A Deterministic and Probabilistic Cost Estimate for Nuclear Power Plants

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1. Introduction

There are many cost estimate methodologies for some future projects. Revenue Requirement Method (RRM), Cost/Benefit Ratio method, Return on Investment, Pay Back Period Method. etc. This paper uses the RRM method which is the amount of revenue that must be collected from customers to compensate a utility for all expenditures associated with implementing an alternative decision involving money. This RRM can be combined with a random sampling statistical simulation computer program to calculated the Probability Distribution Functions(PDF) of the cost elements for generating cost. EPRI developed this combined statistical techniques into RRM, named Statistical Revenue Requirement Method(SRRM). The statistical technique is a random sampling statistical simulation. The simulation tool is usually Monte Carlo sampling, Latin Latin Hypercube sampling, etc. SRRM is used to estimating for future power plants, apartments, hospital, marketing, etc. In this paper, RRM calculation and SRRM simulation have been practiced for PWR1400MWe nuclear power plants.

2. Deterministic Method

The cost analysis performs constant dollar analysis and current dollar. Constant dollar analysis is a base year monetary value without the effect of inflation (although real escalation is included in 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

Constant cost analysis is not included the effect of inflation. Constant cost analysis gives a clear picture of real cost trends, and prefers for longer term studies When someone plans a project, he estimates point cost for elements which are necessary that project. Then, total cost completing that project is point value. This method is deterministic cost estimate method. Current dollar analysis is included the effect of inflation. In this

case , the discount rate is the cost of money. The generating cost of the power plant compose of fixed charges and expenses. The duration of the nuclear power plant needs about 10 years from plan to commercial date, so we consider cash flow of time. To construct the nuclear power plant, cost cash flow must be considered. The term "levelized" means " A series of transaction is converted to an equivalent annuity by use of present worth arithmetic" Levelized carrying charges rate is function of discount rate, book life, depreciation method, taxes, insurance. Levelized Expenses are determined by annual expenses, levelized factor, capacity factor house load rate. etc. Figure 1 shows the elements of RRM.

2.1 Deterministic Analysis Process and Tool

Each elements of RRM is estimated by regulatory law, taxes, insurance, engineering judgement, a cost data of commercial operation plant, scaling factor . etc. All value of the elements of the power plant are point value
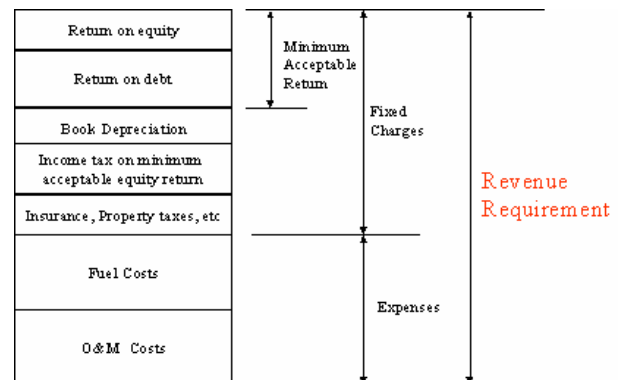

Figure 1. Revenue categories for the RRM

2.2 Estimate Results

Generating cost is composed of fixed cost, O&M cost, fuel cost, these value determined under constant dollar analysis

Table 1. Point Estimate Results

Items	unit	PWR (1400MW×2)	Coal 800 (800MW×2)
Generating cost	won/kWh	35.89	38.06
o fixed cost	"	21.68	15.65
o O&M cost	"	9.50	6.32
o Fuel cost	"	4.71	16.10

3. Probabilistic Method

Many cost field experts are invited to do probability distribution function for the elements of nuclear power plantte. Invited cost experts select high level uncertainty elements and min, max, median values are determined by discussion, their experience or engineering judgment. Cost evaluator develops probability distribution function for each cost elements. Next step, screening analysis is practiced. If uncertainty problem does exist, that problem return to the cost experts. Cost experts discuss that problem and make more efficient probability distribution function. Final probability distribution functions are drawing and simulation is performed.

