To Main Proceedings Document

" A SD approach to the Efficiency Improvement of Electric Power Industry in Korea "- Focused on the Nuclear Industry

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Abstract

In this paper, we propose a System Dynamics (SD) model for the efficiency improvement in the electric power focused on the nuclear power plants. This strategic model will contribute to cope with promptly the business situation, energy generation, production, and pollution.

The current study methodology, using SD approach, deals with the detailed drawing of our key points on nuclear power generation systems in electric power industry of Korea. These include such factors as the operation of nuclear industry and parameters related to the decision making for business policy. Based upon the above-mentioned influence diagram drawn, we developed SD simulation model to evaluate and analyze strategic management of KEPCO (Korea Electric Power Corporation).

Recently, according to report from KEPCO, they are considering of delaying a new power plant construction. It is based on Business fluctuation downsized from Korean economic crisis in 1997 and freezing of fund from raise in exchange rate.

Thus, these results enable Electric power industry authorities to develop an evaluation model of strategic management.

Based on our analysis, we could demonstrate how simulation model can be applied to the real electric power generation in Korea.

Introduction

1. The purpose and background of study

A stablized supply of low-priced, high-quality electricity is the kernel of national economy. To cope with changes in various circumstances of the 21st century actively, stabilization of power supply-demand, promotion of the efficiency of power industry and the environment-friendly power industry, and establishment of reasonable plans cannot be stressed too much.

Recently, it is reported that KEPCO (Korea Electric Power Corporation) is under consideration to postpone the construction of its major power plants for a certain period. According to the paper (The Korean Economic New Daily, P. 11; April 3, 1998), KEPCO is in discussion with the parties concerned with delaying or withholding the time of starting and completion of 14 power plants, which have already given orders, including Uljin nuclear power generators No. 3 - 6 for 3 months at least to 22 months longest.

KEPCO's situations can be fully understood as it seems difficult to raise funds due to surplus of electric power in severe economic slump and due to the increase of financial burden by a raise in exchange rates. However, any change or modification of a power plant construction plan, one of representative SOC, should be decided in more careful consideration.

Upon investigation of worldwide energy preferences, they can be classified roughly into three patterns:

First, the pattern of countries rich in water-power resources, such as Canada, Sweden and Switzerland; second, the pattern of countries rich in coal, such as U.S.A., U.K. and Germany, and; third, the pattern of countries poor in national resources, such as France, Italy and Japan. Meanwhile, even the countries rich in water-power and/or coal resources applied nuclear energy for most of increased demand for electric power since 1973 after the oil crisis early in the 1970's.
However, only Italy which depended on fossil fuel is still importing electric power from France. In our country, nuclear energy, LNG and coal have been used concurrently for diversification of fuel resources. Particularly, nuclear power generation continued to expand, despite negative reports of the press and objections by environmental groups, and could have reduced from 85.9% oil energy portion in 1976, when nuclear power generation began, to 20.7% portion in 1996 after the lapse of 20 years.

As a result, our national demand-supply balance of energy could be maintained even in the vortex of Gulf War. The amount of energy imported in 1997 was 27.2 billion dollar, with an increase of 12.5% over the previous year. Our energy environment is very poor because most of our energy, that is, 97.3% of our national demand, depends on the import from abroad. Therefore, the stabilized demand-supply of energy is an important factors on a national security level in Korea.

In this context, our electric power supply-demand should be considered based on long-term prospects foreseeing dozens of years, and then the electric power source development plan should be established and performed. Even just our experiences suffered from continuous power shortage early in the 1990's, due to reduction of power plant construction plans in the beginning of the 1980's, may explain the reason enough.

Our nuclear power generation attained the 20th anniversary on April 29, 1998 since commercial operation of Gori-1 Generator on the same day, 1978. With an increase in demand for electric power and an oil-free power development policy from the commencement of the nuclear age under operation of a 600,000kw-class nuclear reactor, construction of nuclear power plants continued after completion of Gori-1 Generator, and entered into the world's ten nuclear powers, with 12 nuclear generators of total output 10,316,000Kw as of 1998.

However, even until 1997, the power reserve rate in high-demand summer season decreased every year, causing power-shortage crisis. Furthermore, demand for power can abruptly increase, but it is difficult to increase supply. The construction of nuclear power plants usually takes more than ten years at least from starting work to completion. Therefore, although the situations may be remarkably changed due to foreign exchange control crisis, any reduction or postponement of nuclear power plant construction should be deemed as risky.

The purpose of this study is to build up a model to improve the efficiency of our national nuclear power industry using SD (System Dynamics). It is considered that we can build up the best power resources development plan, as well as cope with changes, promptly and systematically, by preparing an instrument to establish a management strategy free from dependence on repeated manual operation, through a management strategy model using SD.

2. The contents, scope and methods of study

Our national electric power industry including nuclear power focused on how to establish technical independence until quite recently. Technological policies like a standardization project or new model reactor projects led our nuclear power industry, and those policies can be evaluated as relatively successful. However, recently, new problems are being formed in nuclear power industry: how the site for nuclear power plants can be selected; how the site for waste disposal can be prepared, and; how the NSSS (Nuclear Steam Supply System) and waste disposal work can be transferred without trouble, and so on. Thus, regarding major problems pending in domestic nuclear power industry, solutions of social, cultural and political problems including the related technological characteristics are given much weight. This phenomenon occurs in our power industry (bituminous coal, LNG and water power, including nuclear power), energy industry and in our whole industry. In this regard, Richmond, a researcher of social dynamic structure, points out that it is a general characteristic of modern society being formed with complicated dynamic structure between systems.

Unlike pure technological problems, social problems related to the existing

technological problems are connected with numerous Feedback Loops, causing severe non-linearity, and are characterized by a wide range of subjects to be considered. A general method against these problems proceeds by separating technological problems from social problems, then using a technological method for technological problems while a mental model for social problems. So, it makes an alternative plan using brain-storming, and comes to draw a conclusion through qualitative analysis of the alternative plan's merits and demerits. In this traditional approach, there are some problems: how to separate technological problems from social problems, how to make a conclusion in stable conditions, and so on. Consequently, technological problems and social problems are closely connected by Feedback Loops; simplification for many people's understanding is open to errors; qualitative analysis may possibly contain prejudice at any time, and; stress on the conclusion in stable conditions may overlook the evaluation on the side effects occurred in the process.

There have been indications since old times that complicated social phenomena should be analyzed quantitatively, using a technological method. As a solution for the necessity, SD occurred. SD was invented and developed by Prof. Jay Forrester of MIT in late 1950's, then applied to national energy policy, environmental policy, food and real estate policy, project control strategy, production control, stock market analysis, reengineering, learning organization, industrial structure modeling, officials training and up to general firms in a wide range. In particular, the complicated modeling process, which was pointed out as a defect, is extending the application range with new technologies being supplemented by computer softwares under rapid development.

As a kind of decision-making analysis method invented by Prof. Forrester of MIT (Massachusetts Institute of Technology) in U.S.A., SD is a basic technology being widely used to understand the systems of industry, market and natural world (in case of a model against greenhouse effect), as well as the field of decision-making, and to solve the problems there of.

In the 1960's and 1970's, owing to adverse points of using a computer language in the form of DYNAMO, studies were made in the fields limited to management strategy, real estate and energy policies mainly by MIT as the central party.

Since the beginning of mid 1980's, development of computer software (Stella or ithink, Vensim, etc.) reduced restrictions on users, and their applications are expanding rapidly in solving the problems of various public fields, including the whole range of business administration (marketing, production control, etc.), traffic, communication, and pollution.
In the 1990's, with the concepts of 'organization learning,' 'system thinking,' etc., it shows signs of indirect applications, such as staff training and system conduct, in addition to direct instruments for decision-making.

