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Implementation of a Demand-Side Management Solution for South Korea's Demand Response Program

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Abstract: In this paper, we show the development of a demand-side management solution (DSMS) for demand response (DR) aggregator and actual demand response operation cases in South Korea. To show an experience, Korea's demand response market outline, functions of DSMS, real contracted capacity, and payment between consumer and load aggregator and DR operation cases are revealed. The DSMS computes the customer baseline load (CBL), relative root mean squared error (RRMSE), and payments of the customers in real time. The case of 10 MW contracted customers shows 108.03% delivery rate and a benefit of 854,900,394 KRW for two years. The results illustrate that an integrated demand-side management solution contributes by participating in a DR market and gives a benefit and satisfaction to the consumer.

Keywords: demand response; demand-side management solution; electricity market; energy management

1. Introduction

In a power system, electricity demand changes constantly. Power suppliers need to generate more power generation when demand is high, and less when demand is low. Traditionally, to coordinate supply and demand has been the supplier's responsibility and the demand side has been considered secondary. The power system supplier predicts the demand and, then, generates the supply capacity to meet the demand. After that, market price changed to supply capacity serves as criteria for deciding the facility capacity. The capacity that cannot be adjusted on the supply side is supplemented by DSM (demand-side management) such as temporarily reducing or moving the load on the demand side [1,2].

Recently, there has been a growing interest in considering the demand as the same as the supply side. Technological changes are occurring both on the supply side and on the demand side. Demand response is an alternative to additional infrastructure to maintain the safe margin between generation or distribution capacity and demand. The definition of demand response from the United State Department of Energy says, "Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized" [3]. The most significant technological change on the demand side is the spread of smart meters and advanced metering infrastructure. According to this environment, traditional DSM programs should redesign to an automated market-based mechanism. The responses from the demand-side resources should also be reliable, fast, flexible, and large enough to compete

with the supply-side resources. DSM programs can be classified into load management (LM) types and energy efficiency (EE) types [4–8].

In order to deal with peak load conditions, electric utilities have to invest in system capacity, which is underutilized during most times. Not surprisingly, utilities have been seeking methods to improve capacity utilization. Demand response (DR) is one mechanism utilities use to curtail or shift peak customer load [9–11].

Regarding the remuneration, a price-based and an incentive-based DR program are used. In a price-based DR program, consumers reduce their power consumption by responding to the electricity tariff set by the electricity market. In an incentive-based DR program, consumers are contracted by individuals or groups to reduce their power consumption for a certain period that the economic transactions requested in the electricity market.

For a price-based DR program, researchers investigated a multi-agent modeling and optimization algorithms under DR programs for real-time prices [12]; a coordination strategy between a micro network and a price-based demand response program for adjusting loads [13]; a bidirectional communication smart meter design between the household smart meters and the distribution management system [14]; a dynamic price scheme for electricity in a smart network, by analyzing the behavior and the possible demand response of the consumer [15]; and a modified real-time price model that encourages customer choice in electricity rates and is based on the amount of risk customers are willing to take and a real-time grid condition index developed by the California Independent Service Operator [16].

For an incentive-based DR program, research has shown that a fuzzy-based dynamic incentive scheme for residential customers can effectively incorporate the influences of socioeconomic conditions, expected curtailment, probability of curtailment, and notice period [17]. The dynamic adjustment of the offered prices is analyzed to reduce the demand and maximize its performance within T days [18]. The uncertainty of the demand in the network planning is modeled and includes the integral control of the load disconnection in search of the minimum cost [19]. The participation of smart homes with the help of a controller is capable of managing the electrical installation and restructuring the demand profile by changing the operation of the flexible loads [20]. The incentives motivate clients to participate in automatic DR programs with the purpose of compensating imbalances between offer and demand [21], and a DR program is shown from the economic point of view based on optimal incentives [22].

Demand resources have played an important role in Korea for more than 20 years. To reduce peak demand during summer and winter, DR programs and the operating system have been researched and implemented as a demonstration since 2010. In 2014, any customers who joined the DR market were able to sell their reduced demand in the electricity market as supply resources [23,24].

In this paper, a development and case studies of demand-side management solution (DSMS) in South Korea is presented. After that, the DSMS is verified with a one-year experience of the Korea DR program. To implement this solution, a design structure of the DSMS is proposed and tested. Customer baseline load (CBL), relative root mean squared error (RRMSE), load curtailment value, and money-saving of contracted customer's data are also displayed from the DSMS. To calculate CBL, a short historical period close to the event day was chosen, then, the CBL was calculated by merely averaging the data of the previous not-event days. After deciding the CBL, the assessment of the estimated CBL is needed. In order to verify the accuracy of the calculated CBL, RRMSE is used to assess the estimation error by comparing the actual electricity load and the estimated CBL. If the estimation error is close to zero, it means there is the high accuracy of the estimated CBL; if it is greater than zero, it means overestimated CBL; and if it is less than zero, it means underestimated CBL [25]. The calculation process of CB L and RRMSE are explained in Section 2.

