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Component Reliability Data Collection in HANARO

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Abstract

In this paper, the reliability data used in PSA performed at HANARO design stage are compared with the generic data compiled by IAEA. In order to produce specific-site data, reliability data collection has been initiated. Appropriate database format has been developed and coded database until the year, 2001 has been analyzed for some selected components. These are also compared with the generic data. This study will be continued for more components and PSA application that can contribute for the safe and effective operation of HANARO will be proposed from the result of this study. The specific-site reliability data produced will be a source to review HANARO PSA and to perform PSA of similar reactors.

1. Introduction

It was back in 1994 that the last level I PSA report for HANARO was issued. Considering one and a half years of commissioning and another year of long-term operation test and adjustment, there has been 5 years of stable operations maintained in HANARO until the year, 2001. It is a good point to review PSA and to raise a question what PSA application can be adopted for HANARO. The performance monitoring, optimization of maintenance, and ageing analysis are good examples of PSA applications. Although those have been already considered and are being performed effectively by reactor operation and maintenance staff, it is a responsibility of PSA to propose reasonable and persuasive ways of improvements with systematic and quantitative analysis. Only when they can see the direct usefulness of PSA applications, the improvements and feedback suggested from PSA can be realized in the field. Moreover, this accordance can produce a better quality of information and data from the field, which is essential to the reliability data. Fortunately, the environment for field data collection is better in research reactors since PSA analysts can maintain a closer relationship with operation and maintenance staff than in power plants.

In order to achieve this end, three steps of work scope are planned. In the first step, reliability data coding is initiated and the data comparison is performed among the reliability data used in PSA at the reactor design stage, generic data of research reactors, and specific-site data of HANARO that is currently carried on. The reason the power plants data are not included in the data comparison is due to differences in component type, size and application that result in increased uncertainty when they are applied to research reactors. The first step is important because it is at this stage that insights and experiences in data coding and analysis can be obtained, and the basis for the next steps is built up in the right direction. The reliability data and initiating event data produced are valuably applied to various PSA applications. In the second step, appropriate way of maintenance optimization is sorted out and applied to the field. Much of confidence from the first step is needed to perform the application supported by operation and maintenance staff. In the last step, a data analysis is performed and the specific-site data is produced. This data will be a good reliability data source to perform PSA on any similar research reactor.

In this paper, the preliminary study of the first step is introduced and the projection for the nest step will be followed.

2. Reliability Data of HANARO

Component reliability data is either from generic or specific data. The generic data is collected and analyzed from other reactors, and hardly reflects the characteristics of a target reactor. The specific data are from the maintenance and failure record of the target reactor and reflects the reactor characteristics of its own. There is, however, a difficulty to produce reliability data out of short operation history. The component reliability data include failure rate, number of failures per demand, out of service rate, unavailability, average maintenance time, and average out of service time. The information needed to obtain these are data failure mode, maintenance time, out of service time, operation time, and number of demands. Also needed in the component reliability data are component specification, operation history, and failure and maintenance record. The initiating event frequency is estimated from the number of reactor trips although some of the initiating events do not happen and do not result in reactor trips. The precursor study is possible through the reactor trip record also.

The maintenance record should describe the information related to the maintenance and failure in detail. The failure mode and the failure severity are categorized carefully and the component failure should be evaluated in view of its function. The failure data is collected with understanding how the component failure affects the system. The failure severity is categorized into loss of function (catastrophic or critical), function degradation, and occurrence of failure symptom (incipient). The examples of failure mode in loss of pump function are failure in running, failure to start on demand, and spurious start or command fault. The failure modes in pump function degradation are external leakage, high vibration, over-temperature, and over-current. The noise is a good example of a failure symptom. The failure cause and status (component status when the problem is found), the way the failure is found, and the last actuation point should be also recorded in the maintenance record. Since the loss of function during periodic inspection or the failure corrected by inspection personnel is not always able to be outstanding, it is necessary to examine the results of inspection and to notify its importance to maintenance and operation staff.

The maintenance is categorized into preventive maintenance (without loss of component function) and maintenance on failure (in case of function loss) in which priority, amount of work, and how the maintenance affects system operation are described. In case of maintenance on failure, some experience is necessary in estimating out of service time when the failure is detected later on. In case of preventive maintenance, when the system is not available during the maintenance, out of service time is equal to maintenance time. When the system is available during maintenance, it does not have to be included in the reliability database.

