The Identification of Human Errors in the Power Dispatching Based on the TRACEr Method

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Abstract. Most of the power dispatching accidents were caused by human errors. Human error should be symptoms of systemic problems and opportunities to learn about the features of complex systems. Therefore, the identification and analysis of the human errors in the power dispatching is the significant to guide against the human risk and ensure the stable and safe operation of power nets. Human error identification methods have been used to identify the nature of the human errors and causal factors, and recovery strategies in many industrial domains such as the aviation, nuclear power and chemical processing industries. The Technique for Retrospective and Predictive Analysis of Cognitive Errors (TRACEr) is a human error identification technique that was developed for use in the air traffic control domain. In this study, the TRACEr was improved in the combination of the task features of the power dispatching and human information processing, and was used to identify the human errors in the power dispatching. A total of seventy-two incidents or accidents performed by operators were analyzed. The analyzing processing was carried out with the objective of classifying task error, identifying external error modes, internal error modes and psychological error mechanisms, and identifying the performance shaping factors. The performance factors analysis considered the time, interface, training and experience, procedures, organization, stress and complexity which may have an impact to the task and help to propose some recovery strategies. The results revealed that the identification was a necessary and effective step toward the safety improvement of power dispatching.

Keywords: Human factors · Power dispatching · Human error identification

1 Introduction

The safety and reliability of the power system operation are critical issues for maintaining stable electricity supply, ensuring economic growth and guaranteeing people's normal life order. With the development of the technologies in the power system, increasingly sophisticated automation has been introduced into the power system

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operation, including power dispatching. To a large extent, safety benefit from the increasingly the reliable automation. However, the system complexity and lack of the transparency put forward higher requirement on the dispatchers. Statistically, about 75% of the accidents in the power dispatching operations were attribute to the human factors [1]. Therefore, the identification and analysis of the human errors in the power dispatching is the significant to guide against the human risk and ensure the stable and safe operation of power nets.

In addition to the power dispatching, human error has been considered as a significant factor in the incidents and accidents in complex systems, such as nuclear power and civil aviation [2]. Reason defined human error as “All those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency”. Furthermore, Reason proposed the classification of human error, including the slips, mistakes and violations [3].

The human error identification methods are widely investigated in the complex systems. In the new view, researchers think that human error is not a cause of an incident or accident. It is the consequence, the effect, the symptom of the accident deeper in the whole system [4]. Human error provides information to help diagnosing the systems. Therefore, human error identification methods are developed to identify the nature of operator errors and causal factors, recovery strategies.

Several human error identification methods have been developed in the different domains. The systematic human error reduction and prediction approach (SHERPA) was developed for the nuclear reprocessing industry, which is a classification method to identify potential errors associated with human activity [2]. The human error template (HET) method was developed for the civil flight deck [5]. The hazard and operability study (HAZOP) method was first developed by ICI for the safety of a plant or operation [6, 7]. The Cognitive Reliability and Error Analysis Method (CREAM) was developed for an analysis of the human reliability analysis approaches, which can be used both to predict potential human error and to analyze error [8]. The Human Error Identification in Systems Tool (HEIST) adopted a series of error identifier prompts to identify potential errors [9]. The Human Factors Analysis and Classification System (HFACS) was developed to investigate and analyze human error in aviation based on the “Swiss cheese” model of accident causation [10, 11].

The technique for the retrospective analysis of cognitive errors (TRACEr) was developed specifically for human error identification in the air traffic control (ATC) domain, which can be used either proactively to predict potential error and analyze operators’ performance or retrospectively to investigate accidents [12]. The method combines the psychological, physical and external factors based on the experiment and applied psychology, human factors and communication theory. Moreover, the TRACEr method has been applied in the railway domain [13], ship accident [14] and maritime transportation industry [15].

In this paper, the TRACEr method was used to identify and analyze a set of dispatching accidents in the power system in consideration of similarity of the tasks in power dispatching and ATC. The objective is to characterize dispatching incidents and accidents in terms of task errors, human-machine interface and cognitive domains involved the accidents.

