iter} = w^{\max} - (w^{\max} - w^{\min}) \times \left(\frac{iter}{iter^{\max}}\right) \tag{16}$$

The size of population is 1000 for the case study. Maximum number of iteration is set to 100 for case 1 and case 2 as well. The inertia max weight, min weight and acceleration coefficients of c_1 and c_2 for case study are set to 0.9, 0.4, 2 and 3 respectively.

VI. CASE STUDY AND DISCUSSION

It is assumed that CES operates generators composed of photovoltaic generators(2), gas turbine(2), boiler(1) and CHP(1) in this case study to supply customers in CES's control area with electric power and thermal energy. SVC(Static Var Compensator) compensates for lack of reactive power.

CES buys active and reactive power from individual DGs, and re-sales active power to customers in CES's control area. The parameters of DGs operated by CES are given by Tables I, II and III.

TABLE I. PARAMETERS OF DGS

	α	β	γ	$\mathrm{CE}_{\mathrm{CES,DG}_i}$	$\eta_{\mathrm{CES,DG}_i}$	Active/Thermal Rate	Limit [MW]	
							Min	Max
GT 1	21	1.258	2.978	0.05508	0.38	1/0	2.0	25.8
GT 2	23	2.271	5.264	0.05508	0.30	1/0	1.6	15.0
Boiler	19	2.025	2.698	0.09648	0.41	0/1	0	17.2
CHP	31	1.354	2.787	0.07200	0.86	1/0.8	2.3	21.5

TABLE II. PARAMETERS OF PVS

	A_p	η_p	K_p
PV 1	65	0.12	0.8
PV 2	107	0.12	0.8

TABLE III. ENERGY PRICE

	customer		Individual DGs		Market	
	Active [$/MW]	Thermal [$/MW]	Active [$/MW]	Reactive [$/MVAr]	Active [$/MW]	Reactive [$/MVAr]
Buy	0	0	85	2.8	95	3
Sell	100	85	0	0	90	2.8

Generally the supplying prices of active power and thermal energy to the end user are flat. On the contrary, it is assumed that the hourly prices of active/reactive power transacted through interconnected network and individual DGs are variable. Active/reactive power price to buy or sell in Table III are the maximum values.

SVC compensates for lack of reactive power from -2 to 2 [MVar]. Also, it is assumed that PF sets over 0.9

Thermal load of customer is a matter of the highest priority to CES. Hourly active/reactive power and thermal load data modified RBTS summer weekday load data are used as Fig. 2.

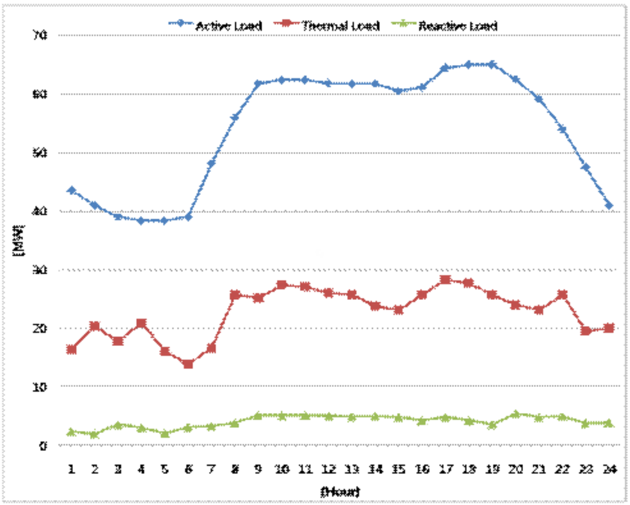

Fig. 2. hourly active, reactive and thermal load in CES's control area

A. Case 1: without CE

If CES provides customers with generation power of DGs without considering CE, Figs. 3 and 4 shows the amount of hourly active generation and amount of hourly reactive generation and PF.

