# Research on Influencing Factors and Typical Paths of Power Grid Unsafe Behavior

**Xin Tian, Xinyang Han, and Xiaoling Jin**

**Abstract** As the reliability and safety of technical systems and equipment continues to improve, the reliability of human–machine systems is increasingly dependent on human reliability. The safe state of objects is affected by the escalation of unsafe human actions, reducing the protective effect of objects. It is necessary to emphasize improving the management system of people's intrinsic safety behavior and comprehensively improve the safety level of the whole system on the basis of improving the intrinsic safety of equipment. Only then can the safety work of power enterprises reach a new level and truly eliminate any unsafe conduct. This paper selects the unsafe behaviors in power grid accidents as the research object. By studying the unsafe behaviors of people in 109 domestic and foreign power grid accidents, the semantic analysis method is used to extract and analyze the unsafe behaviors of people in power grid accidents. The influencing factors of power grid unsafe behavior are obtained, and combined with the logical relationship of the influencing factors, the generation path of power grid unsafe behavior is proposed, which provides a reference for improving the ability of power grid behavior management and control.

**Keywords** Power grid · Unsafe behaviors · Semantic analysis · Factors · Mechanism

## 1 Introduction

People are the most active factor in safe production. The "reliable output" of safety behavior can only be guaranteed by fundamentally improving people's safety capability and achieving a controllable, realizable, and efficient safety status. As an important part of the power system, the power grid, similar to other complex industrial systems, has new features such as automation, complexity, opacity, and fault tolerance. Human safety behaviors have a huge impact on the safe operation of the power grid. This paper will study the influencing factors of power grid unsafe behavior,

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analyze the correlation between influencing factors and safe behavior, and analyze the typical generation path of unsafe behavior from the process of safe behavior, so as to provide theoretical and practical basis for power grid safety behavior control.

## 2 Unsafety Behaviors Research in Power Grid

The research history of human reliability (HR) and human error (HE) can be traced back to the 1950s. In terms of the development history of the safety discipline, the research of human factors, human reliability, and human error has made great progress in the late twentieth century and early twenty-first century, with constant new beginnings in theorization, basic methods, industrial application, and case analysis. Because of the subjective differences between people and the drastically different interactions with different environments, any small error can have very serious consequences. Despite relatively short history, domestic safety behavior research is developing rapidly. Literature [1] discusses the design of human–machine interaction of energy management system (EMS) in smart grid under the guidance of human factors engineering. It focuses on the analysis of key technologies of human–machine interaction. Literature [2] analyzes the power operation mode in depth and makes improvements from three aspects, namely situational environment evaluation, control mode, and CPC score. Thus, the uncertainty of the model is reduced. Literature [3] analyzes the characteristics of power system safety accidents and human safety characteristics. It provides the concepts of human error and human reliability for power system operation and analyzes the types, mechanisms, and various safety influencing factors of human error for power system operation in combination with the actual situation in power companies. Related literature [4] establishes a human safety influence factor model for power enterprises through literature review at home and abroad. Literature [5] proposes a human factor analysis and classification system suitable for power accidents in combination with the actual situation and characteristics of safe power generation, based on the human factor analysis and classification system of aviation safety accidents. Literature [6] summarizes the research status of electrical malfunction and the influence of people and things in malfunction and related preventive measures. Literature [7] focuses on analyzing the main human factors causing the misoperation of distribution network dispatching and expounding the specific technology and preventive measures of accident handling in distribution network dispatching operation. Literature [8] proposes the 24 model, in which the causes of accidents are divided into internal and external causes of accident organization, and the accident prevention measures are related to the accident mechanism. On the whole, with the focus on the human factors of various problems related to the specific technology of power system, the domestic research lacks the systematic and comprehensive research on the unsafe behavior in power systems.

# 3 Research on Factors Influencing Unsafety Behaviors in Power Grid

## 3.1 Text Analysis Method of Grid Operation Accident Report Based on Semantic Analysis

At present, accident case data is mainly stored in the form of accident report text. Semantic analysis technology belongs to the field of artificial intelligence. It is a modern advanced big data technology and a technology for natural language processing, which can effectively improve the quality and effect of work. The goal of semantic analysis is to effectively establish models and systems, achieve automatic semantic analysis of each language unit, and achieve a better understanding of text semantics. In this paper, the semantic analysis method is applied to the extraction of unsafe behavior influencing factors in power grid accident reports.

