A Probability Analysis of the Generating Cost for APR1000+

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1. Introduction

The nuclear power plant market is expected to grow rapidly in order to address issues of global warming, cutting CO_2 emissions and securing stable electricity supplies. Under these circumstances, the main primary goal of the APR1000+ development is to ensure export competitiveness in the developing countries in the Middle East and Southeast Asia. To that end, APR1000+(1,000MWe, 3.5 generation) will be developed based on APR+ (1,500MWe, 3.5 generation). And comparing to OPR1000(Korean Standard Nuclear power Plant, 2.5 generation), APR1000+ have many design features such as the 60 year design life time, comprehensive site requirement of 0.3g seismic design, stability improvement, operability improvement and provisions for severe accidents.

2. Design Features of APR1000+

APR1000+ have several advanced design features to OPR1000, as outlined below in Table 1.

Table 1. Summary of APR1000+ advanced design features

	item	APR1000+	OPR1000
1	Plant life time	60yr	40yr
2	Seismic design	0.3g	0.2g
3	CDF	<10E-6/yr	<10E-4/yr
4	Safety Injection	DVI	CLI
5	I&C	Digital	Analog
6	H_2 Control	PAR+Igniter	Igniter
7	Over Pressure Protection	POSRV	PSV+SDS
8	Containment Integrity	Aircraft Impact Design	-
9	Safety System	4-Train	2-Train
10	Auxiliary Feed Water System	PAFS	AFS
11	EDG	4/unit	2/unit
12	AAC	GT	DG
13	Load Follow Operation	Automatic	Manual
14	RWST Location	In Containment	Yard
15	Fuel	HIPER16	PLUS7
16	MSIV	2/line	1/line
17	SC/CS Pump/Hx	4/4	2/2
18	Fluidic Device	FD	N/A
19	H_2 Control	PAR+Igniter	Igniter
20	MCR AHU	100% x 4	100% x 2

3. A Probability Cost Analysis of APR1000+

3.1 The Elements of Generating Cost

The probability density functions(PDFs) of twenty one cost elements were developed through expert group meetings. Many cost field experts were invited to undertake the PDFs for the elements of nuclear power plants. The cost experts invited to select high level uncertainty elements minimum, maximum, and median values were determined through discussions, their experiences, and engineering judgments. The cost evaluator developed PDFs for each cost element. Next, the screening analysis was undertaken. If an uncertainty problem existed, the problem was returned to the cost experts. The cost experts then discussed the problem again and provided a more efficient PDF. The final PDFs were decided and the simulation was performed.

Table 2. The Elements of Generating Cost

No	Cost Element	No	Cost Element
1	NSSS Domestic	12	Foreign Material Handling Cost
2	NSSS Foreign	13	Land Cost
3	T/G Domestic	14	Contingency Cost
4	T/G Foreign	15	Interest During Construction
5	BOP Domestic	16	O&M Cost
6	BOP Foreign	17	Fuel Cost
7	Main Facility Construction Cost	18	Capacity Factor
8	Ancillary Facility Construction Cost	19	Discount Rate
9	AE Domestic	20	Exchange Rate
10	AE Foreign	21	Decommissioning Cost
11	Owner Cost		

3.2 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 used. In this paper, we use Crystal-Ball, ver.11.1. The minimum, maximum, and median values are determined by the cost experts.

