The Effect of the New Capacity Investment Behavior in the Korea Wholesale Electricity Market

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Abstract

Since 2001 the generation facilities used be owned by Korea Electric Power Company (KEPCO) have been divested to six independent firms as a part of industry restructuring. Market mechanisms are in place that there is a competitive bidding by these firms in the wholesale market, albeit strictly on a cost basis.

Related, Korean government continues to make use of "Basic Plan of Long Term Electricity Supply & Demand" in order to insure (generation) resource adequacy. While the plan is to provide insights to nation's outlook on electricity supply capability, often addition of new generation capacities is controlled by this plan. It should be noted that if the restructuring is to be complete, generation companies should not bear any obligation to invest unless their profitability is guaranteed. Nevertheless, many experts argue that government intervention is still necessary to avoid the undesirable price spikes in the wholesale market.

In this study, simulations for two scenarios are conducted to examine whether competitive market can help to stabilize the wholesale price in Korean market. The simulation results show that government intervention can prevent the price spike although the wholesale price in the competitive market turns out to be lower than that in the regulated market due to the additional new investment. The model used in this simulation has some significant limitations including the assumption that only gas power plants can respond the market price.

Key word: Wholesale electricity market price; Investment Behavior; Basic Plan of long term electricity supply & demand; System Dynamics

Introduction

The Korea electricity wholesale market is operated under the cost-based-pool system and the government regulation, "Basic Plan of Long Term Electricity Supply & Demand' in order to insure the resource adequacy. Addition of new generation capacities is controlled by this plan. While the plan is to provide insights to nation's outlook on electricity supply capability, often addition of new generation capacities is controlled by this plan. It should be noted that if the restructuring is to be complete, generation companies should not bear any obligation to invest unless their profitability is guaranteed.

In competitive electricity market, the government regulation and the investors' behavior affect the market prices. That impact lead to modification in government regulation and new generation investment. But such dynamics effects has not yet been analyzed in Korea electricity market.

In this paper, simulations for two scenarios are conducted to examine whether competitive market can help to stabilize the wholesale price in Korean market using system dynamics model. One scenario assumes that all new capacity is made based on government plan. The other assumes that new gas plant capacity comes from investors' investment according to their expected profitability.

The government's 'Basic Plan of Long Term Electricity Supply & Demand'

Korea government develops "Basic Plan of Long Term Electricity Supply & Demand" every two years. The time horizon of the plan is 15 years. Figure 1 shows the 3rd Basic Plan of Long Term Electricity Supply & Demand. The plan for construction of plants is computed based on the simulation result of WASP (Wien Automatic System planning Program, IAEA) which uses optimization model to calculate adequate capacity of plants by fuel type to minimize the cost. The procedures for building the long term plan are developed through the generation company survey. Government investigates the intention of new investment from generation companies including IPP(Independent Power Producer). After government considers the transmission conditions, site acceptances, and demand growth, it decides the candidates for new investment. The latest 3rd report was published in 2006 includes the plan for 2006-2020. Following table 1 shows outlook of the basic plan.

Year	2006	2010	2020	Annual avg. Growth Rate
Demand (million kWh) (After Demand side Management)	353,086	416,623	478,555	2.5%
Peak Demand (MWh)	58,990	64,160	71,810	1.8%

Table 1. Outlook for the Korea electric demand

3rd report supposes that the average demand growth rate and the peak load growth rate will be each 2.5% and 1.8%, respectively in 2006 to 2020. Total capacities will be about 94,280MW in 2020. The nuclear and coal will be the main sources to produce the electric power, at each 29% and 28%, respectively as shown in figure 1.

