The analysis of public behavior choice and psychological response under power failure

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Abstract. Since August 2021, large-scale power failure have occurred abroad for various reasons, including the imbalance between coal supply and demand, the pressure of dual control target of energy consumption, and safety operation problems of the power grid, which have negatively affected the national economy and social development. The study on the behavioral choices and psychological reactions of the public under large power outages is beneficial for the government to respond more scientifically to large power outages and mitigate their impacts. The results show that when the average duration of power outage increases, the public's psychological state becomes more anxious and angrier, and their behavior is more inclined to actively seek solutions from relevant authorities. Moreover, there were significant differences in the psychological states and behaviors of different educational groups when power outages occurred. The public with a college education and below are more likely to complain, those with bachelor's degrees tend to have no special reaction when a power outage occurs, those with master's degrees tend to seek help from relevant departments, and those with doctoral degrees tend to solve the problem by their own and consult the government collectively.

Keywords: public behavior, psychological response, power failure

1 Introduction

Since August 2021, large-scale power failures abroad have negatively impacted national economic and social development due to coal and power supply imbalances, dual-control energy consumption targets, and power grid safety concerns. Power grid outages disrupt factory operations, communication, lighting, and have a significant adverse effect on people's lives, economic development, and social stability. Notably, the 2003 blackout in the United States and Canada, the 2012 power outages in India,

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and the 2022 power failure in Taiwan Province had far-reaching consequences, affecting millions of people and causing substantial economic losses. These major power outages disrupt various sectors like communications, healthcare, and transportation, posing threats to public safety and endangering society's well-being.

Xi, the chairman, proposed "accelerating the formation of a new pattern of development in which the domestic cycle plays a major role, and the domestic and international cycles reinforce each other". On the one hand, under the new development pattern of "double cycle", it is necessary to accelerate the implementation of energy transformation, build a new power system, ensure the safety of the power system, and prevent the occurrence of large-scale power outage are the key work in the construction process of a new power system. On the other hand, the electric power industry is the basic industry of national economic development. A safe, stable, and high-quality power supply is the key factor in ensuring the stability of the national economy and people's livelihood. The safe and stable operation of the electric power system is directly related to the production and construction of the country and the order of people's life.

The reverse distribution of energy resources and the growing power demand necessitate the construction of an Ultra-High Voltage (UHV) power grid to achieve regional interconnection. Power failures in such interconnected systems can result in significant losses and have unpredictable consequences for social security, stability, economic development, and people's lives. The complexity of modern power systems contributes to the widespread and rapid occurrence of power grid accidents. Therefore, conducting a comprehensive study on the direct economic losses caused by large-scale power outages is essential. This research not only promotes socio-economic development but also aids in mitigating the social and economic impacts of power failures. It provides valuable insights for the government and power companies to implement timely and scientifically informed measures to manage future power outage events. Additionally, it supports the construction of a new power system capable of addressing these challenges effectively.

When a large area of power failure occurs, it has a serious impact on people's production and life, and the public's psychology and behavior also have different degrees of reaction. The result of the treatment is not only related to the public's evaluation of the government but also may lead to behaviors affecting social stability, such as clustering. Therefore, it is very urgent to study public psychology and behavior after a large area of power failure.

2 Literature review

2.1 Causes of large power outages

In order to summarize the implications for power grid security from power outages, a large number of scholars conducted a series of studies on the existing power outages and classified the causes of power outages into four aspects: natural disasters, equipment failures, power grid management mode, and network attacks. Wu et al. [1] analyzed the power grid blackout in Brazil caused by extreme weather in 2009 from the

three stages of occurrence, development, and recovery of the blackout. Zeng et al. [2] summarized the major power outage in Australia caused by new energy off-grid under extreme weather in 2016. Chen et al. [3] Chen et al. [4] Liang et al. [5] analyzed the direct causes of the power failure in India in July 2012. This paper summarizes the experience of this accident from the aspects of power grid dispatching, safety analysis, grid structure, local backup, protection and automatic device configuration and microgrid, reviews the major international power outages in recent years, and summarizes the similarities and differences of these major power outages. Yi et al. [6] pointed out that the major causes of the 2018 blackout in Brazil were the lack of necessary stability analysis before the accident, defects in security control, and unreasonable configuration of the "third line of defense". Duan et al. [7] analyzed the major power outage in Brazil and put forward reflections from the perspective of power grid planning, construction, and operation.