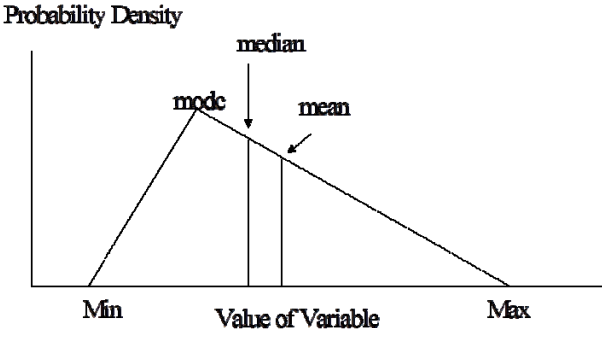
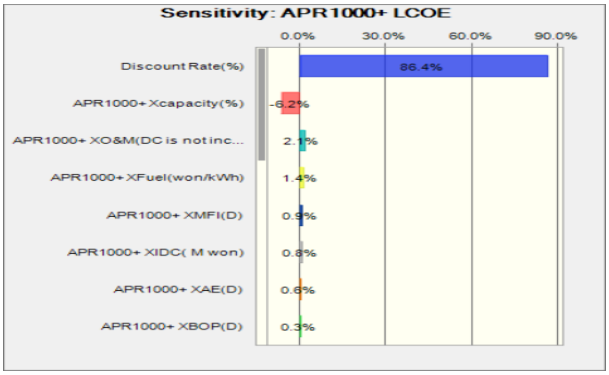


Figure 1. Triangular PDF

3.3 Simulation Results

The results of the probability cost estimate are diverse, including sensitivity chart, cumulative charts, frequency and column data. Etc.. The most important element in generating cost is discount rate.



*LCOE : Levelized Cost of Electricity

Figure 2. Sensitivity in APR1000+ LCOE

Statistics:	Forecast values
Trials	30,000
Base Case	56.03
Mean	57.18
Median	56.51
Mode	---
Standard Deviation	4.24
Variance	17.94
Skewness	0.5761
Kurtosis	2.71
Coeff. of Variability	0.0741
Minimum	48.37
Maximum	74.22
Range Width	25.86
Mean Std. Error	0.02

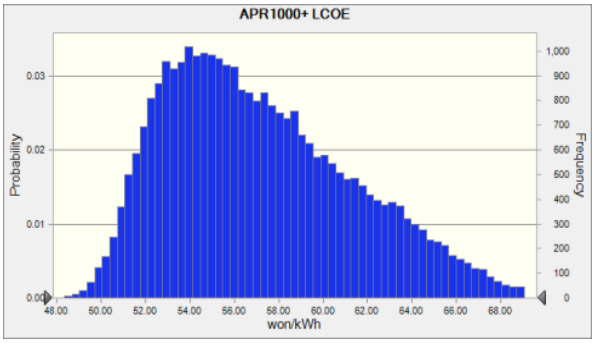


Figure 3. Probabilistic Results for the APR1000+

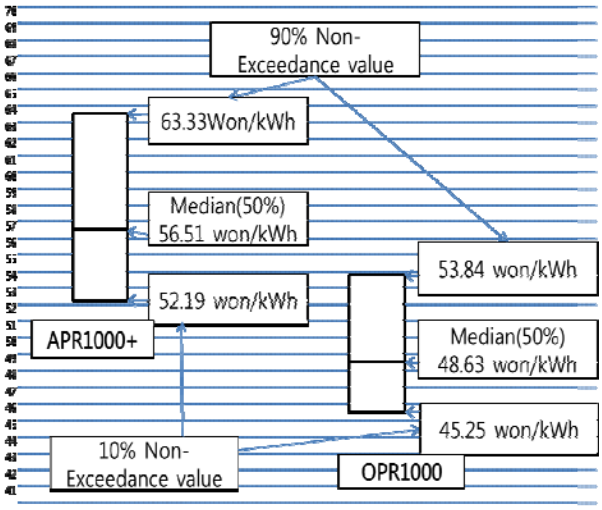


Figure 4. LCOE of APR1000+ and OPR1000

4. Conclusions

In this simulation, the results of generating cost for APR1000+ preliminary conceptual design using a probability method was shown to be 48.37 ~ 74.22 won/kWh(median value 56.51 won/kWh). Those of OPR1000 was 42.08 ~ 61.77 won/kWh(median value 48.63 won/kWh). APR1000+ has -16.2% cost advantage over OPR1000 nuclear power plant. The main reason of this results is due to adding several safety designs .

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