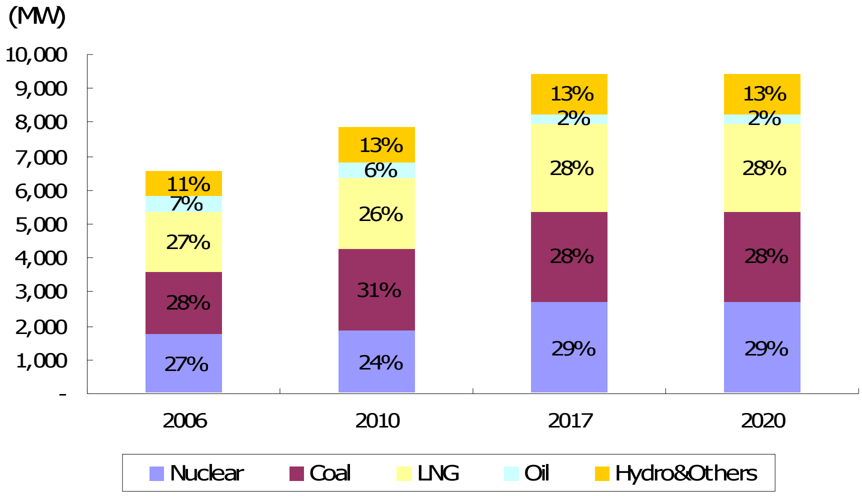

Fig.1. Outlook for the generation capacity

The goal of government's regulation is the electricity market stability by attracting proper generation investment while keeping the reliability of system. The power market's capacity reserve margin would be maintained about 22% level according to the government plan.

Model Description

In this study, main modeling ideas make use of Andy Ford's study (1999, 2001). The model assumes that Korea electric system will act as one market. In this market, price is determined by electricity demand and supply i.e. the market clearing price for electric energy is adjusted such that ISO schedules sufficient generation to meet the demand. Electricity demand is used based on the government's forecasting data while electricity supply is calculated by the generation unit's heat rate endogenously in this model. The model simulates the spot price over the 24 hours in a typical day, with one day for each quarter.

We assume that investors may select the only gas plants to construct depending on the price of natural gas in competitive market while the others will be invested according to government plan.

Figure 2 is a causal loop which shows the market price and gas plant investment. It represents the adjustments in generation responding to the changes in the market price. If the profitability of gas plant will be expected high, it leads to an increase of the number of new gas plant and generation. In turn, this affects the market price

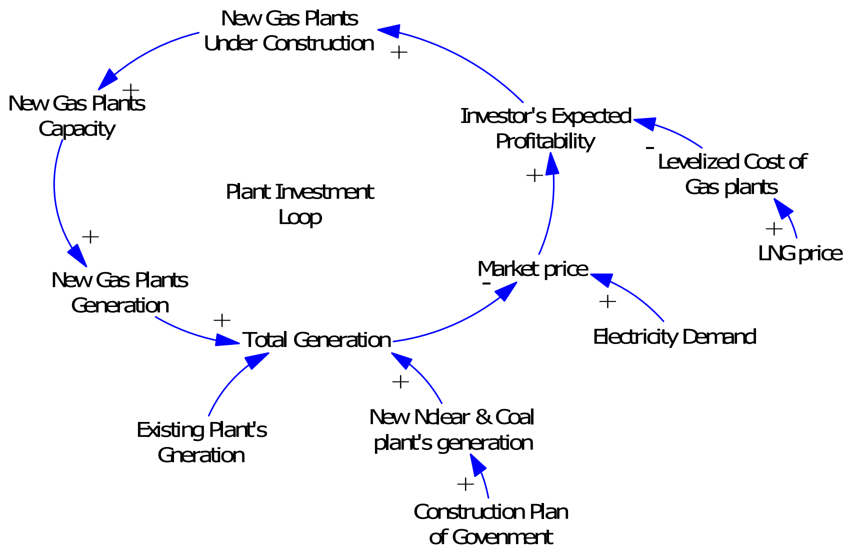

Fig.2. Causal loop for determining the electricity market price

Figure 3 shows the stocks and flows used to simulated investor decisions on permitting and construction. The investors estimate the market prices based on their estimate of the future reserve margin. The estimated price is compared to the estimated cost of a gas plant to determine if there are investors with permits who will start the construction.

