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Analysis on the Reliable Role of Nuclear Power Generation Under the CO2 Emission Constraints

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1. Introduction

There are many important issues to decide the reliable role of the nuclear power in the long term expansion program in Korea power system. Climate changes regime, increasing demand on renewable energy, public acceptance of looking for a site for the nuclear facility and so on are currently faced with the nuclear industry. This study analyzes the reliable role and portion of the nuclear power in the fuel mix of the power generation system under the CO2 emission constraints. It shows the how many nuclear power plants need to be added to meet the increased electricity demand according to the different emission target, changes of the total system cost and CO2 savings due to the increase of nuclear power generation.

2. Methods and Results

2.1 Scenario Approach and Computational Model

The purpose of this study is to estimate the system cost changes, CO2 emission reduction and system reliability, based on the Business-As-Usual (BAU). The methodological tool used in the study is the WASP IV (Wien Automatic System Planning Package) for system cost and CO2 emission projection.

WASP IV code permits finding the optimal expansion plan for a power generation system over the period of up to thirty years, within constraints given by the planner. The optimum is evaluated in terms of minimum discounted total costs. A simplified description of the model follows. Each possible sequence of power units added to the system (expansion plan or expansion policy) meeting the constraints is evaluated by means of a cost function (the objective function), which is composed of ;

- Depreciable capital investment cost : equipment, site installation costs (I)
- Salvage value of investment costs (S)
- Non-depreciable capital investment costs: fuel inventory, initial stock of spare parts etc (L)
- Fuel cost (F)
- Non-fuel operation and maintenance costs (M)
- Costs of the energy not served (O)

The cost function to be evaluated by WASP can be represented by the following expression:

The optimal expansion plan is defined as the minimization of the objective function (B) like;

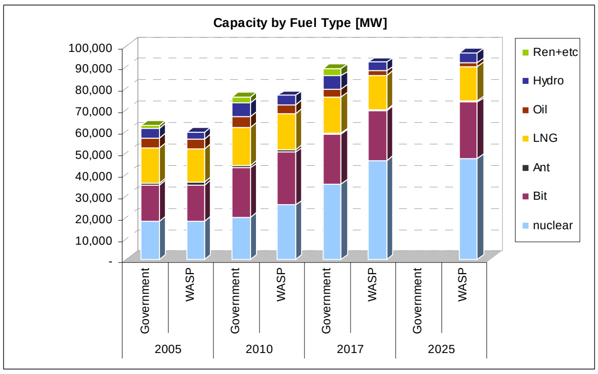
$$B_j = \sum_{t=1}^{T} [I_{j,t} - S_{j,t} + L_{j,t} + F_{j,t} + M_{j,t} + O_{j,t}]$$

- Bj is the objective function attached to the expansion plan j,
- t is the time in years
- T is the length of the study period (total number of years) and all values are have the meaning of discounted values to a reference data at a given discount rate i.

This study analyzes the long-term power expansion planning in the point of view such as benefit of carbon reduction and system reliability as well as least cost operation, which shows the trade-off between the incremental system cost and the benefit of the CO2 reduction.

Total analysis period is from 2005 to 2020 and discounted rate of 7% is used. Constraints of LOLP and reserve margin are 0.5 day/yr and 10 ~ 45 % are assumed. Different carbon emission limit [kg-c/kWh] is applied to like 0.11, 0.12, 0.13, 0.15, and 0.20. Additionally 0.15 limit is kept through 2011 and after 2011 more stringent target of 0.11 is applied (0.20 → 0.11)

