Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 26-27, 2017

A Probabilistic Cost Estimate of EU-APR

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1. Introduction

Korea Hydro & Nuclear Power Ltd. (KHNP) has been developing EU-APR design to customize and improve the APR1400, the Korean Generation III reactor, to be complying with the up-to-date safety and performance requirements of most nuclear regulators and utilities in Europe.

The deterministic cost estimate has mainly focused on the design changes of EU-APR compared to APR1400 design and consequential changes in economic aspect. Construction and operation of EU-APR is assumed to be performed at the new sites in Korea under the same conditions as Korean commercial nuclear reactors generally have. After deterministic cost estimate, a probabilistic cost estimate of EU-APR was performed by the developing PDF (Probabilistic Density Function) through expert's discussion and Crystal Ball software.

2. Design Features of EU-APR

EU-APR has the additional design features regarding the safety-related issues. Additional redundancy for the important safety functions is provided to improve the reliability and to enable on-line maintenances. Severe Accident mitigation systems, such as Passive Ex-vessel corium retaining and Cooling System (PECS) and Containment Filtered Vent System (CFVS), which are independent of the systems for normal operations or postulated accidents, are provided to ensure the containment integrity in the event of SA. The rated frequency of 50 Hz is adopted for all AC electrical systems in the EU-APR. The design of electrical and I&C systems is in accordance with international codes and standards such as IEC.

Table 1. Summary of EU-APR design features

	Item	EU-APR	APR1400
1	Seismic design	0.25g	0.3g
2	RX Building Type	Double Containment	Single Containment
3	EDG	4 /unit	2/unit
4	AAC	2/unit (Gas TBN)	1/unit (Diesel)
5	Electrical Frequency	50 Hz	60 Hz
6	Safety System	4 Train	Semi-4-Train
7	Molten Core Cooling System	Core-catcher	CFS※ IVR-ERVC

※ CFS : Cavity Flooding System
IVR-ERVC : In-Vessel Retention –External Reactor Vessel Cooling

3. A Probability Cost Estimate of EU-APR

3.1 Developing PDFs of Input Cost Elements

The probability density functions(PDFs) of twenty generating 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 were invited to select high level uncertainty elements minimum, maximum, and median values determined through discussions, their experiences, and engineering judgments. The cost evaluator developed PDFs for each cost element..

Table 2. Cost Elements

No	Cost Element	No	Cost Element
1	NSSS(D)	11	Shipping
2	T/G(D)	12	Land
3	TG(F)	13	Contingency
4	BOP(D)	14	IDC
5	BOP(F)	15	O&M
6	MFI	16	Fuel
7	AFI	17	Decommissioning
8	AE(D)	18	Capacity Factor(%)
9	AE(F)	19	Discount Rate(%)
10	Owner	20	Exchange Rate(won/$)

D : Domestic, F : Foreign
MFI : Main Facilities Installation
AFI : Accessory Facilities Installation

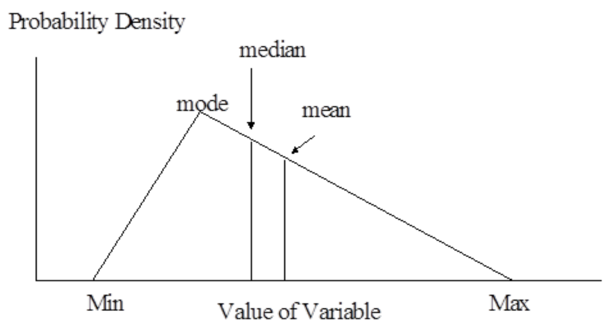


Figure 1. Probability Density Function

The peak of PDF is known as the "mode". The mode is the "best estimate". Although the probability density is highest at the mode, this does not mean that the mode represents the "most probable" value of the distribution. The peak merely means that the relative likelihood of obtaining a value near the mode is higher than the relative likelihood of obtaining values elsewhere on the distribution. The median of a distribution is a value such that there is a 50 percent probability that the actual value of the random variable may be either higher or lower. The median value indicated in figure 1 by a vertical line which separates the distribution into two regions of equal probability(equal areas). The mean is the centroid or first moment of the distribution, and in decision analysis terminology it is referred to as the expected value.

