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KSNP HRA Model Calculation Using the Standard HRA Method

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1. Introduction

In the implementation of human reliability analysis (HRA), "Technique for Human Error Rate Prediction (THERP)" [1] was applied to both pre-accident human errors and post-accident operator action failures as a major methodology in all the domestic power plants, while "Accident Sequence Evaluation Program, Human Reliability Analysis Procedure (ASEP)" [2] was applied to the post-accident operator action failures in KSNP (Korea Standard Nuclear Power plants). Another methodology, "Human Cognitive Reliability (HCR)" [3] was used to estimate the operator diagnosis errors in Kori unit 3&4 and Yonggwang unit 1&2. In this way, several HRA methodologies have been applied to domestic nuclear power plants (NPPs) without any procedures or rules, and this condition resulted in difficulty of the HRA model comparison between plants. Consequently, integration of the current methodologies or establishment of a standard evaluation method has been required to apply consistent and systematic HRA method to domestic NPPs.

This evaluation used the standard HRA method [4] developed by KAERI in 2005 to recalculate the human error probabilities (HEPs) for KSNP and to compare the resultant HEPs to the previous values. Furthermore, feasibility of the standard HRA method application to entire domestic NPPs was reviewed through this opportunity.

2. Calculation of Operator Error Probabilities

This analysis is based on the HRA model which was developed during Yonggwang unit 5&6 PSA in 2001. At the time, ASEP was used as a HRA methodology. The same operator available time as that of the 2001 PSA evaluation is applied to the updated post-accident operator action failure basic events, and the operator action failure probabilities are recalculated through determination rules for the correction factors, work types, and stress levels in the standard HRA method. For pre-accident human error probabilities, it is supposed that maintenance frequency on major pump discharge valves is once per 18 months and the maintenance is performed according to a systematic procedure in the very low stress level condition.

The reevaluation showed that about 50% of major post-accident operator error probabilities were increased and the other probabilities were decreased. The operator action failure probabilities related with auxiliary system were mostly decreased except for failure probabilities on the prefilter replacement for an instrument air supply system and on the transfer operation between CCW heat exchangers. For pre-accident human errors, the probabilities which the valves on auxiliary pump recirculation pipes are not restored after test are recalculated. 3 months are supposed as a test interval for a recirculation flow test of auxiliary feedwater pump discharges. For other pre-accident operator error cases, analysis results included in the standard HRA report are used. All pre-accident human error probabilities are reduced through the standard HRA method.

Table 1. Calculation Results on Some of Analyzed HEPs

NO	Basic Events	Previous Mean HEPs	Changed Mean HEPs
1	SDOPHEARLY	1.46E-01	1.32E-01
2	MXOPHDPLI	1.50E-01	1.67E-01
3	HSOPHHLCLR	9.35E-04	1.28E-03
4	MSOPHSR-L	2.31E-03	2.05E-03
5	AFOPHALTWT	1.45E-03	1.28E-03
6	MXOPHEBOR	4.85E-03	1.27E-03
7	MFOPHSUFWP	1.30E-02	8.14E-03

3. CDF Quantification & Accident Sequence Analysis

3.1 CDF Quantification

Yonggwang unit 5&6 PSA model developed in 2004 was used as a base model for requantification. According to the previous analysis method, the cutoff value of 1.0E-12 was used. The previous CDF value due to Level-I PSA internal events was 5.46E-6/RY, and the changed CDF which is recalculated with new operator action failure probabilities is 5.37E-6/RY.

Analysis on the accident sequences showed that 20 sequences above 1.0E-7/RY were same as those of the 2004 PSA result. But, each accident sequence frequency and its ranking among 20 sequences were changed due to the reevaluated operator error probabilities. Frequencies of 10 accident sequences out of the major 20 accident sequences were affected due to following 3 post-accident operator error probability changes. Changed 10 accident sequences are presented below according to the related operator error basic events.

