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An Integrated Approach of Component Reliability Data on KSNPs Using Plant Reliability Data Information System (PRinS)

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1. Introduction

During the construction phase, regulatory requires to implement Probabilistic Safety Assessment (PSA) that measures the safety with the designed safety features and presents quantitative values of risk metric. Usually, PSA in construction phase uses only generic data sources that represent general characteristics of components and system reliability. This work presents an integrated approach using the Bayesian updated generic source with KSNP specific plant data.

It could be possible because of the design of the reference plant is based on KSNP (Korea Standard Nuclear Power plant), and because we have the database system of PRinS (Plant Reliability Data Information System)[1], which could store and analyze the component failure raw data from NPPs in Korea.

To make generic data set, the component failure data of EPRI ALWR URD[2] were preferentially used with some data of NUCLARR[3] and NUREG/CR-5500[4]. The error factor for most component failure data were estimated by using the information of NUCLARR. However, the error factors of NUREG/CR-5500 were applied to those for the components of plant protection system. Also, annual trend analysis was performed for the functional losses of components using the statistical analysis and chart module of PRinS.

2. Method and Results

2.1 Failure Data Analysis Procedure

The calculation process for the failure rate and the failure probability of components is demonstrated in Fig 1. First, the database algorithm of PRinS determines the full power period or the outage period according to an operating mode in the FMA (Failure Maintenance Analysis) module. The level 1 PSA uses the raw data collected during only the full power period, and the raw data acquired during the outage period are deposited into the database.

In PRinS, a user should identify FMCCs (Failure Maintenance and Classification Codes) defined as the complete failure, the degraded failure and the incipient failure in order to count the number of failures using the raw data in ERP system. In case of the degraded failure, a user should determine the weighting factor after reviewing the possibility of a failure that can proceed into complete failure. Using this weighting factor, the number of failures is automatically counted in PRinS. Eq.(1) shows the number of failures depending on the weighting factor. In this paper, the weighting factor is considered as zero percentage.

$$\text{No. of failures} = \text{Complete failure} \times 1.0 + \text{Degraded failure} \times \text{W.F.} + \text{Incipient failure} \times 0 \quad (1)$$

The denominator data set required besides the number of failures is composed of the number of total demands or the total running time for evaluating the component failure data. And the data set is calculated in BD (Basic Data) module in PRinS. The specific data are combined with generic data set such as ALWR URD or NUREG/CR-6928[5] through Bayesian analysis in PRinS. The results are continuously deposited into the database. The statistical analysis model embodies the following functions which analyze data selectively.

- CpCode (component code)
- SysCode (system code) & CpCode
- Unit system &CpCode / PSA basic
- Component unavailability / PSA pattern unavailability
- PSA component type
- PSA system & component type
- Component group / PSA pattern
- PSA basic event unavailability

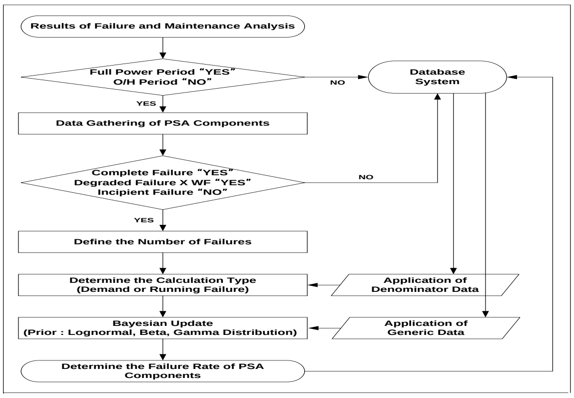

Fig.1. Simplified structure diagram for data calculation in PRinS

2.2 Evaluation of component failure data using generic data and plant specific data

Table 1 shows the failure rates and the probabilities of main components for integrated KSNP data and generic data according to a failure mode. A comparison of the failure data between the integrated KSNP data and EPRI ALWR URD case is presented. For the reference plant(SK3,4), the plant specific data collected from 1995 to June of 2008 are used. The failure data are estimated through Bayesian analysis in which lognormal distribution of EPRI AWLR URD is used as prior distribution, i.e. generic data. And, the likelihood of information was obtained from specific component data in the reference plant and modelled with the binomial (demand failure) and Poisson (running failure) distribution. Most components show a decreasing trend in their failure rates & probability.

Table 1. Failure rate/probability of main components

Component	Failure Mode	New Data (SK 3,4)	Generic Data (EPRI URD)	Increase Rate(%)
AFW Pump(MDP)	Fail to start	1.55E-03	3.00E-03	-48.33
AFW Pump(MDP)	Fail to run	1.50E-04	1.50E-04	0.00
AFW Pump(TDP)	Fail to start	7.49E-03	1.50E-02	-50.70
AFW Pump(TDP)	Fail to run	3.00E-04	3.00E-04	0.00
CCW Pump	Fail to start	8.53E-04	1.30E-03	-34.38
CCW Pump	Fail to run	1.61E-06	5.00E-06	-67.80
CS Pump	Fail to start	6.12E-03	5.00E-03	+22.40
CS Pump	Fail to run	5.00E-05	5.00E-05	0.00
SI Pump	Fail to start	4.56E-04	1.00E-03	-54.40
SI Pump	Fail to run	5.00E-05	5.00E-05	0.00
RHR Pump	Fail to start	8.55E-04	2.30E-03	-62.83
RHR Pump	Fail to run	1.00E-05	1.00E-05	0.00
NSCW Pump	Fail to start	4.34E-03	2.40E-03	+80.83
NSCW Pump	Fail to run	7.39E-06	3.20E-05	-76.91
Heat Exchanger	Fail to operate	2.25E-07	1.00E-06	-77.50
Chiller	Fail to start	6.26E-03	6.00E-03	+4.33
Chiller	Fail to run	1.21E-04	1.00E-05	+1110.00
Diesel Generator	Fail to start	2.41E-02	1.40E-02	+72.14
Diesel Generator	Fail to run	1.55E-03	2.40E-03	-35.423
Instrument Air Compressor	Fail to start	1.38E-02	2.00E-02	-31.00
Instrument Air Compressor	Fail to run	3.57E-05	1.00E-04	-64.30

2.3 Trend Analysis and Insight

The annual functional losses for main components of KSNPs were analyzed. As a result of the analysis, ten to fifteen complete failures for the main components were found. The failure experiences from NPPs in Korea have been continuously collected, but the data are not sufficient enough to make a data book. So, it is necessary to keep collecting and analyzing the information related to component failures to make the data book.

Fig.2. Example of complete failure for KSNP

As a result of analyzing the information of notices and work orders, which are the basic data sources, the information on the causes of component failures is insufficient. Therefore, the work process and the culture of dealing with notices and work orders are considered to be improved. To ensure the quality of data sources, it is important to identify current problems, and to keep improving and maintaining the database system and work process.

3. Conclusions

This paper presents the failure data analysis using PRinS which provides Bayesian analysis on main components for integrated KSNP and generic data. As a result, the failure data of integrated KSNP data show better results compare with generic data (EPRI ALWR URD). This is considered because the recent maintenance processes and procedures have been systematically, well managed and operated. This analysis on the main components could be applied to planning and decision-making related to maintenance. This paper also addresses the trend analysis of number of complete failures and insights. The proposed web-based PRinS would be useful for PSA and risk-informed applications. Application of this systematic database would support the development and application of the preventive maintenance template, the implementation of maintenance rule(MR), the equipment reliability(ER) improvement program, and the maintenance optimization initiatives such as the life cycle management and single point vulnerability(SPV) analyses which will be actively implemented in the Korean nuclear industry.

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