2 TRACEr Method

TRACEr method is focused on the human-machine interface and the cognitive processes of the operator. According to the TRACEr, some environmental or situational factors influence the operator's mental state, which causes the failure of the cognitive processes, and finally lead to an accident. Therefore, it does not only analyze the external and observable manifestation of the task error but goes deep in the cognitive domain that help analysist to explore the context that lead the operator make errors.

According to Shorrock and Kirwan [12], TRACEs method has a modular structure with various layers: Task Error, External Error Modes (EEMs), Internal Error Modes (IEMs), Psychological Error Mechanisms (PEMs), Performance Shaping Factors (PSFs).

The TRACEr method was used in this study to identify the human error in the power dispatching as follows:

1. Defining the task error, such as communication error, material check error, monitoring error.
2. Defining the error or violation.
3. Identifying the external error modes. Table 1 presents the EEM taxonomy.

Table 1. External error mode taxonomy.

Timing and sequence	Selection and quality	Information transfer
Action too early	Omission	Unclear info transmitted
Action too late	Action too much	Unclear info recorded
Action too long	Action too little	Info not obtained
Action too short	Action in wrong direction	Info not transmitted
Action repeated	Wrong action on right object	Info not recorded
Mis-ordering	Right action on wrong object	Incomplete info transmitted
	Wrong action on wrong object	Incomplete info recorded
	Extraneous act	Incorrect info transmitted
		Incorrect info recorded

4. Identifying the failure of cognitive domains. The four cognitive domains comprise perception, memory, planning and decision-making and action execution.
5. Identifying internal error modes and psychological error mechanisms. IEMs describe what cognitive function failed or could fail, and in what way, and provide an interface between EEMs, PEMs, and the cognitive domains, and thus give an intermediate level of detail. For example, the 'perception' was divided into 'visual' and 'auditory'. PEMs describe the psychological nature of the IEMs, such as 'expectation bias', 'perceptual confusion' and 'distraction' in 'perception' domain.
6. Identifying the performance shaping factors. In the study, PSFs included time, interface, training and experience, procedures, organization, stress, and complexity. PSF categories and associated keywords are presented in Table 2.

Table 2. Psychological error mechanisms taxonomy.

Category	Examples
Time	Emergency tasks; night shift
Interface	No information; unclear information; conflicting information
Training	No enough training or experience
Procedures	No procedure; fuzzy procedure; too simple procedure; wrong procedure; unreadable procedure
Organization	Insufficient personnel; insufficient cooperation; poor working environment
Stress	High workload/stress; fatigue
Complexity	New task; complex task

3 Accident Analysis

In this study, 72 incidents and accidents reports have been analyzed using the TRACEr method. The accident reports came from State Grid East China Electric Power Control Center and covered dispatching accidents in a period from 2015 to 2017. Since there was more than one error in an incident or accident, the analysis have produced 113 task errors using the TRACEr method described in the previous section. The flowchart of human error analysis was presented as Fig. 1.

3.1 External Error Modes

The TRACEr method provides 3 catagories for the external error modes as mentioned in the previous section (timing and sequence, selection and quality, and information transfer). The main EEM is information transfer with a percentage of 46.05%, while the percentage of the 'timing and sequence' and 'selection and quality' were 35.53% and 18.42%, respectively, as shown in Fig. 2.

The main error mode in the category 'information transfer' was 'incorrect information transmitted' (13.16%, Fig. 3). For example, the operator transmitted incorrect electrical generation or peak values. The second error mode was 'incomplete information transmitted' (10.53%), such as transmitting incomplete repair schedules. The category 'information not transmitted' was also an important error mode (9.21%). The operator in the provincial power gird or power station forgot to transmit the failures of the system or transmit their maintenance activities. In addition, 'incorrect info recorded' occupied the percentage of 6.58%, such as recording wrong device. Other relevant EEMs were 'unclear info transmitted' (2.63%), 'info not obtained' (2.63%) and 'incomplete info recorded' (1.32%).

The 'action too early' was the most among all the EEMs with a percentage of 19.74%, as shown in Fig. 4. when a failure happened, operators often took actions other than reporting to the Control Center as required. The 'action too late' (7.89%) typically involved detecting the warning too late, and the 'action too long' (6.58%) involved that operator did not process failures within the required time.