This paper is composed as follows: Section 2 shows Materials (status of demand resource market in South Korea) and Methods (development of DSMS); Section 3 presents the money savings and energy conservation results using DSMS; finally, the discussion and conclusions are given in Sections 4 and 5.

2. Materials and Methods

2.1. Status of Demand Resources Market, South Korea

The role of the Korea Power Exchange (KPX) is to control the operation of South Korea's electricity market and the power system, as well as execute real-time dispatch and establish the basic plan for supply and demand. Every year, the KPX has issued an annual report for the electricity market trend and analysis. In this section, the status of the demand resource market from the 2016 annual report is summarized. Demand response refers to a suite of policies and institutions to provide efficient and stable electric power service at the lowest cost by helping consumers change their consumption pattern. Under the current contract-based utility rate schemes in South Korea, consumers have a very weak incentive to voluntarily participate in the demand response [26].

The introduction of the demand response program can effectively stabilize the electricity market and the operation of its system. The demand response can decrease investment in the power system including generation, transmission, and transformation networks; enhancing reliability in electric-power supply. Consumers can take part in the demand response programs by reducing their electricity usage at critical times through monitoring demand or securing a load that can be shut down by KPX and then making a bid on a load.

In early 2008, when the demand response market opened, it was bidding-based sponsored by the Electricity Industry Fund and, now, is making a transition into an advanced demand response market where market price and real-time system operation are linked with each other for resource transaction. In 2012, a smart demand response market opened where demand resources in small and medium quantity were traded in an effort to tap into the highly reliable and easily accessible demand resources using smart grid technology. The smart demand response market makes payment at a fixed rate on the condition of keeping the capacity to be curtailed unchanged. A payment is also made to those who cut down demand at the system operator's request for load curtailment. As the Electricity Business Act was revised to allow demand resource trading in the electricity market, in 2014, the demand response market and smart demand response market sponsored by the Electricity Industry Fund were abolished in late 2014, and the elimination of the two-month-ahead and week-ahead programs followed in late 2015 [26].

At the end of 2015, a new demand response market replaced these previous programs and was integrated into the electricity market. Figure 1 shows the process of the trading mechanism of a demand response market. The demand response market trades demand resources arranged by retailers, each demand resource is required to come from more than ten end users, and must be valued at above 10 MW. The DR aggregator collects consumers to organize demand resources. After registering with KPX, these resources are certified for trading under the same rules governing the centrally dispatched generators. Demand resources are put on a bid against power generation resources on a daily basis, and when sold, demand curtailment begins. In the system operation process, consumers are required to cut down on demand within an hour of a dispatch order.
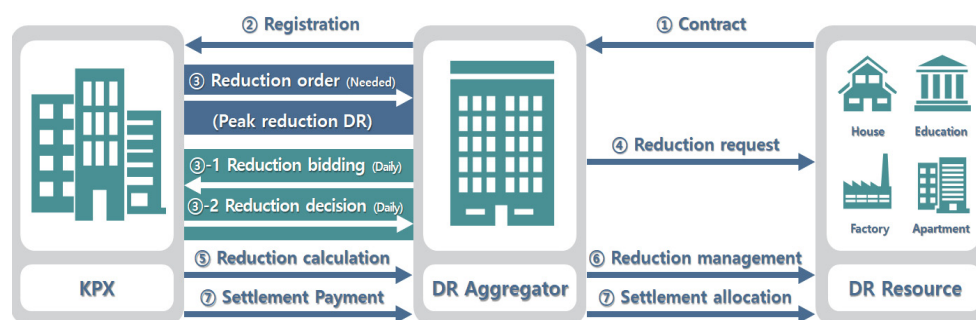

Figure 1. Trading mechanism of a demand response market.

The KPX calculates curtailed energy and makes payment to retailers who allocate the profits to consumers. As indicated in Tables 1 and 2, the demand response market has seen significant progress from both quantity and quality perspectives. The number of consumers has grown from 90 to 3592 and curtailed energy amounts to 175,771 MWh, up by 342.6 times from 513 MWh, becoming a world-renowned global demand response market. The transition to an advanced demand response market is also politically compelling. As the program matures along with demand resources integrated into the electricity market, market participants will feel easy to understand the system and the market will flourish. Furthermore, lower resistance towards generators and greenhouse gases are expected along with eased market exploitation and a more efficient market [23].

**Table 1.** Consumers and curtailed power before market opening [23].

Year	2010	2011	2012	2013	2014
No. of consumers	90	119	158	159	159
Capacity available for curtailment (MW)	2219	3049	3612	3615	3615
Curtailed energy (MWh)	513	690	785	556	682

Table 2. Consumers and curtailed power after market opening (provided by KPX, July 2018).