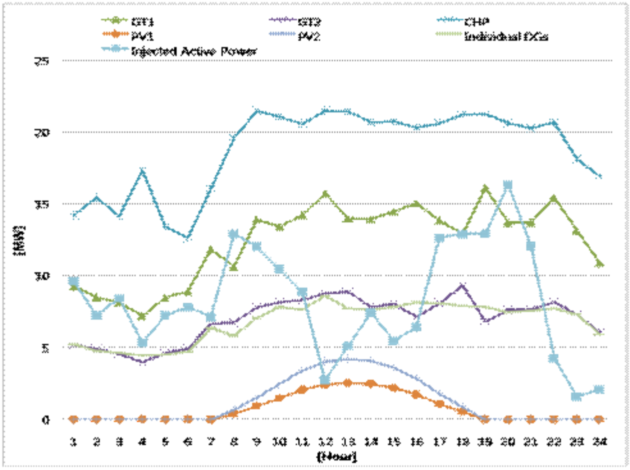

Fig. 3. The amount of hourly active generation

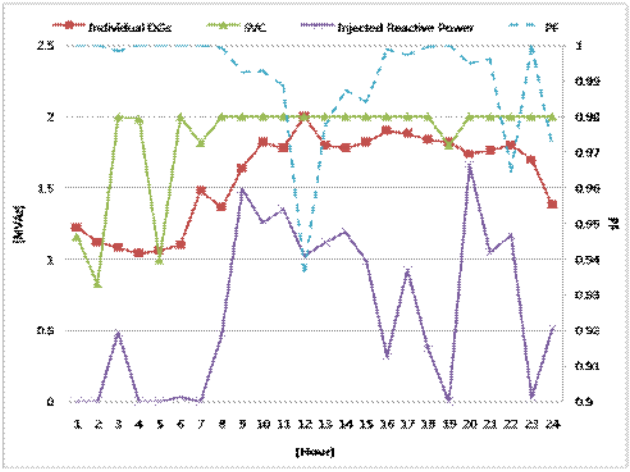

Fig. 4. The amount of hourly reactive generation and power factor

Thermal demand of customer is provided by CES's boiler and CHP. Then, hourly thermal generation can be depicted in Fig. 5.

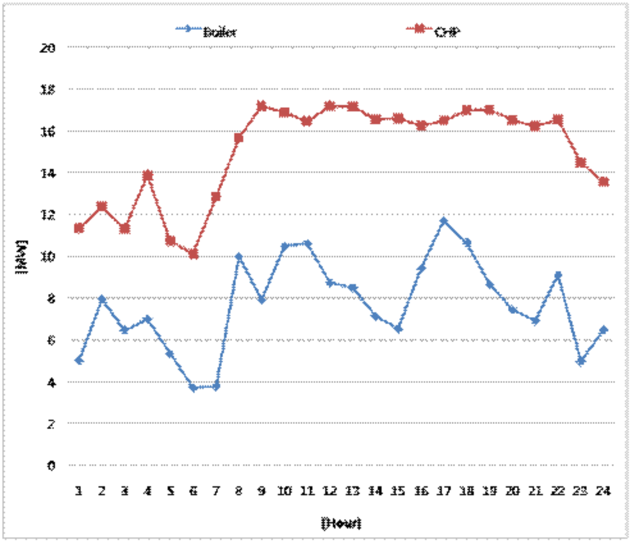

Fig. 5. The amount of hourly thermal generation

B. Case 2: with CE

Considering CE depending on the amount of generation by DG types, the operation cost of respective generators will change. Then, the amount of hourly active generation and the amount of hourly reactive generation and PF are shown in Fig. 6.

