A Deterministic & Probabilistic Economic Analysis for APR+

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1. Introduction

As a part of a national long-term R&D program, the Advanced Power Reactor plus (APR+) project was launched in 2007. The APR+ project consists of three phases. In the first phase, the basic design was developed. The second phase involves the development of the standard detailed design and the submittal of the request for Standard Design Approval (SDA) to the Korean nuclear regulatory body. The third phase is the completion of the APR+ design optimizing core part. This paper describes the cost estimate results in the middle of the process of the APR+ standard detailed design. This paper uses the Revenue Requirement Method (RRM), which accounts for the amount of revenue that must be collected from customers to compensate a utility for all expenditures associated with implementing an alternative decision. The RRM can be combined with a random sampling statistical simulation computer program to calculate the Probability Distribution Functions (PDF) of the cost elements to generate the cost.

2. Deterministic Method

The cost analysis performs a constant-dollar analysis using current dollar values. A constant-dollar analysis determines the base year monetary value without the effect of inflation (although real escalation is included for future years). The discount rate in the absence of inflation must be used.

$$i = (1+i')(1+f) - 1 \qquad (1)$$

where i : apparent discount rate
i' : real discount rate
f : inflation rate

$$e = (1+e')(1+f) - 1 \qquad (2)$$

where e : apparent escalation rate
e' : real escalation rate
f : inflation rate

A constant cost analysis does not include the effect of inflation. A constant cost analysis gives a clear picture of real cost trends, and it is preferred for longer term studies. When someone plans a project, he estimates the point cost for elements which are necessary for that project. The total cost of completing that project is referred to as point value. This method is a deterministic cost estimate method. A current dollar analysis includes the effect of inflation. The duration of a nuclear power plant is about 10 years from planning to the commercialization date. Therefore, we considered the cash flow over time. To construct a nuclear power plant, the cost cash flow must be considered. The term "levelized" refers to "...a series of transactions that is converted to an equivalent annuity through the use of present worth arithmetic." The levelized carrying charges rate is a function of the discount rate, the book life, the depreciation method, taxes, and insurance. Levelized expenses are determined by annual expenses, the levelized factor, the capacity factor, and house load rate, as well as other factors. Figure 1 shows the elements of the RRM.

2.1 Deterministic Cost Model

The generating cost of a power plant is composed of fixed charges and expenses in the RRM.

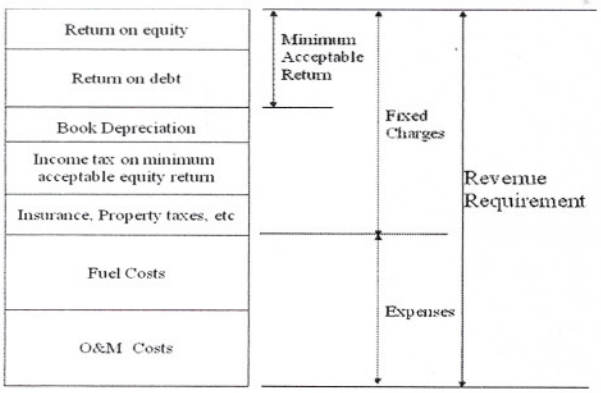


Figure 1. Revenue categories for the RRM

2.2 Estimate Results

The generating cost is composed of fixed costs, O&M costs, and fuel costs. These values are determined during the constant dollar analysis

Table 1. Point estimate results

Items	unit	APR+ 1st (1500MW×2)	Coal 1000 1st (1000MW×2)
Generating cost	won/kWh	47.92	56.75
o fixed cost	"	23.76	15.00
o O&M cost	"	14.90	5.01
o Fuel cost	"	9.26	36.74

3. Probabilistic Method

Many cost experts are invited to determine the probability distribution function for the elements of a nuclear power plant. The invited cost experts select high-level uncertainty elements, and the minimum, maximum and median values are determined after a discussion and depending on experience or engineers' judgments. The cost evaluator develops the probability distribution function for each cost element. In the next step, a screening analysis is conducted. In the event of uncertainty, that problem is returned to the cost experts. The cost experts discuss the problem and create a more efficient probability distribution function. The final probability distribution functions are set and a simulation is performed.