Year	2014.12~ 2015.05	2015.06~ 2015.11	2015.12~ 2016.05	2016.06~ 2016.11	2016.12~ 2017.05	2017.06~ 2017.11	2017.12~ 2018.05	2018.06~ 2018.11
No. of DR aggregators	11	15	14	15	14	17	20	22
No. of consumers	861	1323	1519	1970	2223	3195	3580	3592
Capacity available for Curtailment (MW)	1520	2444	2889	3272	3885	4352	4271	4222
Curtailed energy (MWh)	117,075	91,034	98,898	293,955	113,661	62,110	121,206	-

2.2. Development of Demand-Side Management Solution (DSMS)

To realize the trading mechanism of a demand response market, as shown in Figure 1, the structure of a demand-side management solution is designed, as shown in Figure 2. The DSMS directly captures usage data by sensor every 5 min from demand resources such as a house, building, apartment, and factory. After that, these usage data are sent to the KPX server every 5 min. If a power shortage occurs, the KPX sends a reduction order to the DSMS. When the request is generated from KPX, the DSMS calculates the CBL of the DR duration time and, then, contacts the DR resources to request the contracted power reduction amount, and after that, demand curtailment begins. In the system operation process, consumers are required to cut down on demand within an hour of the dispatch order. The DSMS also calculates the RRMSE (relative root mean square error), the CBL (customer baseline load) of the DR resources, regularly to keep the DR resources in the Korea electricity market.
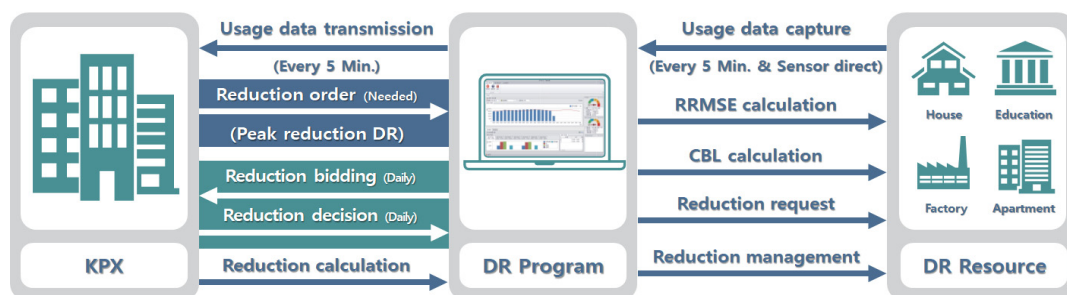
Figure 2. The structure of a demand-side management solution.

The CBL is the prediction of the amount of electricity that would generally be used if electricity consumption had not been reduced by the KPX directive [27]. Figure 3 shows the power consumption and CBL of the desired date and time. The bar graph illustrates power usage at 5 min, 10 min, and 30 min, respectively and the line means the CBL of every hour. At the bottom, the dialog box shows contracted curtail power, CBL, load, result of curtailed power, and remained contracted curtail power in order.
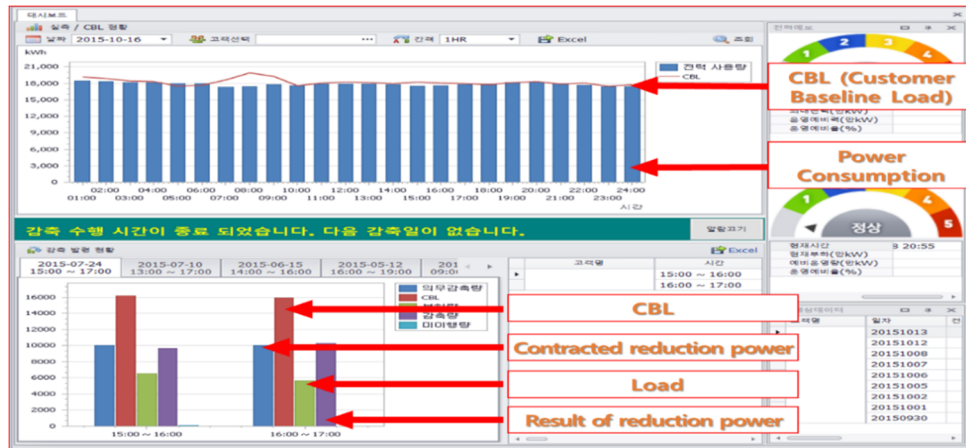

Figure 3. Dashboard of power usage.