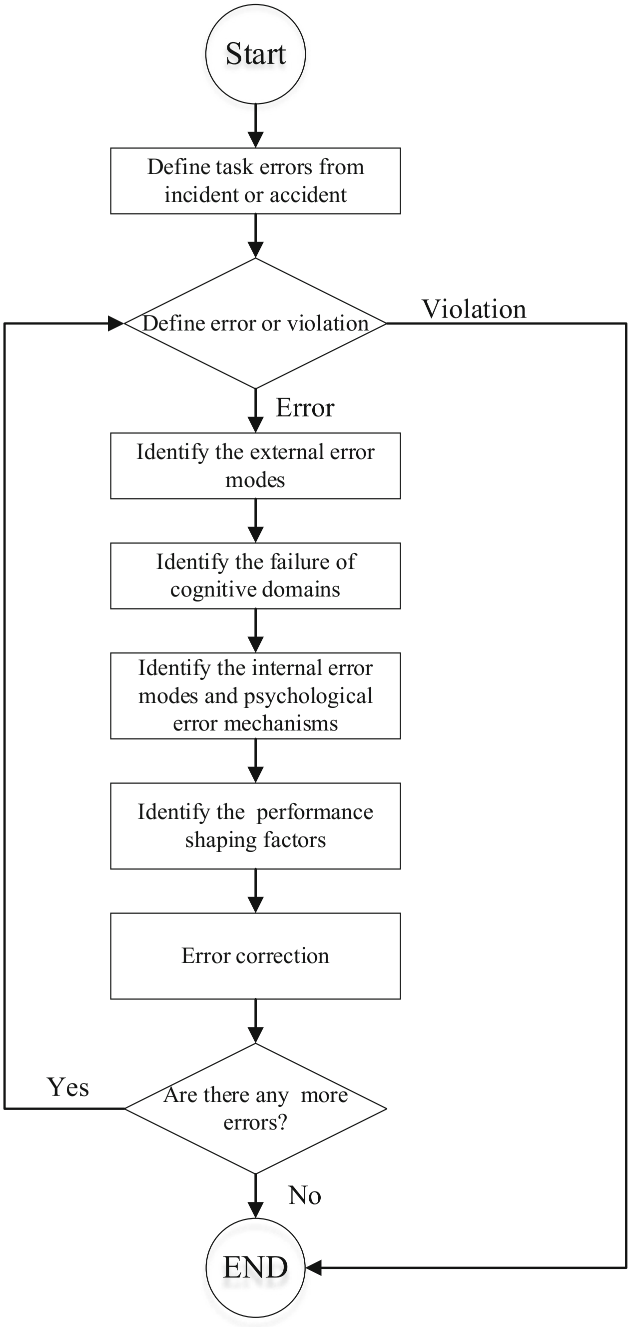

Fig. 1. Flowchart of the error analysis in the study

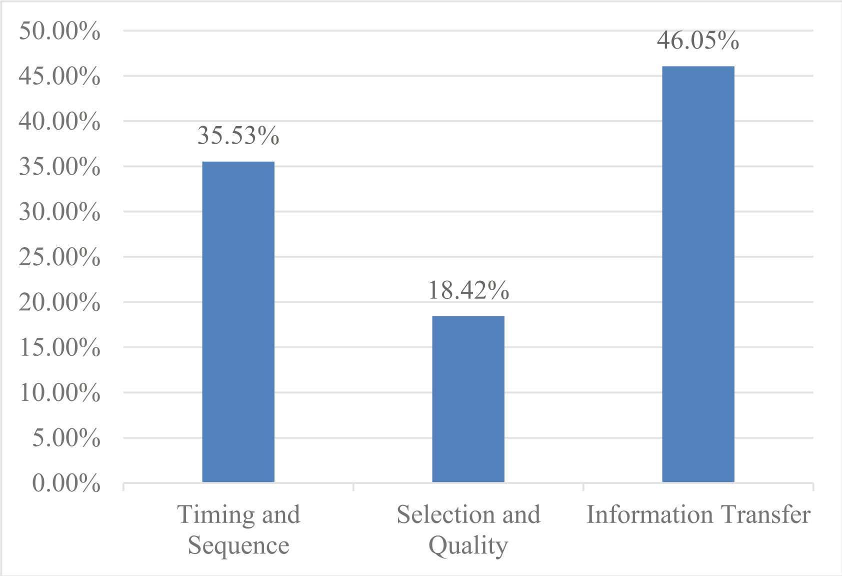

Fig. 2. External error modes

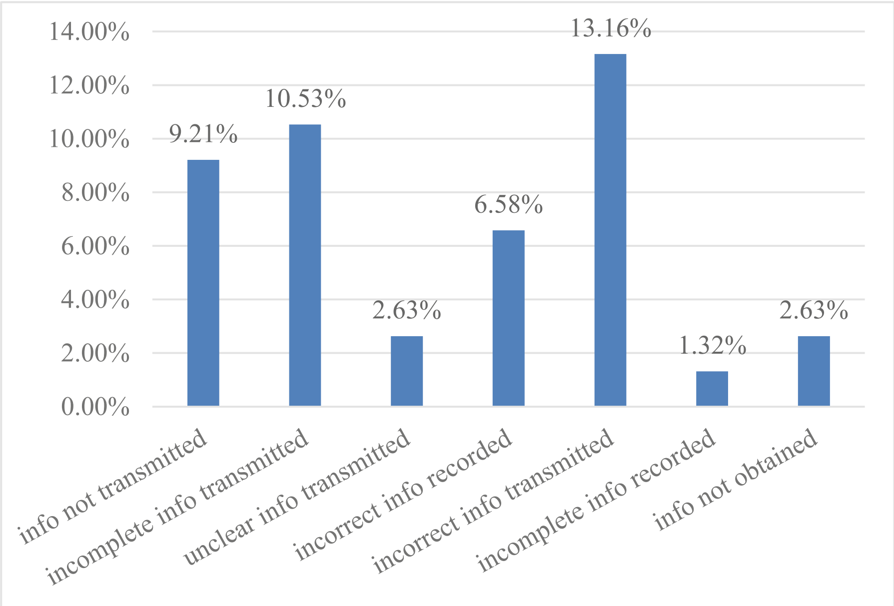

Fig. 3. Percentage of error modes in 'information transfer' category

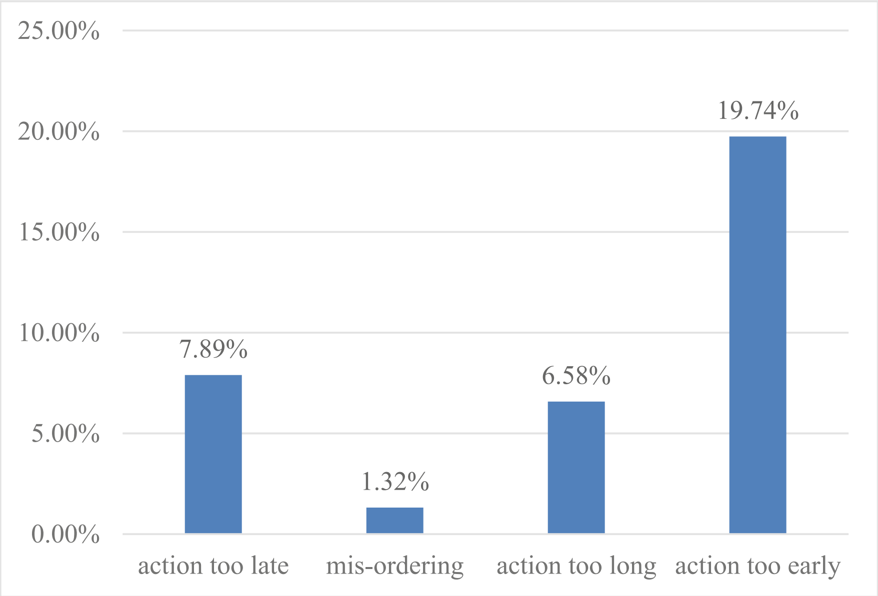

Fig. 4. Percentage of error modes in 'timing and sequence' category

The 'selection and quality' category had main error mode of 'omission' with a percentage of 9.21% (Fig. 5). Operators often omitted some information when formatting the operation tickets. Other relevant error modes were action in wrong direction (3.95%), action too little (2.63%), right action on wrong object (1.32%) and extraneous act (1.32%).