Mao [8] analyzes the power outage in the United States and Mexico in September 2011 caused by abnormal weather combined with dispatch management model defects, Guo [9] and Li [10] described the massive power outage caused by a hacker attack on Ukraine's power grid in 2015; Gong [11] analyzed two major power outages in Venezuela in March 2019; Zhou [12], Luo [13], Xue [14] conducted research on loss assessment of power outages, power grid restoration strategies and risk prevention mechanisms. Lei [15] introduces the basic situation of the power grid in Taiwan, then describes the operation mode, accident process, and recovery process before the "3.3 Blackout" accident in Taiwan, and analyzes the causes of the accident from many aspects. Li [16] analyzes the main causes of the power failure in Pakistan in January 2021 from the aspects of the grid structure, protection mechanism, and management process. The blackout accident in Texas is very representative, and many domestic scholars have analyzed and summarized its causes (Yue and Zheng [17], Yan [18] and Hou [19])

2.2 Psychological and Behavioral Impacts of Major Power Outages on the Public

At present, there is relatively little literature on the psychological and behavioral effects of power outages, and relevant researches are not in-depth enough. The research on public behavior and risk management in extreme power disasters such as large-scale blackouts is helpful in improving the efficiency of urban emergency response. Shao [20] analyzed the key factors affecting public behavior and their correlation and built a mechanical model of public behavior. Based on scenario inference analysis and the public behavior mechanism model, a public survey questionnaire was designed, and relevant data were collected. This paper studies the public's risk perception and emergency ability status quo, existing deficiencies, and appeals to government departments, and puts forward countermeasures and suggestions for the government and the public to improve the power emergency ability. Fan [21] conducted a questionnaire survey and interviews in seven cities in Guangdong, Guangxi, and Hainan with a large area of power failure from 2014 to 2015, and studied the influence of individual factors on the public's psychological response and behavioral choice in

different stages of power failure through correspondence analysis. And the difference in the group intention and role tendency of the different public. In the early stage of power failure, most of the public's psychological reaction is large, but their behavior tends to be flat. However, with the increase in power failure time, the public's psychological reaction and behavior performance tend to be intense. During the whole period of power failure, the psychological reaction and behavior of low-income groups were more intense; Young and middle-aged people, people with bachelor's degrees, employees of enterprises and public institutions, and workers with an obvious desire to cluster, and groups with high income and high education are more likely to become leaders of collective activities. Cheng [22] extracted four key influencing factors of public behavior, including individual characteristics, material supply, information environment, and psychological environment, on the basis of theoretical and literature research and survey data. According to the characteristics of public behavior under different power failure times, the development process of public behavior is divided into four stages: initial stage, development stage, expansion stage, and explosion stage. The hierarchical analysis method is applied to study the influence intensity of various factors on civic behavior in each stage. Finally, according to the corresponding relationship and weight between these four factors and public behavior, the importance ranking of influencing factors under power disasters is obtained.

2.3 Economic impact of power outages

Many scholars have studied the loss and impact of power outages on society. The user survey method obtains the original data of power outage loss through field research, which is widely recognized by various countries. Guo [23] describes the United States, Canada, the United Kingdom, and other western countries adopting the user survey method to obtain the power failure loss data of different types of users and calculate the relationship between the power failure loss value and the average electricity price. For example, the actual economic loss of 1kWh for commercial and residential users in the United Kingdom is 70 times the average electricity price. Wang et al. [24] propose the power failure loss survey method suitable for Chinese power users, introduces the steps of the questionnaire survey and the specific contents of the user survey in detail, analyze the survey results statistically, and establish the power failure loss model for users. By designing different types of user questionnaires, Bai et al.

2.4 Methods and models related to the study of major power outages

Various methods for assessing economic losses from accidents are discussed, including the constructor's method, generation ratio method, and average price conversion multiple methods. Zhou [25] investigated economic losses in urban power grids, established a comprehensive user loss function, and estimated the losses for different user types. Liu [26] estimated power failure losses by analyzing existing regions and their economic benefits. Li [27] focused on power distribution network outage loss,

determining the economic loss function for different user types through surveys. Wang [28] developed a power failure impact evaluation index system using the AHP method and fuzzy comprehensive evaluation method. Lin [29] proposed a comprehensive assessment method for the impact of power failure on customers. Li [30] investigated short-time power outages in a coastal city, estimating economic losses and identifying characteristics of sensitive users. Zhang [31] introduced block technology to divide the distribution network, determining blackout durations and calculating blackout losses for each area.

3 Data processing and regression analysis

3.1 Data processing

The field research in this study mainly comes from document investigation. The questionnaire mainly adopts single-choice questions, including age, occupation, highest education, annual income range, duration of power failure, psychological feelings, and behavior choices after power failure.

Among them, the article subdivides the public's psychological state and behavior choices when a power failure occurs into the following categories:

(1) The psychological state after a power failure can be divided into five dimensions, from mild to severe, including no response, worry, anxiety, panic, and anger.
(2) Behavior choices after power failure are divided into five dimensions from negative to positive: no special action, trying to solve by oneself, complaining, seeking help from relevant departments, and consulting the government collectively.

