Status and Perspective of Demand Resource Market in Korea's Electric Power Industry

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Abstract—**This paper calls attention to the demand resource market in Korea which opened in 2008 to reduce customers' consumption at critical times and, at the same time, secure the load that can be shut down. In Korea, the demand resource market is operated by either forward market or spot market. The discussion here is limited to the operations of the demand resource spot market. As the demand response program has matured in the smart grid environment, KPX (Korea Power Exchange) will shortly complete the development of the real-time demand resource trading system, taking into account an integrated dispatch system.**

Keywords-demand response; demand resource market; Korea's electric power industry

I. INTRODUCTION

According to Wikipedia [1], demand side management (DSM) entails actions that influence the quantity or patterns of use of energy consumed by end users, such as actions targeting reduction of peak demand during periods when energy-supply systems are constrained. In Korea, DSM activities consist of load management programs to attain energy conservation by changing the level and/or timing of customers' electricity demand and energy efficiency improvement programs. The DSM programs benefit utilities, customers, and the society by reducing electricity-related total costs and environmental damages. In fact, necessity of enormous investments in power facilities tends to increase power supply costs and barriers to add sorts of energy power generation capacity due to environmental regulations and siting difficulties will be further aggravated.

Most of all, the objectives of DSM can be categorized as follows: First, it can reduce uncertainties caused by facility barriers and competition. Second, it can decrease required investment and increase availability of facility, stabilizing electricity price. Third, it can save the nation's total energy consumption and costs. Lastly, it can mitigate environmental burdens such as global warming, acid rain, and so on.

The history and features of DSM programs are summarized in Fig. 1 [2]. The DSM programs in Korea can be divided into two groups, load management and energy efficiency improvement, as depicted in Table I [3]. Here, the year in parenthesis stands for the starting year of the corresponding program. The process and structure of DSM implementation in Korea are briefly displayed in Fig. 2 [3].

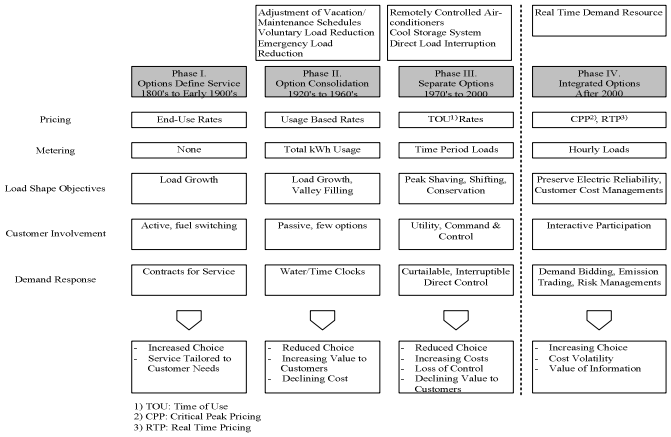

Figure 1. Histoty and features of DSM programs

TABLE I. DSM PROGRAMS IN KOREA

● Load Management

Load Reduction	**Load Shifting**
- Month ahead market (formerly, summer vacation/maintenance schedule adjustment) (1985) - Week ahead market (formerly, voluntary load reduction during summer afternoon peak hours) (1995) - Remotely controlled air-conditioners (1999) - Demand controller (2005)	- Cool storage system (1991) - Ice storage air-conditioners (1999) - TOU (Time-of-use) tariffs (1977) - Smart vending machines (1999)
Contingency Programs	**Load Building**
- Average load reduction upon request (2003) - Direct load interruption (2001)	- Heat storage appliance (1986) - Night thermal-storage power service (1972)

● Energy Efficiency Improvement

- Energy efficient lighting (1994)
- Inverters for improving motor efficiency (2001)
- High efficiency electric motor (2002)
- High efficiency electric transformer (2005)

The KEPCO (Korea Electric Power Corporation) was responsible for the funds in DSM until May, 2001. Since then, the DSM programs have been managed by Electric Power Infrastructure Fund which would be raised by the Electric Power Business Law revised in December, 2000. Traditionally, the management in demand resources was unilaterally performed by the utility, depending on the power supply and demand conditions simply to enhance the system reliability.