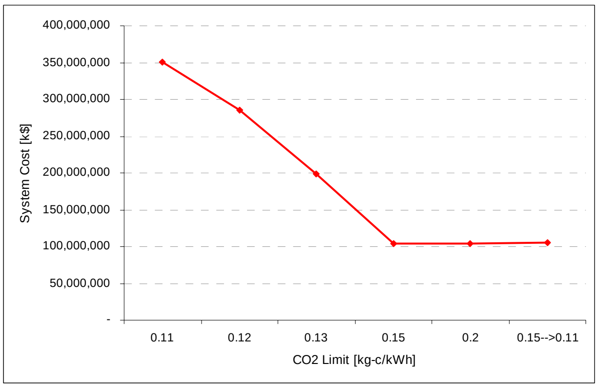
2.2 Results



[Figure 1] Comparison of Expansion Capacity between Government Plan and Model

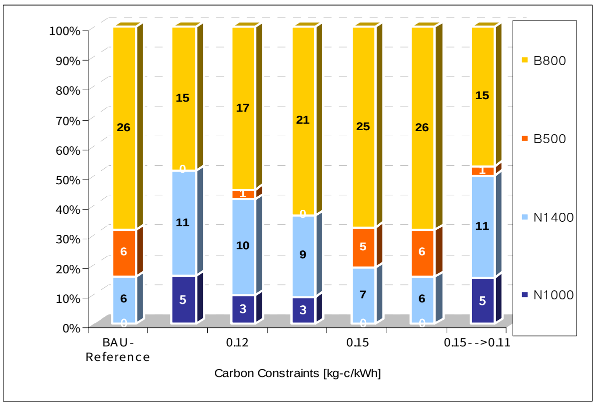
First of all it needs to check how well the model reflects the real power system and how close it is to the actual Korean system, because exact calculation of the capacity and generation should be the basis on the estimation of CO_2 emission as well as system cost. Capacity and generation by fuel types have the same trend as the reference of the 2nd expansion plan by the government. Slight difference of comparison by fuel type is because the renewable and community energy system are included only in the government estimation while the model doesn't consider them.

The higher system cost can be expected when the stricter CO_2 emission target from 0.20 kg-c/kWh to 0.11 kg-c/kWh is applied. It means that nuclear power can take a major role as a system stabilizer in economics point of view and as an abatement method of CO_2 emission in environmental point of view as the new nuclear power plants come on-line.



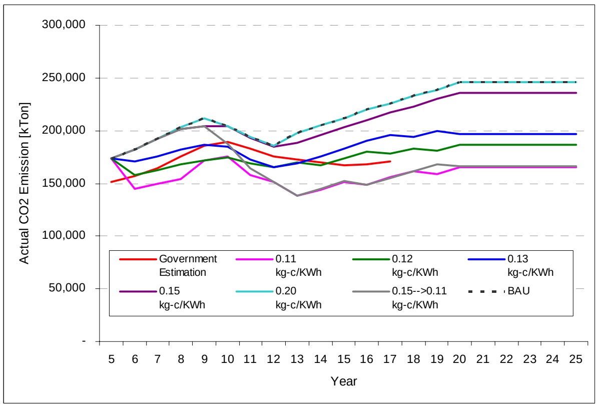
[Figure 2] System Cost Changes according to the Various CO_2 limit

Change of fuel mix, i.e., number of plants shows the more stricter carbon emission limit introduces the more nuclear plants to mitigate the carbon level and the nuclear plants is added as much as the decrease of coal plants to meet the demand. From this result it can be expected that system eliminates the uneconomical plants preferentially and adds the large units.



[Figure 3] Fuel Mix Changes according to the Various CO_2 limit

Estimation of the actual CO_2 emission according to the different carbon emission limit derived from model and government estimation from 2005 to 2017 is compared. As the emission limit becomes stricter, the less CO_2 are emitted and CO_2 emission increases until 2010 and after that decreases rapidly. It means that many fossil power plants in the current system plays a major role before 2010 and as the economical and non-carbon source plants such as nuclear plants are connected to the system, total CO_2 emissions are decreased.



[Figure 4] Changes of CO_2 emission according to the Various Emission Limit

3. Conclusion

This paper is to make it clear that Korea have no options in terms of the economics and less CO_2 emission except use of nuclear energy and its government cannot but expand the nationwide nuclear power program because the increased energy demand will be inevitable and any other resources will not be the unique solution in the economic and sustainability point of view. The results from this analysis are useful for the Korean government in charge of long-term resource planning to go over what kinds of role of each electric resources play and what are the pros and cons of power generation strategies in terms of triangular dilemma as economics, environmental friendliness, and stable supply of the electricity.

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Acknowledgement

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[2] Ministry of Commerce, Industry and Energy, Electricity Supply and Demand Basic Plan, 2004