3.1 Estimating Process and Tool

Probability cost estimate methodologies involve the generation of best estimates for all variables. Screening is done to identify the most important or "sensitive elements in generating the cost" for sensitive variables, followed by the encoding of empirical data and expert judgments into subjective probabilities for sensitive variables. A probabilistic analysis involving a cost model and a statistics model by a random-sampling statistical simulation computer program is commonly used. Examples are the Crystal Ball, Risk, and Range Estimating programs. In this paper, we use Crystal Ball, ver.11.1. The minimum, maximum, and median values are determined by the cost experts.

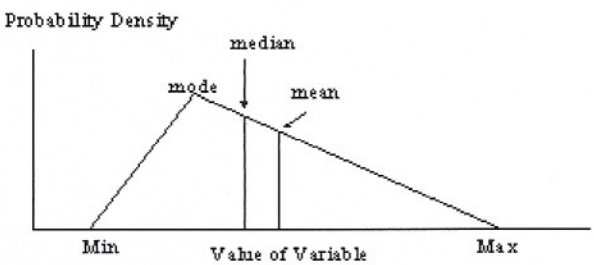


Figure 2. Triangular PDF

3.2 Estimating Results

The results of the probability cost estimate are diverse, including cumulative charts, frequency and column data, reverse cumulative charts, and the area types.

Statistics:	Forecast values
Trials	5,000
Base Case	47.92
Mean	48.72
Median	48.34
Mode	---
Standard Deviation	2.62
Variance	6.85
Skewness	0.4883
Kurtosis	2.58
Coeff. of Variability	0.0537
Minimum	43.02
Maximum	57.67
Range Width	14.65
Mean Std. Error	0.04

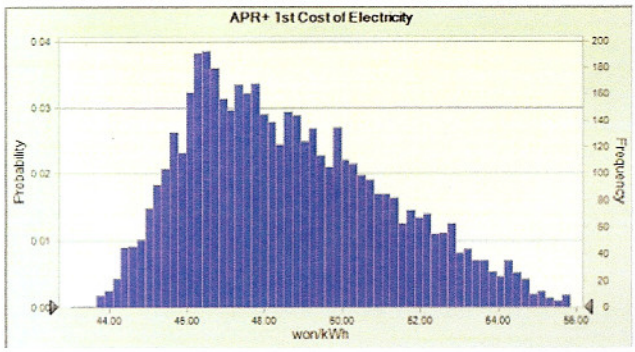
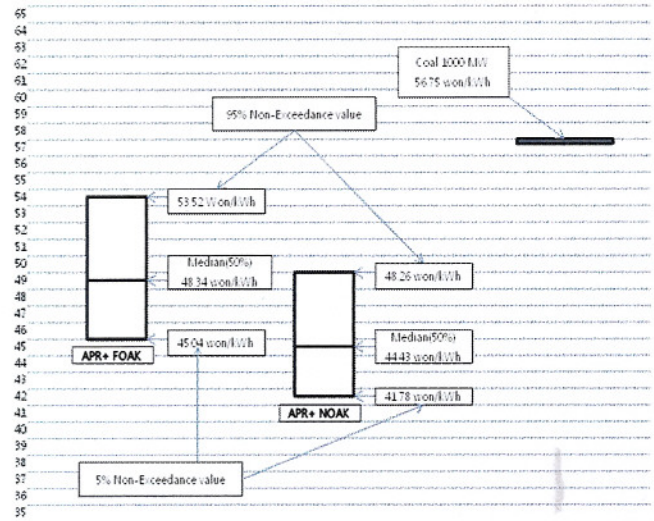


Figure 3. Probabilistic results for the APR+ design



Figures 4. Generating a cost distribution of a probabilistic analysis for the APR+ design

4. Conclusion

The generated cost for the APR+ design using a deterministic method was found to be 47.92won/kWh. This figure by a probabilistic method was 48.34won/kWh (median value). The probabilistic generating cost of the APR+ design is about 0.42won/kWh higher than the deterministic generating cost of the APR+ design. The APR+ (FOAK, NOAK) design has 15% - 24% cost advantage over a 1000MW coal power plant.

REFERENCES

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