Figure 4 illustrates a customer baseline load (CBL) calculation. The CBL is an average hourly energy consumption calculated as follows: According to the KPX guideline, the CBL calculation method is either MAX 4/5 or Mid 6/10. The Max 4/5 method is calculated using the electricity usage in normal working for 5 consecutive days. To calculate the CBL, first, the smallest electricity usage day of the 5 days is excluded, then, the average usage for 4 days is used as Max 4/5 CBL. The Mid 6/10 method is calculated based on the power electricity usage in normal working for 10 consecutive days. Two days are excluded from the top and bottom usage of the 10 days, respectively. The average usage of the remaining six days is used as Mid 6/10 CBL. Table 3 explains how to calculate the CBL as MAX 4/5. First, D-2 is the smallest electricity usage day, therefore, this day is excluded. Then, the average usages of the remained 4 days are added, and then divide by 4 [27].
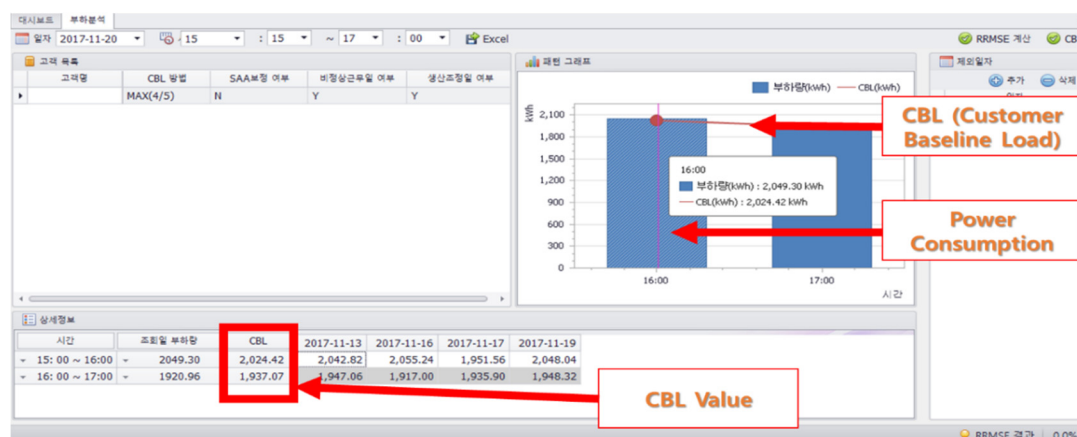

**Figure 4.** Customer baseline load calculation.

Table 3. Calculation example of the customer baseline load (CBL) (Max4/5 Method).

	Energy Consumed (kWh)	Selection
D-1	2048.04	O
D-2	1889.74	X
D-3	1951.56	O
D-4	2055.24	O
D-5	2042.82	O
CBL	Average of selection value = 2024.42	

To estimate the DR reduction value, the pattern of regular power use should be fairly uniform, and an objective evaluation technique is required. For this objective evaluation, the RRMSE was used as an index to specify the uniformity of the pattern of power usage. Figure 5 shows the RRMSE for the customer who wants to participate in demand response market and Equation (1) shows that RRMSE calculation [26]. In this equation, D is an investigation day, $D(n)$ is the number of investigation days, T is a time duration of an investigation day, $T(n)$ is number of time durations of an investigation day, $CBL_{d,t}$ is a customer baseline load at t hour on d day, and $Load_{d,t}$ is an electricity usage at t hour on d day.

$$\sqrt{\frac{\sum_{d \in D, t \in T}\left(CBL_{d,t} - Load_{d,t}\right)^2}{D(n) \times T(n)}} \div \frac{\sum_{d \in D, t \in T} Load_{d,t}}{D(n) \times T(n)} \tag{1}$$

$D(n)$: Number of investigation days
T: Time duration of investigation day
$T(n)$: Number of time durations of investigation day
$CBL_{d,t}$: Customer baseline load at t hour on d day
$Load_{d,t}$: Electricity usage at t hour on d day
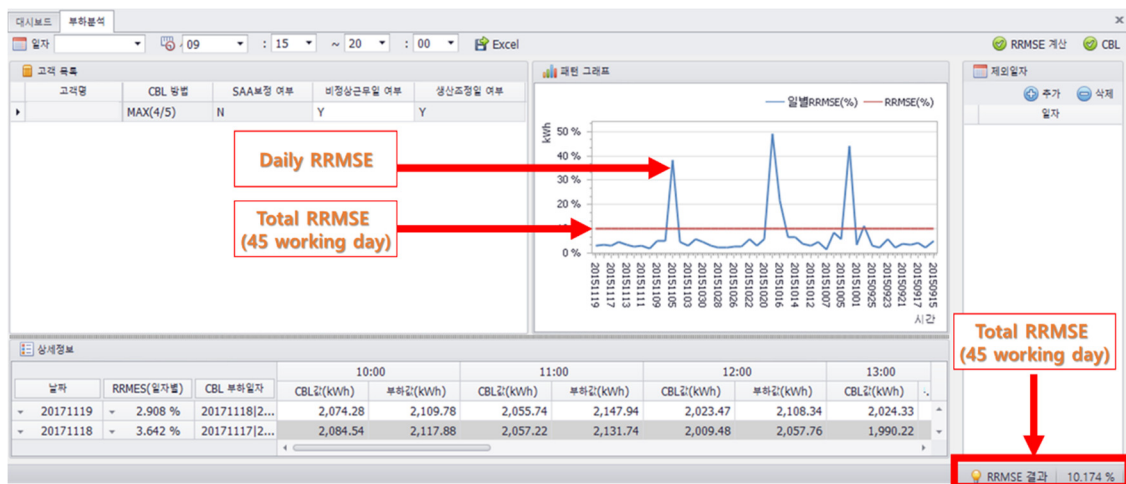
Figure 5. Relative root mean squared error (RRMSE) for a customer.

