Proceedings of the Korean Nuclear Spring Meeting
Gyeong ju, Korea, May 2003

Human Error Analysis in Trip Events Considering Risk Significance

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Abstract

In this study, we performed cause analysis of human errors in trip event of Korean nuclear power plants, and used risk information to prioritize human error causes according to their significance. 11 items of K-HPES (Korean Human Performance Enhancement System) were used for analysis of trip events. Analysis was performed through group discussions to reduce subjectivity of one's own opinion. Then, risk significance of trip events were evaluated using CCDP (Conditional Core Damage Probability) as a risk measure to consider risk information in prioritizing 11 items of K-HPES. Use of risk information in the process of analyzing trip event would be beneficial for enhancement of human performance by finding risk-significant human error causes.

1. Introduction

In the analysis of large accidents like TMI-2 or Chernobyl, it was revealed that human error was one of the important contributor of accidents. Moreover, the effect of the human error on the nuclear power plant safety is growing more important as hardware reliability being increased. Accordingly, the human error cause analysis of incidents or accidents in terms of human error is meaningful and necessary work to improve nuclear power plant safety by preventing recurrence of similar events. But there has been no work to analyze trip event in view of human performance in Korea. In this study, a number of 48 events were selected and analyzed using 11 items of K-HPES. And we proposed use of risk significance information in trip events for prioritizing 11 items of K-HPES according to their importance to nuclear power plant safety. Because many trip events have different conditions, the events have different risk significance from each other. To find risk significant human error causes, the differences in risk significance of trip events must be considered in cause analysis.

2. Event Analysis

KTRIP is one of the trip event databases in Korean nuclear power plant which contains 536 trip event data from April 1978 to December 2000. Human performance related 48 trip events were analyzed in this study. Analysis process was consisted of group discussions to reduce subjectivity of one's own opinion.

11 items in K-HPES were used for the analysis of trip events in view of human performance. K-HPES is "Korean Human Performance Enhancement System" which was developed in Korea, based on HPES of INPO (Institute of Nuclear Power Operations). 11 items in K-HPES are as follows.

1. Verbal communication
2. Written procedure and documents
3. Man-machine interface
4. Environmental conditions
5. Work schedule
6. Work practice
7. Work organization/planning
8. Supervisory method
9. Training/qualifications
10. Change management
11. Managerial method

<u>An Example of Event Analysis</u>

An example of event analysis using 11 items of K-HPES is provided below.

Name of Event :

Plat trip by Gland Seal Water Pump A/B misconnection.

Related System :

Main Feedwater Pump Seal System

Description of Event :

In plant's full power operating mode, Gland Seal Water Pump A which role was providing seal water to Feedwater Pump was tripped due to low suction pressure while closing Suction Valve for maintenance of Gland Seal Water Pump B. Because of Gland Seal Water Pump A trip, Main Feedwater Pump B and C tripped causing Steam Generator low-low level reactor trip.

Causes of Event :

1) One month ago before trip event, Operation Department replaced Gland Seal Water Pump with the new one because the old one had the problem. When installing Gland Seal Water Pump, Pump A must be connected to P.S 4791 and 4792 while Pump B must be connected to P.S 4789 and 4790. But doing replacement of Gland Seal Water Pump, Electrical Maintenance Department Engineer connected them reversely. Junction Box was not designed appropriately in view of stereotype. After replacement, testing was performed but misconnection problem was not detected.

⇒ '3. Man-machine interface' : In appropriate design of Junction Box in view of human's stereotype.

⇒ '6. Work practice' : Electrical Maintenance Department Engineer connected Pump to Junction Box reversely because of his unconsciousness.

⇒ ‘ 10. Change management‘ : Inadequate evaluation on the effect of replacement of Gland Seal Water Pump.

2) There was not enough deliberation between I&C (Instrumentation and Control) Department and Electrical Maintenance Department in performing replacement. Supervisory Department failed to reconfirm adequately after replacement.

⇒ ‘ 7. Work organization/planning‘ : Lack of deliberation between departments.

⇒ ‘ 8. Supervisory method‘ : Lack of supervision and confirmation.

3) In P&ID drawing, Valve Numbering in Gland Seal Water System was not written.

