Development of an Integrated Power Market Simulator for the Korean Electricity Market

Jin Hur† , Dong-Joo Kang* and Young-Hwan Moon**

Abstract: At present, the Korean electricity industry is undergoing restructuring and the Cost Based-generation Pool (CBP) market is being operated in preparation of a Two Way Bidding Pool (TWBP) market. In deregulated electricity industries, an integrated power market simulator is one of the tools that can be used by market participants and market operators analyzing market behaviors and studying market structures and market codes. In this regard, it is very important to develop an electricity market simulator that reflects market code providing a market operation mechanism. This paper presents the development of an integrated market simulator, called the Power Exchange Simulator (PEXSIM), which is designed to imitate the Korean electricity market considering the various features of the market operating mechanism such as uniform price and constrained on/off payment. The PEXSIM is developed in VB.NET and composed of five modules whose titles are M-SIM, P-SIM, O-SIM, T-SIM and G-SIM interfacing the Access database program. To verify the features and the performance of the PEXSIM, a small Two Way bidding market with a 12-bus system and a One Way bidding market for generator competition will be presented for the electricity market simulations using PEXSIM.

Keywords: Korean electricity market, PEXSIM, Power Market Simulator, Uniform Price

1. Introduction

Power system deregulation has become a worldwide trend for the purpose of introducing competition into the traditionally monopolized industry in order to realize efficient electricity production and investment. At present, the Korean electric power industry is in the midst of transition from a vertically integrated structure to a competitive market and is undergoing restructuring. The Cost Based-generation Pool (CBP) market is being operated in preparation of a Two Way Bidding Pool (TWBP) market. As the circumstance of the traditional system is changed according to power system deregulation, market simulation techniques and market simulators are needed to analyze market issues and study the electricity market. In this regards, it is very important to develop an electricity market simulator that reflects the market code providing a market operation mechanism [1]. The electricity market simulator is one of the tools that can be used by market participants and market operators to analyze market behaviors. After a new market code is adopted, a power market simulator will be useful to allow market participants to become familiar with the market structure and the market operating mechanism, and to help participants to develop strategies toward different market scenarios [5]. Also, the power market simulator is an effective learning and training tool. As the new structure and the operating mechanism of the power system is very different from the past, market simulations provide practical experiences and assist in understanding the market operation of the new environment [4].

In this paper, we present the development of an integrated power market simulator, the Power Exchange Simulator (PEXSIM), which is designed to imitate the Korean electricity market considering the various features of the market operating mechanism such as uniform price and constrained on/off payment. The PEXSIM is developed by the Visual Basic .NET language and is supported by the Microsoft Access DB. The PEXSIM adopts the Microsoft .NET framework as a platform for a faster simulation than a traditional COM environment system. In the unique simulator, all formulations for market simulation are constructed by the Linear Programming (LP) based model and so the PEXSIM utilizes the optimization LP solver, which is a commercial product. The PEXSIM is divided into two parts. One is an input and output module for market database and the other is a simulation engine for market simulations. The input and output function of the market data is implemented to M-SIM and the simulation engine including an optimization solver is composed of P-SIM, O-SIM, T-SIM and G-SIM.

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For the purpose of understanding the electricity market modeling and determination of market price such as SMP, MCP and LMP, we focus on M-SIM and P-SIM in this paper. To evidence the features and the performance of the PEXSIM, a small Two Way bidding market with a modified 12-bus system [3] and a One Way bidding market for generation competition will be presented for the electricity market simulations.

The following sections of this paper are organized as follows. In Section 2, we present an introduction to the Korean electricity market including the CBP and TWBP markets. In Section 3, the framework and characteristics of PEXSIM focused on M-SIM and P-SIM are presented. In Section 4, two competitive markets are applied to market simulation with PEXSIM. One is the Two Way bidding market for generators and purchasers, which has a 12-bus, 8-supplier and 7-customer system similar to the TWBP market. The other is a generator competition market of one side bidding, similar to the CBP market. A conclusion is given in Section 5.

2. Korean Electricity Market

The establishment and operation of the electricity market are necessary along with the restructuring of the electricity industry to enable market participants to buy and sell electricity. The three stages of transition were designed for the electricity market in step with each phase of the Korea Electric Power Corporation (KEPCO)'s separation and privatization according to the restructuring plan. Table 1 presents the timetable for the restructuring plan of the Korean electricity industry. In the second stage, the X that signifies the open TWBP market has not been fixed until now.