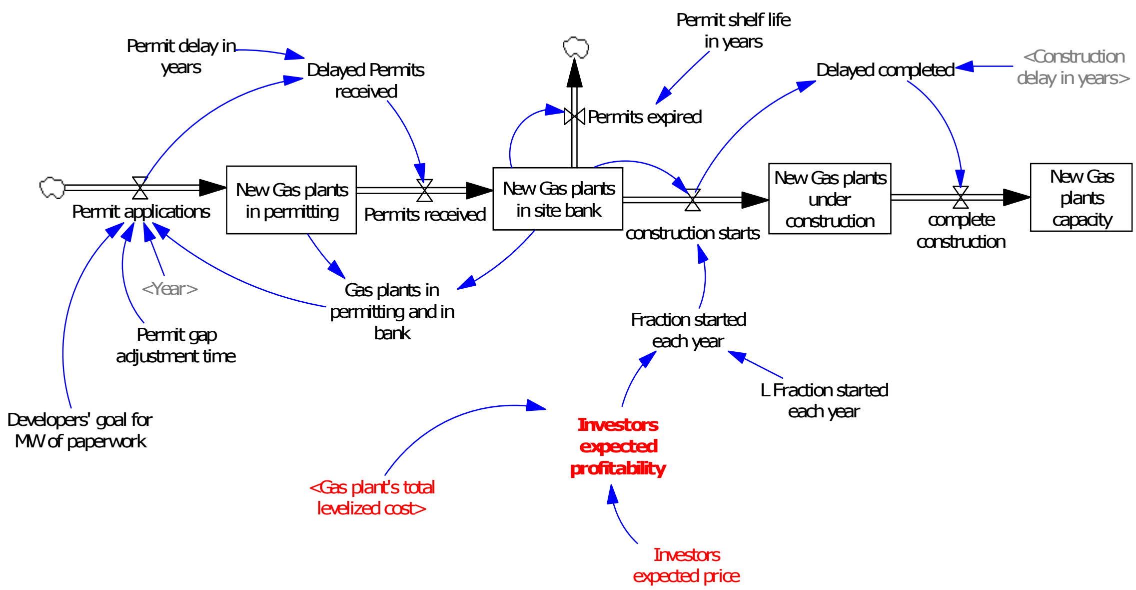

Fig.3 Stock and flows for new gas plant construction

The "Profitability" is the ratio of the expected price over a year to the total levelized cost. If the ratio is 1, the investors would expect to meet their profitability goal. If the ratio is 0.95, the price is 5% short of the value needed to meet their profitability goal. The start of construction is simulated as an endogenous variable. The key variables for determining the investors expected profitability are the gas plant's levelized cost and the investors' expected price.

Figure 4 shows the variables used to calculate the gas plant's levelized cost and Natural gas price. The total levelized cost of a new gas-fired power plant is calculated in $/MWh. The total cost consists of the fixed and variable costs. The levelized cost provides a benchmark for investors to make comparisons. If their expectation of future market prices falls below this benchmark, for example, they will be reluctant to invest. The prices of natural gas used in this simulation are obtained from the historical data and forward price in Korea gas market.

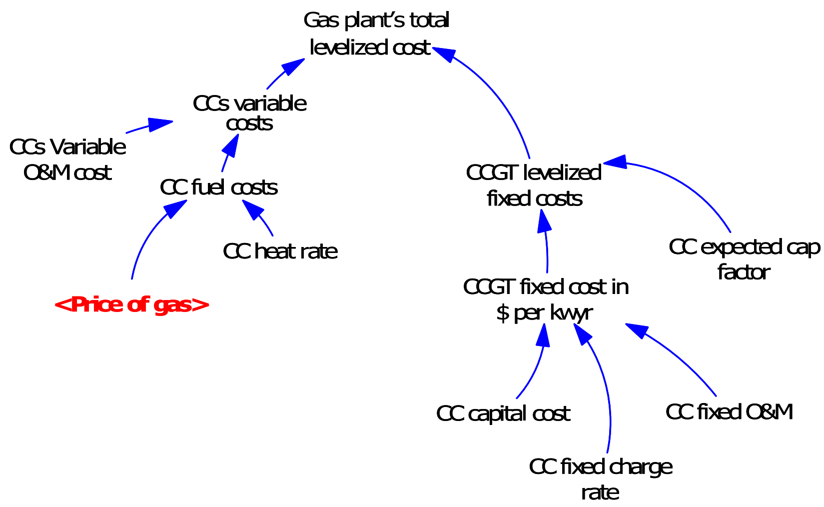

Fig. 4. Modeling to calculate the gas plant' levelized cost

Investors determine the expectation of reserve margin in the future using the expectation for future demand and supply. The investors are assumed to assemble a forecast of the supply available during the time of summer peak two years into the future. Also, they would see additional supply and would count it in their assessment of the market. Lower reserve margin implies tighter conditions and higher prices. Then, the model finds the expected profitability to compare against the total levelized cost of new gas plant.