⇒ ‘ 11. Managerial method‘ : Deficiency in quality management of P&ID drawing.

3. Risk Significance Analysis of Events

In the risk significance analysis of events, we used the results of level 1 full power PSA of Pressurized Water Reactor (PWR) Yonggwang 5&6 Unit for representative Korean PWR plant PSA. Therefore, only events that occurred during full power operation of PWR were included for risk significance analysis and the others were excluded. Among 48 events, 29 events were included and 19 events were excluded from the analysis. Because KTRIP contains trip events from several Korean nuclear power plants, it may be appropriate to use PSA results of the nuclear power plant where the event occurred. But in this study, all events were analyzed using Yonggwang 5&6 Unit PSA for ease of the analysis.

Risk significance of events can be presented by CCDP. Trip events were regarded as initiating events in PSA. So CCDP of a trip event was induced using following equation.

$$CCDP_k = \frac{CDF_k}{I_k}$$

$CCDP_k$ = CCDP of initiating event (trip event) k
CDF_k = CDF contribution of initiating event (trip event) k (per year)
I_k = Initiating event k’s frequency (per year)

In KTRIP database, the events are categorized by EPRI category. So we used EPRI category to redefine trip events as initiating events in PSA model. For instance, the above-introduced event : “Plant trip by Gland Seal Water Pump A/B misconnection” was categorized as EPRI-16 which is defined “Loss of All Feedwater”, and can be considered as Loss of Feedwater (LOFW) initiating event. In Yonggwang 5&6 Unit PSA model, initiating event frequency of LOFW is 5.50E-01/yr and CDF contribution is 1.22E-06/yr. So CCDP is 2.22E-06 (=1.22E-06/5.50E-01).

Among 29 events included in risk analysis, 16 events were categorized as General Transient (GTRN), 1 event as Loss of Condenser Vacuum (LOCV), 2 events as Loss of Component Cooling Water (LOCCW), and 1 event as Loss of Feedwater (LOFW). The others (9 events) were excluded because they could not be regarded as initiating events of Yonggwang 5&6 Unit PSA. Samples of analysis results are provided in table 1.

In this analysis, we defined importance of 11 items in K-HPES as follows.

1) When risk significance of events were <u>not</u> incorporated ;

$$W_i = \frac{\sum_k d_{ki}}{\sum_i \sum_k d_{ki}} \qquad (k=1, \ldots , N), (i= 1, \ldots , 11)$$

W_i = importance of item i   (0 W_i 1)
d_{ki} = if,   item i is cause of event k d_{ki} = 1
else, d_{ki} = 0

2) When risk significance of events were incorporated ;

$$W_i = \frac{\sum_k d_{ki} CCDP_k}{\sum_i \sum_k d_{ki} CCDP_k}$$

For instance, when risk significance of events were not incorporated, $W_{(i=1)}$ which is importance of item 1 can be given using results of table 2 ;

$W_{(i=1)}$ = 5 / (5+16+ …+6+24) = 0.03

4. Results of Analysis

Importance ranking results of K-HPES 11 items based on cause analysis of trip events in terms of human error are provided table 3. Cases of analysis were divided as follows.

- Case 1 : Risk significance of events were *not* incorporated. Total of 48 events analyzed.
- Case 2 : Risk significance of events were *not* incorporated. 29 events (PWR, full power operation) were analyzed.
- Case 3 : Risk significance of events were incorporated. 29 events (PWR, full power operation) were analyzed.

Figure 1 and 2 provide graphs which show differences in importance of K-HPES items between case 1 and 2, and between case 2 and 3. The effect of risk significance incorporation into event analysis can be seen by comparing results of case 2 and 3. Table 1 and figure 2 shows there are differences in importance ranking, though not much, between the results of case 2 and case 3.

In all three cases, '6. Work practice' was the most important item in events. It is because that most of 48 trip events were induced by operator or maintenance personnel mistake. Likewise, '11. Managerial method' was the second in all three cases. In most trip events, there had been organizational or managerial deficiency which was the precondition of incident. With the exception of '6. Work practice' and '11. Managerial method', ranking results were different between case 2 and case 3.