Table 1 General timetable for restructuring plan

Stage	Process	Term
1	Generation Competition	2001-Present
2	Wholesale Competition	X -2008
3	Retail Competition	2009-

2.1 Cost-Based Generation Pool (CBP) market

In the CBP market, each day before trading, all generators are required to submit offers to the Korea Power Exchange (KPX) indicating the generating capacity available in MW. The KPX produces a price-setting schedule and calculates the marginal price under the principle of minimizing system variable cost. Base load plants, primarily nuclear and coal, are subject to a base load marginal price (BLMP). Peaking plants, oil and LNG-fired, are subject to the system marginal price (SMP). Fig. 1 shows the general structure of the CBP market. The BLMP and SMP are determined by the variable cost of the most expensive base load or non-base load plant dispatched for the trading period. All generators are required to provide details of their production costs, which are then independently checked and approved.

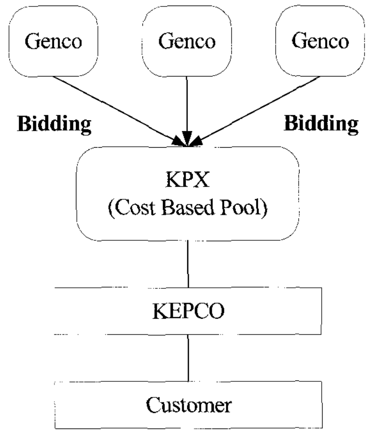

Fig. 1 General structure of the CBP market

After real time dispatching, settlement takes place according to the market price such as SMP, BLMP, Base Load Capacity Payment (CP) and Peak load CP. The Base Load CP reflects the projected capital cost and fixed O&M cost of the most recently planned 500 MW coal fire unit, whereas the Peak Load CP reflects the capital cost of a standard gas turbine unit and its fixed O&M cost. Because the market price reflects actual generation cost, the current system is termed the Cost Based Pool market. The supplier (KEPCO) purchases electricity according to prices determined by KPX and then supplies customers with electricity tariffs approved by the government.

2.2 Two Way Bidding Pool (TWBP) market

In the TWBP market, market prices are determined by bids from generation companies, disco/retailers and wholesale customers. Generation companies and purchasers will be able to trade with each other according to market principles. Fig. 2 shows the general structure of the TWBP market and the characteristics of that market are as follows:

- KPX is the sole market and systems operator
- All generators and purchasers must offer or bid the quantity and price of electricity through KPX
- Market Clearing Price (MCP) is determined by the balance between the supply and demand on the unconstraint 5 minutes dispatch schedule
- Real time dispatch on the constraint 5 minutes dispatch schedules
- KPX obtains Ancillary Service (AS) through contracts with AS providers

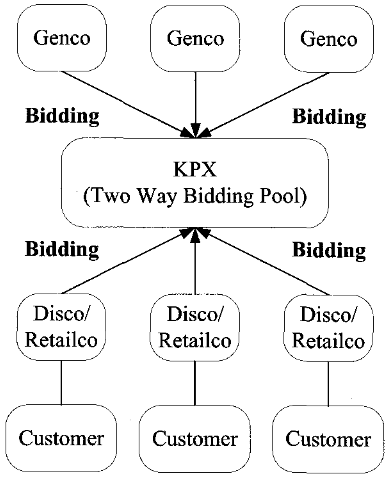

Fig. 2 General structure of the TWBP market

3. Implementation of Power Exchange Simulator

The PEXSIM requires a Window 32 bit system, which is developed by the Visual Basic .NET language and is supported by the Microsoft Access DB. The PEXSIM adopts the Microsoft .NET framework as a platform for a faster simulation than a traditional COM environment system and so the PEXSIM simulation engine is written on the Microsoft .NET Common Language Runtime (CLR). In the integrated power market simulator, all formulations for market simulation are constructed by the LP based model. Table 2 shows the summarized specifications of the PEXSIM.

Table 2 Specifications of PEXSIM

PEXSIM	Specification
Operating System	Window 32 bit System
Input & Output DB	Microsoft Access DB
Optimization Method	LP Solver
Platform	MS .NET Framework
Development Language	Visual Basic .NET & Fortran

The PEXSIM is divided into two parts and composed of five modules. One is an input and output module for market database and the other is a simulation engine for market simulations. The input and output functions of market data are implemented to the M-SIM module and the simulation engines including optimization solver are composed of the P-SIM, O-SIM, T-SIM and G-SIM modules. Fig. 3 illustrates the framework design of the PEXSIM. In the system operation module (O-SIM), there exists a function to provide Security Constrained Economic Dispatch (SCED) using DC-Optimal Power Flow (OPF). The network congestion analysis module (T-SIM) provides the function of AC-load flow considering contingency analysis in order to analyze transmission congestion problems. The gaming and strategies module (G-SIM) it presents the bidding strategies. The Cournot model is applied to establish the bidding strategies of market participants and then it is possible to forecast market price considering Short Run Marginal Cost (SRMC) and Long Run Marginal Cost (LRMC).