The RRMSE is calculated by dividing the RMSE (root mean square error) with the average value of electricity usage data. The fluctuation between the CBL and actual electricity usage is a critical judgment criterion as a reliable DR resource. To register as a DR resource in the Korea electricity market, the RRMSE value must be less than 30%; if the value exceeds 30%, it is not allowed to join the DR market. If the RRMSE value becomes more increased, conformity of power usage pattern decreases, which makes it difficult to judge the reduction value accurately. Although the U.S. PJM

power DR market is set at less than 20%, the Korea DR market is set to within 30% at the beginning of the system. To determine the suitability of the DR customer, the KPX enforces an annual RRMSE assessment, and then that result determines whether the DR customer can participate in the DR market for one year. This calculation is based on data from 45 weekdays from the date of verification [26]. For example, the flat line of the electricity usage graph in Figure 5 indicates 10%, that means Figure 5 is a reliable DR resource, and therefore this customer can participate in the DR market.

The incentive for participating in the DR market can be classified into basic settlement and performance settlement, and the monthly basic settlement payment is as shown in Table 4. According to the reduction duration time, the actual performance-settlement payment is different under the KPX condition [27].

Table 4. Monthly basic settlement payment 2016–2018.

Month	Basic Settlement Payment [KRW/kW]	Weekday
2016.12	5186.22	22
2017.01	4994.68	20
2017.02	4475.45	20
2017.03	3767.84	22
2017.04	1462.24	20
2017.05	1335.86	20
2017.06	3858.63	21
2017.07	5395.95	21
2017.08	4930.56	22
2017.09	3694.44	21
2017.10	1213.57	17
2017.11	2919.16	22
2017.12	4,697.14	19
2018.01	5,763.12	22
2018.02	4,249.36	18
2018.03	3,519.93	21
2018.04	1,245.46	21
2018.05	1,036.46	21
2018.06	3,300.72	19
2018.07	5,803.64	22
2018.08	5,354.86	22
2018.09	3,150.83	17
2018.10	1,003.48	21
2018.11	2,717.80	22
Total	85,077,404	493

To calculate the basic settlement money, Equations in (2) are applied to the integrated demand-side management solution [26].

$$\text{DRBP}_{i.m} = \text{ORC}_{i.m} \times \text{BP}_m \times 1,000$$
$$\text{IBPC}_{i.m} = \frac{\text{TDRBP}_i}{\text{ORC}_{i.m} \times \text{MRT}} \times \sum_{t}^{m} DRD_{i.t} \times 2 \times DF_{i,t}$$
$$DRD_{i.t} = Max(RSO_{i,t} \times 0.97 - DR_{i,t},\ 0)$$
$$\text{BPC}_{i.m} = Min(\text{DRBP}_{i.m},\ \text{IBPC}_{i.m})$$
$$\text{FDRBP}_{i.m} = \text{DRBP}_{i.m} - \text{BPC}_{i.m}$$

(2)

$DRBP_{i.m}$ Demand response basic payment by monthly (KRW)
$ORC_{i.m}$ Obligation reduction capacity (MW)
BP_m Basic price by monthly (KRW/kW)
$IBPC_{i.m}$ Initial basic penalty charge (KRW)
$TDRBP_i$ Total basic settlement money during the contract period (KRW)
MRT Maximum reduction time (Max 60 h)
$DRD_{i.t}$ Dispatch reduction deficiency (kWh)
$RSO_{i,t}$ Reduction ordered by system operator (MWh)
$DR_{i,t}$ Dispatched reduction (kWh)
$DF_{i,t}$ Dispatch flag (1 for active, 0 for non-active)
$BPC_{i.m}$ Basic penalty charge by monthly (KRW)
$FDRBP_{i.m}$ Final demand response basic payment by monthly (KRW)

To verify the DSMS functional test, the sampled data is divided into the following three categories: (1) large amount, (2) medium amount, and (3) small amount. Table 5 shows sampled data.

Table 5. The data for functional verification of demand-side management solution (DSMS).

