Transactions of the Korean Nuclear Society Autumn Meeting
Jeju, Korea, May 12-13, 2016

Time Based Workload Analysis Method for Safety-Related Operator Actions in Safety Analysis

Yun Goo Kim*, Eung-se Oh

Korea Hydro and Nuclear Power Co., ltd, Central Research Institute, Daejeon, Korea
**Corresponding author: ygkim.stpn@khnp.co.kr*

1. Introduction

During the design basis event, the safety system performs safety functions to mitigate the event. The most of safety system is actuated by automatic system however, there are operator manual actions that are needed for the plant safety[1]. These operator actions are classified as important human actions in human factors engineering design[2]. The human factors engineering analysis and evaluation is needed for these important human actions to assure that operator successfully perform their tasks for plant safety and operational goals. The work load analysis is one of the required analysis for the important human actions.

2. Time based workload analysis

There are several characteristics to determine workload of operator in mental and physical point of view. The analysis of operator response time is one of representative method to determine workload. For the important human actions, the safety analysis assumes that the operator manual action is performed at a certain time in analysis scenario to mitigate the event and keep the plant in safe. This time is the time available to operator (T_{Ava}). Then operator needs a time to perform that action. This time is the time required by operator (T_{Req}). The workload is defined as the ratio between T_{Req} and T_{Ava}. It means that if there less time between T_{Req} and T_{Ava} then the workload is increased. For the workload analysis, the following definition of times in operator response analysis by ANSI/ANS 58.8 are applied[3].

- Start time of event (t_{St}) : The time at which the DBE begins.
- Indication time of event (t_{Ind}) : The time at which information is readily available.
- Earliest credited action time (t_{ECA}) : The time at which credit for the initiation of a safety-related operator action can be taken.
- Manual action initiated time (t_{MAI}) : The time at which the analysis credits the initiation of operator action.
- Safety-related action completed time (t_{SAC}) : The time at which the analysis credits the initiation of operator action.
- Safety-related function completed time (t_{SFC}) : The time at which an indication is received that a safety-related system has performed its required safety-related function.
- Event limit time (t_{Lim}) : The time at which the limiting design requirement would be exceeded if a safety-related function has not been completed.

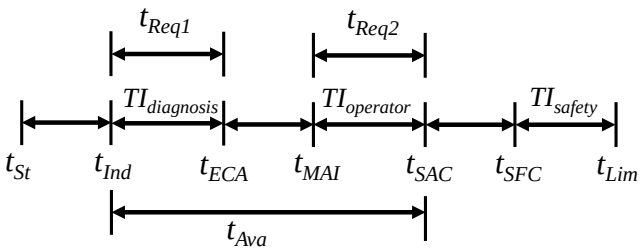

Fig. 1. The time lines for workload analysis

T_{Req} and T_{Ava} can be defined with the times as shown in Fig 1. T_{Req} is consist of time for diagnosis and time for operator action. T_{Ava} is from time indication of event to time safety-related action completed. Therefore, the workload is defined as :

$$\mathrm{WL(Workload)} = \frac{T_{Req}}{T_{Ava}} = \frac{(t_{ECA} - t_{Ind}) + (t_{SAC} - t_{MAI})}{t_{SAC} - t_{Ind}} \quad (1)$$

3. Workload analysis for important human action

Workload analysis method is applied to one of important human actions from transient and safety analysis, which is “Inadvertent opening of SG relief or safety valve.” This event assumes that an atmospheric dump valve (ADV) or a turbine bypass valve is inadvertently opened by an operator or a failure of the control system that operates the valve. For the analysis, times defined in section 2 should be calculated or estimated based on the scenario of the event. The opening of a steam generator ADV increases the rate of

heat removal by the steam generators and the RCS is cooled down. Because of the negative moderator temperature coefficient, the core power increases from the initial value of 102 percent of rated core power, reaching a stabilized value of 113 percent after 40 seconds from the event initiation time. It is assumed that the operator may notify the core power difference. Therefore, the t_{Ind} is estimated as 40 second in this analysis. For the t_{ECA}, time for operator diagnosis ($TI_{diagnosis}$) should be estimated. In this analysis the assumption in ANSI/ANS 58.8 is applied. The $TI_{diagnosis}$ is assumed as 10 minutes because this event is classified as an anticipated operational occurrences (AOO).

The safety analysis for this event assumes that the initial operator action is delayed until after 30 minutes following the event initiation so the operator trip the reactor by manual at 30 minutes from the start time of event. However the safety analysis do not consider the time for operator action. In the scenario, trip signal is generated at 30 minutes. Therefore, it can be estimated that the safety-related action completed time is 30 minutes. The time for operator action ($TI_{operator}$) is also estimated from the assumption in ANSI/ANS 58.8 as 3 minute. Then workload is calculated from each estimated time and the result is 44.3%. Table 1 shows each estimated time and calculated result.

Table1. Time based workload analysis result for the sample scenario

Type of time	Estimated time (sec)
Start time of event (t_{st})	0
Indication time of event (t_{ind})	40
Earliest credited action time (t_{eca})	640
Manual action initiated time (t_{mai})	1620
Safety-related action completed time (t_{sac})	1800
Safety-related function completed time (t_{sfc})	1804
Event limit time (t_{lim})	Not estimated
Time diagnosis ($ti_{diagnosis}$)	600
Time for operator action ($ti_{operator}$)	180
Time available to operator (t_{ava})	1760
Time required by operator (t_{req})	780
Workload	**44.3%**

In current safety analysis, the t_{Lim} is not usually calculated. However, the time between t_{SFC} and t_{Lim} is safety timing margin. This margin is not included in safety analysis, but if t_{Lim} is calculated then t_{MAI} can be adjusted. Therefore the ratio between timing margin and T_{Req} is workload margin as :

$$\mathrm{WM(Workload\ Margin)} = \frac{TI_{safety}}{T_{Req}} = \frac{(t_{Lim} - t_{SFC})}{(t_{ECA} - t_{Ind}) + (t_{SAC} - t_{MAI})} \quad (2)$$

4. Discussion

Time based workload analysis method is proposed and one example is analyzed with the method. Proposed workload analysis method can be applied to the task analysis of important human action. For the accurate evaluation, followings are need to be considered. 1) the operator diagnosis time and action time in digital main control room should be developed. The current estimation use the assumption in analog main control room. 2) When the time of operator manual action is defined in safety analysis, it should be decided whether the time includes the time for safety action completion (t_{SAC}) or time for safety function completion(t_{SAF}). 3) The t_{Lim} should be calculated for every important human action for the calculation of workload margin. 4) When the important human action is the action for plant cooldown, the series of operator actions should be considered.

REFERENCES

[1] M. S. Lee, S. S. Lee, M. S. Park, G. C. Lee and S. W. Kim, A Study of Time Response for Safety-Related Operator Actions in Non-LOCA Safety Analysis, Trans. of KNS Autumn Meeting, 2014.
[2] NUREG-0711, Revision 3, "Human Factors Engineering Program Review Model," US NRC, November 2012.
[3] American Nuclear Society Time Response Design Criteria for Safety Related Operator Actions, ANSI/ANS 58.8 1994