Table 2. Y5&6 Level-I CDF reflecting HEP Reevaluation

Previous CDF	Changed CDF	ΔCDF(%)
5.46E-6/RY	5.37E-6/RY	- 1.7%

3.2 Accident Sequences affected by changed SDOPHEARLY

SDOPHEARLY, which means failure of early feed & bleed operation, is a failure event on the operator action which removes residual heat by opening safety depressurization system relief valves. This basic event's value was decreased after the standard HRA reevaluation. This change reduced frequencies of the accident sequences such as LOFW-26, LOOP-26, LSSB-26, LODC-26, LOCCW-26, and GTRN-26.

3.3 Accident Sequences affected by changed MXOPHDPLI

MXOPHDPLI, which means quick depressurization of reactor coolant system (RCS) for low pressure safety injection (LPSI), is a failure event on the operator action which reduces RCS pressure through auxiliary feedwater and atmosphere relief valves for steam generators when HPSI actuation failed during small LOCA. This basic event's value was increased after the HRA reevaluation. This change increased frequencies of accident sequences such as SGTR-37 and SLOCA-32.

3.4 Accident Sequences affected by changed HSOPHHLCLR

HSOPHHLCLR, which means a hot leg and cold leg recirculation, is a failure event on the operator action which prevents the boron accumulation through continuous cold leg recirculation during large LOCA or medium LOCA. This basic event's value was increased after the HRA reevaluation. This change increased frequencies of accident sequences such as LLOCA-3 and MLOCA-3.

4. Review on the standard HRA Application

4.1 Pre-accident Operator Action Failure

The ASEP method calculates a pre-accident operator action failure probability through multiplying a step omission probability of a worker to a checker's detection failure probability for the error, while the standard HRA has the rules which enables to determine the correction factor according to a work complexity and procedure level, etc., and which helps to select the recovery probability according to dependency between a worker and a checker. Therefore, the standard HRA method could produce various results from combination of these rules. This review indicated that pre-accident human error probability could be reduced by the standard HRA method, and actually showed that frequencies of several accident sequences out of the 20 high ranking sequences were lowered due to reduction of related pre-accident human error probabilities.

4.2 Post-accident Operator Action Failure

For post-accident operator action failures, this review found that the determination factors of ASEP were similar to those of the standard HRA method. But, ASEP doesn't have a rule to determine a correction factor for a diagnosis error probability, so the weight factors according to an expert's comments are used, while the standard HRA method has a decision rule for a diagnosis error probability correction. This review showed that correction on a diagnosis error probability through the standard method was relatively sensitive to the procedure levels. For commission errors, both ASEP and the standard method have a similar scheme. However, the standard method could have various analysis results since it has a more systematic rule for work type or stress level determination. But, in a time urgent case, it should be noted that the standard HRA method could result in a very high operator error probability because it gives a very high priority to the available time. ASEP considers an information feedback level and checker's recovery probability respectively, therefore, multiplication of these two factors could lower HEPs. But, since the standard method consider the information feedback level within a rule to determine checker's recovery failure probability, this could increase HEPs in time urgent cases.

5. Conclusion

The KSNP HRA model reevaluation through the standard HRA method found that decision of correction factors for diagnosis errors or recovery failure probabilities for commission errors could be made by the systematic rules such as time urgency, work conditions, and procedures, not by the expert's subjective comments or experiences. Consequently, it is concluded that the standard HRA method could be used as an alternative for the ASEP methodology which has been applied to the PSA for KSNP. In addition to KSNP, if the standard method's applicability to the other plants is verified, this method could be used as an integrated tool to implement the HRA evaluation of domestic NPPs.

REFERENCES

[1] NUREG/CR-1278, "Handbook of HRA with Empasis on Nuclear Power Plant Applications", Swain, 1983
[2] NUREG/CR-4772, "Accident Sequence Evaluation Program, Human Reliability Analysis Procedure", Swain, 1987
[3] EPRI RP 2170-3, EPRI/NP-6560, "Human Cognitive Reliability (HCR)", Hannaman, 1986
[4] TR-2949, 2950, "Human Reliability Analysis of Post-Accident Human Errors in the KSNP", KAERI, 2005.