Another key endogenous variable is the fraction of approved permits to be exercised each year. When the profitability reaches 1.0, we assume average investors will expect to meet their goal. We assume that there is some diversity in investors' conditions. Half of the investors will feel that their goals will be met; the other half will be unsatisfied. So, we set the fraction of investors starting investment in this year to 50%.

Major input data

The wholesale market simulations begin in 2000 with 40,784MW of peak demand and 47,867MW of total generation capacity. There are four sets of 24 "shape factors" to obtain the hourly loads for a typical day in each quarter. Figure 5 shows the demand shape factors for Korea dividend Peak load in each season. The future demand is calculated by this factor and expected future peak demand. Historical data were used for electricity demand and capacity by 2005. For the remaining period, the government's projected data was used.

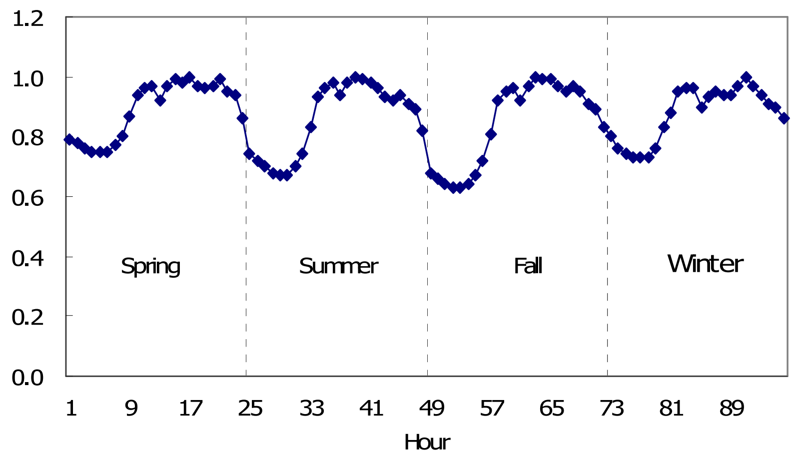

Fig. 5. Seasonal demand shape in Korea

Hourly generation for non-base load plant is calculated by the spot market price and resource's variable cost after deducting the forced outage rate and planed maintenance rate from total capacities. The base load plan is must-run and hourly generation multiplied by the available capacities by plant factor.

The prices vary continuously over 24 hours in a typical day. After 24 hours, we take the day as representative of an entire quarter. This part of the model keeps track of the prices for the quarter. When the simulation over quarter is done, the model updates the record for the price in the previous quarter. This is done with conveyor stocks.

New gas plant's capital cost is set to $600/kw, fixed charge rate is 14.7%/year, heat rate is 6800BTUs/kWhr, and variable O&M cost is zero. We assume that permitting delay takes 12 months. After 24 months, the construction is completed, and newly constructed gas plant begins its operation.

Simulation Result

Base case scenario; all new capacity will be made based on government plan

Figure 6 shows market prices from base case simulation. In hourly prices (the blue line), price spikes represent the prices during the hourly peak demand. At the beginning of simulation, the market prices are increased because of higher peak demand growth rate. However, the quarterly market prices remain steady since sufficient supply is supposed from government plan. This result represents that the wholesale market will be operated stable without exhibiting price spikes under the government control. In addition, there is no decrease in prices.

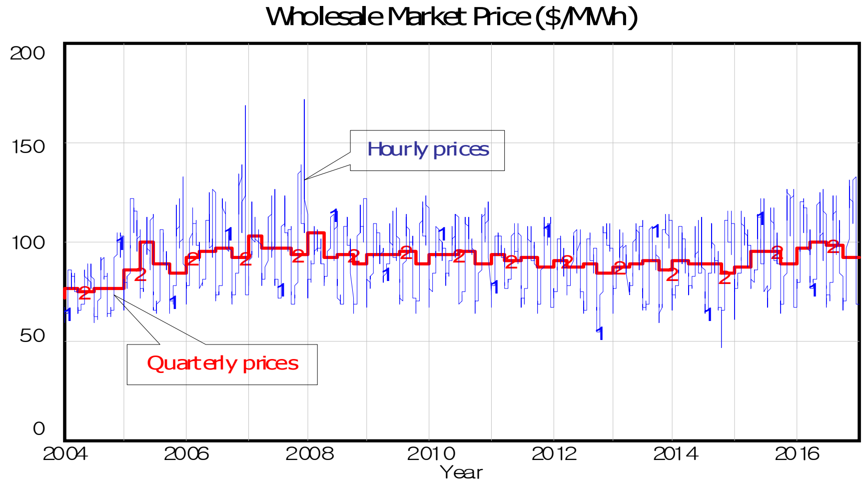

Fig. 6. Simulated Prices in the base case scenario

Figure 7 shows the comparison of demand with the capacity available to the system operator in the base case. It shows a tight condition of reserve margins during all simulation duration.