In the fields of nuclear industry and electric power industry, Prof. Hansen introduced these concepts first at the Energy Lab of MIT. The SD model approach related to the efficiency of nuclear power plants is a promising field.
The contents to be worked in this study can be summarized as follows :

2.1 Contents of study

The concrete contents of this study consist of 'system research,' 'qualitative model-making and verification' and 'performance analysis of management strategy.'

The contents of this study can be materialized as follows:

2.1.1 System research

The system in the construction process of a management strategy model of nuclear power industry is a set of factors related to management of nuclear power industry and decision variables related to the factors. The first work to do is finding what variables are related to long-term management strategies of nuclear power industry directly and/or indirectly. The investigation on the scope of system and the related variables is performed in this research team's internal discussions, further in exchange of opinions with management strategy-makers and many working-level officials.

2.1.2 Qualitative model-making

The second stage is preparing Causal Loop Diagram (CLD) after clarifying the relations between factors. This qualitative model, a simplified pattern of SD model as a Flow Diagram (FD) to be completed later, can be used for exchange of opinions with a third party or decision-maker. Meanwhile, through analysis of this CLD, we can find major circulatory loops around which normal and adverse functions of specific management strategies can be studied.

CLD is prepared through the team's internal discussions, on which basis CLD is continuous supplemented in the regular process of exchange of opinions with working-level officials around the circulatory loof. In addition, this CLD is supplemented in the process of quantitative model-making and verification to be performed at the next stage, thereafter it is determined as final.

2.1.3 Quantitative model-making and verification

The third stage is changing a draft of CLD to FD, and then the very result is SD model. This SD model is composed of three variables; level, fluctuation ratio and auxiliary-variable. Level is a variable which can be expressed as a FD, such as budgets, numbers of employees and services. Fluctuation ratio is a variable which expresses the level's temporary changes. And, auxiliary variable is necessary to calculate level, fluctuation ratio and auxiliary variables. To calculate these variables, input materials may be required. The variable like a budget can be obtained through the past performance or investigation of intended data, and most of others through questionnaires or interviews.

The model completed like this passes through the process of verification. The verification methods may include a study of model conduct through analysis of susceptibility, discussions with the officials concerned, and comparison with the past

performance records.

2.1.4 Studies on case analyses of management strategy

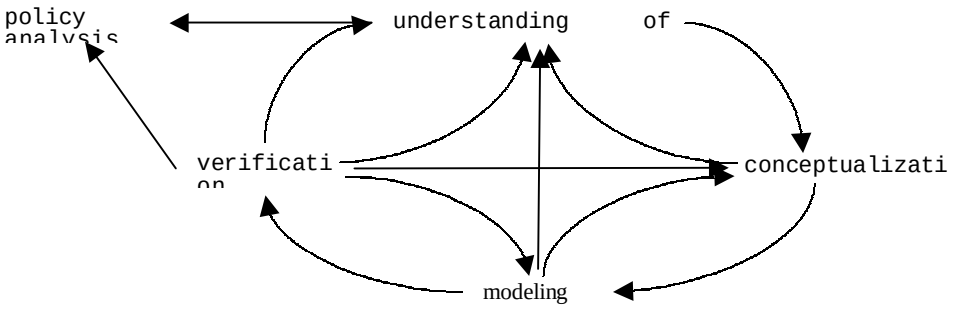
The model completed through the process of verification is converted into a user-friendly simulator for its use without knowledge of SD or computer modeling. The simulator programmed thereby will be modified for the data and the model itself conveniently in accordance with changes in circumstances. The finished simulator can be used to establish management strategies, further applied to staff training for understanding of their performance roles in the whole system (learning organization). The final stage analyzes several cases of policy issues.

2.2 Methods of study

SD defines the systems which consist of variables related to given problems or a set of problems directly or indirectly, clarifies the dynamic characteristics of systems through a serious of simulations after computer-modeling by a quantitative study of relations between variables, and renders help to solve problems.

The problems here are not limited to a certain range basically, but mean social problems related to human activities. This is because the general technological problems have been solved traditionally by quantification and thereby well-defined by structured problems.

SD Modeling Process can be divided into four stages, as in Fig.1:



[Fig. 1] SD Modeling Process

2.2.1 Understanding and conceptualization of system

Understanding of a system is a process modifying the model-making team's mental model of the problem and therefore, the results are conceptualized as a CLD. Various modeling stages are helpful to understand the system. The increased understanding must be re-reflected in models through modification of CLD. CLD is a diagram which expresses the qualitative relations between variables.

SD modeling begins with preparation of CLD after arrangement of model-maker's knowledge and experience. For this CLD, first, the team's joint plan is prepared through internal discussions, then it is modified in regular sequence in the process of the modeling team's interviews and discussions with the officials and experts concerned.

2.2.2 Model-making

Model-making is the process of changing CLD to FD and of entering numerical expressions. FD is composed of level, fluctuation ratio, auxiliary-variable, etc., as in figure below.....
Level is the quantity in which the law of quantitative conservation is formed as in a power industry budget, power generation quantity, the number of employees or customers, tools and materials. The fluctuation ratio is a numerical value indicating the level's changing rate per hour, which includes nuclear power utilization ratio, load factor, and coefficient of utilization. Meanwhile, the auxiliary-variable is a variable necessary to represent level, fluctuation ratio and other auxiliary-variables and in case of power industry, it includes the residents' attitudes for or against the nuclear power plant, change in power consumption due to seasonal factors, etc.

Upon preparation of this FD and inclusion of proper numerical value and expression in each variable, the model is completed. Using this model, changes in each variable can be observed through simulation. Meanwhile, such simulations can be performed repeatedly by changing the input data or numerical expressions diversely (analysis of sensitiveness), and also the structure of model itself can be transformed conveniently as needed.

2.2.3 Verification

The finished model should pass through the verification process before using. The verification method is performed through analysis of actual performance data or exchange in opinions with user groups. The verification through analysis of the past performance data is the most prevalent method, and if the results of simulation based on the principle of operation show a dynamic phenomenon similar to the past performance, the model may be considered as feasible. However, there are many cases without proper performance data comparable with a new business. In this case, the model-making group and the user group must decide in mutual discussion whether usable, then modify the model repeatedly, in comparison with the actual performance data, while using.

2.2.4 Policy analysis

The model through the verification process can be used for analysis of the past, estimation of the future, and evaluation on various policies.

For example, let's suppose that the utilization ratio increased abruptly over the last 10 years, and that SD model for nuclear power industry is completed and verified : then the model will show the result of simulation similar to the performance data for the last 10 years; through causal follow-up functions of SD softwares, the reason for abrupt

increase in nuclear power utilization may be analyzed based on the principle of action; the future prospect of nuclear power industry can be predicted, and; the effects of various policies on the future utilization ratio of nuclear power can be evaluated. Meanwhile, in the evaluation process of policies, the future side effects may be identified. Also, in the analysis process of the past performance or side effects, understanding of nuclear power industry will be promoted, making a contribution to preparation of better policies.

The contents of study progressed up to now following SD approaches include investigation of domestic/foreign literature, data analysis, and decision of system-boundary (types of decision-making variables, investigation of system, preparation of a draft for CLD, etc.).

For the purpose of completing this study, related theories of SD was analyzed broad range, and then SD model is designed and simulated which it is based on them. To valuate our model and causal map, we communicate with many nuclear experts on nuclear institute and KEPCO (Korea Electric Power Corporation) & KAERI (Korea Atomic Energy Research Institute).

3. Domestic & Foreign research trends

3.1.1 Foreign trends of SD

SD, invented by Prof. Jay Forrester of MIT in the end of 1950's, has been developed centering around Sloan School of Management, MIT. In Sloan School of Management of MIT, education of business administration is performed using theory and SD, and at each department, the applied fields are studied in close cooperation with the departments concerned. Meanwhile, independent MIT organizations are utilizing SD at the Organization Learning Center, Energy Lab, etc. The department organizations are active in application of the related public fields, while the Organization Learning Center and Energy Lab are much interested in general models applicable to private enterprises.

