Basic Characteristics of Human Erroneous Actions during Test and Maintenance Activities Leading to Unplanned Reactor Trips

Jaewhan Kim, Jinkyun Park
Korea Atomic Energy Research Institute
jhkim4@kaeri.re.kr

1. Introduction

Test and maintenance (T&M) activities of nuclear power plants are essential for sustaining the safety of a power plant and maintaining the reliability of plant systems and components. However, the potential of human errors during T&M activities has also the potential to induce unplanned reactor trips or power derate or making safety-related systems unavailable.

According to the major incident/accident reports of nuclear power plants in Korea, contribution of human errors takes up about 20% of the total events. The previous study presents that most of human-related unplanned reactor trip events during normal power operation are associated with T&M activities (63%), which are comprised of plant maintenance activities such as a 'periodic preventive maintenance (PPM)', a 'planned maintenance (PM)' and a 'corrective maintenance (CM)' [1]. This means that T&M activities should be a major subject for reducing the frequency of human-related unplanned reactor trips.

This paper aims to introduce basic characteristics of human erroneous actions involved in the test and maintenance-induced unplanned reactor trip events that have occurred between 1986 and 2006 in Korean nuclear power plants [2]. The basic characteristics are described by dividing human erroneous actions into planning-based errors and execution-based errors. For the events associated with planning failures, they are, firstly, classified according to existence of the work procedure and then described for what aspects of the procedure or work plan have deficiency or problem. On the other hand, for the events associated with execution failures, they are described from the aspect of external error modes.

2. Classification of Error Types

James Reason's basic error types, which are composed of mistake, slip/lapse, and violation, are used to classify test and maintenance human errors associated with unplanned reactor trip events [3]. Definition of each error type is given in [4]. Results of error classification of the T&M human errors involved in unplanned reactor trips are given in Table 1.

Table 1. Results of the classification of error types for test- and maintenance-related human errors involved in unplanned reactor trips

Maintenance Type / Error Type	PPM	CM	PM	Sum
Planning failure (P)	2	12	9	23 (48%)
Execution failure (E)	9	13	2	24 (50%)
Rule violation (V)	-	(2)	(1)	(3)
Uncertain	-	1	-	1 (2%)
Sum	11	26	11	48 (100%)

3. Characteristics of Maintenance Human Errors by Error Types

2.1 Characteristics of human errors caused by planning failure

The human error events caused by a planning failure are classified firstly according to the existence of a relevant procedure for required test and maintenance activities, i.e., (1) the events that relevant work procedures were provided for the work activities, (2) the events that relevant work procedures were not provided for the work activities. Among the total of 23 events that occurred due to a planning failure, the former case includes 16 events and the latter case does 7 events.

Firstly, the characteristics of human errors in the cases in which work procedures are provided are summarized. It is notable that most of the events (14 of 16 events) occurred during low-power or startup conditions. Only two events occurred during a full-power operation. One event occurred due to omission of the checking of signal interrelatedness; this event is considered to be identifiable in advance before a work is initiated through the checking of 'the state of signal interrelatedness'. The other event is deemed to be very difficult to identify in advance before a maintenance task is initiated because it occurred under the situational context of an unexpected/unanticipated component failure.

Secondly, the characteristics of human intentional errors in the cases in which work procedures are not provided are summarized. It is revealed that all the events related to this case have occurred during corrective

maintenance, which means that some corrective maintenance activities are performed without preparing work procedures even though the administrative procedure of the plant instructs that all the maintenance activities that have the potential for incurring unplanned reactor trips or plant transients should prepare a work procedure to perform the work in a safe and systematic way. Four of the seven events have occurred during a full-power operation. This means that the impact of human errors during a corrective maintenance is significant and an adequate management is crucial to reduce the human errors associated with a corrective maintenance.

2.2 Characteristics of human errors caused by execution failure

Execution errors take up 50% of total T&M human errors, as shown in Table 1. Most of the events caused by execution errors occurred during a full-power operation (15 of the 24 events; 63%), and both a corrective maintenance and a periodic preventive maintenance have the most contribution of the events. While the main concern of the events caused by planning failure is on the work plan or procedure, the interest of the events caused by execution failure is in recurrent error manifestations or external error modes.

Execution errors can take various forms, but it is notable that all the human events related to an execution error that led to reactor trips take one of the following four error modes: 'wrong object', 'omission', 'too little or inadequate', and 'wrong action'. Among the 24 events in total, 10 events are represented as 'wrong object' (42%), 5 events as 'omission' (21%), 6 events as 'too little/inadequate' (25%), and 3 events as 'wrong action' (12%).

The 'wrong object' error mode is defined as an action taken on an object other than a required one. Most of the events include an action on a neighbouring object similar to a required one.

The 'omission' error mode can be classified into 'omission of a procedural step' and 'failure to recognize an abnormal state'. The 'omission of a procedural step' consists of 'omission of a prior preparation action' and 'omission of a restoration action'. The 'omission of a prior preparation action' includes the omission of an important action for making a stable testing condition which is required prior to a main testing procedure, and the 'omission of a restoration action' includes a failure to return a system train after a test to a normal state. The 'failure to recognize an abnormal state' includes a failure to identify an abnormal or failed condition of a function or component which is concealed in a system.

The 'too little' error mode means an insufficient or excessive force or effort being taken than required. The 'inadequate' mode represents that level of adequacy for a maintenance action is less than perfection, even though a right action is performed on a right object. The 'inadequate' mode was assigned to the events for which the 'too little/too much' mode cannot be applicable. Two of the six events occurred during a full-power operation, another two events occurred during power ascending, and remaining two events occurred during a plant overhaul period. All the events of the 'too little' error mode are associated with an inherent vulnerability or a temporariness that a work method has against a work object. The events related to the 'too little' error mode are usually revealed in the form of a detachment or separation due to the temporariness or vulnerability of the work method itself.

The 'wrong action' error mode features an inadvertent contact with peripheral components/devices while working at a local place. It also includes an unintended contact between a work apparatus or tool and peripheral components/devices of the workplace. Analyses of the work process, paths, specific actions, and tools/apparatus to be used with peripheral components/devices are required to predict the possibility of an occurrence of a 'wrong action'.

3. Conclusion

Thus far we analyzed the characteristics of the T&M human errors by error type that led to unplanned reactor trips. According to the analysis results, the human errors showed distinctive forms or patterns by error types. For the management of human errors due to a work planning, a more detailed and systematic approach would be required; this approach might include a structured method or computational tools to identify the potentials for human error. For the management of human errors during an execution, development of a detailed analysis procedure or guidance for identifying specific human errors at a certain step of a work procedure that could be used by a plant maintenance team such as in a pre-job meeting would be beneficial for reducing the human errors at T&M settings, thereby reducing the frequency of unplanned reactor trips and derates.

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