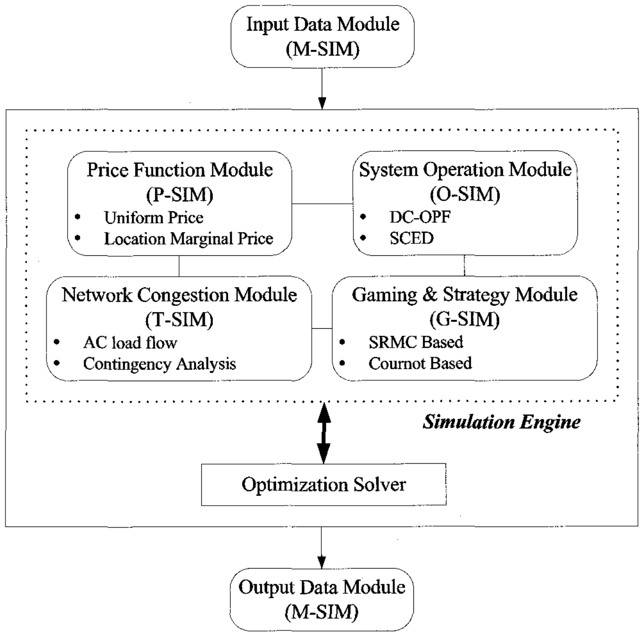

Fig. 3 Framework design of the PEXSIM

The Market Modeling Module (M-SIM), which has a designed market model and stored market database, and the Price Determination Module (P-SIM), which has calculated market clearing price are introduced in details as follows.

3.1 Market Modeling Module (M-SIM)

The database is an important part of the simulator. In the M-SIM, the .NET framework is a software development environment that interfaces with the Access database. The input data module can store the electricity market data and construct a market model using objects and classes. Major objects have regions, nodes, companies, generators, purchasers or loads, lines and reserves. Generally, the market database contains market data and technical data for the electricity market and the power system. For market data, it includes generator units, bid information and loads. For technical data, it comprises generation cost data, transmission data and bus data. In calculating MCP, it is needed to obtain a minimum dataset of generators and purchasers or loads. The minimum dataset includes number of unit, maximum capacity, offer (bid) price, offer (bid) quantity and ramp rate. Fig. 4 illustrates the connection diagram of the PEXSIM database. The ItemSpec field defines names and orders of market objects such as generator, load, reserve and transmission. In the case of generators, market data are entered to the generatorData field and generator-CostData field. For example, the simulation results, the stack curves and the MCP are stored to the MCPdata field after the market simulations.

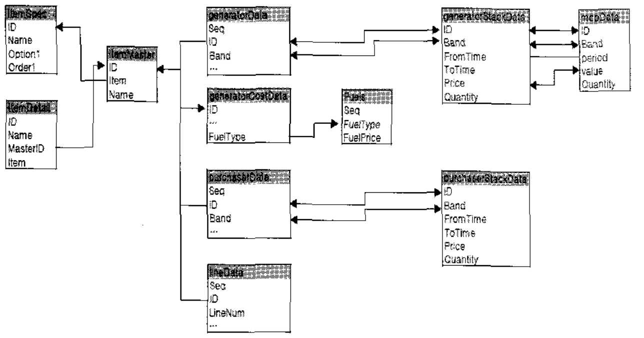

Fig. 4 Connection diagram of the PEXSIM database

The simulation output module produces the various simulation results such as cleared market price, cleared generation output, profit, cost and constrained on/off payment with graphical view and data tree view simultaneously. This module should have a function to query and view the market data simulated by various market scenarios and also, it is important to provide a quick and convenient way to view any solution data graphically. Users of the power market simulator can open the queried data according to simulation properties and display data across trading periods. The simulation results can also be saved with CSV format file in this module.

3.1 Price Determination Module (P-SIM)

In the P-SIM, the price formulation is constructed by an optimization problem based on LP based models. The general principle of the electricity market model is to maximize the benefit from electricity trading in the spot market, subject to satisfying the operating constraints. Fig. 5 shows the general process of determining the MCP.