According to the individual characteristics of the public, this paper is divided into the following aspects:

(1) Age: Below 18 years old, 18-25 years old, 25-35 years old, 35-45 years old, 45-55 years old, 55 years old and above.
(2) Education: junior college or below, Bachelor, master, Doctor.
(3) Occupations: students, public officials, private employees, self-employed and other freelancers
(4) Average blackout duration: 1-12h
(5) Individual annual income can be divided into less than 100,000 yuan, 100,000 to 200,000 yuan, 200,000 to 300,000 yuan, 300,000 to 400,000 yuan, and more than 400,000 yuan.

In the survey sampling process, we took into account various factors such as regional diversity, occupation, education level, gender, and age to ensure a representative sample and survey accuracy. Among the respondents, the largest proportion falls within the age range of 18 to 25 years old, accounting for 51.02%. Regarding educational background, the majority hold bachelor's degrees, comprising 48.98% of the sample.

3.2 Regression analysis

SPSS regression analysis employs the stepwise regression method to select key influencing factors from a pool of independent variables in classical linear regression. Consequently, the model's coefficients can be utilized to predict dependent variables and examine the relationship between independent and dependent variables. The subsequent results are derived from the regression analysis conducted on the aforementioned independent and dependent variables.

Table 1. Regression analysis of mental state and individual characteristics when a power failure occurs

Model	Standardization coefficient	t	significance
Educational background	-0.031	-0.232	0.818
occupation	-0.048	-0.347	0.730
Ages	-0.148	-1.133	0.263
Income yearly	-0.201	-1.620	0.113
Duration of outage	0.561	4.463	0.000

Table 2. Regression analysis of behavior selection and individual characteristics when a power failure occurs

Model	Standardization coefficient	t	significance
Educational background	-0.069	0.215	-0.048
occupation	-0.283	0.212	-0.208
Ages	-0.247	0.162	-0.226
Income yearly	0.044	0.126	0.049
Duration of outage	0.198	0.072	0.388

Based on Table 1-2, the regression analysis of psychological state, behavioral choice, and individual characteristics during power failures reveals that the variable "average duration of power failure" exerts a positive and significant impact on the public's psychological response and behavioral choices. As the power outage duration increases, the public's mental state experiences heightened anxiety and anger, leading them to actively seek solutions from relevant authorities. From a practical standpoint, it can be inferred that longer blackout durations amplify fluctuations in the public's psychological state and prompt more drastic behavior.

The public's attitude toward power outages reflects their psychological state to some extent through a "psycho-behavioral" adjustment mechanism. As the duration of power outages extends, the public naturally becomes anxious, which influences their perception of how relevant departments handle the situation—both through physical behavior and emotional states such as anger. This may result in radical actions being taken. With prolonged power outages, the public's attitude towards the outage becomes increasingly negative. When faced with a week-long power failure, individuals express their anxiety and anger through observable behaviors.

During regression testing, the overall significance of R-squared is significant. However, due to partial missing questionnaire data and a small sample size, the test results for each parameter are less than ideal. For instance, the influence of educational background, range of occupational annual income, and other parameters on the results does not exhibit complete significance.

3.3 Corresponding relationship analysis

3.3.1 The corresponding relationship between educational background and public psychological reaction.

According to Figure 1, there is no significant correlation between education and the correspondence analysis with the psychological state of the public at this stage, so the correspondence cannot be analyzed. Before the experiment, the authors believed that the public with higher education showed less psychological stress and was more calm and active in choosing appropriate channels to solve the problem, but the results of the experiment were not as expected, which confirmed that there is not a simple positive correlation between education and the psychology of the public during power outages, but a complex psychological mechanism.

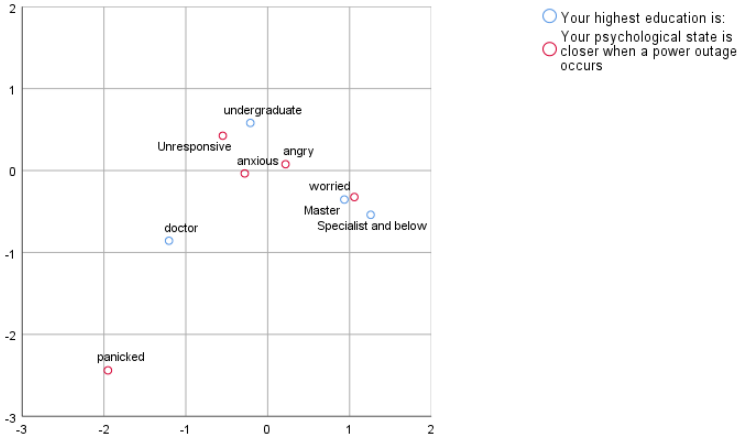

Fig. 1. Corresponding analysis of the highest degree and the Psychological state during power failure

3.3.2 The corresponding relationship between educational background and public behavior choice.

According to Figure 2, the public with college degrees and below are more likely to complain, those with bachelor's degrees are more likely to have no special response, those with master's degrees are more likely to seek help from relevant departments, and those with doctoral degrees are more likely to solve the problem themselves, followed by consulting the government collectively.