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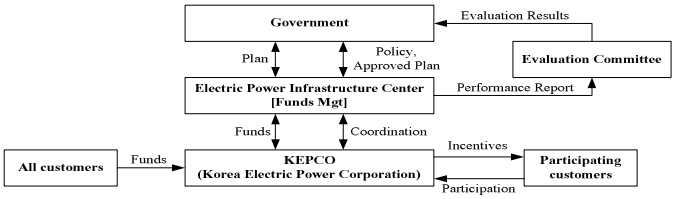

Figure 2. Structure of DSM implementation in Korea

In recent years, the changes in the emerging competitive electricity market structure and the advances in IT technology have enabled the demand resources to be utilized and operated in real time, resulting in the significant improvement in efficiency and economics of power systems and electricity markets. The changes of institutional and technical paradigm in operations and management sectors of demand resources are sketched in Fig. 3.

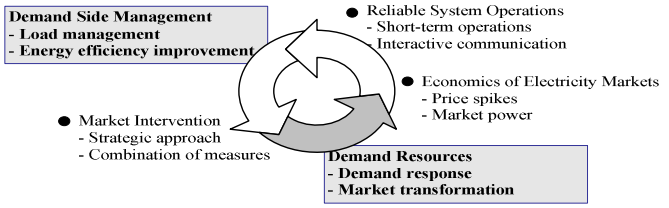

Figure 3. Changes of paradigm in demand side resourses operations

Unfortunately, Korea's current price regulations on electric bill do not motivate consumers to voluntarily control their load demands for energy conservation and/or savings in electricity bills since the electric rates are determined solely by contract classifications, not location and hours. Also, serious inefficiency ensues from the resultant cross-subsidy among customer groups (residential, commercial, industrial, educational, agricultural, etc.). To partly overcome this problem, the demand resource market was introduced in 2008. It has been generally observed that controlling the non-elastic electric power demand helps keep power supply and demand in balance and stabilize market prices by cutting the peak load.

This paper attempts to address the overview of the demand resource market which has been established over the last two years in Korea and elaborate the functions required to develop the real-time demand resource operating system.

II. Overview of Demand Resource Market in Korea

A. Forward Market vs. Spot Market

The amount of load reductions, applicable periods, and incentive rate are known *a priori* in the forward market, while the amount of load reductions and market prices are determined by consumers' biddings in the spot market. Besides, the flat rate of incentive is based on the auction or avoided cost, whereas the payment to the bids is subject to the marginal price principle. To maximize the efficiency of load management, all customers are entitled to freely participate in both the forward market and the spot market. The programs in Korean demand resource market are presented in Table II, where the capacities in week ahead market and spot market were expanded in 2009.

TABLE II. Programs in Demand Resource Market of Korea

Name of program (2008)	Notification time of event	Cancellation
Summer vacation/maintenance schedule adjustment	Six months ago	Impossible
Voluntary load reduction during summer afternoon peak hours	Six months ago	Impossible
Demand resource market (a year-round load control)	One day ago	Impossible
Emergency load reduction	Upon request	Impossible
Direct load control	Below 2,000 MW in reserve margin	Impossible

Name of program (2009)		Notification time of event	Cancellation
Forward market	Month ahead market	One month ago	Impossible
	Week ahead market	One week ago	-
Spot market	Day ahead market	One day ago	Impossible
	Hour ahead market	One hour ago	Impossible
Emergency resource	Direct load control	The same as direct load control in 2008	

The demand resource market is intended to cut the peak load which may happen within about 40 hours per year, thereby substituting the generation facility with the capacity factor of just 0.5 %. In 2009, each market aimed to curtail the peak load, as depicted in Fig. 4.