3.2 Simulation

As a result of performing the probability cost analysis, using the Crystal Ball software, the most sensitive factor in generating cost was determined to be the discount rate. The next factors were capacity factor, O&M cost, fuel cost, installation cost, contingency, NSSS, and so on, as shown in Figure 2.

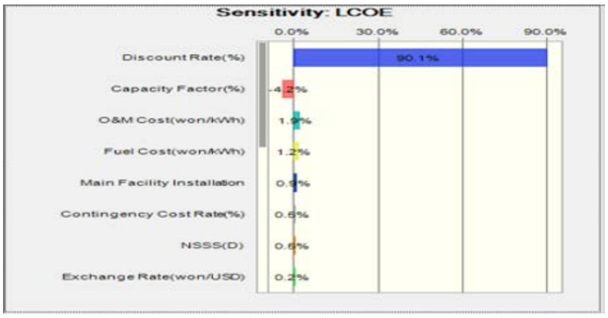
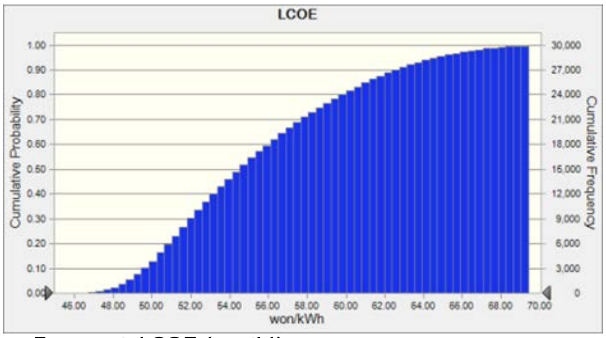


Figure 2. Sensitivity Chart

The median(50% cumulative probability value) Levelized Cost Of Electricity(LCOE) was 54.69 won/kWh, the 10% non-exceedance value was 49.84won/kWh, and the 90% non-exceedance value was 62.77 won/kWh for EU-APR single unit generating cost.



Forecast: LCOE (cont'd)

Percentiles:	Forecast values
0%	45.54
10%	49.84
20%	51.08
30%	52.17
40%	53.36
50%	54.69
60%	56.17
70%	57.89
80%	59.97
90%	62.77
100%	73.88

Figure 3. Probabilistic Cost Estimate results for EU-APR

4. Conclusions

In this simulation, the results of LCOE on EU-APR single unit were determined using the probabilistic cost estimate technique, The range of LCOE was shown to be 49.84 ~ 62.77 won/kWh. The median value of EU-APR is 54.69 won/kWh. Meanwhile, LCOE range of APR1400 was shown to be 42.13~ 49.41 won/kWh. The median value of APR1400 is 45.20 won/kWh.

EU-APR has enlarged building volumes and areas, quantity of bulk material and BOP equipment compared to APR1400. In terms of specific EU-APR design, double containment, diversity and redundancy for safety function, severe accident mitigation, 50Hz electric frequency , physical separation of safety and non-safety equipment designs are judged to be major factor in increasing the LCOE of EU-APR.

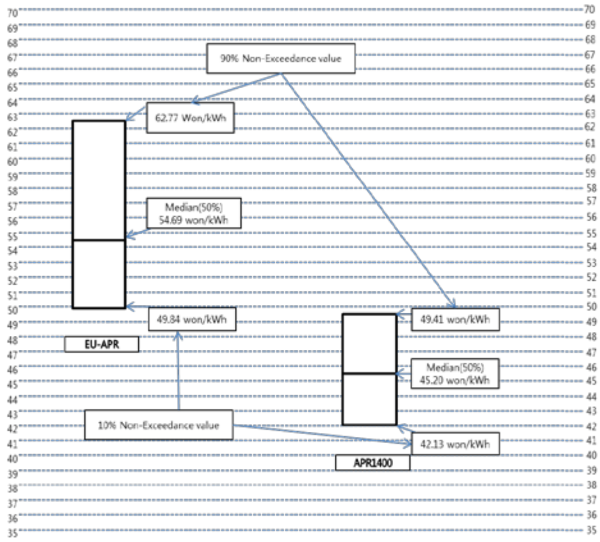


Figure 4. LCOE Range of EU-APR

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