Performance Analysis of the Safety-related I&C Components Based on the Operational Experience during the Period of 1995 through 2000

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1. Introduction

The performance anslysis of the safety-related I&C components for plant protection system (PPS) was conducted, based on the operating experience of the Korean standard nuclear power plant (KSNP). The PPS operational data was collected from the trouble reports (TR) to record details of test and maintenance activities at sites. The total operating experience of 8.63 commercial reactor years at four units during a period of 1995 through 2000 at four KSNP units was studied in this paper.

2. Operational Data Analysis and Results

The reliability analysis for the safety-related I&C components from the operational experience data of PPS was performed by the following four steps:

(1) The data screening process
(2) The operational data analysis and classification
(3) The estimation of the total number of demands or operating time
(4) The component unavailability estimation

2.1 Data Screening Process

Total 316 trouble reports were identified from four KSNP units. Of these, approximately 100 reports remained through the data screening-out process. The following were the rules applied to screening analysis:

1) The component failures not affecting safety function, *e.g.*, indicators, recorders, test circuits, etc., were not involved,
2) The failures occurred during pre-operational periods and refueling time were eliminated,
3) The failures of which maintenance activities were postponed until plant overhaul were included, and so on.

2.2 Data Analysis and Classification

The process of the data analysis and classification means to determine the number of failures, mainly focused on the failure severity. The failure severity was divided into four groups – failure, degradation, incipient, and no failure. The classification of system impact – complete out-of-service (OOS), partial OOS, unknown, and no impact - was also carried out, but was not easy because of the limited information. Eventually, the failure count scheme was based on only failure severity in the study, regardless of the system impact. It causes the component unavailability estimation to be highly conservative. The component failure count was also performed by a weighting rule, like 1.0 for failure, 0.5 for degradation, 0.0 for incipient and no failure. Of approximately 100 reports remaining from step 1, 65 events were classified into failure and degradation. Note that a typical example of incipient is small drift or hunting of sensor within a half of the allowable band. Also note that we assigned 1.0 for components with zero-failure or only one degradation event. The total numbers of component failures are presented in Table 1.

2.3 Estimation of the Total Number of Demands or Operating Time

The total number of demands was estimated from test intervals of components. The KSNP PPS channels – bistables, logic matrices, initiation circuits - are tested on a sequential monthly basis. Generally, the channels to be tested are placed in bypass. Each train of the engineered safety feature actuation system (ESFAS) auxilliary relay cabinet (ARC) is tested every two months (on a staggered monthly basis). All of sensors/transmitters are tested and calibrated every refueling, except for refueling water tank levels tested every three months. The diverse protection system (DPS) is tested every three months. Finally, each trip circuit breaker is tested seven times per month during operation, and five times during refueling.

For the convenience of the analysis, plant scram histories were neglected since the number of scram was identified to be small (fourteen scrams during 8.63 commercial operating years). The operating time was calculated from the investigation. All of the planned shutdown periods were not included. The unplanned shutdown periods were neglected due to the same reason above. The number of components was investigated to calculate the demand and operating time of components.

The total number of demands and operating time of components are listed in Table 1.

2.4 Statistical Analysis for the Component Unavailability Estimation

The simple Bayesian updating technique[1] was employed to estimate the safety-related I&C component failure probabilities or rates. In the Bayesian updating, data was pooled due to the fact that no significant differences in plant-to-plant variation were found. Component failure data was regarded as sampling from binomial distribution or Poisson distribution in the analyses for failure probabilities or rates, respectively. The assumed prior distributions were identical to the ones used in CEN-327[2], for the comparison of the resultant component failure probabilities and rates. The BURD (Bayesian Updating for Reliability Data)[3] was used in the study.

The resultant (posterior) failure probabilities or rates of the safety-related I&C components were mostly similar to the ones of CEN-327, though this study included lots of failures that occurred in the beginning of the commercial operation without percolation. The results of the statistical analysis to estimate component failure probabilities or rates were summarized in Table 1.

3. Conclusion

The individual component failure probabilities or rates (Table 1) were derived from operating experience of the total 8.63 commercial reactor years during a period of 1995 through 2000. They are generally comparable to the estimates listed in the previous study for CE-type plants, such as the CEN-327 [2], NUREG/CR-5500 [4], etc. Results of the data analysis are close to ones published for other CE-supplied plants, though this study includes a lot of failures that occurred in the beginning period of commercial operation without percolation. The results of the study can be useful for the risk-informed applications like the improvement of technical specifications for the KSNP RPS and ESFAS.

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Table 1. Failure probabilities or rates of the safety-related I&C components for KSNP

Component Type	No. of Failures	No. of Demands or Operating hours	Failure Probability or Rate*	Remarks
Trip Circuit Breaker	1**	3072	1.52E-4/d	
Undervoltage Trip Devices	1**	40***	1.87e-3/d	
Shunt Trip Devices	1**	40***	1.92e-3/d	
Initiation Relays	1**	6214	3.52E-5/d	
Logic Matrix Relays	1**	17398	2.24E-5/d	
Bistable Relays	2	39494	2.90E-5/d	
Bistables	1**	5922461hr	2.94E-7/hr	
Pressure Sensor	3	1965569hr	2.68E-6/hr	
Differential Pressure Sensor	1**	604790hr	3.60E-6/hr	
Level Sensor	2	1814371hr	2.15E-6/hr	
RCS Temperature Element	1	604790hr	1.78E-6/hr	
Ex-core Neutron Flux Detectors	10	907186hr	1.21E-5/hr	
Calibrated Average Power Calculator	4	302395hr	3.64E-6/hr	
Logarithmic Power Calculator	3	302395hr	3.11E-6/hr	
Subchannel Power Calculator	1	302395hr	2.29E-6/hr	
Power supplier	1	4071840hr	5.33E-7/hr	
Core Protection Calculators	13	302395hr	1.15E-5/hr	
CEA Calculators	12	151198hr	1.28E-5/hr	
Hand Switch	1	5178	1.86E-5/d	
DPS AFAS Control Circuit	1**	453593hr	2.20E-6/hr	evidence only
DPS MG Set Control Circuit	1*	151198hr	6.61E-6/hr	evidence only
DPS Signal Processor	2	453593hr	4.41E-6/hr	
Interface Relay	2	8699	7.91E-5/d	
Interposing Relay	1**	3314	4.38E-5/d	
RCP speed sensor	5	1209581hr	4.13E-6/hr	evidence only
Reed Switch Position Transmitter	3	5518712hr	5.44E-7/hr	evidence only

*) Bayesian estimates, **) zero failure component, ***) The demand count was based on overhaul tests because the failure of undervoltage and shunt trip devices cannot be detected by monthly logic matrix tests.