Amount	Large	Medium	Small
Name	N Company	Provincial Government	G store
Type	Factory	Building	Retail
Peak (kW)	24,561	2002	57
Average power consumption (kW)	22,306	1534	52
Contracted capacity (kW)	10,000	1000	40

Baseline load, peak, average power consumption, and CBL are calculated based on the customer's power usage which is monitored and recorded from an electricity smart meter. Figures 6–8 show the data on 26 June 2017. The large amount, N company, is a chemical company located in the southwestern area of South Korea. The power consumption pattern of N company is a typical factory type. Figure 6 illustrates the power consumption pattern baseline load and peak. The medium amount, a provincial government building, is located in the central area of South Korea. The CBL of this customer is 1938.56 kW at 13:00~14:00 on 26 June 2017, as shown in Figure 7. Lastly, the small amount, G store, is a retail store located in the southeastern area of South Korea. Figure 8 shows the RRMSE value as 9.815%, less than 30%.
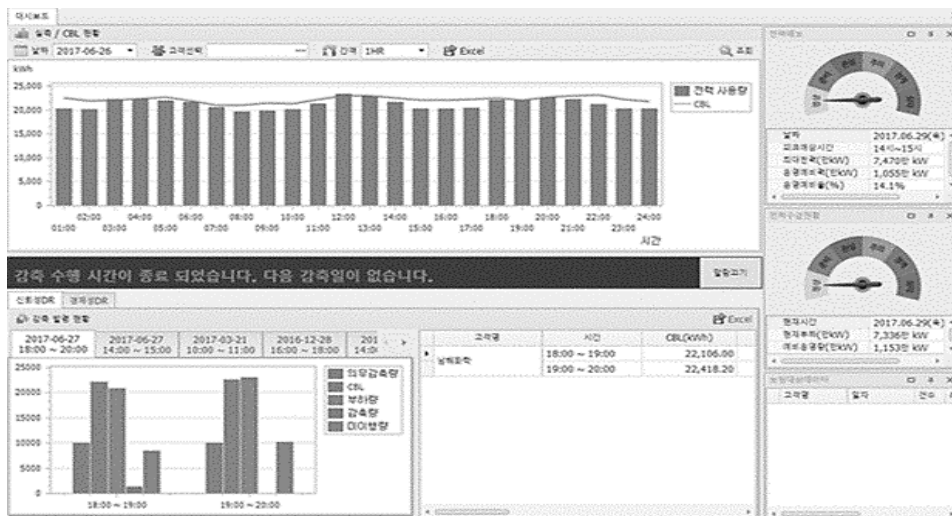
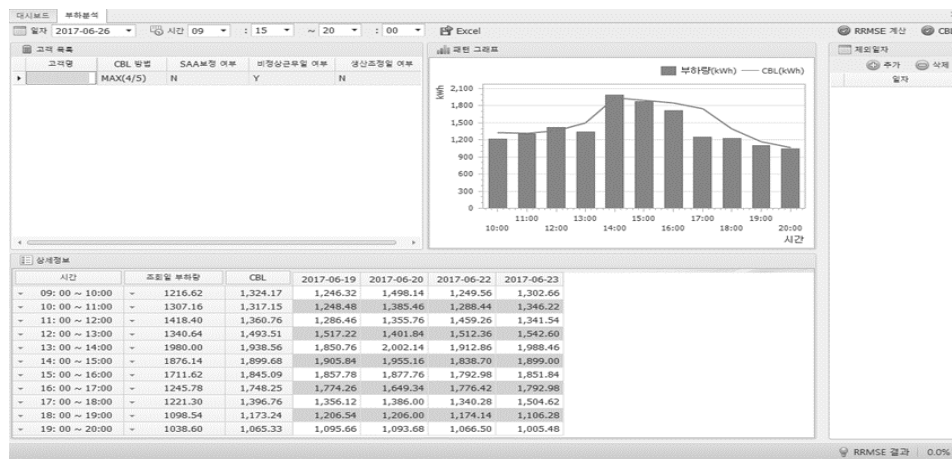**Figure 6.** N company power consumption and baseline load.

Figure 7. Provincial government building CBL calculation.
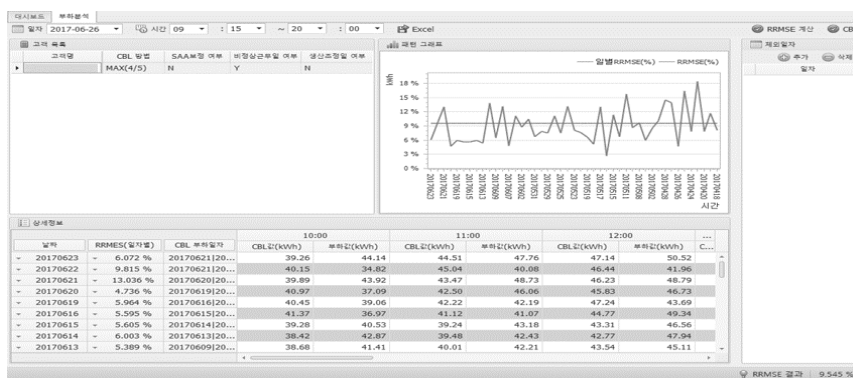

Figure 8. G store power RRMSE.