The probabilistic safety assessment has been performed in the design stage of HANARO. The component reliability data was obtained from the manufacturer if it was available at that time. The other data are from component reliability data for nuclear power plants or from other research reactors. When the failure mode is not clear, data for failure of all modes has been used for conservative analysis. The reliability data on valves, pumps and control rods used in PSA at the design stage (reactor code of KR) are compared with the generic data from the reference 1 in Table 1. The description on the component code and reactor code in Table 1 can be found in reference 1, too. There is a tendency that HAHARO PSA data are underestimated compared to the generic data. The mean failure rates of motor operated pumps are plotted with 5% lower bound and 95% upper bound in Fig. 1. The last two center points are HANARO PSA data. It shows wide range of failure rate depending on component design, operating mode, and maintenance practice even when the data are collected in accordance with strict definitions and rules, and analyzed using the same statistical methods[2]. The failure rate in the failure mode of failure to function for control rod driving mechanism has, however, rather small range of scattering.

3. Reliability Database Format for Data Collection

For data collection, the components should be selected first from the component list and the component boundary and failure modes should be established according to the guidelines. The database format has been developed for systematic data collection. The raw data are from the documents such as operator log, non-confirmation report, work request, test report, and trip report. In the first phase, non-confirmation reports and work requests are coded to the database formats as shown in Table 2. The items in italic characters are added to the original formats of non-confirmation report and work request for reliability analysis. There are three classes in structure, system and component classification in Safety Analysis Report; safety class (3 and NNS), seismic class (I, II, and NON), and quality class (Q, T, and S). Safety class of 3 always has seismic class I and quality class Q. When the abnormal condition has occurred in the system or component of Q or T class, Non-confirmation report is issued. Work report is issued when the S class system or component shows abnormal condition. The system number and component number are from P&ID. Reactor operation mode is one of reactor operation and shutdown when the abnormal condition has been discovered. Impact to the system means the availability of the system. Failure mode is selected from Table 3[2]. These definitions are essentially the same as the generic failure modes for power plants. The generic failure modes cover safety related components, non-safety related components and research reactor specific components. For each of the generic failure modes, a detailed definition and an area of applicability for research facilities are described in the reference 2. The failure modes of Degraded and Spurious function are included in the failure severity of degraded and the other 15 failure modes are in the failure severity of critical. Examples of degraded failure types are external leakage on the seal of a rotating pump, partial opening of valve, slow movement of control rod, etc. The component codes are composed from three capital letters. The first letter of the code specifies the principal component categories; mechanical component, electrical component, and instrumentation and control equipment categories. The second and third letters of the code are the component group and type description, respectively. Maintenance time and out of service time are recorded by a person who has completed the action required. The maintenance time is an active maintenance time which is spent for the maintenance (inspection, test…) itself excluding the time required in planning and administrating. The out of service time is the time between the detection of the failure and the required action confirmation as satisfied.

4. Status of Reliability Data Analysis

Fifty-nine non-confirmation reports and forty-nine work requests between 1997 and 2001 are coded in the database. The component types of pump, valve, and control rod are selected for data analysis. For many devices, the behavior of failure rate follows the classic bathtub curve: early in life the failure rate for such a device is high because of wear-in failures or failures arising due to poor quality assurance during manufacturing or installation. HANARO started its normal operation in 1995 and the average number of work requests issued in 1995 and 1996 is 67% greater than that issued from 1997 to 2001. Hence, it seems that the failure data after 1997 occurred at a rather uniform rate corresponding to random failures. The failure mode should be carefully determined by well-experienced analyst in accordance with the definition and the failure events are properly compared with the generic data. Some data on control rod, valve, and pump are compared with the generic data as shown in Table 4. Some of the failure events occurred in HANARO are not included in the table when there is no generic data to be compared with. The failure rate or failure probability for the components of which the information on component operating time or number of demands is not at hand yet, will be estimated later on. Most of work requests and non-confirmation reports on the pump are regarding noise or no severe leakage. These are not presented in the table.