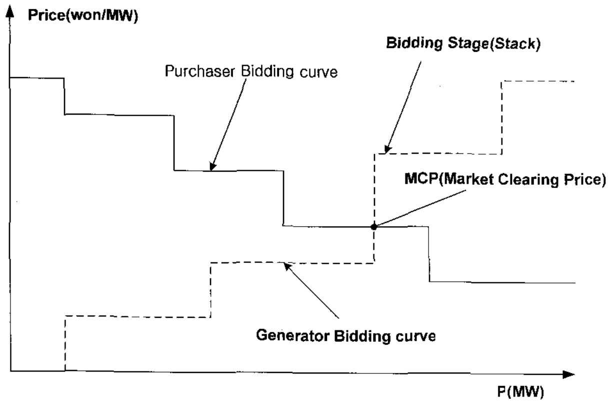

Fig. 5 Determination of the MCP

The aggregated supplier-bidding curve is obtained by adding all the curves of all generators. Similarly, by adding all the curves of all purchasers, the aggregated customer-bidding curve is obtained. The intersection point of the two curves is the clearing point. The price and quantity cleared are decided in this point [3]. In this clearing process for the TWBP market, the MCP is determined by a co-optimization of energy and reserve considering regulation reserve (RR), frequency control reserve (FCR), 10 minute stand-by reserve (SR10) and 30 minute stand-by reserve (SR30). Though the uniform pricing mechanism is adopted under the current market code, we implemented the locational marginal price (LMP) in order to study network congestion and various market issues adding to the existing function implemented for the SMP and MCP. The formulation of price function module is described as follows. In these formulations, the object function is to maximize the social benefit, which is the difference between the purchasers' benefits from electricity purchases and the generators' expressed cost of electricity production.

Object function

$$\text{Max} \sum_{t\in SL(t)} \sum_{t\in ST} LQ(i,j,t) \text{ X } LP(i,j,t) - \sum_{t\in SG(t)} \sum_{t\in ST} GQ(i,j,t) \text{ X } GP(i,j,t) \qquad (1)$$

Constraints:

$$\sum_{t\in ST} GQ(i,j,t) - \sum_{t\in SL(t)} \sum_{t\in ST} LQ(i,j,t) = 0 \qquad (2)$$

$$Fmin(p,q) \le F(p,q,t) \le Fmax(p,q) \qquad (3)$$

$$PGmin(i,j,t) \le GQ(i,j,t) \le PGmax(i,j,t)$$
$$0 \le LQ(i,j,t) \le PLmax(i,t) \qquad (4)$$

$$F(p,q,t) = \sum_{t\in SG(k,t)} \sum_{t\in ST} GQ(i,j,t) - \sum_{t\in SL(k,t)} \sum_{t\in ST} LQ(i,j,t) \qquad (5)$$

Notations:

i : Index for the number of generators or purchasers
j : Index for the number of bidding stages
k : Index for the number of nodes
t : Index for the number of time periods (hours)
ST : Number of stages of a bid, for example, the ST=7 means that suppliers or customers submit bidding data for seven stacks including offer prices and offer quantities
SG(t) : Set of suppliers offers at hour t
SL(t) : Set of customers bids at hour t
N : Number of nodes

T : Number of hours
GQ(i, j, t) : MW of generation stage j by supplier i at hour t
GP(i, j, t) : Price of generation stage j by supplier i at hour t
LQ(i, j, t) : MW of load stage j by customer i at hour t
LP(i, j, t) : Price of load stage j by customer i at hour t
F(p, q, t) : Branch flow from p bus to q bus at hour t
Fmin(p, q) : Minimum branch flow from p bus to q bus
Fmax(p, q) : Maximum branch flow from p bus to q bus
PGmax(i, j, t) : Maximum output of stage j by supplier i at hour t
PGmin(i, j, t) : Minimum output of stage j by supplier i at hour t
PLmax(i, t) : Maximum load demand of stage j by customer i at hour t

Fig. 6 illustrates the basic feature of PEXSIM. The data tree enables users to model an electricity market easily on the left hand side and if the generator object is selected, generator explorer displays all generators in a hierarchical structure. Users should view specific data of the selected generator such as offer quantity, offer price and technical information on the right hand side.

