Conceptual Framework of Economic Evaluation on SMRs

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1. Introduction

Korea Atomic Energy Research Institute(KAERI) launched a project to develop an integral reactor in 1996. The reactor called as System Integrated Modular Advanced Reactor(SMART) which is a kind of small modular reactors (SMRs). Since the early 1990s, there has been renewed interest in the development and application of small and medium sized integral reactors. 2009 assessment by the IAEA under its Innovative Nuclear Power Reactor & Fuel Cycle (INPRO) program concluded that there could be 96 SMRs in operation around the world by 2030 in its 'high' case, and 43 units in the 'low' case, none of them in the USA [1]. The reason of the increased demand mostly comes from the fact that SMRs are thought to be more suitable for developing countries with small electrical grid capacity, insufficient infrastructure and limited investment capability than developed ones. However, it has disadvantage in the point of scale of economy. So, it should be compared the amount of this advantage and disadvantage which differ from the circumstances of the countries. In this work, conceptual framework was built up for suitable evaluation model of SMRs to be utilized in the future detailed study.

2. Methodology

2.1 Variable pool

Generally, economic evaluation on fixed assets should include many kinds of variables related to both internal and external aspects. In this study, the variables are categorized to three groups: SMRs, Client and Circumstances, etc.

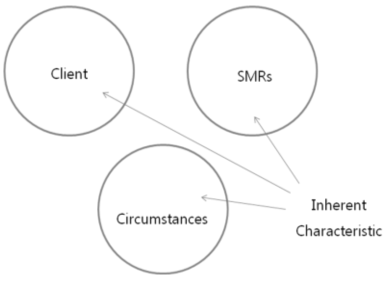

Fig. 1. Inherent Characteristic of SMRs, Client, and Circumstance

The first variable group, SMRs, is defined as the variables which are, in economic evaluation, inherent to SMRs such as power generating capacity, construction specification, technical requirement, etc. And the second variable group is Client. This consists of many variables in the stance of a buyer: Capital cost, Location, Human resource, Electricity needs, Infrastructure including power transmission & distribution and electrical power grid, etc. The last group is Circumstance of which variables are not inherent of both SMRs and Client but can influence to economic evaluation on SMRs: Global capital economic condition, international law & treaty, etc.

Especially, in the emerging economies, some context or market conditions can limit the adoption of NPPs when usually framed into Large size Reactors (LRs), e.g. i) electrical grids with limited capacity, where power variations in excess of 10% of the total grid capacity can endanger grid operation and stability; ii) remote areas requiring smaller, localized power centers, to avoid long and expensive transmission lines; iii) a geography and demography featuring mid-size urban and power consuming areas fairly scattered, rather than concentrated in a few ''metropolitan areas''; iv) financial capabilities which preclude raising the huge capitals required by LRs; v) the need for cogeneration (i.e. desalination, district heating, industrial steam) although, in principle, cogeneration is independent on the size of the NPP, in practice economic consideration has driven the LRs to be essentially pure electricity producers [2].

This explains well what kind of clients' inherent variables can affect economic evaluation on the each type of NPPs. And also, other variable groups' (SMRs and Circumstances) can affect the evaluation as well. Moreover interaction among them should be considered, because each variable of three groups, Client, SMRs, Circumstances, can interact with each other, and this interaction can make influence on evaluation of SMRs.

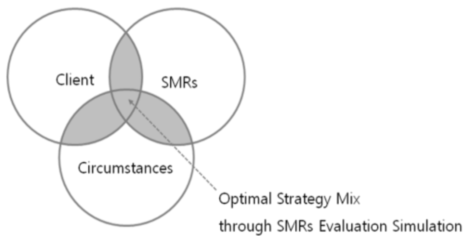

Fig. 2. Optimal Strategy Mix through Evaluation Simulation

However the problem is that these variables change as time passes, and the lifetime of NPPs' is too long to figure out optimal solution only with equation solving. In this reason we adopted System Dynamics (SD) as methodology to put out satisfying or optimal solution through proper simulation.

