Factors influencing human errors during work permit issuance by the electric power transmission network operators

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Abstract

Prediction, identification, and control of errors effect on human performance and improve human actions. Human reliability has an important role in increasing the reliability of electricity production, transmission, and distribution networks and its direct/indirect damages. Right implementation of an effective work permit issuance system can meet safety of employees working in the control centre and other facilities and also can increase reliability of being used facilities. In the present research, effective factors for human errors in the process of work permit issuance by operators of control rooms working in the electricity transmission stations were studied. Substation operators’ tasks, as the main human errors sources in the process of work permit issuance, were analyzed using hierarchical task analysis (HTA). Errors related to tasks were then predicted using systematic human error reduction and prediction (SHERPA) technique. The process of work permit issuance, as one of the main operators’ tasks in which errors can be traced, was selected to analyze the impacts of some variables such as age, work experience, education level, hours of training, and number of maneuvers (number of permits issued by each operator). In the end, relationship between above variables and recorded errors was determined through Spearman’s correlation coefficient. The results reveal that the action error and the error of maneuvering task have the most frequency respectively among the 107 predicted errors in six main tasks and 61 subtasks. The results also indicate a significant correlation (confidence level=95%) between the number of errors in the work permit issuance process and the Number of maneuvers (number of issued permits) (correlation coefficient=0.31 & P=0), Training period (correlation coefficient=0.195 & P=0.014), the work experience (correlation coefficient=0.191 & P=0.016) and the age (correlation coefficient=0.164 & p=0.014). There is also no significant correlation between the education level and the number of operator’s errors in the work permit issuance process (correlation coefficient=−0.064 & P=0.413). A reduction in human errors can be expected through the application of the identified factors effecting on operators’ errors in power production and distribution networks.

Keywords: Operator, Work permit, Human error, HTA, SHERPA

Introduction

The work permit system is a key mechanism to minimize human errors guaranteeing workers and facilities’ safety. The proper application of this system depends on all involved employees including work permit issuers, supervisors, and workers (Barry, 2002; Harrison & Stanton, 2006). The process of work permit issuance is one of the critical and human error tending tasks (Mostia, 2002). Any error committed by the involved employees can diminish system’s safety leading to accidents.

Power production and distribution networks use the work permit system to ensure safety in tasks. Work permit issuance is applied based on risk management. The workforce as the main factor in the work permit issuance process plays an important role in proper implementation of this system. Hence, efficiency of this system directly depends on the performance of employees involved in it. The studies show that around 25.2% of all human errors identified in high voltage stations’ operators are related to the work permit issuance process (Haji Hoseini, 2011).

Human errors can be identified and predicted by various methods (Patrick et al., 2006; Ghasemi, 2009). These methods can be used to identify and evaluate human errors in the design and manufacturing, operations, and maintenance of systems and tasks’ duties. Potential errors, probability of errors, consequences of errors, and techniques to reduce and control errors are outputs of human errors identification and prediction techniques.

Some methods such as human error template (HET) and Systematic human error reduction and prediction approach (SHERPA) are mainly applied to identify and rank user’s errors. Some other methods such as technique for human error assessment (THEA) and human error identification in system toll (HEIST) are used to detect and predict errors in a comprehensive system. Human error assessment and reduction technique (HEART) determines numerical probability of errors. The validity of method, sensitivity to detect valid errors (believable), speed and the simplicity of each method are the main factors in selection of a suitable human error identification and prediction technique (Haji Hoseini, 2010, Shah Gholi-Nejad et al., 2012).

Annett et al. (1971) introduced some industrial examples of hierarchical task analysis (HTA). Their examples indicate how the analyst works in a process of
continual reiteration and refinement (Stanton, 2006). Annett (2003) indicated that the recent developments in HTA were originated in response to the need for greater understanding of cognitive tasks. HTA have a capability for applying as a basis for predicting errors. for example, SHERPA by Embrey (1986) uses an error taxonomy to predict potential errors from the HTA sub-goal hierarchy (Stanton & Young, 1999).

Human error identification and prediction techniques are highly dependent on analysts' judgment. It is possible that different analysts using a certain technique to identify and evaluate errors in a specific task have different assessments and predictions on potential errors of that task. Also, an analyst could have different assessments while using a method to analyze different tasks.