Because 19 events were excluded from the risk analysis, overall results cannot be drawn only by case 3 results. In order to get comprehensive results of all 48 events, analysis results of 19 events will also have to be incorporated in an appropriate way.

5. Conclusions

In this study, cause analysis of trip events in Korean nuclear power plant was performed in terms of human performance. Risk significance of trip events were also analyzed using CCDP as a risk measure. Use of risk information in the process of analyzing trip event seems to be useful in enhancing human performance in terms of nuclear power plant safety.

Because only events that occurred during full power operation of PWR were included for risk analysis, analysis results of excluded 19 events will also have to be incorporated in an appropriate way in order to get comprehensive results. Events were analyzed using only Yonggwang 5&6 Unit PSA for ease of the analysis in this study, but analysis using PSA results of the nuclear power plant where the event occurred will be needed.

Through the analysis of trip events, it was discovered that all 11 items of K-HPES have cause and effect relationships from each other. So it was noted that additional work may be needed to develop diagrams that show causality of K-HPES items effectively. Classifying error causes into direct cause or root cause may also be useful.

6. References

1) “Development of K-HPES (Korean Human Performance Enhancement System) in Nuclear Power Plants”, Korea Electric Power Research Institute, 1998 , (Korean Language)
2) “PSA Notebook for Yonggwang Units 5&6 (Internal Events Analysis : Main Report)”, Korea Electric Power Research Institute, 2001. 3 (Korean Language)
3) J. Park et al, “Development of a Database System for Shutdown and Abnormal Events of Nuclear Power Plants in Korea”, Proceedings of Korea Nuclear Society Spring Meeting, 2001 (Korean Language)

Table 1. Risk significance analysis result of trip event

Event Number	Event Name	System	EPRI Category	Initiating Event	CCDP
1	Plant trip by Gland Seal Water Pump A/B misconnection	Main Feedwater Pump Seal System	EPRI 16-Loss of All Feedwater	LOFW	2.22E-06
2	Plant trip by opening Instrument Compressed Air Storage Tank Relief Valve	Instrument Air System	EPRI 15-Partial Loss of Feedwater	GTRN	1.16E-07
3	Plant trip by loss of Condenser vacuum	Circulating Water System	EPRI 25-Loss of Condenser Vacuum	LOCV	1.00E-08
4	Plant trip by Reactor Protection System test error	Reactor Protection System	EPRI 39-Auto scram	GTRN	1.16E-07
5	Plant trip by water leakage to Fire Protection System	Fire Protection System	EPRI 39- Auto scram	GTRN	1.16E-07
...	....	.....			.....

Table 2. Cause analysis results of trip events

	K-HPES items										
Event No	1	2	3	4	5	6	7	8	9	10	11
1			1			1	1	1		1	1
2		1	1			1	1		1		1
3	1		1				1		1		
4		1				1		1			
5						1					1
....	..	..	..	..	..	..	..	..	..	..	..
Sum	5	16	17	4	2	39	17	9	10	6	24

Table 3. Importance ranking of K-HPES 11 items

<table>
<tr><th rowspan="2">Ranking</th><th colspan="3">K-HPES items</th></tr>
<tr><th>Case 1
(48 events)</th><th>Case 2
(29 events)</th><th>Case 3
(29 events)</th></tr>
<tr><td>1st</td><td>6</td><td>6</td><td>6</td></tr>
<tr><td>2nd</td><td>11</td><td>11</td><td>11</td></tr>
<tr><td>3rd</td><td rowspan="2">3 , 7</td><td>3</td><td>7</td></tr>
<tr><td>4th</td><td>2</td><td>3</td></tr>
<tr><td>5th</td><td>2</td><td>7</td><td>8</td></tr>
<tr><td>6th</td><td>9</td><td rowspan="2">9 , 8</td><td>10</td></tr>
<tr><td>7th</td><td>8</td><td>2</td></tr>
<tr><td>8th</td><td>10</td><td>1</td><td>9</td></tr>
<tr><td>9th</td><td>1</td><td rowspan="2">4 , 10</td><td>1</td></tr>
<tr><td>10th</td><td>4</td><td rowspan="2">4 , 5</td></tr>
<tr><td>11th</td><td>5</td><td>5</td></tr>
</table>