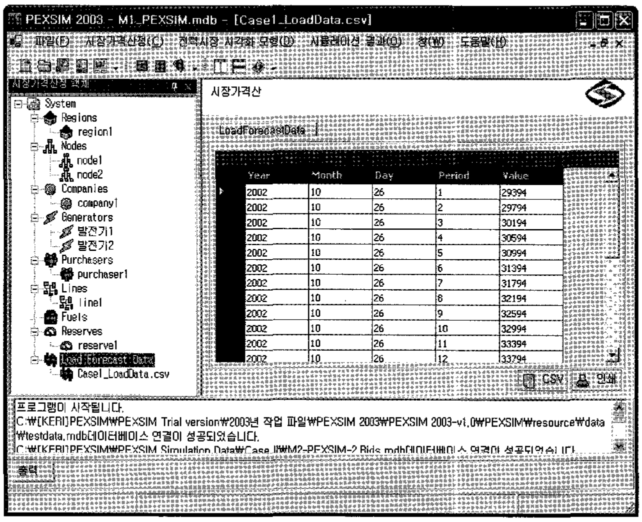

Fig. 6 Basic feature of the PEXSIM

In order to understand the principle of market simulation effectively, the PEXSIM provides a visualization model of the electricity market using the dynamic maps so that users can display simulation data graphically through the objects in the map for purposes of education.

4. Application of Market Simulation

To evidence the features and the performance of the PEXSIM, a small Two Way bidding market with a 12-bus system and a One Way bidding market for generation competition will be presented for the electricity market simulations.

4.1 Two Way Bidding market simulation

A market with 12-bus, 8-generator and 7-purchaser system is used to illustrate the operation process of the electricity market simulation and to test the function of determining market price in the developed PEXSIM. The modified market configuration is referred to sample system [2] by changing unit commitment information. Fig. 7 shows the small Two Way bidding market, which is located at the visualization model on PEXSIM.

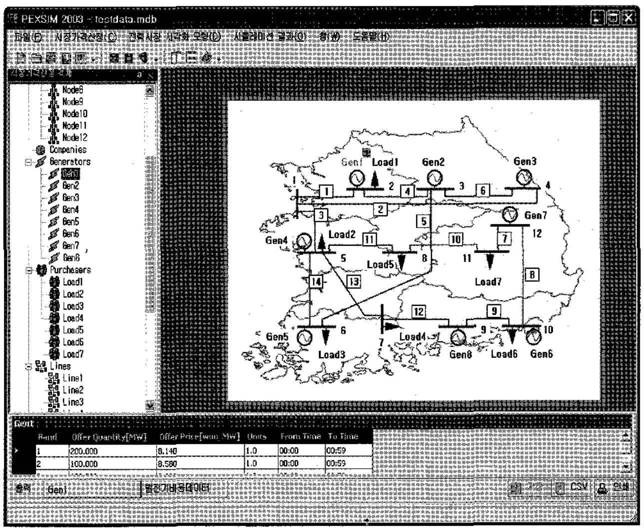

Fig. 7 Simple market on PEXSIM

The visualization model has been customized to a simplified South Korea grid configuration and generation /load resources will be further modified as required. The visualization model enables market participants and trainees to understand market simulation analysis. Table 3 presents the bidding data of 8 generators and we assume that they should submit the offer quantity (GQ, MW) and offer price (GP, Won/MW). Table 4 shows the bidding data of 7 purchasers and they should submit the bid quantity (LQ, MW) and bid price (LP, Won/MW).

Table 3 Bidding data of 8 generators

Gen	G1	G2	G3	G4	G5	G6	G7	G8
GP1	8.14	8.08	8.34	11.35	11.38	8.36	13.41	5.39
GP2	8.58	8.46	8.81	11.66	11.71	8.88	13.78	5.65
GP3	8.93	8.81	9.25	11.97	12.02	9.32	14.09	5.87
GQ1	200	200	200	100	100	200	40	300
GQ2	300	300	300	150	150	300	80	450
GQ3	400	400	1200	400	600	400	200	500

Through the market clearing process, the PEXSIM produces the MCP, 8.81 Won/MW under the unconstraint dispatch process and Fig. 8 shows the results of the final cleared generation dispatch for the trading period obtained using PEXSIM. In this simulation, G8 is operated by full available capacity because of the lowest offer price considering ramp up and down rates, and G4, G5 and G7 do not dispatch generation for the trading period.