5. Conclusions and Further Study

The reliability data for research reactors were not available adequately in 1980's when the design of HANARO has been started. The reliability data according to different failure modes could not be found and hence the data for failure of all modes were used instead. Although the conservative approach was taken in choosing reliability data for PSA at that time, the data used in PSA seems to show a higher reliability (or lower failure rate) compared with the generic data of research reactors compiled by IAEA. The non-confirmation reports and work requests are formatted into MS Access file adding more data fields necessary for reliability data analysis. Faithful and complete maintenance recording by operation and maintenance staff is very important for the data to be worthwhile. In this case, training and education of operation and maintenance staff is very much helpful. Some data such as failure mode and trend analysis should be reviewed or coded by an experienced PSA analyst. Reliability data analysis has been performed for some selected components such as pumps, valves, and control rods with coded reliability database.

More component reliability data of HANARO will be compared with generic data. Test periods considered in the design stage should be compared with the current ones and adjusted properly. Careful and complete maintenance recording is essential to produce a reliable specific-site data.

Acknowledgements

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References

1] Generic component reliability data for research reactor PSA, IAEA-TECDOC-930, (1997)
2] Manual on reliability data collection for research reactor PSAs, IAEA-TECDOC-636, Vienna (1992)

Table 1. Comparison of PSA data used in design stage and generic data

code	Component type description	Reactor code	Failure mode	Failure rate (1e-6/h)
VA1	Air operated valve	KR	D	0.11
		CND	E/O	7.1
VCA	Check valve	KR	All modes	2.21
	Valve self operated check	PRC-M	F	3.9
		PRC-H	F	22.4
		CND	E/O	1.0
VDA	Solenoid valve	KR	Mechanical hot short	0.86
		KR	O	0.11
	Valve solenoid operated	AUS	F	4.5
		AUS	K	0.9
		AUS	Y	7.2
		AUS	Y	6.8
VMA	MV (gate valve)	KR	All modes	1.15
	MV (globe valve)	KR	All modes	0.85
	Valve motor operated	A	E	20.2
		PRC-M	O	7.9
		PRC-M	I	3.9
		PRC-M	D	1.4
		PRC-H	A	3.1
		AUS	B	13.5
		CND	F	0.5
		CND	C	6.0
		CND	F	3.6
VWB	Isolation valve (ball type)	KR	All modes	2.40
	Ball valve	AUS	K	4.5
		AUS	Y	2.3
VWT	Butterfly valve	KR	All modes	0.61
	Valve butterfly valve	AUS	B	156.7
		AUS	F	45.9
		AUS	Y	21.6
VXA	Manual throttle valve	KR	All modes	0.09
	Valve manual	A	F	0.3
		PRC-M	B	5.5
		PRC-H	B	4.6
		AUS	F	13.5
		AUS	Y	13.5
PMA	Pump (PCS & SCS)	KR	R	17.6
		KR	S	1.0
	Reflector cooling pump	KR	R	7.1
	Pump motor driven	CZ	R	88.2
		CZ	H	17.6
		CZ	I	17.6
		A	F	10.1
		SLO	R	50.0
		VN	R	192.7
		IN-Y	R	7.1
		IN-B	F	14.2
		PRC-M	R	70.5

Table 1. Comparison of PSA data used in design stage and generic data (continued)

code	Component type description	Reactor code	Failure mode	Failure rate (1e-6/h)
PMA	Pump motor driven	PRC-M	S	24.4
		AUS	B	33.8
	Main pump AC motor	CND	R	31.8
	Purification pump motors	CND	R	35.7
OCR	Control rod	KR	Rod fails stuck	0.47
	Control rod electro magnetic clutch	KR	Fails hot short	0.10
		KR	Fails close	1.96
	Control rod single control rod assembly	A	M	6.7
		PRC-M	M	19.0
	Electromagnet failure	CND	F	0.16
ORA	Stepping motor of control rods fail	KR	All modes	10.0
	CRDM	CZ	C	489.4
		A	C	6.7
		CZ	D	26.5
		SLO	D	50.0
	Control rod drive	VN	C	139.1
		IN-Y	F	9.5
		IN-B	F	8.3
		PRC-M	S	5.9
		PRC-M	F	23.7
		PRC-H	F	14.6
		CND	F	22.6