The natural language processing tool ICTCLAS is used to preprocess the text of the power grid operation accident report. Afterward, part-of-speech analysis is performed on all the terms in the accident report, and business template-driven entity discovery (BT) and entity significant factors (FBC) based on business characteristics are performed on the terms of each text in the power grid operation accident report collection. Method of calculation. The method calculates the formula for each term as follows:

$$\mathrm{BT}-\mathrm{FBC}(t_i)=\mathrm{BT}(t_i)*\mathrm{FBC}(t_i)=\mathrm{NT}_j(t_i)*\log(N/\mathrm{BC}(t_i)) \tag{1}$$

Among them: BT-FBC$(t_i)$ represents the BT-FBC value of the current term $t_i$, which is equal to the product of the business template-driven entity discovery B$T(t_i)$ of the term $t_i$ and the entity saliency factor IDF$(t_i)$ based on business characteristics. Any term in accident report j can be calculated by entity discovery BT$(t_i)$ and log($N$/ BC$(t_i)$). $N$ represents the total number of all texts in the text collection, and BC$(t_i)$ represents how many texts in the text collection have term $t_i$. Perform the above analysis on each term in the accident report collection to obtain the term BT-FBC value of the entire text. Then, use these BT-FBC values to build a vector space model for each text. After obtaining the feature vector of each accident report, HowNet is used to calculate the semantic similarity of words. HowNet's formula for calculating the semantic similarity between keywords is as follows:

$$\mathrm{Sim}(T_1,T_2)=\beta/(\beta+\mathrm{dist}(T_1,T_2)) \tag{2}$$

Among them: $T1$, $T2$ represent two sememes; dist($T_1$, $T_2$) represents their path length; $\beta$ is an adjustment parameter, representing the path length when the similarity is 0.5.

Let $V_i$ and $V_j$ be the feature word vectors of two different texts. $V_i = (t_{i1}, t_{i2}, t_{i3}, \ldots, t_{im})$, $V_j = (t_{j1}, t_{j2}, t_{j3}, \ldots, t_{jm})$, and the formula for calculating the semantic similarity of words between texts is defined as follows:

$$\text{TextSim}(V_i, V_j) = \alpha * \text{VectSim}(V_i, V_j) + (1 - \alpha) * \text{CosSim}(V_i, V_j) \tag{3}$$

Among them: $\alpha$ represents the weighting factor of the similarity between word vectors $V_i$ and $V_j$, and its value is usually less than 1; VectSim$(V_i, V_j)$ represents the semantic similarity between word vectors $V_i$ and $V_j$, which is shown by the following formula:

$$\text{VectSim}(V_i, V_j) = \frac{1}{2}\left\{\frac{1}{m}\sum_{k=1}^{m}\max_{1\le l\le n}[\text{sim}(t_{ik}, t_{jl})] + \frac{1}{n}\sum_{l=1}^{n}\max_{1\le k\le m}[\text{sim}(t_{il}, t_{ik})]\right\} \tag{4}$$

Among them, Sim$(t_{jl}, t_{ik})$ represents the semantic similarity between keywords $t_{jl}$ and $t_{ik}$, which is calculated by formula (2). Furthermore, CosSim$(V_i, V_j)$ represents the cosine similarity between word vectors $V_i$ and $V_j$, and the formula is as follows:

$$\text{CosSim}(V_i, V_j) = \left(\sum_{k=1}^{\delta}\text{TFIDF}(t_{ik}) * \text{TFIDF}(t_{jk})\right) \Bigg/ \sqrt{\sum_{k=1}^{m}(\text{TFIDF}(t_{ik}))^2 * \sum_{l=1}^{n}\text{TFIDF}(t_{jk})} \tag{5}$$

Among them: $\delta$ refers to the number of occurrences of the same term in the quantities $V_i$ and $V_j$. Based on the above steps, the similarity matrix of the accident report is obtained. Next, the similarity matrix is used for clustering. The direct *K*-means method of the CLUTO toolkit is used for text clustering. A similar method is used to analyze the power grid accident report obtained by collecting funds, and the causal factors and related data of the accident are summarized.

This study uses the text similarity measurement method of the vector space model and adopts the business template-driven entity discovery (BT) and the business feature-based entity significant factor (FBC) method to calculate the weight of the term in the vector. And the calculation is further based on the semantic similarity of words, which effectively avoids the inaccurate influence caused by only word frequency statistics. Then K-means clustering is used to determine the influencing factors of power grid human accidents with high similarity.