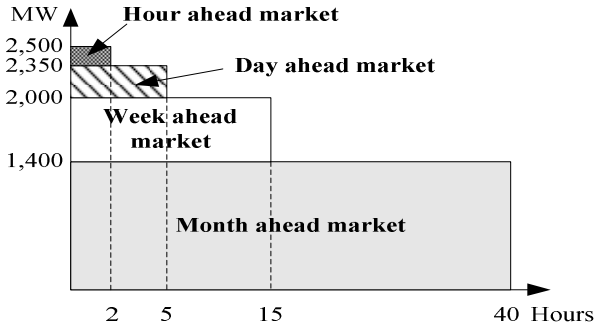

Figure 4. Target amount of peak load reductions by each market in 2009

B. Procedures for Operations of Demand Resource Market [4]

When there is an acute shortage of generation compared to the load demand or the yearly peak load occurs at a certain point of time, the substantial load reductions in the demand resource market are achieved on the basis of appropriate bid prices as well as the amount of available load reductions which are submitted by the market participants. Accordingly, it can be regarded as the advanced consumer-based load management scheme which is expected to cut down the electric power production costs and fulfill the security of power supply by the intense competition between customers. The procedures for operations of the demand resource spot market in Korea are naturally described in Fig. 5. The amount of load reductions and market price are determined as seen in Fig. 6.