3.1 Estimating Process and Tool

Probability cost estimate methodologies consist of generation of best estimates for all variables. Screening to identify the most important or "sensitive elements in generating cost" for sensitive variables, encoding of empirical data and expert judgement into subjective probabilities for sensitive variables. Probabilistic analysis involving a cost model and a statistics model Random sampling statistical simulation computer program widely used are Crystal Ball, Risk, and Range Estimating Program. In this paper, we use Crystal Ball ver.4.0. Min, Max , and Median are determined by cost experts. And simulation's tool was Latin Hypercube sampling method
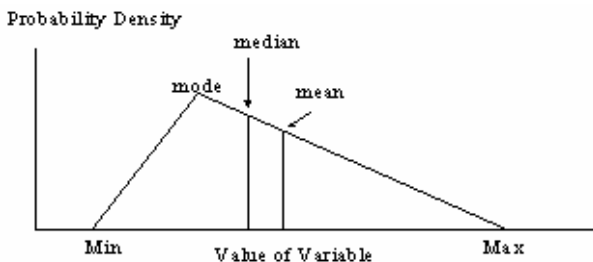

Figure 2. Triangular PDF

3.2 Estimating Results

The results of probability cost estimate are diverse, cumulative chart , frequency and column, reverse cumulative, area type. etc..

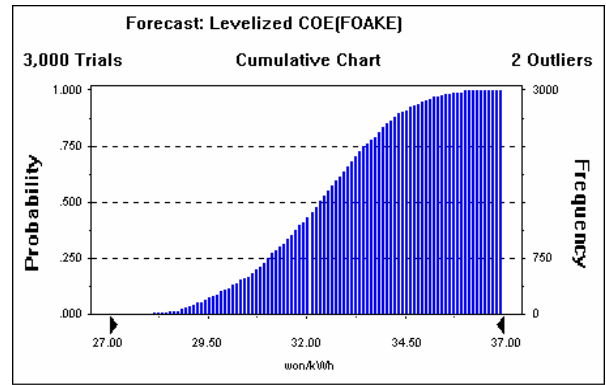| Statistics:	Value
Trials	3000
Mean	32.29
Median	32.38
Mode	---
Standard Deviation	1.73
Variance	3.01
Skewness	-0.15
Kurtosis	2.61
Coeff. of Variability	0.05
Range Minimum	27.23
Range Maximum	38.27
Range Width	11.05
Mean Std. Error	0.03

Figure 3. Probabilistic results for PWR1400

4. Comparison of Two methods

4.1 A Comparison of Generating cost

A generating cost for PWR using deterministic method is 35.89won/kwh. And that of probabilistic method is 32.38won/kwh. The generating cost of PWR1400 is about 2.5won/kwh below compared to the deterministic method deterministic method. In this case, cost expert method has been practiced conservatively.

4.2 Comparison

Deterministic analysis and probabilistic anlysis is compared in Table 2.

Table 2. Comparison of Two method

Item	Deterministic Analysis	Probabilistic Analysis
Estimate method	RRM method	SRRM method [RMM + Probabilistic Technique)
Generating cost	Point values	Cost scope and probabilistic values
Reliance	Very sensitive by generating cost elements	Reliance Improvement

5. Conclusion

Probabilistic simulation technique is not limited to to estimated the Nuclear power plant. It can be used to others project. Power plant under construction is not allowed to much contingency, because probabilistic simulation results consider or include the contingency

REFERENCES

[1] EPRI, Advanced Light Water Reactor(ALWR) Utility Requirements Document Chapter 1, APPENDIX C, June. 12, 1995
[2] OECD, Expert Group on Projected Costs of Generating Electricity, 13 Jan. 1998
[3] Projected Cost of Electricity for Major Alternatives to Future Nuclear Power Plants, Palo Alto, CA, Sep.1995.