For recent several years, ten-odd advisory companies using SD were established around MIT, which include : Cambridge Decision Dynamics based on college operation model; Pugh and Roberts Associates; HGK Associated based on power plant strategy model; High Performance & Ventanna Systems based on softwares and general business consultants. These companies are commercializing actually applicable SD models without exception.

In nationwise aspects, U.S.A. and U.K. show decided superiority, but Japan and Germany are recently in a hurry for introduction of technology, presenting various theses in the SD transactions. In particular, Japan once held the SD world society in 1995. In addition to these countries, almost all Asian countries including India, Taiwan, China and Singapore, except Korea, introduce application cases in the public fields, and it is known that Portugal, Colombia, Brazil, etc. are also applying in the public fields.

3.1.2 Domestic trends of SD - Korea

With overseas study boom in early 1980's, SD was once introduced to our country. But, the then SD was an initial technique centering around Dynamo (a sort of SD language), which differs greatly from the present technology applying the Visualized Programming Method (Vensim , ithink, PowerSim, etc.).

Meanwhile, some professors continued their studies independently and read papers at the SD Society, but the contents were given to too much of logical reasoning. At the 1996 SD World Society held in Boston, U.S.A., ETRI presented an application case, though it was an initial model. Last year, SERI (Samsung Economic Research Institute) performed one-year service to establish the concept of learning organization independently, arousing domestic industrial society's interest by presenting the SD as one of the results. Thereafter, it is known that there have been regular meetings centering around researchers and professors of SERI who participated in that service. In the meantime, researchers of LG Economic Research Institute and some researchers of Hyundai Economic & Social Research Institute are studying SD, further some employees of Samsung and LG were sent to MIT short-term course for education.

However, these domestic efforts are within definite limitations, because the members majored in socio-economics such as business administration, histology and public administration, without exception, and are not experienced in practical business. For application of SD, technological ability in analysis of problems and practical experience to draw feasible interpretation are simultaneously required. For these sociologists' efforts to be realized, it is necessary to persuade officials internally in the organization, but the persuasive power is limited due to restrictions on modeling ability. Domestic practice in poor academic exchanges between the departments also serves as a major factor against these efforts. Therefore, these activities may incline toward logical reasoning or use a foreign-made SD model, or stay at a level of developing SD model, for the time being.

Domestically, it is presumed that SD will be applied first in the energy field including electric power industry, the reasons of which can be described as follows :

1) In energy industry, there are many problems having both social and technological factors in terms of industrial characteristics.
2) There are cases being applied in foreign countries, for reference.
3) Domestic industry attained a considerable technological level, and officials in charge began to be interested in social, economic and political problems.

3.2 Expected effect and utilization plan

The greatest merits of SD lie in rapid evaluation and convenience of use. SD Model has demerits of the basic structure being modeled for a long period, but the simulator once finished will perform simulations for scores of years. Furthermore, even in case of simulation under the present PC performance, it will take only a few minutes. Meanwhile, without specific knowledge of computers or SD, anyone can use it easily and thereby user-range would be extended from the beginners to the top management.

For instance, when reviewing the effect of a new long-term power resources development plan on the company, he (she) can inquire within a few minutes about what effects will be made on the company for future ten years, and in case of occurrence of problems, the causes can be traced easily. Considering the above, development of a management strategy simulator may lead to the following utilizations:

- Management strategy evaluation tools: The finished management strategy simulator can be used as a tool for evaluation of various management strategies, and the insights acquired through repeated simulations and analysis process are helpful to establish better strategies. Quick simulations will be substituted for the previous manual operations and repeated evaluations using spread sheet, thereby reducing manpower and time required for strategy-making process.

- Change Management : The finished simulator can evaluate on various changes, as well as on management strategy(plan). Particularly, varied modern society requires quicker evaluation functions on changes. Using a management strategy simulator makes possible quick evaluation on such foreign changes, also it can cope with the changes timely and effectively.

- Complete Databases: Input data used for SD Model is preparation for metrical analysis of comprehensive strategy formulation on management of a business, and it serves as a complete database.

Therefore, the input data of this SD model can be used for other related purposes at any time. In case of any defects in data, SD suggests the direction what data should be prepared in the future.

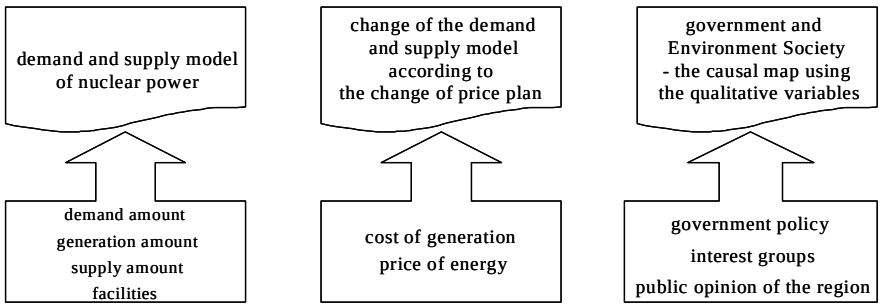
Main Disclosure

1. Causal Map

1.1 Establishment of variables needed to make the causal map

In this study the variables needed to make the causal map are largely divided into two kinds: quantitative ones and qualitative ones. It is an essential approach to plan for the efficient supply and demand policy of the nuclear power industry and to make model suitable for the management and its strategy. For the model for the nuclear power industry which has great portion in the electric field and will be much more important in the future begins with the causal map.

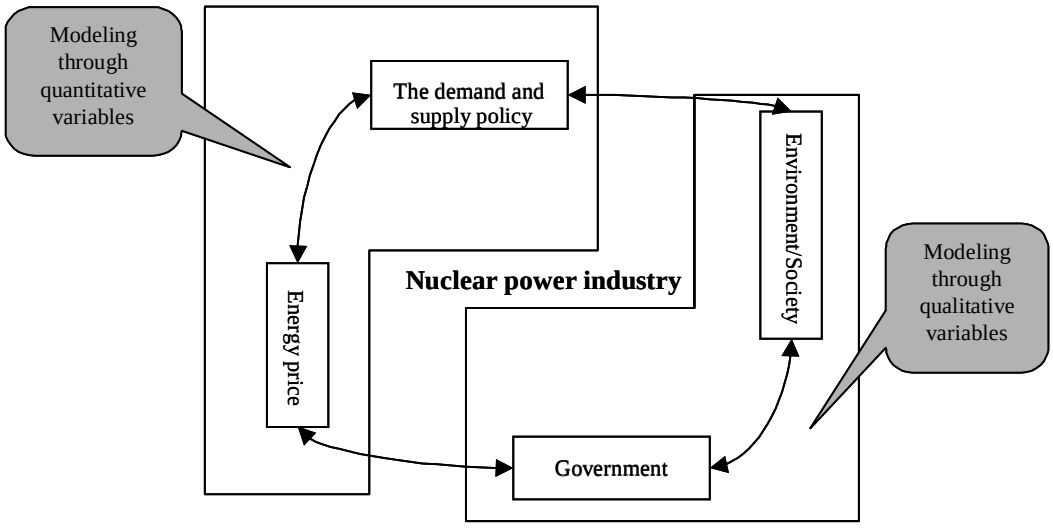
Variables which can reflect real conditions must belong to the model to help the management decision with the simulation of SD model. There are Top-down and Bottom-up ways in modeling. Top down way is to draw out the causal map based on the flow diagram made first and Bottom-up way, which is traditional, is to make the grow diagram with the causal map which can establish the system. In this study the modeling way has been taken that the causal map is made using Bottom-up way and continuously complemented with the advice of professionals which related in the Nuclear Industry.