3. Results

Table 6 shows the DR benefit and reduction rate results for three contracted customers after participating in the DR program. The results show the money-saving and energy conservation using the DSMS. The data used in this paper was collected in two years (from December 2016 to November 2018) from selected customers in South Korea. The N company case is selected to demonstrate the result. In the case of N company, the contracted capacity is 10 MW, participating in the 20 h DR dispatch during the two years. As a result, the DR delivery rate which is an average 108.03% and the benefit from the DR participation which is 854,900,394 KRW (basic settlement benefit is 844,014,870 KRW and actual settlement money is 10,885,524 KRW) are occurring, and the savings in electricity cost over the two years is about 2,160,560 KRW

Table 6. Participation result of annual demand response market.

	Name			N Company	
Month	Reduction Order	Reduction Duration Time	Basic-Settlement Benefit [KRW]	Performance-Settlement Benefit [KRW]	DR Delivery Rate [%]
2016.12	O	2 h	51,862,200	2,224,080	121.65%
2017.01	X	-	49,946,800	-	-
2017.02	X	-	44,754,500	-	-
2017.03	O	1 h	37,678,400	1,129,080	121.44%
2017.04	X	-	14,622,400	-	-
2017.05	X	-	13,358,600	-	-
2017.06	X	-	38,586,300	-	-
2017.07	O	3 h	53,221,870	2,429,646	95.30%
2017.08	X	-	49,305,600	-	-
2017.09	X	-	36,944,400	-	-
2017.10	X	-	11,421,800	-	-
2017.11	O	1 h	23,884,000	878,970	105.14%
2017.12	X	-	46,971,400	-	-
2018.01	O	9 h	57,631,200	1,056,280	108.17%
2018.02	O	1 h	42,493,600	1,094,716	114.69%
2018.03	X	-	35,199,300	-	-
2018.04	X	-	12,454,600	-	-
2018.05	X	-	10,364,600	-	-
2018.06	O	2 h	33,007,200	993,782	106.06%
2018.07	X	-	58,036,400	-	-
2018.08	X	-	53,548,600	-	-
2018.09	O	1 h	31,508,300	1,078,970	104.44%
2018.10	X	-	10,034,800	-	-
2018.11	X	-	27,178,000	-	-
	Total		844,014,870	10,885,524	-
	Name			Provincial Government	
2016.12	O	2 h	5,186,220	211,700	114.32%
2017.01	X	-	4,994,680	-	-
2017.02	X	-	4,475,450	-	-
2017.03	O	1 h	3,767,840	99,475	105.72%
2017.04	X	-	1,462,240	-	-
2017.05	X	-	1,335,860	-	-

Table 6. *Cont.*

	Name		Provincial Government		
2017.06	X	-	3,858,630	-	-
2017.07	O	3 h	5,395,950	336,334	127.28%
2017.08	X	-	4,930,560	-	-
2017.09	X	-	3,694,440	-	-
2017.10	X	-	1,142,180	-	-
2017.11	O	1 h	2,305,028	76,229	91.24%
2017.12	X	-	4,697,140	-	-
2018.01	O	9 h	5,763,120	119,026	121.89%
2018.02	O	1 h	4,249,360	131,721	138.00%
2018.03	X	-	3,519,930	-	-
2018.04	X	-	1,245,460	-	-
2018.05	X	-	1,036,460	-	-
2018.06	O	2 h	3,300,720	106,706	113.88%
2018.07	X	-	5,803,640	-	-
2018.08	X	-	5,354,860	-	-
2018.09	O	1 h	3,150,830	120,557	116.69%
2018.10	X	-	1,003,480	-	-
2018.11	X	-	2,717,800	-	-
	Total		84,391,878	1,201,747	-
	Name		G Store		
2016.12	O	2 h	610,614	21,309	95.73%
2017.01	X	-	599,362	-	-
2017.02	X	-	537,054	-	-
2017.03	O	1 h	446,284	10,547	93.41%
2017.04	X	-	175,469	-	-
2017.05	X	-	160,303	-	-
2017.06	X	-	463,036	-	-
2017.07	O	3 h	647,514	36,711	170.65%
2017.08	X	-	591,667	-	-
2017.09	X	-	443,333	-	-
2017.10	X	-	137,062	-	-
2017.11	O	1 h	262,012	8,323	82.96%
2017.12	X	-	610,614	-	-
2018.01	O	9 h	599,362	11,935	122.22%
2018.02	O	1 h	537,054	10,158	106.42%
2018.03	X	-	446,284	-	-
2018.04	X	-	175,469	-	-
2018.05	X	-	160,303	-	-
2018.06	O	2 h	463,036	10,515	112.22%
2018.07	X	-	647,514	-	-
2018.08	X	-	591,667	-	-
2018.09	O	1 h	443,333	10,113	97.89%
2018.10	X	-	137,062	-	-
2018.11	X	-	262,012	-	-
	Total		10,147,42	119,611	-