Table 4 Bidding data of 7 purchasers

Load	Pur1	Pur2	Pur3	Pur4	Pur5	Pur6	Pur7
LP1	50	50	50	50	50	50	15.5
LP2	50	50	50	9.01	8.57	50	13
LP3	8.45	50	8.37	8.64	8.44	8.8	8.5
LQ1	200	100	200	120	130	150	50
LQ2	230	100	230	160	150	180	80
LQ3	260	100	270	280	160	220	100

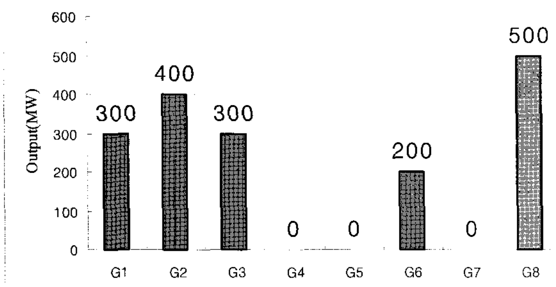

Fig. 8 Each generation dispatch result for trading period

4.2 One Way Bidding market simulation

In the competitive generation market, the SMP is determined by the functions of generation cost (GC) and load demand. The function of GC is calculated by minimum and maximum generation capacity, heat rate (HR), fuel price (FP) and variable operation & maintenance cost (VO&M) and then the GC function of the generators can be written as follows:

$$GC = HR*FP + VO\&M \quad (6)$$

In order to formulate LP models, we calculate a linear approximation to the quadratic function with 10 linearized periods for all generators because the generation cost is a quadratic function. After the linear approximation of function, the supply curve is obtained by aggregating all linearized periods of generation cost from low cost to high cost. The supply curve of all generators is indicated in Fig. 9. This curve is very important to understanding a competitive generator market and it means that the market is a perfect competition market not considering bid strategies.

The load demand curve for one day is shown in Fig. 10 and the load curve varies from 35,689 MW to 41,992 MW. The data of load demand is input to the M-SIM of PEXSIM as a CSV file format.

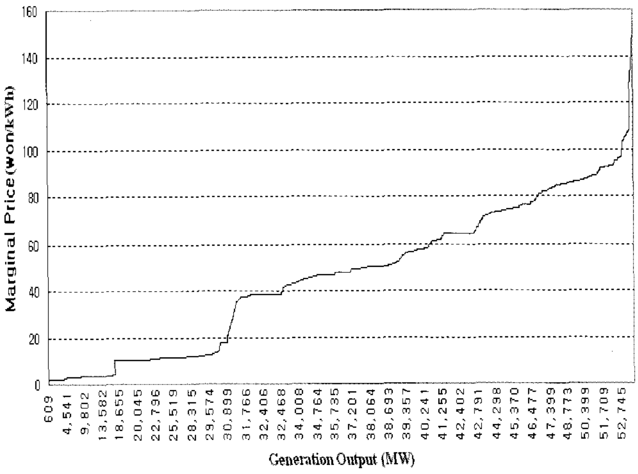

Fig. 9 Supply curve of all generators

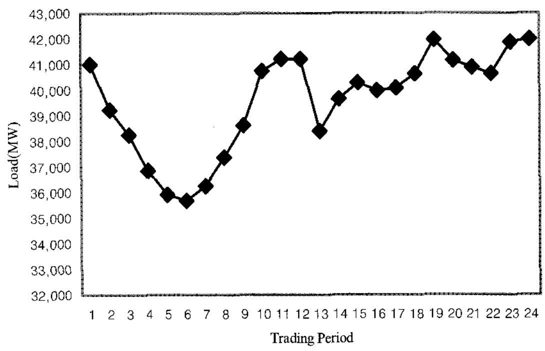

Fig. 10 Load demand curve for one day

In the P-SIM, the marginal price is determined by intersection points of the supply curves and load demand curves Fig. 11 shows the SMP in the generator competition market for one day. The SMP is varied from 47.6 Won/Kwh to 53.0 Won/Kwh with load fluctuation and the average marginal price is 51.2 Won/Kwh per day. The simulation results are very similar to the SMP that KPX published on the website. These results have an important meaning when analyzing market behavior and the market operating mechanism.