[Fig2] Overview of SD approach this study

As you can see in Figure2, to make the model for efficient generation of whole nuclear power the demand and supply model has been made with demand and supply amount and facilities for generation and then the approach according to the scenario of price policy has been used.

The model which can elevate the efficiency may be meaningful with the reflection of price policy which is one of the facts making worst the efficiency of energy policy of our country.



[Fig3] Structure of Model

The demand and supply model consists of the variables, related to the demand and supply model, of whether the demand amount and the generation of the nuclear power plant based upon it are efficient and whether the power plant has been built in the best place. Therefore the forms will be studied through the simulation of past materials. Including the current price plan, which is the main cause of making the efficiency decrease in energy price, into the demand and supply model, the proper price level which is the problem of making KEPCO a private running company, may be able to be

estimated.

Government and environment/society sector reflects the development of the nuclear power plant and government intention about it, and the feedback relationship among interest groups including local governments will be studied. Variables such as mass media, environment groups and the local people supposed to be a land for plant, which make public opinion, will be studied macroscopically.

2. The scope of the study

The purpose of this study was already shown that the variables which are related to management of nuclear power industry and its usages for policy are studied. Therefore cause and effect chart is made, feedback relation among variables are studied and their loop for the relations in qualitative sector, and the model based on past materials to the variables is tested and simulated and then the form of the model will be clear quantitative sector. In addition, the application of the cause and effect map of basic system to the policy analysis with the integrated model will be summarized in this study.

3. The demand and supply policy model

The demand and supply policy is very important one of country policies. The electric policy is different from other products which can be stored and is required to prepare to provide the amount needed with the facilities. Therefore the demand and supply policy cannot be overemphasized in energy field. As the period to increase the facilities is very long, the demand and supply policy needs to be strategic and to forecast the future demand.

In this view, the active SD approach is very meaningful. In this study, the demand and supply policy model for nuclear power business is made based on the materials affecting the policy of KEPCO for demand and supply of electricity. The basic variables composing of the model are as follows;

1) Main variables

- Level Variables - level of generation facilities, demand amount, consumed amount (how much is consumed in practical life considered)
- Rate Variables - the rate of facilities increase, energy generating rate from the minimum energy source (uranium), the gap between product and consumption and variables affecting level variables

Though the relative comparison of whole electricity amount and nuclear power amount is thought to be little meaningful, some relative comparison is made to be a little meaningful with the rate of whole demand amount and nuclear power in portion in Korea. The cause and effect relationship between the generation amount and demand amount with the consideration of the form is thought to consist of positive feedback system. In addition, the work rate and facilities increase of the year and obsoleteness of the facilities have become very great control variables, based on in facilities variable affecting supply amount.

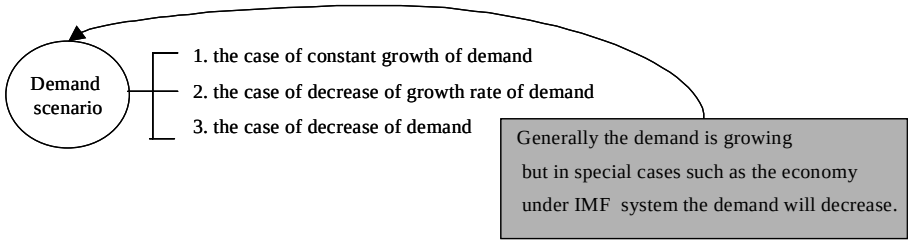
The efficient supply policy can be made preparing for demand increase through the demand and supply policy model, and the model can be utilized through the simulation of past data.
With the thought of the gap from the new plant building the financial burden can justify the delay policy of the new nuclear power plant. Of course though quantitative variables occurring in building the nuclear power plant are excluded, they can be used as basic materials for decision making. If price policy is reflected in the model extension to the active change of demand amount to energy price change is possible.

After all the above demand and supply policy model is possible to conclude that active policy through the systematic approach based on the basic concepts of System Dynamics more useful than mathematical prediction by traditional statistical approach. If it is recognized with relationship to qualitative variables and is used for decision making and management strategy, the special surrounding of geography and culture is possible to meet the financial crisis after Korea has gone under IMF system.

4. Approach according to scenario to price policy

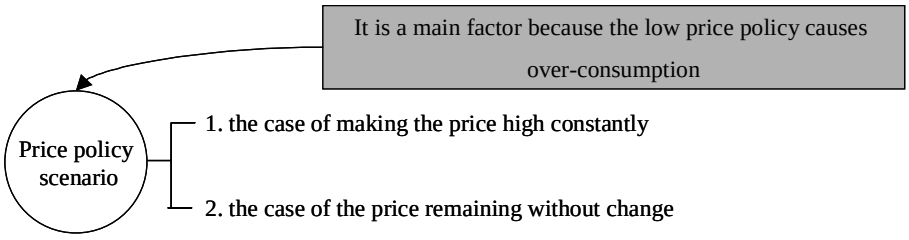
According to the report ‘Reconstruction of electric industry and private running’of KDI(Korea Development Institute), low price policy for price stabilization and supporting industry since 1980s has caused many side effects. Although the price in the report does not include only product from the nuclear power plant, it is thought to be natural that as the portion of nuclear power is becoming larger and KEPCO should invest the money for the nuclear power plant, the price variable should be put into the model.

As it may be difficult to make price policy according to energy source, to make price policy exclusively is very important in the form of increasing efficiency.



Demand scenario can be divided into one that demand for nuclear power will increase along with the increase of electricity demand, another that demand for nuclear power will increase with the environment problems and the international surroundings but the rate will decrease, and the other that the above variables will make demand of nuclear power decrease in the end. Countries such as Korea which import most of the energy is sure to develop nuclear power but the financial burden will depress the demand of the nuclear power plant. Though some researchers have discussed about the demand of the nuclear power plant in a positive or a negative way, they haven't reached the conclusion. This is because the problems which decision making has by measuring and discretional approach and normal judging variables have not considered synthetically.

The second scenario approach is one about price policy.



Price policy scenario causing the efficiency of energy industry to fall may be divided into the case of constant growth of price policy and maintenance of the current policy. There were five times decreasing the price between Nov 1987 and May 1990 for price stabilization and reduction of cost of companies, it is thought that there was no chance to actualize the price. This policy has, therefore, resulted in waste of energy, the problems to the investment for power plants, worsening of financial problem and the weakness of KEPCO. The increase rate of demand amount of electricity was 12.1% between 1987 and 1997, which is over the increase rate of GDP, which means excessive demand.

Therefore, with these problems reflected in the model, the simulation is tried with price policy to the demand supply policy model based on generation amount and demand amount.

Adding price variable into the demand and supply policy model which has only generated amount, demand quantity and facilities and trying to extend the model, this study is aimed to make price policy for decision making to nuclear power industry of government and high efficiency.

5. Government Policy

The government makes demand and supply policy to heighten the energy efficiency with the consideration of the nation's economic conditions.

As Korea has low level of energy independence, she has developed nuclear power according to cost of each plant, but social and managemental variables including the problems of environment and security have occurred.

In addition, as government made the low price policy which caused energy efficiency to fall, the role of government is very important. Though KEPCO has tried to be a private running company, The realization looks far away, and since the decision making of building the nuclear power plant rests on government, it must be a very important sector.

Government sector has relationship with the quantitative variables of demand and supply policy, price policy and facilities planning, but it may be used as part of feedback structure with qualitative variables.

Quantitative variables of government policy model can be divided into as follows;

1. Demand and supply policy: simulation with past data of quantitative variables reflected in demand and supply policy
2. Price policy: reflection to the model as an extended form
3. Nuclear plant building planning: reflection by facilities sector of demand and supply

policy of increase and repair of facilities

The extended model including demand and supply policy model and price policy can be defined as quantitative variables. As there are many different qualitative variables composing feedback structure with them they are approached in the views of government sector and environment/society sector.

