The Study on Future Failure Rates of Nuclear Turbine

Hye-young Shin and Young-sheop Park
Korea Hydro and Nuclear Power Co.
shine@khnp.co.kr

1. Introduction

Long Term Asset Management (LTAM) is a concept that explains how to manage nuclear facilities safely, reliably, and economically at the same time during the plant life cycle. This concept includes establishing a component level optimum investment strategy that is balanced with appropriate aging management or maintenance planning within long term based insights. Large amount of conservatism in the design of nuclear power plant (NPP) makes it possible NPP to be longer operated beyond the design life, which is normally 40 years. These days, an additional 20-year operation is almost considered acceptable.

Replacing turbine facilities is a good alternative LTAM plan in the viewpoint of 60-year operation, because it should be done at least once for economic insight as well as for its degradation. In other words, this is probably more beneficial because of the continuous improvement of turbine design technology to increase thermal efficiency. This study developed future failure rates that can be applied to economics evaluation for LP turbines' replacement that is an alternative LTAM plan for a sample domestic nuclear turbine.

2. Methods and Results

While it is impossible to anticipate the Future Failure Rate (FFR) perfectly, it is important to model the future trend as properly as possible in order to get the right results for economics evaluation. FFRs must be developed for the priori and posteriori replacement of the facility and must be related to either the performance experience, maintenance practices, or aging trends. In this study, two functional types were selected to model FFRs for nuclear turbines among four types given by EPRI [1].

2.1 Exponential Function Type

This exponentially increasing failure rate mode is expressed in the manner as follows:

$$P_i = P1 * (1+P2)^i \tag{1}$$

The method to determine the values of parameters P1 and P2 was explained specifically in the paper that was published last year by the author [2]. Plant specific Preventive Maintenance (PM) based failure rates and the industry mean value as the output of analyzing EPIX DB were utilized in order to determine the values. The results are shown in Table 1.

Table 1. The Parameters of the Exponential Failure Mode

Facility	Inputs	P1	P2
Existing	P_{b0}=0.060, P_{bEoD}=0.158	0.0600	0.0352
New (Retrofit)	P_{a0}=0.0768, P_{aEoD}=0.158	0.0768	0.0173

Figure 1 presents the determined FFR functions in graphical forms.

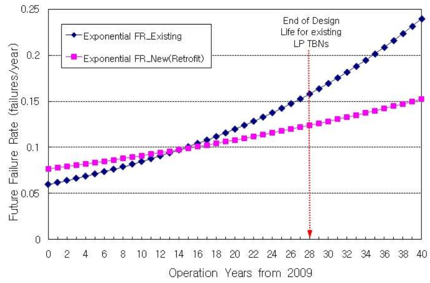

Figure 1. Exponential type of FFR

Figure 1 indicates that the posteriori future failure rate starts a little higher than the priori one, but it increases very slowly. It is worth considering the cross point as an optimum replacement time that can balance maintenance cost and investment cost.

2.2 Constant Function Type

The failure rate of nuclear facilities has been studied in the Probabilistic Safety Assessment (PSA) field. In particular, the bayesian technique has been widely utilized to merge a plant specific data with general industry data. Even if turbine is not modeled in PSA, the methodology can be applied to develop a future failure rate of turbine. In this sample case of zero turbine failure rate, which means there was no occurrence of unplanned failure caused by turbine in the plant, bayesianed constant failure rates for priori and posteriori replacement of LP turbines were obtained by using BURD, which is a useful tool to handle zero-failure data [3].

The general value of the turbine failure rate by EPRI [2, 4] was used for the priori future failure rate while the analyzed value with recent decade data from EPIX DB was used for the posteriori data in this mode. The inputs and results are indicated in Table 2 and Figure 2.

Table 2. The Bayesianned Constant Failure Mode

Facility	Specific value	General value	Error Factor	Output
Existing	0	0.169	10	0.0249
New(Retrofit)	0	0.158	10	0.0219

This type of failure mode represents efforts in preventing failures. That is, failure rate is able to be maintained constantly in the future because of prior efforts to prevent failures. However it doesn't cover the increasing PM burden appropriately. As time goes on, the PM interval should be shortened and the PM cost should be increasing in order to prevent unplanned future failures that were the results of aging.