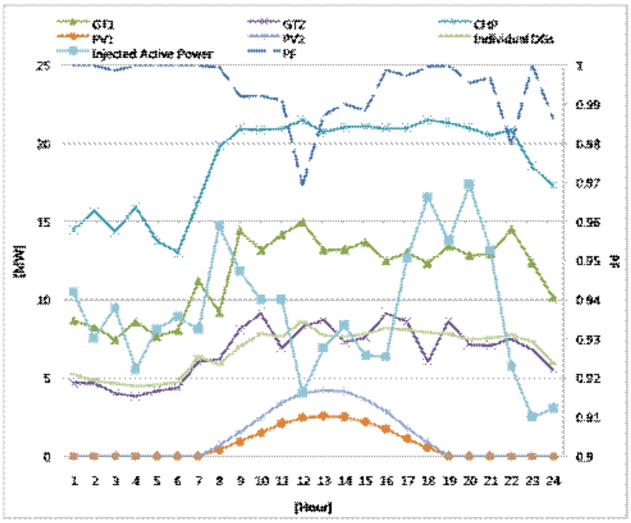

Fig. 6. The amount of hourly active generation and power factor

EUA_p is assumed with 31[\$/ton-CO_2] (EUA in Aug. 2008), daily total generation cost and CE cost by DG types are presented in Fig. 7.

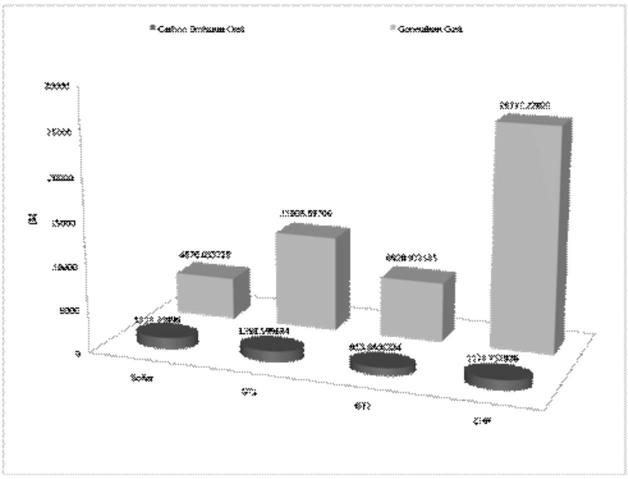

Fig. 7. Total generation cost & CE cost by DG types

A CHP has higher generation efficiency than the other generators. As a result, it is represented that CHP has lower CE cost relatively than the others. Hourly total generation cost and total CE cost of CES are as follows.

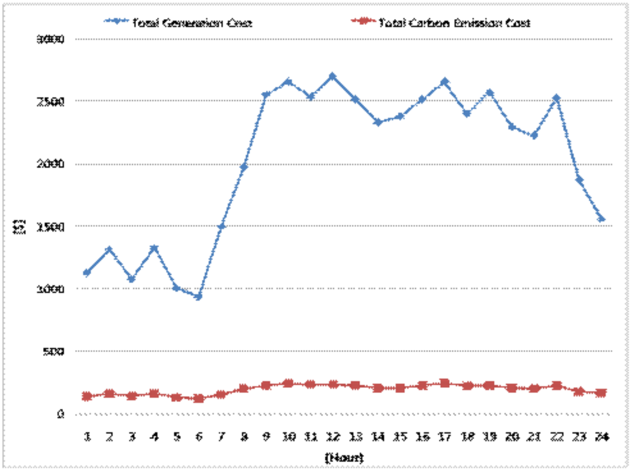

Fig. 8. Total generation cost & total CE cost of CES

Hourly operation profit in case 2 decreases compared with case 1. It is represented in Fig. 9.

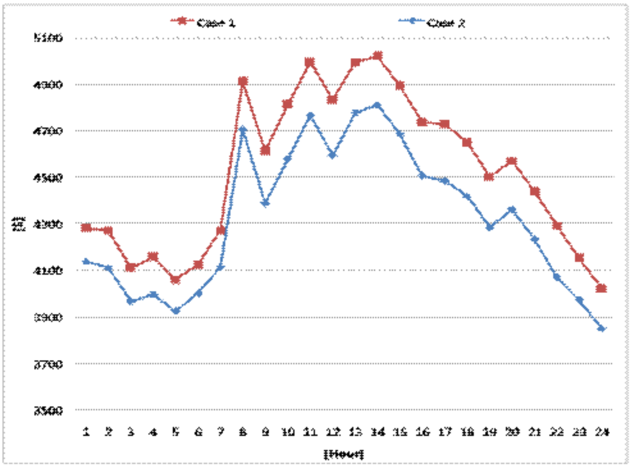

Fig. 9. Total operation profit of CES case by case

The amount of CE and the profit by CE are changed with CES or without CES in which all energy supplied directly through a network. The profit by CE reduced, the amount of CE with CES and without CES is depicted in Fig. 10.