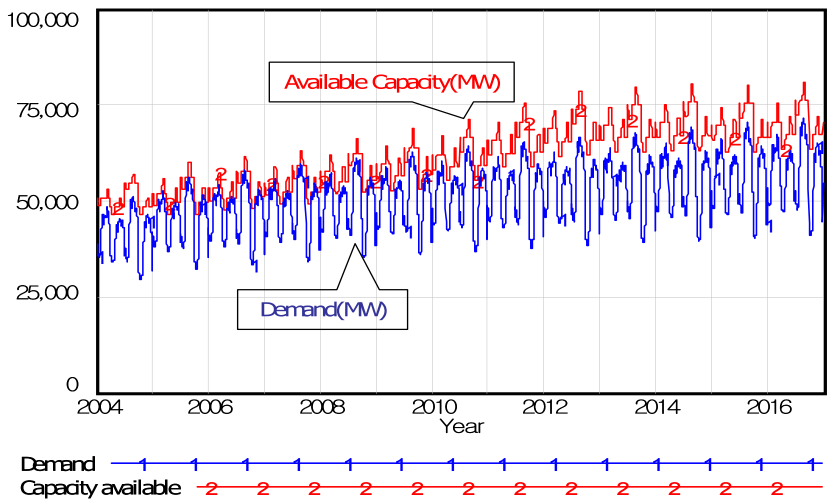

Fig. 7. Comparison of demand with capacity available in base case

Figure 8 shows the comparison of wholesale price with simulated prices and actual SMP(System Marginal Price)in Korean wholesale electricity market. As shown in Figure 8, the simulated wholesale price generally shows the similar agreement to the actual SMP. However, there are some significant big gaps at the end of 2006. The main reason is the expected gas prices which may be forecasted lower than actual gas prices. The model doesn't consider plant's starting time or exact pumping storage generations.

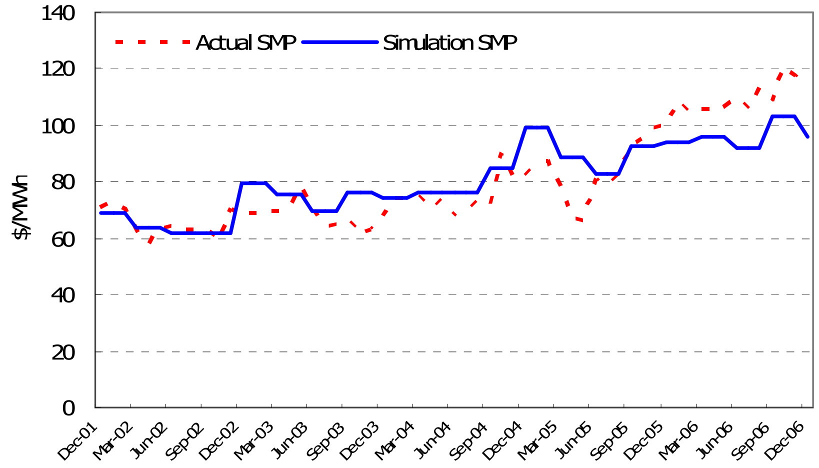

Fig.8 Comparison of actual SMP and simulated price

Investment scenario; the new gas plant capacity will come from Investors' investment, The other conditions are same as in the base case

Investment scenario reflects some competitive situation in the wholesale electricity market. While investors may select from technologies ranging from distribution technologies to coal and nuclear plants, only gas plants were assumed to be built depending on the investor's decision for simplification.

Figure 9 shows the quarterly price comparison with base scenario and competitive investment scenario. The simulation results reveal that investment scenario generates lower prices but some peak price in 2007.If other technologies like coal can be invested by investor, we may expect that the price volatilities may be even higher. The average market price will be lower because the marginal cost of coal is lower than that of gas plants.