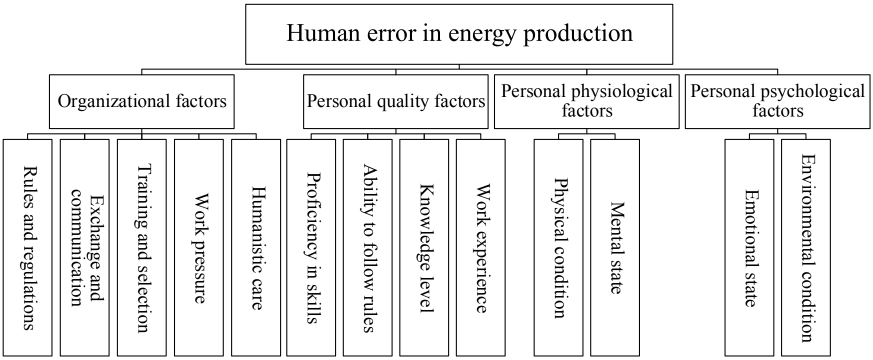


**Fig. 1** Classification of factors of unsafe behaviors

## *3.2 Text Analysis Method of Grid Operation Accident Report Based on Semantic Analysis*

This paper studies the 109 domestic and foreign power grid accidents collected by the text analysis method of power grid operation accident report using semantic analysis and extracts the influencing factors of unsafe behavior of the power grid. Factors influencing unsafe behaviors in power grids can be divided into two types: personal and organizational. According to the type, the factors are shown in Fig. 1.

**Organizational factors**

The factors of organizational unsafe behaviors include rules and regulations, exchange and communication with employees, employee training and selection mode, work pressure brought to employees, and humanistic care for employees.

Rules and regulations refer to safety regulations to be mandatorily followed by operators in energy production and various work instructions, codes, and guiding texts used by professionals. Rules and regulations will influence people's behaviors, and people's safety activities need to learn to adapt to the requirements of rules and regulations. However, "rigid compliance" with complicated and inhuman rules and regulations should be prevented.

Exchange and communication refers to the process of information transmission and exchange inside and outside the organization in oral or written form, formal or informal way. In terms of human factor organization, the key point is the exchange of safety information, two-way and effective communication between management and front-line staff, the management's listening to front-line safety suggestions seriously, unblocked channels, and smooth transfer of work instructions between employees.

The training of safety knowledge and skills will also influence people's behaviors. With regard to training plan, unreasonable time arrangement will bring additional burden to employees. The matching of training content, methods and plans with needs, and acceptance of employees is of great importance. Because of influence of talent selection on safety behaviors, human resources departments should increase the assessment of safety knowledge and skills according to the talent selection mode, thus increasing the enthusiasm of employees to learn and master safety skills.

Owing to work pressure, people's unsafe behaviors are prone to be caused. Improper working hours and staff arrangements, low management efficiency of organizational factors such as rules and regulations, exchange and communication, and safety training will bring great work pressure to employees, thus giving rise to people's emotional fluctuations, and contributing to people's unsafe behaviors such as reduced attention and tangled mind.

The most fundamental way for organizations to enhance human safety is to improve humanistic care. Specifically, emotional care for employees is very important. The starting point of safety management should be changed from simple accident prevention to caring about and cherishing people and people's safety needs, and self-realization needs can be effectively integrated with corporate objective to reduce the probability of unsafe behaviors fundamentally.

**Personal factors**

Personal factors of unsafe behaviors include quality factors, physiological factors, and psychological factors.

At present, among human factors for enterprises' safe production, quality factor is of the most concern. The quality factors influencing the probability of personal unsafe behavior include personal skill proficiency, compliance with rules, knowledge level, and working experience. With high skill proficiency and compliance with safety regulations, the probability of personal misoperation can be reduced to a certain degree. With high knowledge level and abundant working experience, personal behavior ability can be improved effectively, avoiding misoperation resulting from nervousness and other emotions.

Human physiological factors can be divided into human physical state and mental state. The physical state of people is the basis of all human behaviors, including physical factors, perceptual ability, and athletic ability of people. The physical state of people depends not only on people's natural quality, but also on external factors, such as whether the person is hungry and whether the person lacks rest. Factors influencing people's mental state include pathological factors and pharmacological factors. On-site operation of power grid enterprises includes special operation such as high-altitude operation and electric welding. Accordingly, operators should not have occupational contraindications. Moreover, after operators take drugs during illness or under some special circumstances, the drug reaction will have an impact on human error as well.

Psychological factors are critical with regard to influence of people's inner activities on their external behaviors. Psychological factors influencing people's behaviors mainly include character traits, attitudes, motivations, and emotions. Character is a relatively stable psychological characteristic of a person. It is found through the comparative study between accident group and non-accident group that operators should have four-high and two-low character traits: high stability, high persistence, high self-discipline, high constancy, low fantasy, and low tension. Attitude reflects people's views and opinions on things. However, attitude will vary with behaviors. Need generates motivation and motivation dominates behaviors to satisfy needs. A person's emotional change is the most difficult to grasp. People's ability to perceive and judge external signals will be directly influenced by too drastic emotional change.