To verify the capacity of the demand response from the customer, the request from KPX on 20 July 2017, 14:00~17:00, is displayed in Table 7. The large customer, N company, a big factory which has a contracted capacity of 10,000 kW delivered 97%, 93%, and 96% for each period and the average delivery rate was 95%. Figure 9 Illustrates the CBL load, the DR reduction result, and the delivery rate of each period. For example, Figure 9a shows the CBL is 18,059 kW, the real load is 8378 kW, the DR reduction is 9,681 kW, and the contracted capacity is 10,000 kW at 14:00~15:00.

(a)　　　　　　　　　　　　　(b)　　　　　　　　　　　　　(c)
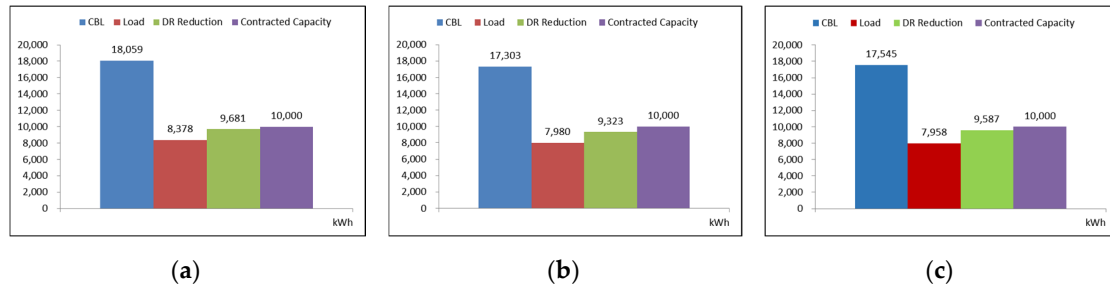
Figure 9. N company demand response result (data of 20 July 2017, 14:00~17:00).

Table 7. Result of demand response from customer.

Amount		Large	Medium	Small
Name		N Company	Provincial Government	G Store
Type		Factory	Building	Retail
Contracted capacity (kW)		10,000	1000	120
CBL (kW)	14:00~15:00	18,059	1944	356
	15:00~16:00	17,303	1904	349
	16:00~17:00	17,545	1882	302
Real load (kW)	14:00~15:00	8378	669	158
	15:00~16:00	7980	634	121
	16:00~17:00	7958	470	113
DR reduction result (kW)	14:00~15:00	9681	1275	198
	15:00~16:00	9323	1270	227
	16:00~17:00	9587	1412	189
DR delivery rate (%)	14:00~15:00	97%	128%	165%
	15:00~16:00	93%	127%	189%
	16:00~17:00	96%	141%	158%

4. Discussion

Unlike the traditional energy management models that focus on the supply side, the DSMS considers the energy demand and control on the interactions between customers and supplier to manage electricity usage reduction and money saving. Through the implementation of the DSMS technology, the end user can automatically check necessary information, such as the CBL, the RRMSE value, and the amount of DR reduction, without the need for complex formulas and contents. Furthermore, the CBL and current usage can be checked in real time by monitoring power usage every 5 min. The DSMS operated in the actual South Korea DR market for a year and based on these results the developed solution was verified. In addition, the result illustrates that the integrated demand-side management solution contributes by participating in the DR market and provides a benefit and satisfaction to the consumer.

The researcher and stakeholders of the DR market should consider the criteria value of the RRMSE. As previously mentioned in Section 2, the U.S. PJM power suggests a RRMSE value less than 20%, but the South Korea DR market sets the value within 30%. This consideration helps an effective DR operation and derives a successful outcome. This unique demand-side manage experience in South Korea could provide the rest of the world with a model to efficiently maintain a national power grid and potentially suggest the development of novel energy managing plans for local situations and policy.

5. Conclusions

In this paper, a case study of the demand-side management solution in South Korea is introduced and explained. The experience from the consumer and the DR aggregator shows that the integrated demand response solution technologies is a fast-responding approach in a cost-effective way. The curtailed energy from contracted customers contributed by reducing peak power in the national power grid and therefore can effectively provide a reliable power system. The demand resource can be an alternative to the redundant generation in short term such as 5 min. The case of a 10 MW contracted customer shows average 108.03% delivery rate and the total benefit of 854,900,394 KRW for two years. It also shows that all customers regardless of the amount of participation have responded well to 20-h DR dispatch during the two years. The results illustrate that the integrated demand-side management solution contributes by participating in the DR market and gives a benefit and satisfaction to the consumer.

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