System Dynamics Modeling of interactive cost factors for small modular reactors

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1. Introduction

As a part of the Study on Economic Efficiency and Marketability of small modular reactors project, we at Nemopartners NEC consulting corporation were studying the various cost factors on small modular reactors (SMRs). To have a better knowledge of the interaction between the cost factors, System Dynamics Modeling has been developed. This model will contribute to our understanding of the interaction on the major factors effecting on the unit cost of SMRs to the SMRs' market share in the market economics as competition.

2. Methods and Results

The purpose of this study is to identify and understand the interaction among the various cost factors, which have been known as the decision criterion to build a new reactor in the market economics as competition. We used the System Dynamics Modeling to analyze the cost and market share changes of the various SMRs according to the SMRs' known developing time frame.

2.1 System Dynamics Model considering interactions among cost factors for SMR

Considering interactions among the major cost factors, System Dynamics Model operates like Fig.1.

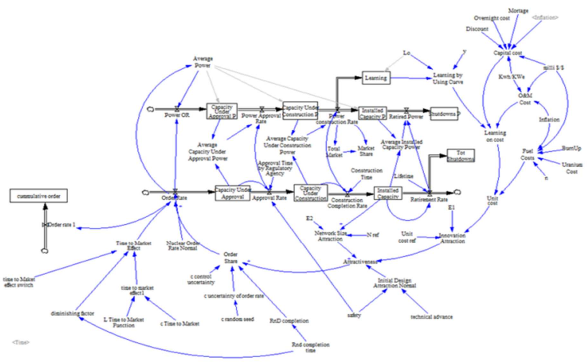

Fig. 1. System Dynamics Model of interactive cost factors for SMR

We assumed the SMR products' features for the model to analyze the cost trends or market share trends, which have been known publicly.

Table I: SMR Products' Assumptions

	SMR1	SMR2	SMR3
Modulator	Water	Water	Fast Reactor
Coolant Type	Water	Water	Lead-Bismuth
Electric Output	100MWe	125MWe	40MWe
Passive Cooling	Partial Passive cooling	Full passive Cooling	Full passive Cooling
Refueling Cycle	3Year	5Year	20 Year
Time to Market	2012	2015	2025
Cost	$7,000/kWe	$5,000/kWe	$7,000/kWe

2.2 Assumptions of System Dynamics Model considering interactive cost factors for SMRs

The model is premised on the major assumption of network size effect, learning effect, time to market and design attractiveness.

2.2.1 Network Size Effect in the Nuclear Installation Process

The utility of a product often depends on how many others are also using it. (Network size effect) This is the effect upon demand in a market for a product, which already has in series a set of units. The network size effect boosts product attractiveness and thus expands the total size of the market (just as the growth of the internet made computer ownership more attractive, leading more people to use the internet). These loops tend to favor the market share leader within an industry, assuming competing products are incompatible. A fundamental effect of feedback results from the creation of an infrastructure that is necessary to the development of each nuclear power plant. The greater the number of units constructed in the past, the more evident this feedback effect will be. In other words, the benefits deriving from the installation of a nuclear power plant progressively and intensively increase with time. The growth effect of this infrastructure influences the choices of the various decision-makers, the constructors of power plants, who therefore feel conditioned in their final evaluation of investments.

2.2.2 Learning Effect in the Nuclear Installation Process

Progress functions clearly incorporate a number of types of learning associated with a new production process. Among these are reduced labor requirements as tasks become routinized through repetition; the effects of learning by management leading to more efficient production and labor scheduling and improved production control; learning by the engineering department of a firm, which redesigns the capital equipment utilized by workers and makes changes in the operation of the plant to improve routing and handling of material; the effects of increased efficiency of suppliers, who themselves experience.

2.2.3 Design Attractiveness in SMR market

Design Attractiveness equation is the following.

Initial Design Attraction Normal [SMRtype] = 3 * safety[SMRtype] + technical advance[SMRtype]

The assumptions for the equation are the following, which are based on the SMR expert options. The SMR experts considered the published reactor developing plans and features to assume the figures. On the next study, we will develop the surveys to measure the design attractiveness for the reliability enhancement.

Table 2: Design Attractiveness Assumption

		SMR1	SMR2	SMR3
Design Attractiveness	Safety	0.1	0.3	1
	Technical advance	0.1	0.3	1

In this study, we found out that the design attractiveness would be one of the important factors to analyze the cost effectiveness change in the market economics as competition.

2.3 Results of Analysis

2.3.1 Unit cost change of each SMR

We found out the unit cost of SMRs would change with time and market situations. The cost of SMR could be determined from the point of the engineer's view at first but competitive situation change would be the important factor to understand the cost competiveness change with time.

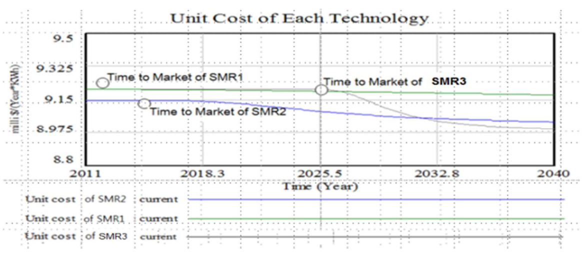

Fig. 2. Unit cost change with time in the market

We could study the market share change to understand the cost change or cost advantage change with time.

2.4.2 SMR Market Share change

As SMR2 entered the market in 2015, SMR1 lost the market share drastically because SMR2's higher technical attractiveness and lower unit cost. SMR1 hold the market share by 2020.

On the other hand, SMR3 led the market after 2025 although SMR3 had higher unit cost.

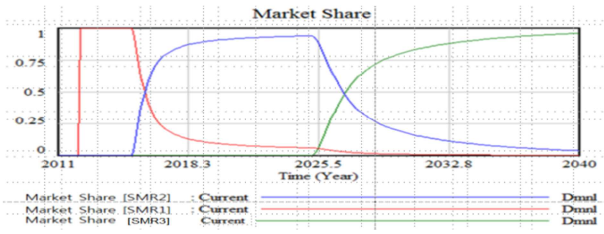

Fig. 3. SMR Market Share change in the market

2.4.3 Use of Model for simulation

We can use or expand this model to understand by when we should develop a SMR reactor with a certain design to have the economic advantage or for other decision purposes.

3. Conclusions

Simulation technique using System Dynamics can be useful tool to analyze unit cost of SMR and market share in competition. System dynamics modeling can be used in the market of small modular reactor by its various assumptions.

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