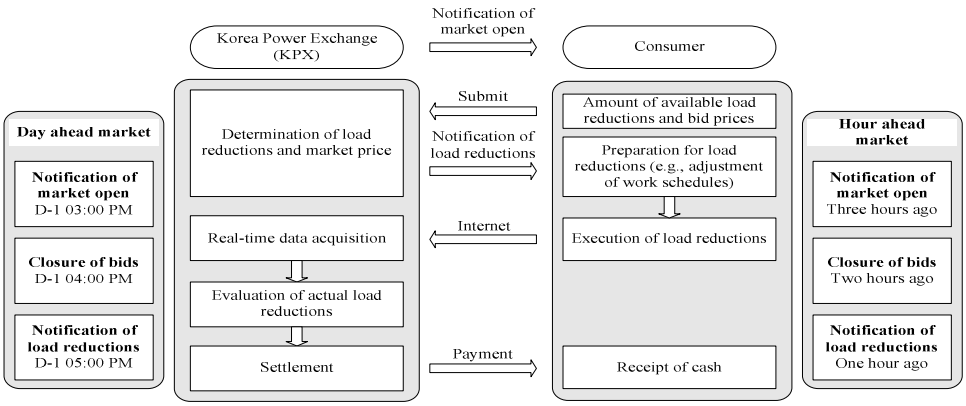

Figure 5. Procedures for operations of demand resource spot market in Korea

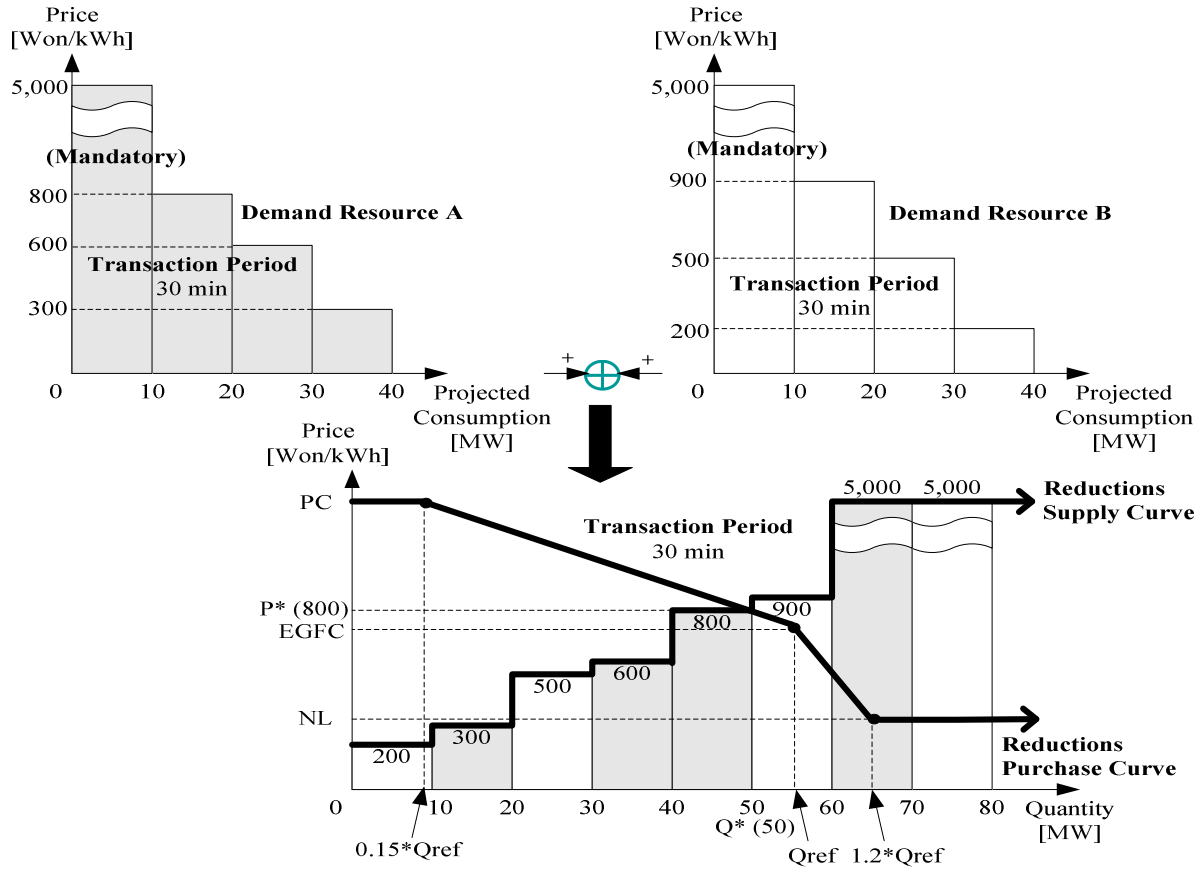

Figure 6. Determination of load reductions and market price in demand resource spot market

Three prices may be given in the reductions purchase curve, as indicated in Fig. 6; PC means the production cost of a gas turbine generator which is operated only for 12 hours per year, EGFC is the variable cost of an emergency diesel generator, and NL is fixed as the difference between the variable cost of an LNG (liquefied natural gas) generator and industrial electric charges. Note that the value of Qref may be defined by up to 150 % of total possible load demand reductions.

C. Settlement

The evaluation of payment to the participants in the demand resource market is made up of two components: One is the settlement for the available amount of load reductions to compensate for costs needed to wait for load reductions. The other is the settlement for actual load reductions in requital of them. The former is mathematically formulated as follows:

TABLE III. BIDDING PRICE FACTOR

Bidding Price	Bidding Price Factor
BP > 2,000	0
1,500 < BP ≤ 2,000	0.25
1,000 < BP ≤ 1,500	0.5
BP ≤ 1,000	1.0

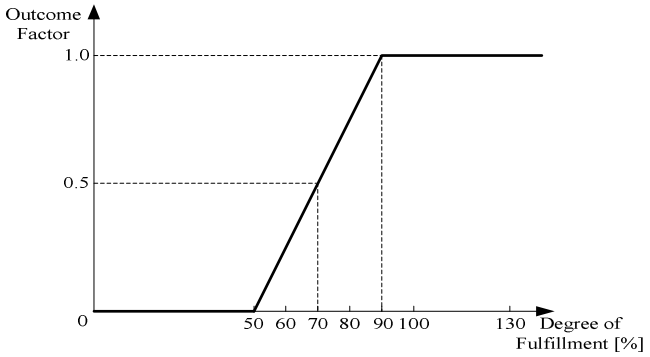

Figure 7. Representation of outcome factor

An adjusted amount for available amount of load reductions

= (available amount of load reductions) × (capacity payment, 7.46 won/kWh) × (bidding price factor) × (outcome factor) × (participation factor for hour ahead market) (1)

where the bidding price factor is tabulated in Table III, the outcome factor is given by Fig. 7, and the additional payment is given out to the customers who want to participate in both day ahead market and hour ahead market.