SHERPA is one of the most valid methods to identify and predict human errors. In this method, human errors are classified into five groups: action error, checking error, retrieval error, communication error, and selection error (Stanton & Salmon, 2004). According to defined activities in the process of work permit issuance in the power industry (based on safety rules in transmission networks); each of the above errors can happen.

In the present paper, possible operators' errors of transmission network in the work permit issuance process are predicted and identified. Also, effective factors are determined. Operators are responsible to control the network and to record, analyze and state all information about power transmission. Any connection/disconnection maneuver in transmission network is up to the operators.

**Methodology**

The present analytical study was conducted to analyze the factors affecting human errors occurrence in the work permit issuance process of power transmission stations. To do so, task duties of substations operators were analyzed using HTA. Also, to identify and predict operator's errors in each task, SHERPA method was applied.

Since permit issuance process in all stations is consistent and is done according to a procedure, errors in the work permit issuance process in all transmission stations recorded in period 2004-2007 were considered. Totally, 670 permits issued by 159 operators were analyzed.

Errors committed by all operators, no matter of their employment type (e.g. permanent, provisional contract, etc.), age, work experience, and education level, were detected. The only condition for participants to get involved in the research was having at least one year work experience. The only condition for the participants to be deleted from the study was the lack of their interest to the research. During the present research, nobody was deleted.

Data required in the current paper were gathered through site investigation and literature review. In the site investigation, following methods were used to gather data:

- Studying design documents and current procedures
- Extracting errors happened in each stations recorded in archives of work permits
- Interviewing with responsible employees to get guides to gather data well

In literature review, databases, books, journals and articles were studied. Also, university professors and advisors were interviewed to get consultancy on human errors and methods to identify and predict them.

Tasks and duties were analyzed through consulting with supervisors, managers, and three experienced operators in the transmission networks and using HTA method and references 7-10. Operators' tasks and duties were classified into working and operational groups using SHERPA method explained in (Stanton and Salmon, 2004). The correlation between recorded errors in the work permit issuance process and variables such as age, number of maneuvers (number of issued permits), operator's previous training, work experience, and education level were determined using Spearman's rank correlation coefficient.

**Results**

A total number of 199 traceable errors were detected in 670 permits issued by 159 operators in three years (Yazd Regional Electric Power Supply and Distribution Company: “The reports of Accident/Incident Investigation Committee” [Persian]). The results show one error in each 7.37 permit issued during this period. Frequency of traceable errors is not the same for all operators. While 52% of operators did not commit any error, 2% of them experienced five errors during the same period. More details are depicted in Fig. 1.

![Fig. 1. Frequency (%) versus different number of errors](http://www.indjst.org)

The correlation between the number of operators who commit errors and the training period, education level, work experience, as well as the number of maneuvers were determined using Kendall’s and Spearman’s rank correlation coefficient. The results show a significant correlation between the number of issued permits by each operator and the number of operator’s errors (confidence level=95% & P<0.05). There is also a significant correlation between the operator’s training period (in hours) and the number of human errors (confidence level=95%). As it is shown in Table 1, no
significant correlation was detected between the education level and the number of errors (confidence level=95%, P>0.05).

Table 2. Safety training records of the operators with error

<table>
<thead>
<tr>
<th>Training Time (hour)</th>
<th>No of operator</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;150</td>
<td>87</td>
<td>54.7</td>
</tr>
<tr>
<td>151 - 300</td>
<td>13</td>
<td>8.20</td>
</tr>
<tr>
<td>301 - 450</td>
<td>19</td>
<td>11.90</td>
</tr>
<tr>
<td>451- 600</td>
<td>9</td>
<td>5.70</td>
</tr>
<tr>
<td>&gt; 600</td>
<td>31</td>
<td>19.50</td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Training records of the operators show that 54.7% of them suffer from the lack of training having <150 hours of safety trainings. Only 19.5% of the operators have the eligible safety training of >600 hours (Table 2).

Results show (Fig. 2) that there is a significant correlation between the number of operators having errors and their work experience (confidence level=95%, correlation coefficient=0.191 & P=0.05). Operators with <5 years experience contributed the highest level of errors (35.8%) following with those having >25 years of experience which shared 23.9% of the errors. The operators with 11-15 years of experience commit the lowest level of errors (5%) see Fig. 1.