2.2 System Dynamics

A system is defined as a combination of elements that act together to perform a certain objective. System dynamics deal with the mathematical modeling of dynamic systems and the response analyses of such systems with a view toward understanding the dynamic nature of each system and improving the system' performance. The System Dynamics Society defines that System dynamics is a methodology for studying and managing complex feedback systems, such as one finds in business and other social systems. System dynamics is developed in the 1950's by J.W. Forrester at MIT who wrote the Industrial Dynamics [3]. The methodology was used to analysis the inter-relationships of the world economy and the environment. System dynamics (SD) and system thinking are methods for studying the world around us. They deal with understanding how complex systems change over time, and how structure influences behavior [4]. Much of the art of system dynamics modeling is discovering and representing the feedback processes, which, along with stock and flow structures, time delays, and nonlinearities, determine the dynamics of a system [5].

3. Evaluation Procedure

3.1 Focus Group Selection & Conceptual Modeling

To gather technical and fundamental data of SMRs, A focus group should be selected which includes staffs, engineers, and project managers, etc., who have enough knowledge about SMRs to suggest ideas on simulation modeling. Before this procedure, the preliminary modeling was done as below considering variables of three groups: Client, SMRs, and Circumstances. At the moment, this is just conceptual, but through a series of modification by communication with the focus group, it will be developed to more defined & simulatable one with equations.

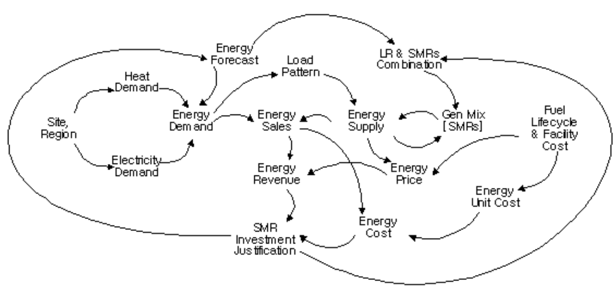

Fig. 3. Conceptual Modeling using System Dynamics for SMRs Evaluation

3.2 Detailed Modeling & Simulation

To develop a diagram model into a simulatable one, proper equations should be defined and linked among variables. However, SMRs are in beginning stage of NPPs industry. So, not only empirical but also of forecasting data seem to be used to build up the equations.

3.3 Considering Qualitative Factors

Besides quantitative data, decision making between SMRs and LRs should include qualitative one as well. Because the investment on NPPs is huge and connected with client's industrial situation directly or indirectly, adoption of NPPs is done based on long–range plan. So, clients usually take qualitative factors into account such as technology transfer, additional benefit, other kind of strategic things in economic evaluation.

3.4 Output Requirement of the Simulation

The model should be designed to produce many kinds of analysis results after simulation ends. The required outputs of the simulation model are as below. Through these outputs, Investment on SMRs could be justified.

■SMRs' investment feasibility analysis
■SMRs' cash flow and breakeven point analysis
■SMRs' construction cost and ROI analysis
■SMRs' optimal investment points of time

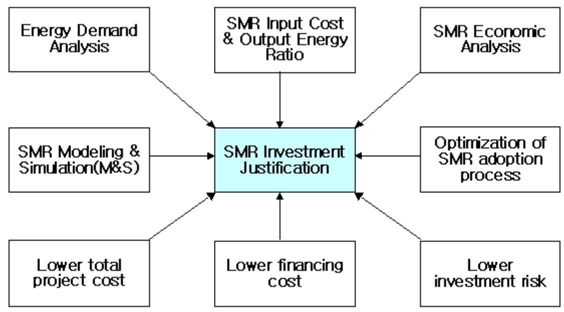

Fig. 4. SMRs Investment Justification Diagram.

4. Conclusions

Through this conceptual framework for evaluation on SMRs, future detailed study could be done more effectively and logically. Consequently, the simulation model is expected to make information on how much more benefit SMRs can bring than LRs.

REFERENCES

[1]http://www.world-nuclear.org/info/inf33.html
Small Nuclear Power Reactors (updated 2 july 2010)

[2] M.D. Carelli, P. Garrone, G. Locatelli, M. Mancini, C. Mycoff, P. Trucco, M.E. Ricotti, Economic Features of Integral, Modular, Small-to-Medium Size Reactors, Progress in Nuclear, p. 1, 2009.

[3] Forrester J, Industrial Dynamics, MIT Press, Cambridge, MA, 1968

[4] Senge PM., The Fifth Discipline: The Art and Practice of the Learning Organization, Doubleday, New York, 1990

[5] Sterman JD., Business Dynamics, McGrawhill, 2000