3.2 Cognitive Domains

The analysis in the study showed that the cognitive domains related to the task errors were 35.40% of planning and decision-making, 24.78% of action execution, 17.70% of Memory, 11.50% of Perception, and 10.62% of Violation, as shown in Fig. 6. Obviously, the 'planning and decision-making' domain was the most failure in the cognitive processing, meaning the operator had a worse situation awareness.

3.3 Performance Shaping Factors

Figure 7 showed the performance shaping factors that might influence the operators' performance and result in errors. The insufficient information in the interface and stress were the main factors with the percentage of 17.05%. The second factor was night shift (16.28%). Moreover, as regarding to the organization factor, the contributors were insufficient personal (10.85%), insufficient cooperation (4.65%) and poor environment (3.10%), respectively.

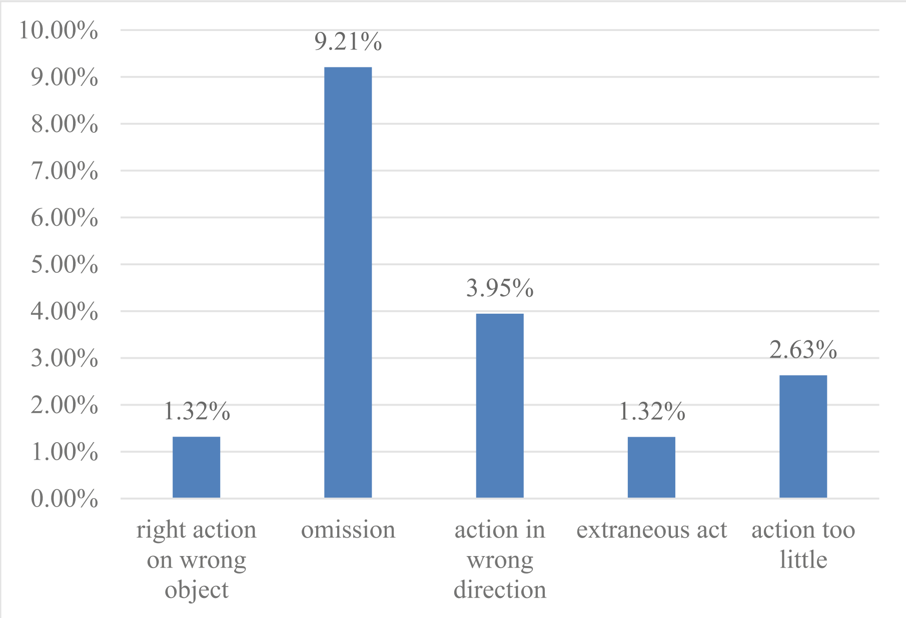

Fig. 5. Percentage of error modes in 'selection and quality' category

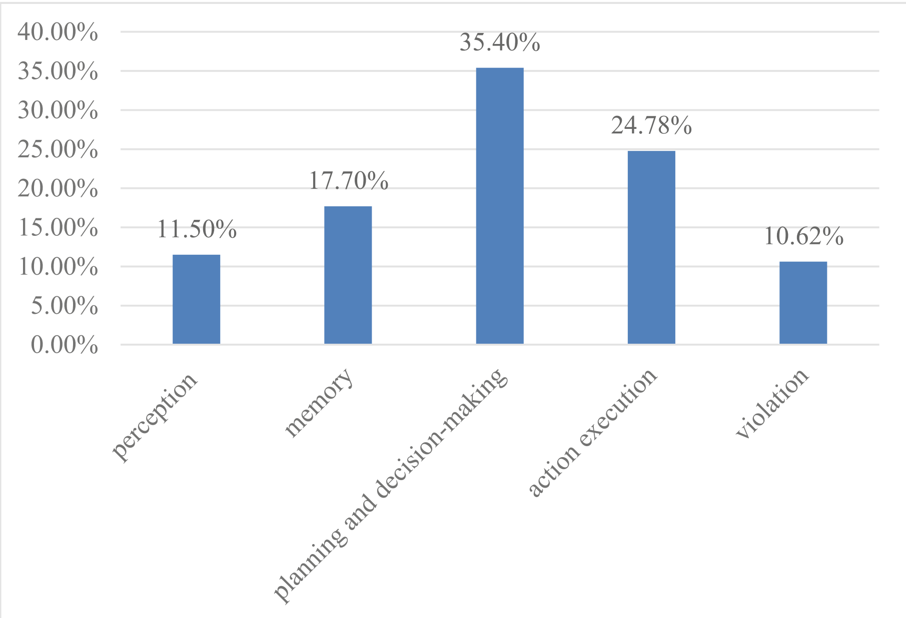

Fig. 6. Percentages of cognitive domains in related to task errors

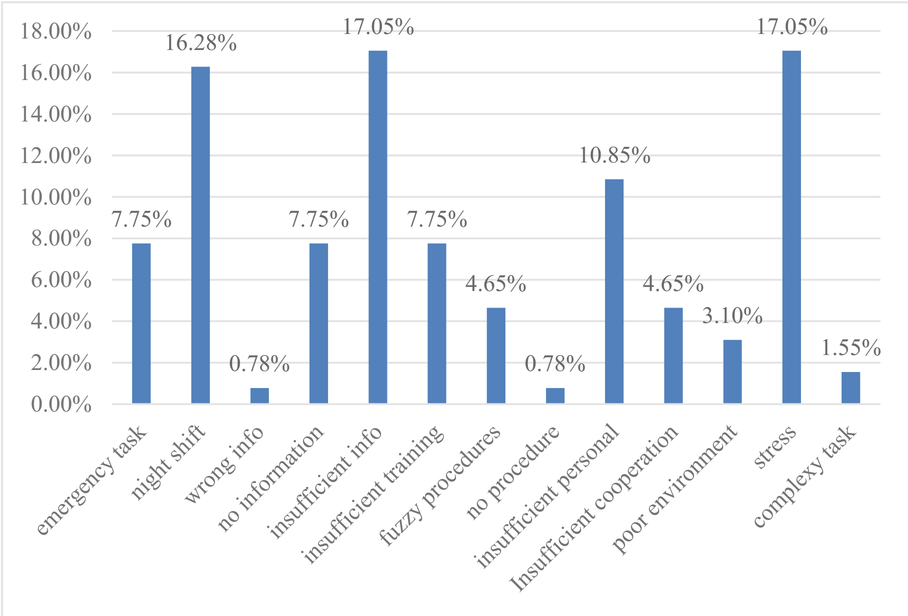

Fig. 7. Main performance shaping factors that might cause the task errors

4 Discussions and Conclusions

The objective of this study was to demonstrate the utility of the TRACEr method for analyze the operators' error in the power dispatching. The results revealed that the method can benefit the identification of the operators' cognitive state and the exploration of the context that influences the operators' performance through EEM, IEM, PEM and PSF analysis.