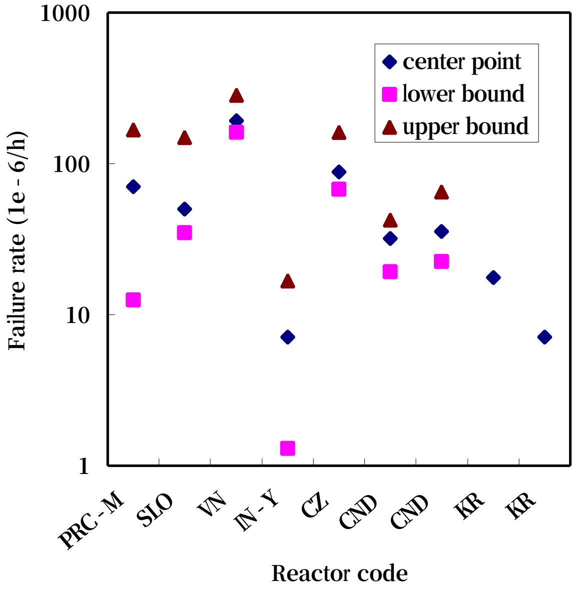

Fig. 1. Failure rate scatter plot for motor operated pump, failure to run

Table 2. Contents of Data Collection Format

Non-confirmation Report
Document type, Serial no., Date of preparation, Quality class, Location, System no., Equipment no., *Component code*, System and component name, Related procedure, NCR details, Found by, Date of finding, Confirmed by, Date of confirmation, Review and approval by, Date of review and approval, QA audit at work, Disposal method, Disposal details, Disposal decision by, Date of disposal decision, Disposal reviewed by, Date of disposal reviewed, Disposal approved by, Date of disposal approved, Action details, Action by, Date of action, Action confirmed by, Date of action confirmed, Action result confirmation, QA inspected by, QA confirmation by, Distribution-original, Distribution-copy, *Others, Trend analysis, Reactor operation mode, Impact to system, Failure mode, Failure severity, Maintenance time, Out of service time*
Work Request
Document type, Serial no., Date of issue, System no., Equipment no., *Component code*, System and component name, Issued by, Supervised by, Importance, Failure cause, Failure details, Safety and technical review, Work requested by, Date of work request, Tag issue status, Cautions at work, Work approved by, Date of work approved, Work result, Date of work completion, work supervisor, Confirmation of work completion by, Senior reactor operator, re-work item *Others, Trend analysis, Reactor operation mode, Impact to system, Failure mode, Failure severity, Maintenance time, Out of service time*

Table 3. Failure Mode

Code	Failure Mode	Code	Failure Mode
B	Degraded	Q	Plug
C	Failure to change position	K	Spurious function
D	Failure to remain in position	R	Failure to run
E	Failure to close	S	Failure to start
O	Failure to open	X	Other critical faults
F	Failure to function	Y	Leakage
G	Short to ground	J	Rupture
H	Short to circuit	M	Control rod failure
I	Open circuit		

Table 4. Comparison of HANARO reliability data with generic data

		Reactor	Components	Cumulative calendar year	Cumulative operating time	Demands	Failure modes		Failures	Failure rate	Failure probability
code	Component type description	code	#	Mill. h	Mill. H	#	crit	deg	#	1e-6/h	1/demand
IAR	Control rod position indication	SLO	1		0.020		M		2	100.0	
		VN	5		0.067			B	4	59.9	
		KR	4				M		3		
OCR	Control rod single control rod assembly	A	3	0.297			M		2	6.7	
		PRC-M	11	0.737			M		14	19.0	
	Electromagnet failure	CND	18	4.250			F		0	0.16	
		KR	4				F		2		
VMA	Valve motor operated	A	1	0.099			E		2	20.2	
		VN	1			1863	E		1		0.0001
		VN	6			5589	O		3		0.0001
		PRC-M	7		0.509		O		4	7.9	
		PRC-M	7		0.509		I		2	3.9	
		PRC-M	7		0.509		D		0	1.4	
		PRC-H	3		0.224		A		0	3.1	
		AUS	3	0.222				B	3	13.5	
		CND	16	2.100			F		1	0.5	
		KR	11	0.482			E		3	6.2	
		KR	11	0.482			Y		1	2.1	
		KR	11	0.482			F		1	2.1	
VWB	Ball valve	AUS	6	0.444			C		2	4.5	
		AUS	6	0.444			Y		1	2.3	
		KR	58	2.54			Y		1	0.4	
PMA	Pump motor driven	CZ	9		0.057		R		5	88.2	
		SLO	1		0.020		R		1	50.0	
		IN-Y	4	0.282			R		2	7.1	
		A	1	0.099			F		1	10.1	
		IN-B	21	1.406			F		20	14.2	
		KR	33				R		1		
		KR	33				F		1		