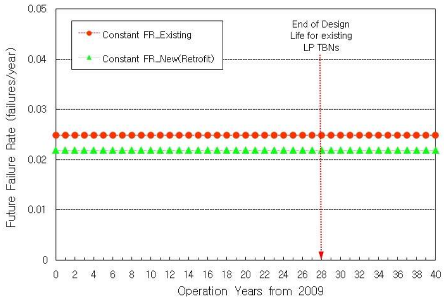

Figure 2. Constant Type of FFR

2.3 Comparison with Analyzing Results

The economics evaluations were performed to determine the beneficial one between the two LTAM alternative plans, A and B. A is the plan to maintain the existing LP turbines without replacement up to the end of 60 years, while B is the plan to upgrade the existing LP turbines by replacing with new LP turbines at a certain time. After considering the aging (deterioration) age, as well as the residual operation age, for the 60-years operation strategy, one of the proper times to replace LP turbines for the alternative plan B in the sample case was assumed around 2018, which is after about 10 years operation from the present.

The FFR functions used in the above evaluation is presented in Figure 3 in the shape of lines, which are magnified near point of time for replacement. The below curved line that is modeled in constant mode is more simplified, but does not cover the increasing maintenance cost that is needed to maintain the potential probability to future failure. In contrast, the upper curved line that is modeled in an exponentially increasing mode seems to explain the increase of PM cost with an increase in the probability of unplanned future failure rate.

It is also noticeable that there is a sudden jump in the exponential mode right after the replacement, which describes higher failure possibility in the initial operation stage of a facility. This curved line models the general shape of a "bath-tub" quite well relative to the curve for the basic LTAM plan, which maintains existing LP turbines without replacement.

Table 3 shows the economics evaluation results on the two LTAM alternative plans which were performed in the two different modes of FFRs that were developed in the above. The results indicate that the alternative plan B is the more preferable LTAM plan because it causes less LTAM NPV_{cost} than plan A in both cases of the FFR modes.

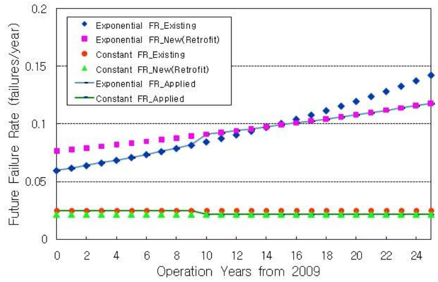

Figure 3. Graphical forms of the two modes of FFRs applied to the sample case.

The difference between the form of two failure modes did not affect the results in selecting better alternative LTAM plan. Only the sizes of the relative NPV(R-NPV= NPV_{costA} - NPV_{costB}) differed.

Table 3. Analysis Results

(billion won/unit)

FFR Mode	Plan	NPV_{cost}	R-NPV
Exponential	A	37.4	NA
	B	28.0	9.4
Constant	A	19.9	NA
	B	11.7	8.1

The FFR functional type did not affect the determination of a better alternative LTAM plan, as shown above. However, the exponential type that was developed in the manner described above was recommended to be utilized for long term based economics assessment because it can presents future efforts to prevent unplanned failure and concurrent increase of maintenance cost.

3. Conclusions

The exponentially increasing FFR functional type is more appropriate in describing the future failure rate for nuclear turbines than the constant type. This was determined after considering the plant specific preventive maintenance practices as well as the recent industry mean value of the turbine failure rate. This methodology is expected to be also utilized in determining an optimum time for nuclear turbine replacement, which can help in promoting long-term operation of nuclear power plants.

REFERENCES

[1] G. Sliter, "LcmValue User Manual and Tutorial, Final Version 1.0", EPRI, pp.4.16-18, 2002.

[2] H. Y. Shin, "A Determination and Application of a Future Failure Rate for LTAM Strategies Development on Nuclear Turbines", Proceedings of the KSME 2008 Fall Annual Meeting, pp. 2845-2849, 2008.

[3] C. G. Park and J. J. Ha, Probabilistic Safety Assessment, Appendix, "PSA Computing Software", Brain Korea, pp. 375, 2003.

[4] G. Sliter and S. Hesler, January 2004, "LCM Planning Sourcebooks, Volume 8: Main Turbine", EPRI, Palo Alto, CA: 2001.1003058, pp.4-8~19, 2001