The TRACEr method integrating Wickens model of information processing [16] into its model is a structured analysis procedure which is useful for the analyst to track and classify errors through the stages of human information processing. In the study, the 'planning and decision-making' was identified as the main cognitive domain related to the task errors. It is attributed to the task characteristic of the power dispatching that an operators in some place seldom get complete information about the state of the power grid, and available, since he typically deals with only a few functional areas of power system operations [17]. Therefore, enhancing the operators' situation awareness is a critical issue for the power dispatching.

The TRACEr method considered the PSFs within the whole system which contributed to errors identified and error correction. In the study, 'night shift', 'insufficient information in the interface' and 'stress' were considered as main factors that might have impact on the operators' performance. The results suggested that the human-machine interface, task assignation and other relevant factor should be adapted.

As mentioned above, the TRACEr method which was developed based on psychological theory could require high training time and an understanding of psychology in order to use the method. Meanwhile, the method highly relies on the background, experience, and knowledge of the domain and task analyzed.

To conclude, the paper demonstrated that the TRACEr method can be applied as a retrospective analyzing tools for the incidents and accidents in the power dispatching. The results might benefit the proposal of some recovery strategies and improvement of the operation safety for the power dispatching. However, the validity and reliability of the method still are required to explore in combined with detecting operators' cognitive state using objective measurements.

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