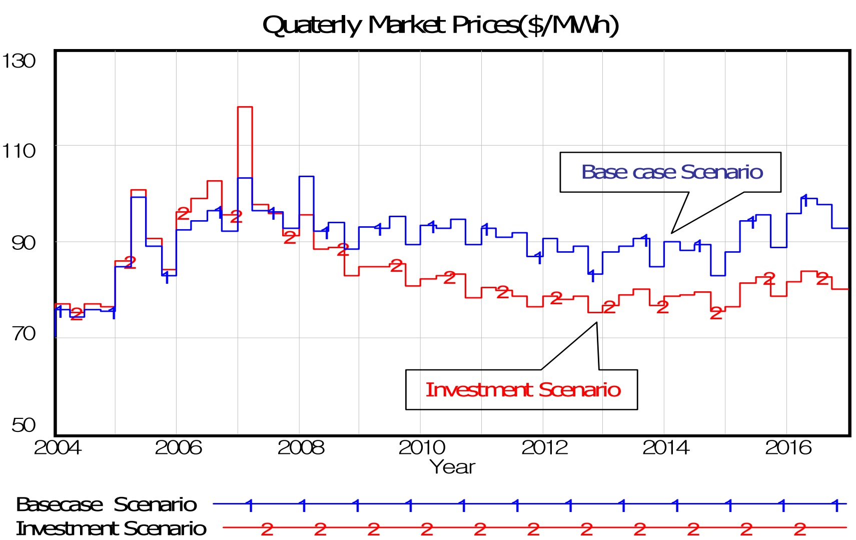

Fig. 9. Market Price comparison for the investment scenario

The higher prices in 2007 appear when the investment in new generating capacity does not keep pace with the growth in demand. After that the price is declining. This declines caused by a large building boom in gas pant and higher generation capacity supply.
Figure 10 shows the simulated construction in the investment scenario. The construction boom peaks in 2008 with over 9,000MW under construction. However, after the peak, the construction decreases and no new capacity addition is made after 2012 because of low expected wholesale prices. The blue curve shows the accumulated installed gas plant capacity growing to over 20,000MW by the end of the first building boom. After 2012, there is no more increase in total installed capacity due to no additional construction. Figure 10 shows a typical cyclical pattern of construction similar to what is seen in real estate markets. Sterman explains that this boom and bust cycles in real world arise from the combination of time delays in negative feedbacks and failure of the decision maker to take the time delays into account (John D. Sterman, 2000 p.707).

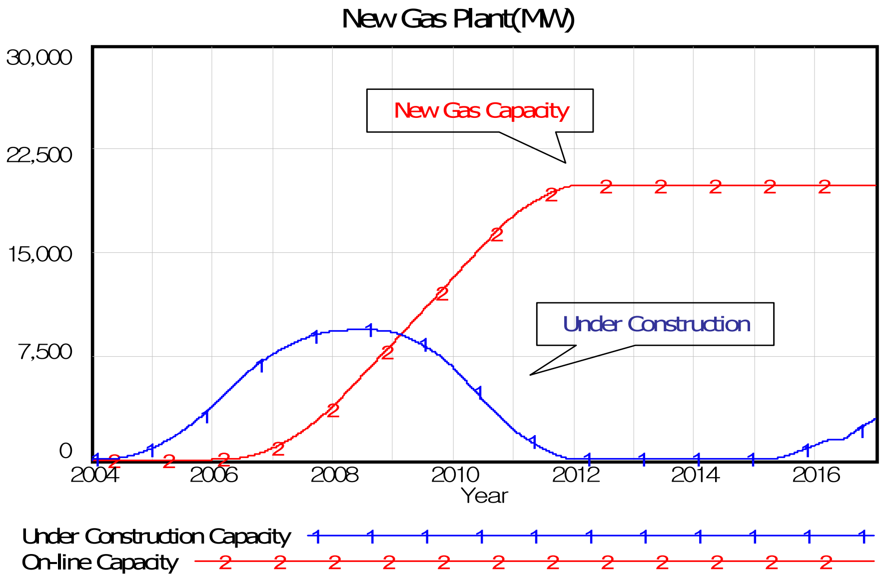

Fig. 10. Investor's construction of new gas plan

Figure 11 shows comparison of accumulated gas plant capacity based on government plan, the actual survey results for intention provided by generation companies, and simulated result. It can be seen that the survey results exhibits building two times higher capacity than government basic plan. The accumulated gas plant capacity from survey comes from the intention of generation companies, which reflects the investor's behavior for their investment. The simulation results, which also consider the investor's behavior, show similar behavior to the survey results.