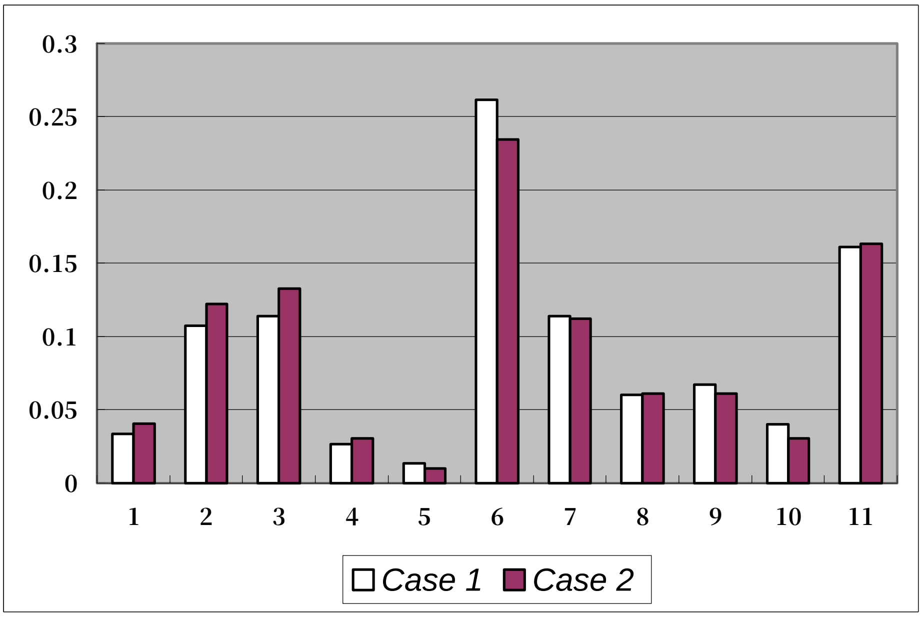

Fig 1. Risk Importance Comparison Between Case 1 and Case 2

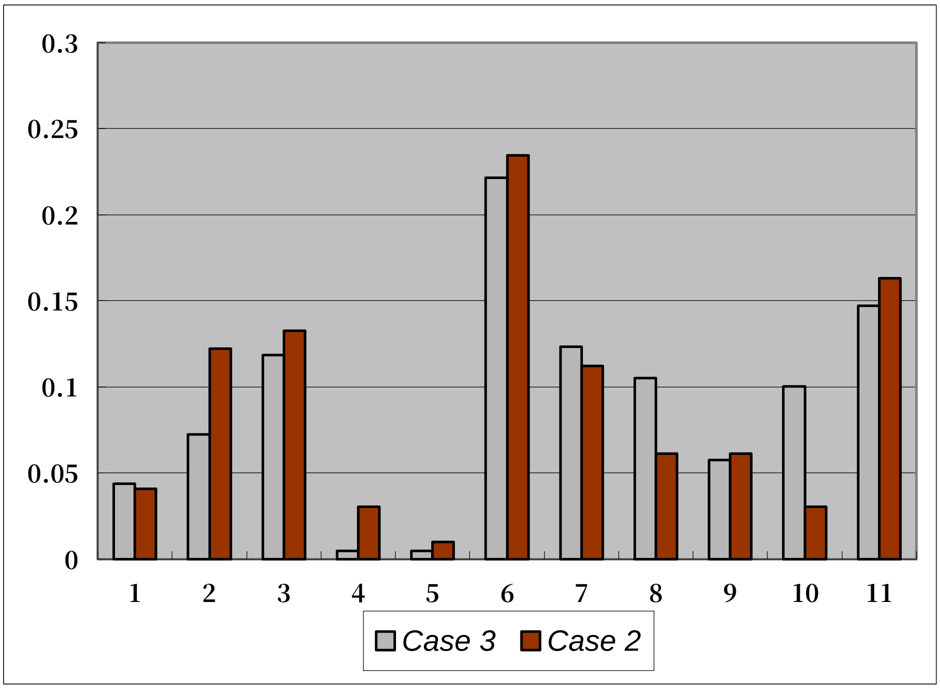

Fig 2. Risk Importance Comparison Between Case 2 and Case 3