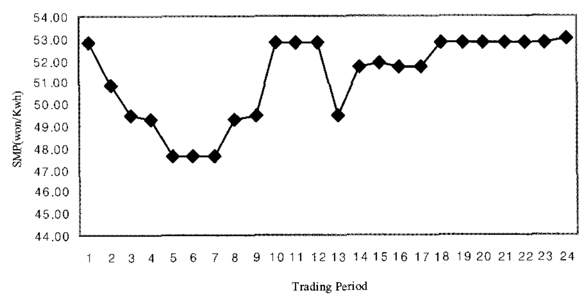

Fig. 11 MP in the competitive generation market for one day

4.3 Five bus system for calculating LMP

In the Korean market, the determination of market prices for the CBP and TWBP markets is calculated by uniform price mechanism under the unconstrained network. On the other hand, there are several Independent System Operators that employ the use of centralized dispatch techniques to alleviate transmission system congestion. In such systems an optimization is performed to ease congestion. The objective of the optimization is to minimize the bid based price of meeting power demand while enforcing the transmission system constraints. For these systems the use of Locational Marginal Prices (LMPs) provides a useful way of pricing the congestion rescheduling actions that are performed [6]. For these reasons, the Korean electricity market will study the LMP market in preparation of adopting it in the future. The basic definition of the LMP is the price of supplying an additional MW of load at each location (Bus) in the system. The major factors affecting the LMP values are the generator bid prices, the transmission system elements that are experiencing congestion on the system and the electrical characteristics. To calculate the LMP and analyze the shadow prices of transmissions, the LMP function is added to the P-SIM module. Generally, the principle of determining market clearing price in our electricity market model is to maximize the social benefit satisfying the operating constraints. In Linearized Programming simula-tions, the primal solutions from our pricing model are the generation dispatch outputs and the dual solutions, which are the shadow prices on transmission constraints. Therefore, the LMP solutions are generated automatically during the primal LP solution process.

In order to verify the LMP function, we utilize the five buses system considering transmission constraints and Fig. 12 illustrates the five buses system on PEXSIM as a visualization model. Furthermore, Table 5 shows the input data for generators, loads and lines of the electricity market model.

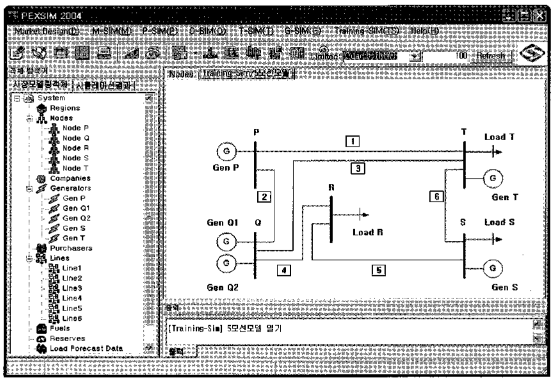

Fig. 12 Five bus system considering network constraints

NAME : **Five Bus-Base**
PROBLEM STATUS : **PRIMAL_AND_DUAL_FEASIBLE**
SOLUTION STATUS : **OPTIMAL**
OBJECTIVE NAME : OBJ
PRIMAL OBJECTIVE : 8.54200000e+003
DUAL OBJECTIVE : 8.54200000e+003

CONSTRAINTS

INDEX	NAME	AT ACTIVITY	LOWER LIMIT	UPPER LIMIT	DUAL LOWER	DUAL UPPER
C1	NodNetInjDef_Node P	EQ 0.00000000e+000	0.00000000e+000	0.00000000e+000	1.00000000e+001	0.00000000e+000
C2	NodPwrBal_Node P	EQ 0.00000000e+000	0.00000000e+000	0.00000000e+000	1.00000000e+001	0.00000000e+000
C3	NodNetInjDef_Node Q	EQ 0.00000000e+000	0.00000000e+000	0.00000000e+000	1.40000000e+001	0.00000000e+000
C4	NodPwrBal_Node Q	EQ 0.00000000e+000	0.00000000e+000	0.00000000e+000	1.40000000e+001	0.00000000e+000
C5	NodNetInjDef_Node R	EQ 2.33000000e+002	2.33000000e+002	2.33000000e+002	3.00000000e+001	0.00000000e+000
C6	NodPwrBal_Node R	EQ 0.00000000e+000	0.00000000e+000	0.00000000e+000	3.00000000e+001	0.00000000e+000
C7	NodNetInjDef_Node S	EQ 2.33000000e+002	2.33000000e+002	2.33000000e+002	3.00000000e+001	0.00000000e+000
C8	NodPwrBal_Node S	EQ 0.00000000e+000	0.00000000e+000	0.00000000e+000	3.00000000e+001	0.00000000e+000
C9	NodNetInjDef_Node T	EQ 2.33000000e+002	2.33000000e+002	2.33000000e+002	1.40000000e+001	0.00000000e+000
C10	NodPwrBal_Node T	EQ 0.00000000e+000	0.00000000e+000	0.00000000e+000	1.40000000e+001	0.00000000e+000