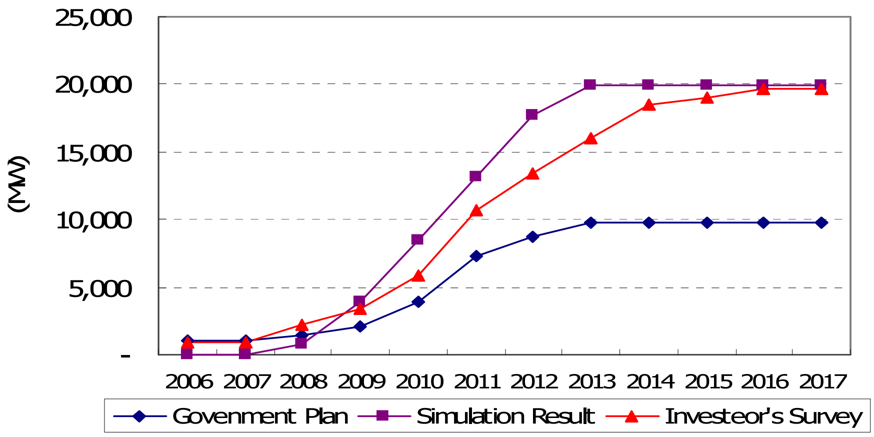

Fig. 11 . Comparison of gas plant construction

Figure 12 shows the capacity reserve margin compared with two scenarios. While the base case maintains a tight reserve margin, investment scenario increases the margin from 8% to 45%. In the total generation company survey for government planning, the investors respond that they will invest by 57.5% of reserve margin by 2020. From this we infer that investors expect that profitability in the competitive wholesale electricity market would be higher.

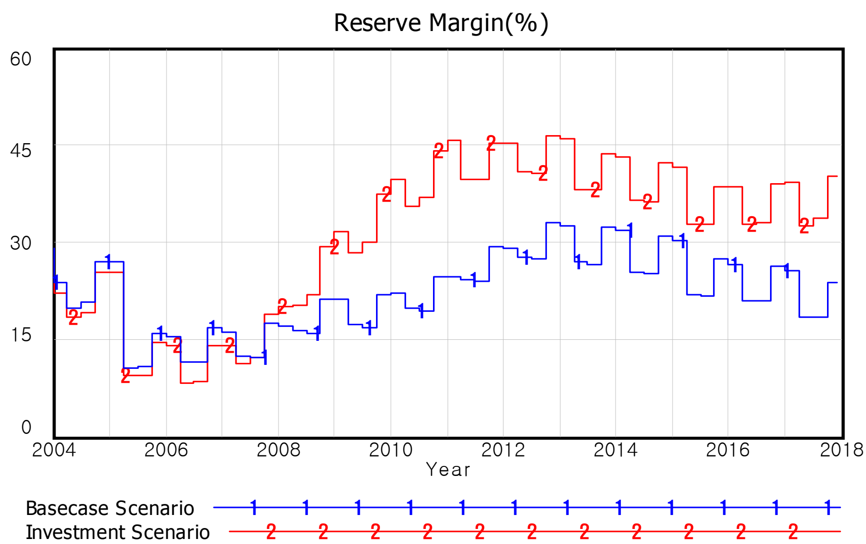

Fig. 12. Comparison of the capacity reserve margin

Conclusion

This paper analyzed the regulation by government and investment behavior by market signal in Korea electricity wholesale market using the system dynamics model. If the present electricity market continues (especially generation capacity is controlled by government), market will be operated stable without resulting in price spike but there is no lower price because of maintaining the reasonable reserve margin. It also shows the advantage in avoiding excessive investment. However, if the competition is introduced and the new investment is determined by the investor's decision without government intervention, the benefits from lower wholesale price are expected. Nevertheless, the volatility in the wholesale market increases, which increases the investment risks. This study provides important insights to Korea electricity market designers with respect to generation adequacy issues. As usual, the market designers need to use more accurate predictive model to capture the benefits of competitive markets and move ahead with the on-going restructuring.

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