On the other hand, the latter is computed in the following:

An adjusted amount for actual load reductions = (amount of actual load reductions) × (market price determined by Fig. 6) × (outcome factor) (2)

In particular, the evaluation of actual load reductions turns to the similar-day average load strategy. The procedure of this methodology is explained in detail with a simple example in Table IV.

- The average loads of the corresponding time period for six days among ten days prior to the trading day are selected, where those of the top two days and the bottom two days are excluded.
- The estimated energy consumption of the corresponding time period in each day is computed by multiplying an appropriate weighting factor by the average load derived from the previous step.
- The actual load reductions are derived by subtracting the meter readings from the estimated energy consumptions summed over the six days.

III. RESULTS OF DEMAND RESOURCE MARKET IN 2009

The demand resource market that was pilot tested in 2008 succeeded in reducing the hourly average of 197 MW of power during the summer and 289 MW during the winter [5].

TABLE IV. EVALUATION OF ACTUAL LOAD REDUCTIONS

Trading Day	Average Load × Weighting Factor
D - 1	100 × 0.25
D - 2	110 × 0.20
D - 3	105 × 0.15
D - 4	95 × 0.15
D - 5	102 × 0.15
D - 6	104 × 0.10
Estimated Energy Consumptions	102.7 [MWh]
Meter Readings	52.7 [MWh]
Actual Load Reductions	50.0 [MWh]

The target curtailed energy for 2009 was increased to 350 MW to further facilitate the demand resource market. The actual load reductions are about 197 MW in 2008 and 364 MW in 2009, implying an increase of nearly 85 %. On the contrary, the market price has been decreased from 1,204 won/kWh in 2008 to 1,154 won/kWh in 2009. It should be pointed out that the actual load reductions have rapidly increased due to the keen competition between customers but the market price has declined more than 4 %. Detailed results related to operations of the demand resource market in 2009 are shown in Table V. Most obviously, the immediately curtailable high quality demand resources were secured in the proximity of the peak load time through the hour ahead market that was open on August 24 and August 25, 2009. That is, the volume of 450 MW that can be curtailed within an hour has been procured. Plus, the hour ahead market has gained a foothold in the flexible load reductions. In so far as the degree of fulfillment is concerned, it is approaching 100 % on average, which clearly revels that most participants tend to faithfully follow the command of load reductions each trading time. There have been no specific changes in the market price, ranging between 1,000 won/kWh and 1,301 won/kWh. The increase of bidden demand resources around 03:00 PM with high probability of reducing load demand makes the market price go down drastically. In Table VI, the bidden demand resources less than 1,000 won/kWh accounts for approximately 70 % to 80 %, resulting from the fact that the makers of cement with the low load reductions cost tendered the lowest bid and the lowest tender was promoted by modifying the trading rules, for instance, the bidding price factor. Furthermore, the bidden amount was tremendously increased after August 24, 2009 since the month ahead market by KEPCO was terminated and a new inflow of demand resources which took part in the month ahead market was caused.

IV. FUTURE DIRECTION OF KOREAN DEMAND RESPONSE SYSTEM DEVELOPEMENT

At this time, KPX is developing the framework for a real-time demand resource trading system [6] in Fig. 8 which is well founded on the DRAS (Demand Response Automatic System) for the independent system operator (ISO)'s demand response server system proposed by DRRC (Demand Response Research Center) of United States. To put it more concretely, the standard interface with which DR clients, i.e., DR resources, are linked, the standard interface for interconnection with ISO's electricity market and power systems, and a number of modules required of a platform to open the trading market are independently included.