VARIABLES

INDEX	NAME	AT ACTIVITY	LOWER LIMIT	UPPER LIMIT	DUAL LOWER	DUAL UPPER
C16	LinFlowF_P-Q{1,1}	UL 4.25000000e+002	0.00000000e+000	4.25000000e+002	0.00000000e+000	4.00000000e+000
C17	LinFlowB_P-Q{1,1}	LL 0.00000000e+000	0.00000000e+000	4.25000000e+002	4.00000000e+000	0.00000000e+000
C18	LinFlowF_P-T{1,1}	UL 1.50000000e+002	0.00000000e+000	1.50000000e+002	0.00000000e+000	4.00000000e+000
C19	LinFlowB_P-T{1,1}	LL 0.00000000e+000	0.00000000e+000	1.50000000e+002	4.00000000e+000	0.00000000e+000
C20	LinFlowF_Q-R{1,1}	UL 2.00000000e+002	0.00000000e+000	2.00000000e+002	0.00000000e+000	1.60000000e+001
C21	LinFlowB_Q-R{1,1}	LL 0.00000000e+000	0.00000000e+000	2.00000000e+002	1.60000000e+001	0.00000000e+000
C22	LinFlowF_Q-T{1,1}	UL 3.00000000e+002	0.00000000e+000	3.00000000e+002	0.00000000e+000	0.00000000e+000
C23	LinFlowB_Q-T{1,1}	BS 1.70000000e+001	0.00000000e+000	3.00000000e+002	0.00000000e+000	0.00000000e+000
C24	LinFlowF_R-S{1,1}	LL 0.00000000e+000	0.00000000e+000	3.00000000e+002	0.00000000e+000	0.00000000e+000
C25	LinFlowB_R-S{1,1}	BS 3.30000000e+001	0.00000000e+000	3.00000000e+002	0.00000000e+000	0.00000000e+000
C26	LinFlowF_S-T{1,1}	LL 0.00000000e+000	0.00000000e+000	2.00000000e+002	1.60000000e+001	0.00000000e+000
C27	LinFlowB_S-T{1,1}	UL 2.00000000e+002	0.00000000e+000	2.00000000e+002	0.00000000e+000	1.60000000e+001

Table 5 Input parameters for calculating LMPs

Generators/ Loads	Offer Price (won/MW)	Offer Quantity (MW)	Lines	Flow/ Flow Back (MW)
Gen P	10	600	Line 1	150
Gen Q1	15	100	Line 2	425
Gen Q2	14	110	Line 3	300
Gen S	30	520	Line 4	200
Gen T	30	200	Line 5	300
Load R/S/T	233		Line 6	200

The dual solutions for the five bus system are as follows. In constraint parts from C1 to C10, the column results of dual solutions provide the LMP for all buses and also, the column results of dual solutions provide the shadow prices of transmissions in variables parts from C16 to C27.

According to dual solutions, Table 6 shows the LMP simulation results in P-SIM. Considering these results, the shadow prices for line 3 and line 5 are all zero and these results indicate that there are no price differences from bus R (bus Q) to bus S (bus T).

Table 6 LMP results for five bus system

Bus	LMP (won/MW)	Lines	Shadow Price (won/MW)
P	10	Line 1	4
Q	14	Line 2	4
R	30	Line 3	0
S	30	Line 4	16
T	14	Line 5	0
		Line 6	16

5. Conclusion

In this paper, the integrated power market simulator, PEXSIM, which should reflect the Korean market code and market structure is presented. We introduce five modules focused on the developed M-SIM and P-SIM adding a visualization model to PEXSIM, and other modules are being implemented by the designed framework of PEXSIM. The PEXSIM adopts the optimization techniques based on LP for fast and accurate simulation results. To show the effectiveness of the designed PEXSIM, two markets containing One Way bidding (CBP market) and Two Way bidding (TWBP market) are simulated for market modeling and price simulation. The finalized PEXSIM as the power market simulator will act as a very useful tool in the analysis of the Korean electricity market and training program for market participants and market operators.

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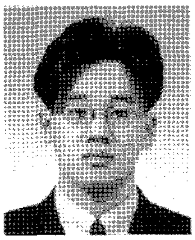

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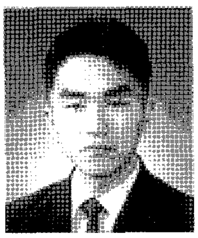

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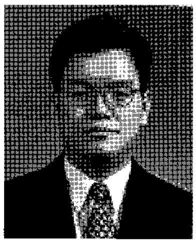

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