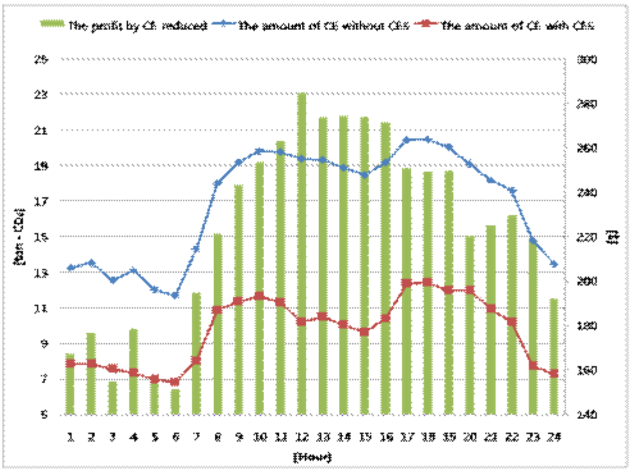

Fig. 10. Hourly profit by CE reduced and the amount of CE without CES and with CES

The amount of boiler's thermal generation decreases while that of CHP increases in case 2 which takes CE into consideration compared with case 1. The Table IV shows hourly thermal generation of boiler and CHP case by case.

TABLE IV. HOURLY THERMAL GENERATION OF BOILER AND CHP CASE BY CASE

	Case 1		Case 2	
	boiler	CHP	boiler	CHP
1	5.0064	11.35	4.7974	11.559
2	7.9342	12.37	7.7592	12.545
3	6.4506	11.315	6.2793	11.487
4	7.0016	13.866	8.1431	12.725
5	5.3413	10.733	5.0525	11.022
6	3.7098	10.108	3.4084	10.41
7	3.7815	12.856	3.5488	13.089
8	9.9811	15.681	9.825	15.837
9	7.9117	17.186	8.3596	16.738
10	10.484	16.87	10.671	16.683
11	10.599	16.473	10.329	16.743
12	8.744	17.2	8.744	17.2
13	8.5003	17.162	9.078	16.584
14	7.1426	16.545	6.8436	16.844
15	6.5252	16.599	6.2502	16.874
16	9.4133	16.249	8.9018	16.76
17	11.697	16.503	11.424	16.776
18	10.652	16.984	10.439	17.197
19	8.6395	17.022	8.5929	17.069
20	7.4499	16.52	7.1754	16.795
21	6.9054	16.219	6.6884	16.436
22	9.1074	16.555	8.9724	16.69
23	4.9603	14.498	4.6407	14.817
24	6.4606	13.561	6.1724	13.85
total	184.3987	360.425	182.0961	362.73

In case 2 which is considering CE when thermal energy is supplied by boiler and CHP of CES, it represents that the output of boiler is on the decrease and the output of CHP is on the increase compared with case 1 not regarding CE.

VII. CONCLUSION

Due to deregulation, environmental reasons and technical improvement, recently DGs connected to network have been diffused. The more DGs are installed, the more CES will participate in power market.

CES tries to make the maximum profit by controlling generation of DGs according to the hourly price of active, reactive power. Considering CE cost resulted from the recent international environmental regulation, however, CES's existing operational strategy of generators is not suitable for the purpose to maximize the profit. By analyzing the result of case studies, this paper proposes the operational technique according to characteristics of DG types and depending on the dynamic market price. It suggests the newest generation scheduling technique for CES with regard to low-carbon paradigm. To present the reliable result of the case study, PSO algorithm proved to be excellent in various fields is used to find the optimal generation of generator type.

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