Therefore, causal map is made the feedback structure system dynamics approach is analyzed and will be able to in use in the future.

In this study, effect and cause map including government sector for nuclear power industry with the macroscopic view rather than delicate causal map according to the process of decision making of government.

While the quantitative approach is made according to planned materials of past accomplishment and the budget, the qualitative approach shows important circulating loop through causal map and with it special management and operation strategy.

6. Environment/Society Sector

There are many various variables in nuclear power industry directed by government to show the image of the country and internal and external policy. The environment problems are seriously recognized internationally and interest groups in them are now in great activity.

Therefore environment/society sector of external variables has cause and effect relationship with management plan including security of nuclear power plants and building them.

- Main Variables

1. Interest Groups

Environment : concern to environment problems from interest groups

NIMBY effect (Not In My Back Yard): the denizen's protest against nuclear power accident and nuclear waste

Local government : governmental policy and collecting the local opinion

2. International Performance

Policy performance : Appearance of international organizations such as Environment Round

Import performance of raw material

Image to other countries : The position of Korea, one of the countries importing most energy

3. Mass Media(public opinion) : Level of public concern

4. Policy against North Korea : Whether the nuclear power plant construction in North Korea affects that in South Korea.

- Formation of cause and effect relationship with financial problem and people's concern

5. Exhaustion of prior energy source and obsoleteness of old facilities (the limitation of increase) Formation of relationship of the increase of nuclear power plants to geographical and economical limitation

6. Development of replacing energy

7. Level of people's concern

8. Technology : Technology of Korean style nuclear power plants, level of its independence

9. Industrial structure : Worsening energy efficiency owing to depending too much on heavy and chemical industry
10. Economic performance : Effect of financial problem and energy demand

The SD approach about nuclear power industry in environmentiety sector is seen in the paper of Hansen at MIT Energy Lab. He put the variables of government, interest groups and Mass Media into SD modeling in his paper, cause and process of decision making and effect relationship in policy decision making are analyzed in many ways. To make cause and effect map, this study includes the variables of the position of Korea as an energy importing country and policy against North Korea based on Dr. Hansen's SD modeling.

Causal map is made based on the quantitative variables related to nuclear power industry with systematic thought, and with the link to demand and supply policy model, it will be able to be used strategically in policy decision making.

6.1 Government policy sector

In Korea, the government is the decision maker on planning the policy for electricity, because the institutions studying nuclear power are supported by it. The industrial structure is a important variable according to the theory that Korea industry depends much on the heavy and chemical industry, and therefore the government should make an aggressive and strategic policy based on the theory. International sector variables such as WTO and Environment Round should be treated as important to follow the international flow for the protection for environment and, in addition, as Korea depends entirely on import for the materials, the international flow is very important.

Economic performance is a variable the government should take a careful look at. It must be related to the demand amount and forms the cause and effect relationship between demand and supply. R&D for technical independence determines the amount of governmental investment and the level of technical independence and it has direct effect on building nuclear power plants. In constructing SD model, the policy against North Korea is not a direct variable, but as it affects the public opinion, the environment/society sector should include it with the thought of the feeling of people and international concern.

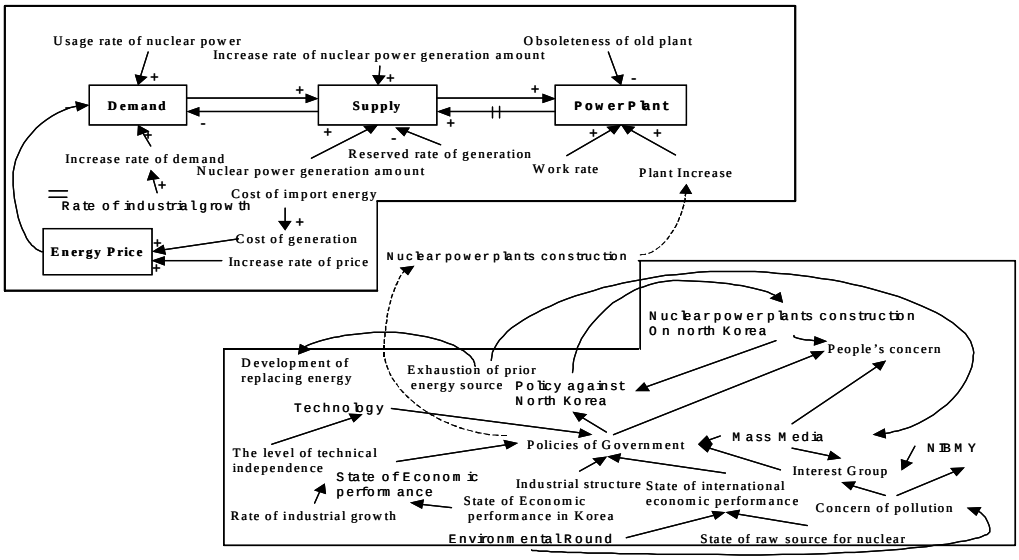
Therefore, the Feedback loop including government policy, people's concern, public opinion and interest groups may have great significance.

6.2 Environment/ Society Sector

As talked above environment/society sector consists of qualitative variables which should be considered related to government policy. First, how much concern people have should be considered. Second, decision making of government should include these social qualitative variables. Next, the concern about the environment of the denizen near the land of the nuclear power plant should be taken in which case the power of environment groups is certain to be important in decision making of government. As the activity of environment groups are very strong, the plan based on the demand and supply amount of electricity will meet the protest from environment or interest groups. It is natural that the negotiation with the local government be needed to

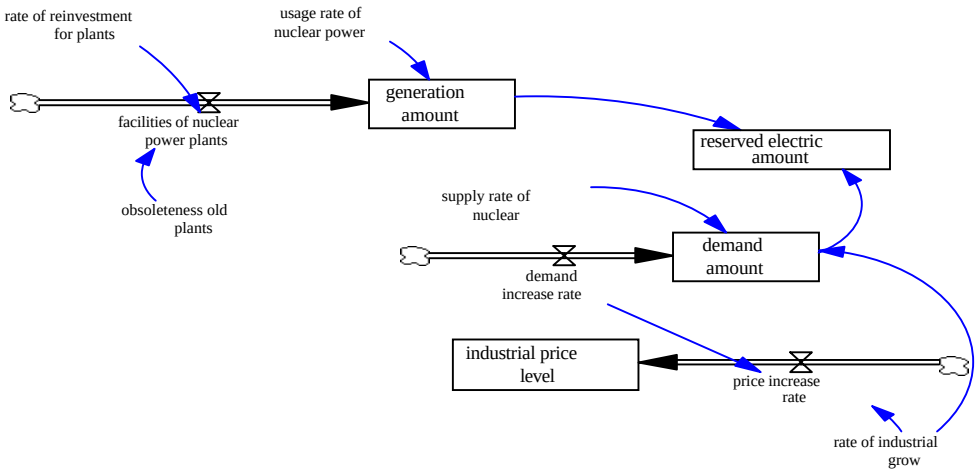
secure the land for nuclear power plant. Advertisement and persuasion should be put into use to people who don't like the nuclear power plant located in their area.

7. Causal map for Nuclear Industry in Korea



Positive analysis

1. The Demand and Supply model considering price variables



To improve the effectiveness of nuclear power industries, a model of electricity Demand and Supply has to be studied firstly. It is be done by making a flow diagram based on the Venim DSS 4.0 and we can analyze both the SD approach model and compare the model in respect to the past supply and demands of electricity industries.
This process will enable us to review if the above-mentioned SD(Supply and Demand)

model is appropriate or not while reviewing the effectiveness of nuclear power industries.