The Action errors contribute the highest level of errors (44.4% of total errors) while the Selection errors with 3.7% of total errors share the lowest level of errors predicted in the work permit issuance process (Fig. 4).

In the present paper, the relationship between defined variables and the types of errors recognized by SHERPA were assessed. Correlation coefficients between the types of operators’ error and variables are shown in Table 4. Results show that there is a significant correlation between action error and training period, number of maneuvers, employment type, work experience, and age (P<0.05, confidence rate 95%). Also, there is no a significant correlation between checking error and education level, training period, and work experience (P>0.05, confidence level = 95%).

The operators with bachelor degree and higher, had the highest number of errors (211.1 errors per 100 persons). The operators graduated from the college (e.g. holding an associate degree) had the lowest number of errors (100 errors per 100 persons) (Table 3).

Results in Table 1 indicate a significant correlation between the number of operators having errors and the operators’ age (confidence level=95%, correlation coefficient=0.164 & P<0.05). The operators at the age of 41-50 years commit the highest rate of errors (169.4 errors/100 persons) while the operators at the age of <30 years contributed the lowest rate of errors (96.5 errors/100 persons) see Fig. 3.

Table 3. Frequency of errors among different education levels

<table>
<thead>
<tr>
<th>Education level</th>
<th>No of person</th>
<th>No of Error</th>
<th>Error/100 person</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;High school (Under Diploma)</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>High school (Diploma)</td>
<td>51</td>
<td>81</td>
<td>158.8</td>
</tr>
<tr>
<td>College (Associate Degree)</td>
<td>99</td>
<td>99</td>
<td>100</td>
</tr>
<tr>
<td>University (≥BSc)</td>
<td>9</td>
<td>19</td>
<td>211.1</td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>199</td>
<td>125.1</td>
</tr>
</tbody>
</table>
correlations with work experience, training course, age, and education level in 95% confidence level (P>0.05). Table 4 also shows no significant correlations between selection error and variables education level, training course, work experience, age, and number of maneuvers in 95% confidence level (P>0.05).

Discussion and conclusion

The study showed that as the number of issued permits increases, the number of errors committed by each operator increases as well (Table 1). This could be mainly due to iteration of tasks which make operators get accustomed to the procedures and leading to skill-based errors (talented to forgetfulness and negligence). Limiting the number of permits that each operator is allowed to issue in a specific time is strongly suggested to reduce the likelihood of skill-based errors among the studied operators. Working overtime as well as in sequential shift of operators is also expected to increase skill-based errors therefore, prohibiting them is suggested.

The results also revealed that as the operators training time increases, they commit less knowledge-based errors. More training is expected to increase the operator’s technical skills leading to lower knowledge-based errors (Haji Hoseini, 2011). Developing new courses for the majority of the operators who suffer from the lack of training is recommended.

Furnees believes that the reason that the employees neglect the commands is that "first, they do not know why they have to obey rules and secondly, how to do their tasks right". Thus, theoretical and practical training could answer to these reasons (Ghasemi, 2009; Jahangiri, 2005; Zarea, 1996). Training should help operators to understand why they need to do their tasks and how to do them well.

The results show a confusing influence of educational degrees of operators on their errors. The number of errors in higher educated operators (e.g. holding BSc and higher degree) as well as in lower educated ones (e.g. holding a high school diploma) are much more than those with mid education (e.g. holding associate degree). Operators with associate degree have the least number of errors among all education levels. If this is true in other power distribution stations, it means that they suite well for this job. Hiring operators graduated from the colleges who hold associate degree is then recommended.

Action errors are primarily based on skills. Action errors are supposed to be originated from forgetfulness or negligence. This type of error happens due to negligence in daily and routine works (Peterson, 1996). Refresh courses are strongly recommended in order to prevent such errors. Details of the task process should be reminded frequently during these refresh courses. Providing a control checklist for the work permit issuance process is also strongly recommended to minimize such errors. Salvendy believes that the probability of forgetfulness error in each step of work is 0.1 whenever there is nothing available to remind the operators. However, the application of a checklist or written task procedure can decrease the probability to 0.003 (Mahdavi, 2007; Ghasemi, 2009). In the present study, 44.4% of errors contributed to action errors. This is much less than of action errors (67.0% of total errors) detected in a similar study conducted by Jahangiri (2005) using PHEA method.

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References