## 4 Typical Generation Path of Grid Unsafe Behavior

Currently, similar to other complex industrial systems, the power grid presents new features such as higher automation, complexity, non-transparency, and fault tolerance, bringing about drastic change in causal relationship of accidents. Technical failure and unsafe behaviors are necessary but not sufficient conditions for accidents. Accidents will be caused only by coupling multiple factors in time and space. Unsafe behavior is caused by simultaneous occurrence of a series of loopholes instead of an isolated incident. The mechanism of unsafe behaviors as shown in Fig. 2 is established according to the analysis of factors of unsafe behaviors in power grids. The mechanism of unsafe behaviors is, respectively, lack of safety concept (root cause), lack of safety management system (primary cause), personal factors (indirect cause), unsafe actions and unsafe states (direct cause), accidents, and losses. The causes of unsafe behaviors are all organizational factors, and organizational loopholes may give rise to loopholes in personal factors, resulting in potential safety hazards and unsafe behaviors.

The loopholes at the organizational level include defect/complexity of rules and regulations, unsmooth exchange and communication, insufficient/impractical/

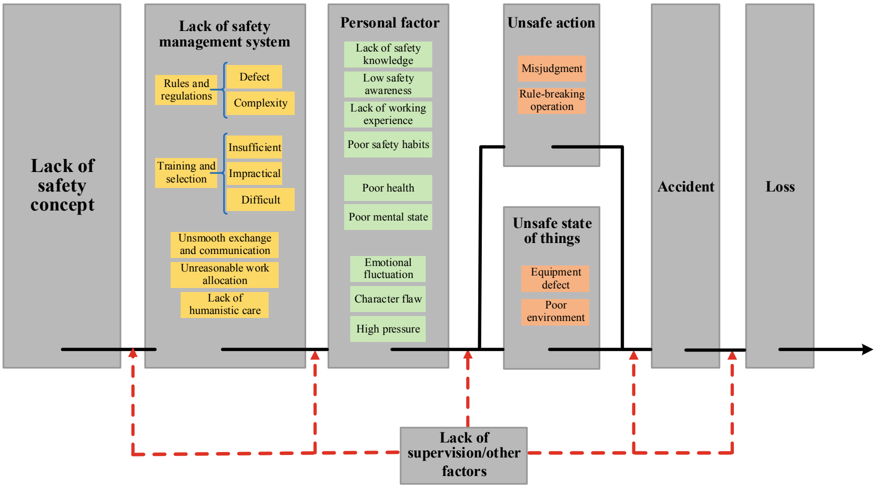


**Fig. 2** Mechanism for unsafe behaviors in power grids

difficult training and selection, unreasonable work allocation, and insufficient humanistic care. Because of defect of rules and regulations, the attention paid by employees to rules may be insufficient, thus causing violation of rules. Owing to complexity of rules and regulations, employees may be restrained at work, resulting in high pressure and poor physical, mental, and psychological state. The lack of effective communication will weaken the efficiency and reliability in production. If training and selection methods are unreasonable, the candidates' physical/character flaws may not be effectively screened, bringing potential hazards to safe production. The fairness and reasonability of work allocation will also influence the physical, mental, and psychological state of employees. Moreover, inadequate humanistic care will give rise to negative emotions of employees, influencing the safety of production process.

The lack at personal level includes three aspects, respectively, personal quality factors, personal physiological factors, and personal psychological factors. The lack at personal level of employees during production will bring about mistakes in action and accordingly unsafe behaviors. With insufficient skill proficiency, employees may operate against rules unintentionally. If the degree of compliance with rules is insufficient, employees may have fluke mind and take risk in operating against rules. If the knowledge level and working experience are insufficient, judgment about the key information may be wrong, leading to operation against rules. Poor health may hinder employees from completing operation correctly, causing operation against rules. Under poor mental state or emotional fluctuation, employees cannot work efficiently, resulting in misjudgment and rule-breaking operation. Employees with character flaws may not be suitable for demanding production work, causing misjudgment and rule-breaking operation.

Rule-breaking operation (mistake) and misjudgment (error) are two kinds of unsafe behaviors. Judgment errors are omissions in consciousness, while rule-breaking operations are omissions in body movements. They are both prohibited in production.

On the whole, organizational factors are the root cause and primary cause of human errors. Personal factors are the indirect and direct causes of human errors which give rise to potential safety hazards to further trigger unsafe behaviors and accidents under lack of hierarchical defense (such as inadequate supervision and influence of environmental factors).

Analyzing the generation ways of human error can facilitate exploration of effective control strategies and minimize human errors.

## 5 Conclusion

The factors and mechanism of unsafe behaviors in power grids were researched in this paper. The factors of unsafe behaviors in power grids include organizational factors and personal factors. The factors of organizational unsafe behaviors include rules and regulations, exchange and communication with employees, employee training and selection mode, and work pressure brought to employees and humanistic care for employees. Personal factors include quality factors, physiological factors, and psychological factors. The mechanism of unsafe behaviors is that lack of safety concept, safety management system, and other organizational factors lead to personal quality, physiological, and psychological factors, giving rise to unsafe actions and unsafe state of objects, ultimately triggering accidents and losses.

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