TABLE V. RESULTS OF DEMAND RESOURCE MARKET IN 2009

	Date	10:30 ~	11:00 ~	11:30 ~	13:30 ~	14:00 ~	14:30 ~	15:00 ~	15:30 ~	16:00 ~	16:30 ~	17:00 ~	17:30 ~	Average
Amount of Reductions Command [MW]	08/14/09	-	-	-	-	370	369	364	364	-	-	-	-	367
	08/18/09	-	349	350	351	363	366	362	358	345	337	324	-	351
	08/20/09	-	-	-	362	384	378	377	373	359	-	-	-	372
	08/21/09	-	-	-	347	371	372	371	369	350	-	-	-	365
	12/08/09	376	371	-	-	-	-	-	-	-	-	361	357	366
	Subtotal													364
	08/24/09	-	-	-	402	432	424	422	422	404	398	-	-	415
	08/25/09	-	-	-	421	450	450	445	442	425	-	-	-	439
	Subtotal													427
Actual Load Reductions [MW]	08/14/09	-	-	-	-	398	404	400	399	-	-	-	-	400
	08/18/09	-	327	336	332	351	354	352	352	333	326	295	-	336
	08/20/09	-	-	-	354	377	377	370	364	345	-	-	-	364
	08/21/09	-	-	-	339	362	365	365	361	342	-	-	-	356
	12/08/09	370	376	-	-	-	-	-	-	-	-	366	346	364
	Subtotal													364
	08/24/09	-	-	-	428	466	450	450	429	405	396	-	-	432
	08/25/09	-	-	-	484	526	489	472	449	443	-	-	-	477
	Subtotal													455
Degree of Fulfillment [%]	08/14/09	-	-	-	-	108	109	110	110	-	-	-	-	109
	08/18/09	-	94	96	95	97	97	97	98	96	97	91	-	96
	08/20/09	-	-	-	98	98	100	98	97	96	-	-	-	98
	08/21/09	-	-	-	98	98	98	98	98	98	-	-	-	98
	12/08/09	98	101	-	-	-	-	-	-	-	-	101	97	99
	Subtotal													100
	08/24/09	-	-	-	106	108	106	107	102	100	100	-	-	104
	08/25/09	-	-	-	115	117	109	106	102	104	-	-	-	110
	Subtotal													107
Market Price [won/kWh]	08/14/09	-	-	-	-	1,227	1,101	1,000	1,000	-	-	-	-	1,082
	08/18/09	-	1,209	1,204	1,301	1,292	1,206	1,206	1,201	1,280	1,248	1,301	-	1,244
	08/20/09	-	-	-	1,201	1,116	1,093	1,066	1,066	1,153	-	-	-	1,116
	08/21/09	-	-	-	1,257	1,219	1,141	1,107	1,094	1,224	-	-	-	1,174
	12/08/09	926	969	-	-	-	-	-	-	-	-	1,178	1,202	1,069
	Subtotal													1,137
	08/24/09	-	-	-	1,231	1,242	1,301	1,201	1,201	1,216	1,264	-	-	1,237
	08/25/09	-	-	-	1,082	1,111	1,111	1,027	1,048	1,051	-	-	-	1,072
	Subtotal													1,155

Note: The day ahead market was open on August 14, August 18, August 20, August 21, and December 8, 2009, while the hour ahead market was established on August 24 and August 25, 2009 for a pilot test run.

TABLE VI. DATA RELATED TO AVAILABLE LOAD REDUCTIONS

Bidding Price	Day Ahead Market		Hour Ahead Market	
	Amount [MW]	Weight [%]	Amount [MW]	Weight [%]
$0< P \leq 500$	181	41.6	230	43.1
$500 < P \leq 1,000$	183	42.1	154	28.8
$1,000 < P \leq 1,500$	19	4.3	65	12.3
$1,500 < P \leq 2,000$	26	6.0	28	5.3
$2,000 < P \leq 4,000$	26	6.0	56	10.5
Total	435	100.0	533	100.0

Undoubtedly, the DRAS should be equipped with not only a standard interface but merely various functions as a platform for the real-time transactions of demand resources, where the DR business logic, bidding, metering, settlement, payment, data management, web server service, information notification are implemented as portrayed in Fig. 9.

The interconnection with the DR resources is made by the XML (eXtensible Markup Language) owing to the realization of OpenADR. The upper-level EMS (Energy Management System) and MOS (Market Operation System) are also connected with the DR system by the XML-based CIM (Common Information Model) which is being standardized as one of IEC 61970. Moreover, the customers need the DR client system to get access to the DR server system, where the modules for interworking are designed by OpenADR or OBIX (Open Building Information eXchange). Then the database schema is designed with the tag and property of XML by analyzing the elements, functions, and data of demand resource trading system. The database server and DFS (Distributed File System) are constructed to store the DFS document in a DFS. In a similar manner, the database of demand resources is created. Finally, the web server will be provided so that the consumer or load aggregator can acquire the related information from the DR engine via PC or cell phone.