The Flow diagram has been made by focusing on the interrelation between the SD and the other variables affected the SD and the electric power generation level. The demand volume in the flow diagram reflects the SD increase and decrease rate, the most fundamental factors in economics. Since the demand of electricity usage rate is usually going up in both domestic and industrial areas, the demand decrease rate is not included in the diagram. However, during the economic crisis a few years ago the electricity usage rate went down in Korea. This decrease is noted in the chart as a negative growth value. For the period after 2000, a Random function is used so as to mirror the increase or decrease of electricity demand. Also the supply rate of nuclear energy is included in the demand rate to be able to compare it with the supply or generation objectively. The electric power generation defined product by nuclear energy, which prevents us from understanding the comparison between the total electricity energy demand rate and the nuclear energy generation rate. This is why I reflected the nuclear energy rate in the demand rate model.

It is very important to find out the relationship between the price variables and the Demand rate to deliberate on the effectiveness of electricity energy. This model is developed on the basic concept that the amount of electricity generated comes from the cost of nuclear facilities.

Originally the cost of nuclear power plants should be categorized into the level variables. But it also has characteristics of variation variables in the flow chart by controlling the generation rate according to the facility reinvestment or obsolete equipment. Using the variation variables also help us to understand better how to interpret the simulation.

The rate of Demand and Generation are substituted by going over the reserved electricity rate that is also used as a basic barometer to establish the effective supply and demand policy.

In this report the reserved electricity rate is researched linked with the demand and generation variables through the feedback loop method. Rather than relating the demand rate in the flow chart with the generation rate, the reserved energy variables are used to see the interrelations between the demand and generation rate. This way of researching is done because it is not accurate to see the increase of the generation rate resulted in by setting up more nuclear facilities directly is tied to the increase of electricity demand.

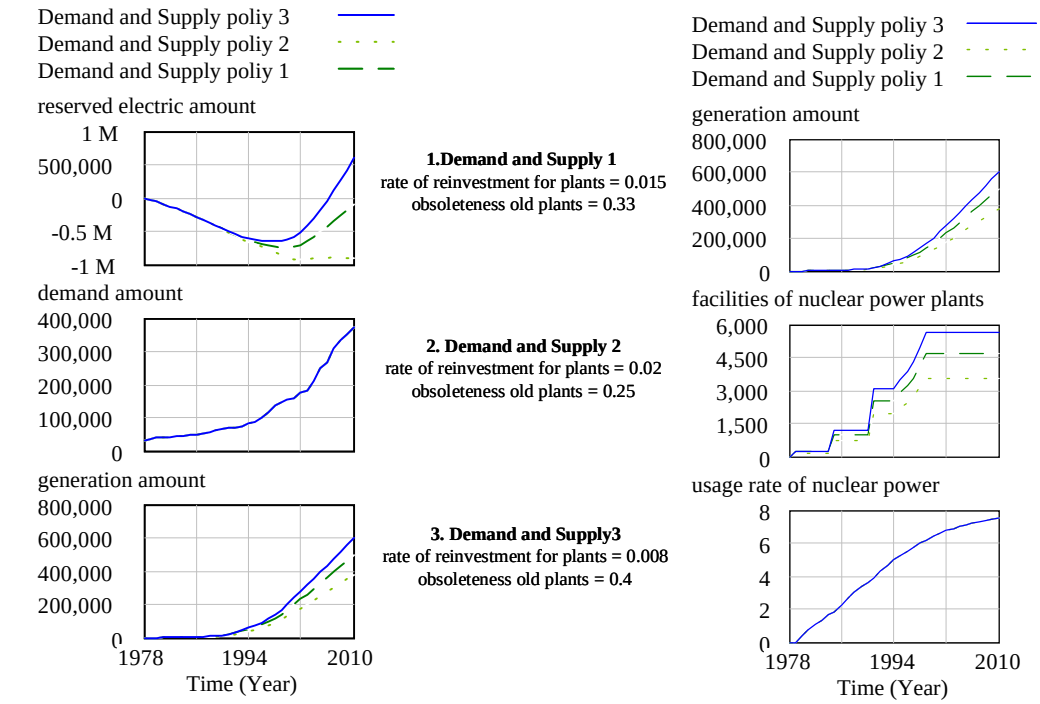
For various reasons, building the new nuclear power plants initiated by the governments plan does not generally meet the public demand for electricity in time. This is why its meaningful to understand the supply and demand by looking into the reserved electricity rate.

In a flow chart considering the price variables, I tried to go over the overall price policy in Korea by keeping in mind the subject of effectiveness in energy usage. As mentioned before the theory that the industrial structure in Korea causes the high level of energy use, which brings the effective usage of electricity down is not appropriate based on the fact that the percentage of the industries using a lot of energy went down from 30% to 3%. Considering the unusual increases of high value industries in Korea the price policy is the most important point to improve the energy effectiveness.

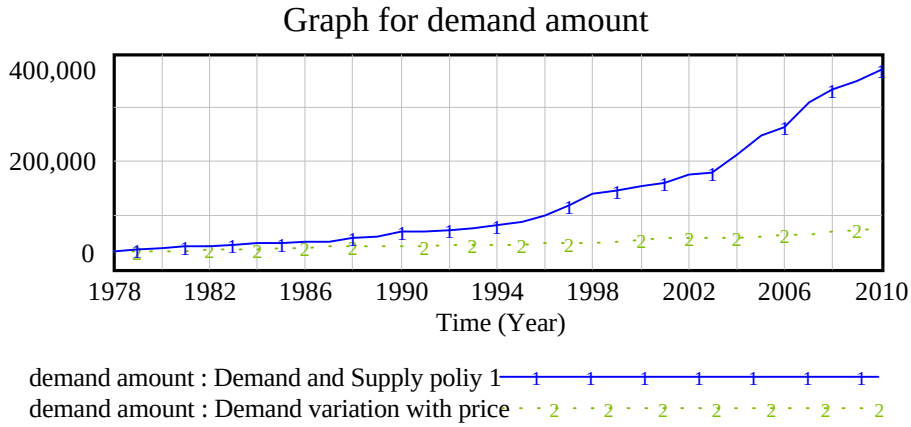
There should have been various reasons for the government to price the energy far below that of the industrialized countries standard. Its very encouraging that the Korean government has started to privatize the electric energy business and this will boost the

liberal competition among the private industries and eventually will bring the electric energy value to the level of the industrialized countries.
Including above-mentioned environment in Korea I created the flow chart to find out if the price variables are the absolute variables to suppress the demand of electric energy and increase the effective power usage.
As seen in the chart, the variables were modeled after the industrial prices because these show the most difference compared to the developed countries prices. This is unlike the domestic or general areas. By defining the price increase rate according to the demand increase and industrial growth, the chart can be used in considering lowering the increase rate of electric energy demand under the increase rate of industrial growth.
The variables are arranged to go up by 2% from 10% in case the increase rate of electric energy demand is larger than the increase rate of industrial growth. If the increase rate of industrial growth is lower than the one of electric energy the variables automatically become 0. This formula is made based on the theory that in case the increase rate of demand is higher than the industrial growth, the price should strategically go up to put the increasing demand under control. Positioning the price increase rate from 0 to 10% will enable us to guess the proper price level.
To find out if raising the industrial price level consistently will work as a useful tool to constrain the demand rate it is recommended to use the supply and demand simulation process regarding price variables. See the above Flow diagram that combines the aforementioned subjects; generation rate, demand rate and price variables. When the electric energy demand rate in simulation decreases far more than the other elements, the price policy is working properly.

As seen in the simulations below there are a lot of different variables determining the demand. Among the variables, the price variables, a subject dealt with in detail in this report, is very effective in controlling the demand. It should not be overlooked that the privatization of the electric energy industries and the government policy of raising the energy price are very important in controlling the energy demand.
The planners in the government office should be aware that Only the public energy saving campaigns can not improved the electric energy effectiveness. It is true that the government is not willing to raise the energy price to the required level because the energy price automatically causes the increase of commodities price. This government reluctance to raise the energy price results in the overuse of electrical energy among the public and affects the industrial price.



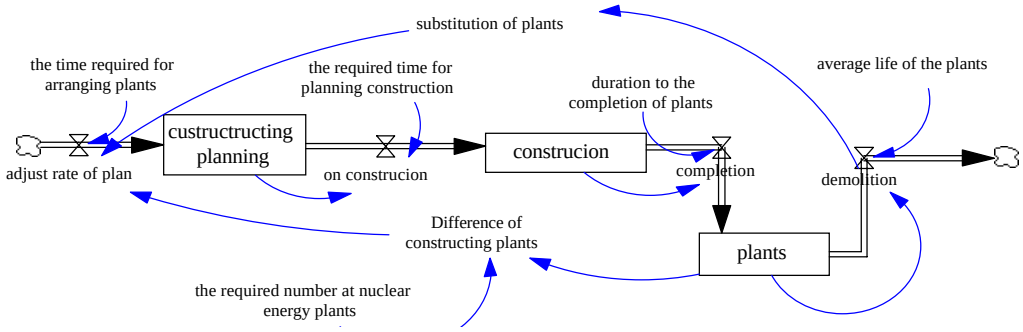
The effect of variables degree changes
The effect of increasing reinvestment for plants > The effect of decreasing obsoleteness old plants



In conclusion, to decrease energy importation and enhance the effective use of energy, the government should try to raise the industrial electric energy price to the appropriate level and also build the facilities that would help to use the energy effectively.

2. Nuclear power plant construction model

2.1 The result of the positive analysis of nuclear power plant construction model



The important variables related to the planning of the nuclear power plant are the following: planning the nuclear power plant construction, building, completion of the plant, operation of the plant and the dismantlement of the plant. This process forms a typical positive feedback loop. The major level variables showing the changes in the system are construction planning and building. It consists of three variables and the variation variables; planning, construction, completion and demolition that affect the three variables. There are also auxiliary variables.

The auxiliary variables include, the average life of the nuclear energy facility, the required number of the plants and the duration of facility building which controls the difference between the number of required plants and the number of completed plants. The primary goals of Koreas electric energy industries are establishing a plan that would make the difference of nuclear energy facility to zero and building the required number of nuclear energy plants.

Improving the nuclear facility construction technology so as to prolong the life of the plants and the facility building planning is very important. Various conclusions will be available by inputting the several variables into the simulations.

2.2.1 The results of simulations

Scenario1 – Plants1

The time required for arranging plants = 15
The required time for planning construction = 2
Duration to the completion of plants = 6
Average life of the plants = 30
The required number at nuclear energy plants = 28

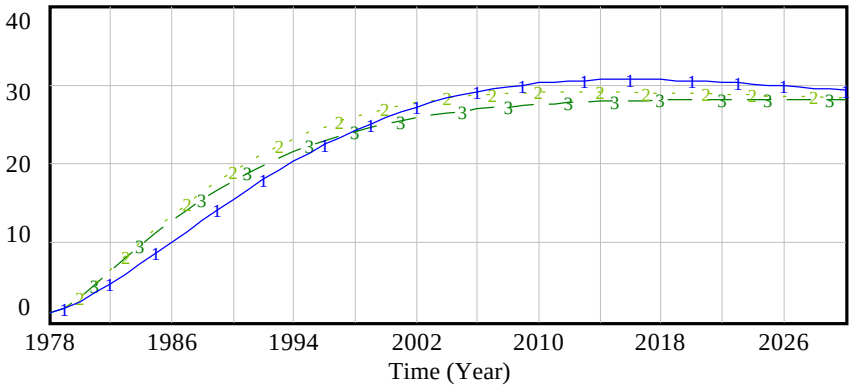
Scenario2 - Plants2

Average life of the plants = 60

Secnario3 – Plants3

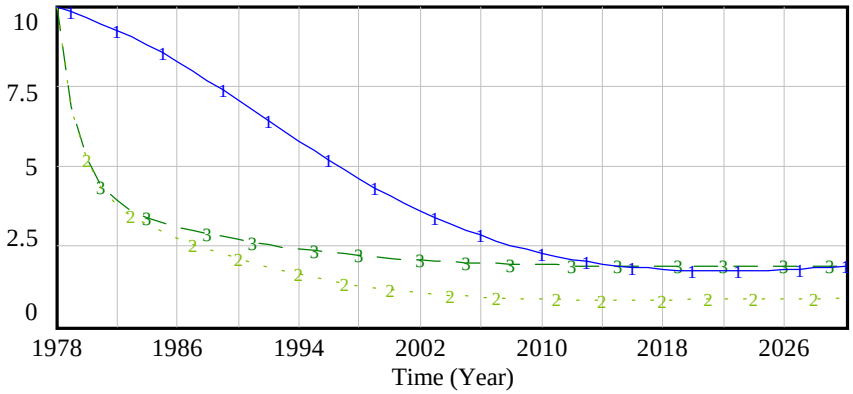
The required time for planning construction = 5

Graph for plants



plants : plants 3
plants : plants 2
plants : plants 1

Graph for custructructing planning



custructructing planning : plants 3
custructructing planning : plants 2
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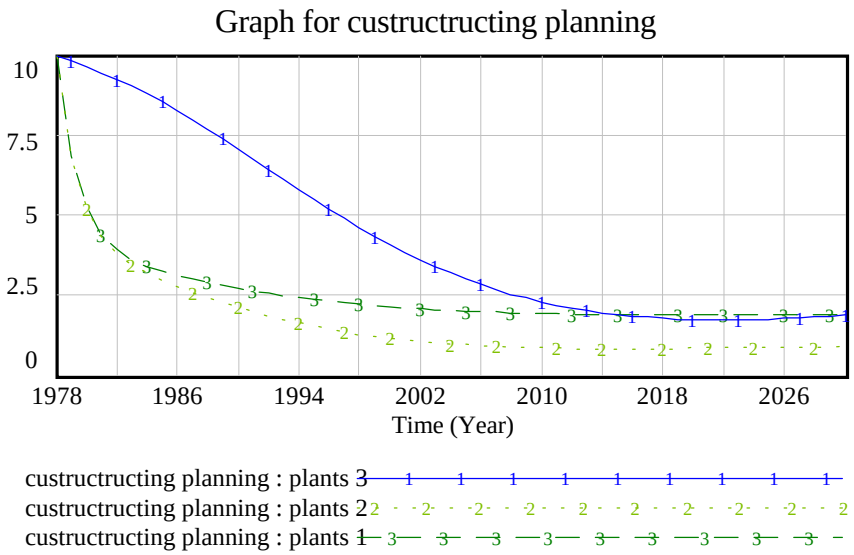

The simulations above show a typical negative feedback loop in which the number of power plants is stabilized as 28. The model also reflects a long-term supply and demand plan of electric energy presented by the Industry and Resources Dept. According to the plan, a total of 28 nuclear power plants are to be under operation by the year 2015. Currently the roles of the residents around the nuclear plant construction sites are becoming more influential and the worldwide environmental movements (for example, the Green Round) are also related to the planning of building new plants. Even though the model does not specify the aforementioned situations as qualitative variables, it reflects the nuclear construction related issues as the quantitative variables.
The following is the simulation based on the average life of nuclear energy facilities and the plant construction project.

The simulation result is based on the assumption that the technology is achieved to expand the average life of the plants from thirty to sixty years. According to the simulation, the difference of the nuclear energy facility has become closer to zero than in the one made based on 30 years of nuclear life span. This result proves that the investment in the research of technology development in building the plant is as important as spending money in increasing the number of new plants. Putting money into improving the nuclear building technology eventually saves the facility maintenance cost.

The following simulation shows the changes depending on the time taken to complete the plan of building new nuclear power plants. It is natural that the period spent planning new nuclear plants takes a lot longer than before considering the increasing fear of the residents about the possibility of environment pollution and deterioration. The factors below tell you how the delays in the planning period affect the simulations.