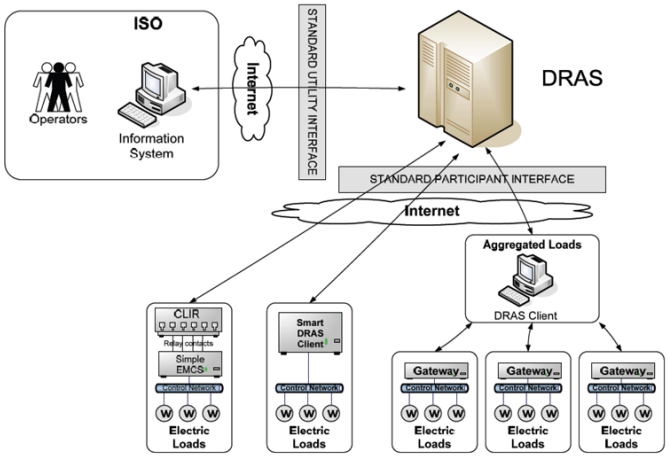

Figure 8. Schematic of DRRC's standard openADR (automatic demand response) operating system

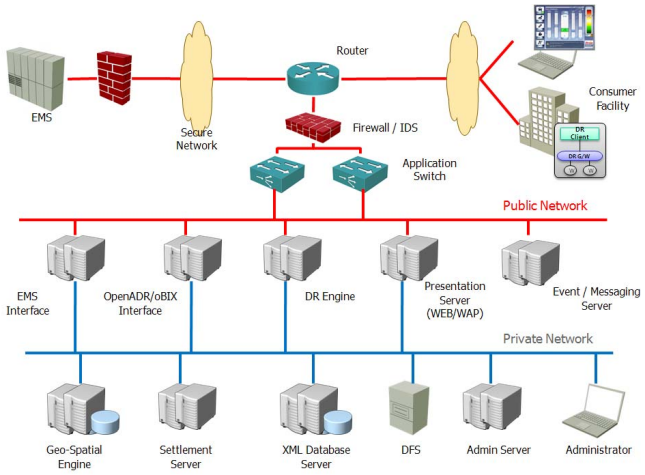

Figure 9. Development of Korean real-time demand resource trading system

V. CONCLUDING REMARKS

In Korea, KPX and KEPCO are working together to manage the load effectively, where KPX takes care of the demand resource spot market, or day ahead market and hour ahead market, by price bidding, while KEPCO handles the forward market, or month ahead market and week ahead market, with predetermined contracts.

To begin with, we have reported the rules of operating the Korean demand resource spot market that commenced in 2008. As we have seen, the main purpose of this paper has been to demonstrate the validity of the demand resource spot market in Korea by enumerating some evaluation criteria, i.e., actual load reductions, degree of fulfillment, and market prices, etc.

It is precisely apparent that the demand response MW gained from managing the demand resources is expected to enhance the systems reliability and capability to prevent the full potential of market power exploitation.

To optimize the customer resources with market and system conditions considered and incorporate the reduced load demand in the dispatch procedure, KPX has been supporting a project on developing the real-time demand resource trading system since the end of 2008.

REFERENCES

[1] http://en.wikipedia.org/wiki/Demand_Side_Management.

[2] http://crm.kpx.or.kr/newsletter/200706/Market_Equilibrium_Analysis_Considering_Demand_Response_in_Korea%28Kim_Jin_Ho%29.pdf.

[3] http://cyber.kepco.co.kr/suyo/new/data/pamphlet.pdf.

[4] KPX, Operations rules for electric demand resorce market, 2009.

[5] KPX, 2008 annual report : electricity market trends & analysis, Nov., 2009.

[6] C. H. Rhee, DR system & program design in Korea, 2010 World Smart Grid Forum, January 21, 2010.