As seen in the above simulations, there's a considerable delay in the difference of nuclear facilities stabilized into zero. The increase rate of completed nuclear plants is

delayed compared to two years ago.
As mentioned before, the differences in the conclusion seem minor but considering the fact that this model doesn't include the other variables related to the actual planning of new nuclear power plants, the meanings of differences become more important.
To be able to come up with the more productive policies regarding the electric energy industries, further researches on the acutely related environments are required. The researches can be done by reviewing the cause and effect map, checking the flow chart and working on the various simulations.

CONCLUSION

1. The Implications of our research

1.1 The implications with actual proof
It has been discussed whether the nuclear power generation is economical, compared with other methods of energy generation, however, the complete conclusion can not be reached at present, due to the fact that conflicting opinions has been stated, in the process of analyzing various factors. Besides, because of the intervention of the political logic and the environmental collective-egotism, it is impossible to evaluate absolutely whether it is economical or not.
In Korea, when the country first adapted nuclear-power station, the construction of nuclear-power stations received a national support because people were passionated by the nuclear energy which could supply energy more stably than petroleum after the Oil Shock. In other words, the convenience of the energy utilization was relatively high, therefore, in that period, it was more or less economical to use nuclear power.
However, in 1980s minor and major accidents happened, accessory costs for repairing facilities and compensation for fishermen occurred, and the waste disposal costs are added after the radioactive waste began to be produced, all of which have been affecting the matter of economics and safety of nuclear power.
In 1990s, it met with a lot of difficulties from the process of selecting the location of new nuclear power stations, as a result of the wide-spread movement against the nuclear power stations. Accordingly, only the negative site of nuclear power has been raised noticeably. As the radioactive waste stored temporarily in nuclear power stations, it has been necessary to construct the permanent nuclear waste disposable facilities, therefore, the additional costs for the facilities are needed. as a result of that, the economics of nuclear power has become worse. In addition, if the matter of demolition of the nuclear Power plants that will be no longer useable is referred, new construction of nuclear stations will be hard hit by the enormous demolition costs.
Meanwhile, the environmental effect of the cooling water and radioactive waste from the nuclear power stations has been unfavourable to the nuclear power generation. But, the idea that the current abnormal climate changes result from the excessive use of fossil fuel is wide spread, and nuclear power became a great energy source as the substitute energy for fossil fuel.
Nevertheless, strictly speaking, there are too many things to be resolved to say the nuclear power is environmentally great. It is true that, in the process of power generation, nuclear power produces the least amount of pollutant, but, in consideration

of the constructions of the stations and the waste disposal facilities, the effect of these processes is unavoidable. Besides, even though it produces less greenhouse gas which is thought to cause the abnormal climate changes, it will be inevitable to receive censure from the public and environmentalists as long as the perfect disposal of the nuclear waste is not completed.
The utilization of the nuclear energy can not be decided by only one certain factor. It is also dangerous to be utilized by the decision of a certain group. Accordingly, it is urgent to have an institutional device for the public to participate in the decision-making process of policies relevant to nuclear-power stations, even if it is difficult to make construction of nuclear power stations discontinue as Sweden did by holding a referendum.
According to the current regulations related to the process of the nuclear power station planning, there is no choice for the relevant local residents to take part in the decision-making process. And, because there is lack of rational legal procedure for the selection of the appropriate location for the nuclear waste disposal facility, frequent conflicts occur between the relevant organization and the local people.
In the end, we have to decide whether we will continue to utilize the nuclear energy on the basis of the public agreement on the nuclear energy, or not. In addition to that, we have to frame a political and technical scheme to maintain the balance of demand and supply. In other words, we have to make the industry structure for the purpose of reducing the power consumption, we have to actively carry out policies to lead the energy efficiency, and we have to make a continuous effort to study and develop the power generation with natural resources such as; solar energy, wind power, small-scaled hydroelectric power, tidal power, etc.

1.2 Theoretical implications

In 90’s energy efficiency in Korean economy has been worsened, and as the world energy is changing, the impact on the nation's economy increases. This model suggests the international trends and the policies Korea has to have as a country which imports all the resources for energy generation.
At first, through the demand and supply policy model, we analyzed and studied what Korea did in terms of the amount of demand and supply, which is essential for the power policy, and then predicted the future. We call it dynamic simulation. And then, we connected and extended it to the cost policy what is the main factor of the worsened efficiency of power generating industry.
We tried a system dynamics approach which means examining closely the basic policies about power generation, by quantitative and qualitative factors, instead of the decision-making process by measuring and repetitive manual works which we used to use when we establish policies in the past. Korean economy has been seriously impacted by the international costs and demand-supply of the energy resources, but it is true that the countermeasure has not made sufficiently. It can become a good model for the strategic policy of power generation industry, If we consider various relevant factors in order to revise the efficiency of the power generation industry, and the related local residents, groups, and relevant industries.
The methodology by the system Dynamics which has already been used in various parts, will be useful for the decision-making process and the theoretical-approach process to

be introduced to various factors discussed previously.
In the United States, through a project, called K-12, there has been an effort made to implant System Thinking, which is the theoretical basis of this research, to teenagers. the System Thinking for solving problems in various social phenomenon as well as the power generation industry should be used more actively.

2. The expectant effect and the usage of the result of the research

The expectant effect and the usage of this research result can be summarized in two like the research model. The first one can be obtained by the simulation result of demand-supply policy and costs policy, which is a model by quantitative factors. It can be possible to predict Korea's power demand and supply in future by dynamically analyzing the changes of power demand and supply in Korea in the past. Especially, It will be possible to see the efficiency of the power supply of the power generation industry.

Moreover, the effect of the low-cost energy policy could be simulated by classified scenarios, and then we can approach to the effect in terms of the demand-supply policy. And we can find out the reason for the increased efficiency, in conjunction with the quantitative factors.

Secondly, it is possible to have the systematic analysis of the nuclear power generation industry which should be considered by the decision makers in the process of policy making, through the guidance of the cause and effect by the quantitative factors. It is true that the approach of economics and accountancy by efficiency-costs analysis sometimes gives a lot of information when in decision making pocess, but, we can also see that it is important to consider various quantitative factors and the proportion of the nuclear power generation in power generation industry.
It reminds that the policy which only focused on the accounting benefit and financial success, considering the power generation industry as a profit-making business can cause a lot of problems. Methodologically speaking, if we use System dynamics properly, we can get various effects as follows.
Firstly, the agreement among the related persons could be led by their participating directly and developing a model together, because all the relevant decision-making process is clearly visioned in the feature of the model.
Secondly, it can promote the learning effect, through the comparison between the theoretical and literal assumption and simulation, and the realistic results.
Thirdly, it can improve the outcome, by increased understanding and interests in the relevant factors, and improving the clarity and quality of decision making.

3. Limits of the research and forth-coming research

This research's limit is that only the factors taken by a bird's eye view are considered, even if there are various factors for modeling by SD Approach. The guidance of cause-effect by quantitative factors has not been simulated, and even if the guidance of cause-effect is made by interviews with relevant professionals and theoretical approaches, it can’t overcome the main limits. When we carry out researches in future on this matter, we have to do modeling, considering the quantitative factors which reflect the characteristics of nuclear power generation and power generation industry in Korea. And, there are other factors like various decision-making factors, Feedback Loop factors as well as the factors present in this research, in demand-supply policy model.

Such factors should be considered in a research of a model which can raise the efficiency of the power generation industry on the whole.

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KDI (Korea Development Institute) Reconstruction of electric industry and private running

✶ Personal Communications

KEPCO (Korean Electric Power Corporation)
- General Manager of Electricity industry restructuring office
- Project Manager., et al.
- Nuclear Power Laboratory
- Nuclear Safety Analysis Group

KOPEC (Korea Power Engineering Company)