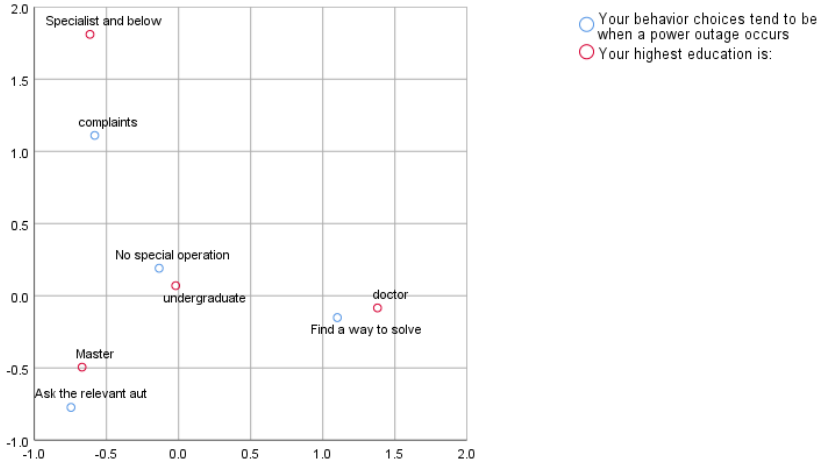

Fig. 2. Corresponding analysis of the highest degree and the behavior tendency during power failure

3.3.3The corresponding relationship between the average blackout time and the psychological reaction of the public.

Based on Figure 3, when the average blackout duration is 0, the public's psychological state is close to non-response. As the average duration of power failure increases to 1 or 2, the public's psychological state tends towards anxiety. When the average power outage lasts for three, the likelihood of worry among the public rises. A blackout duration of 4 is more likely to cause public panic. If the average duration of power outages reaches 6 or more, the public's psychological state tends to shift towards panic.

Overall, the public's response to power outages demonstrates a distinct pattern of transitioning from psychological states to behavior. Negative emotions such as panic and anxiety tend to arise within a short period of time and intensify over time until normalcy gradually returns. This phenomenon can be attributed to various factors, including individuals experiencing frustration upon realizing they are unable to live normally after power restoration. Additionally, prolonged power outages may create a sense of loss that the public struggles to adapt to, resulting in a psychological gap.

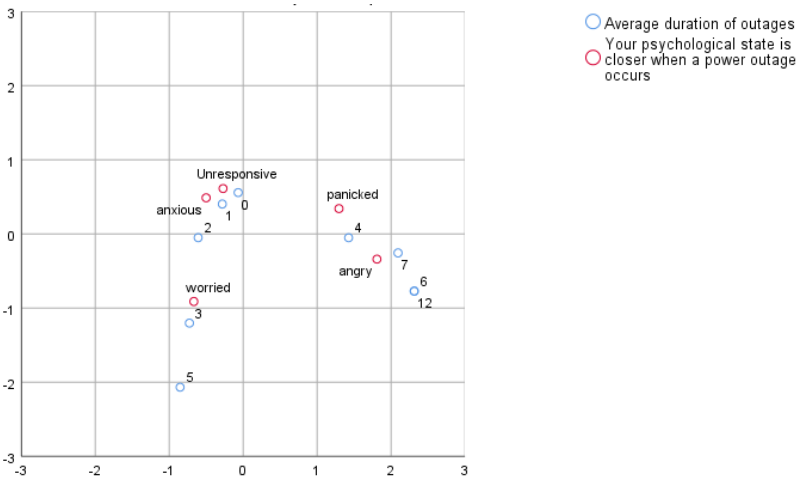

Fig. 3. Correspondence analysis of power outage duration and psychological state during power failure

3.3.4 The corresponding relationship between educational background and public behavior choice.

According to Figure 4, at this stage, there is no significant correlation between the average blackout time and the behavior choice of the public in the corresponding analysis, so the corresponding relationship cannot be analyzed. This suggests that the public's behavior pattern shifts from passive to proactive after a power outage, from reactive to proactive response. It is not difficult to imagine that most people would choose to complain after a power outage lasting more than 6 hours in real life.

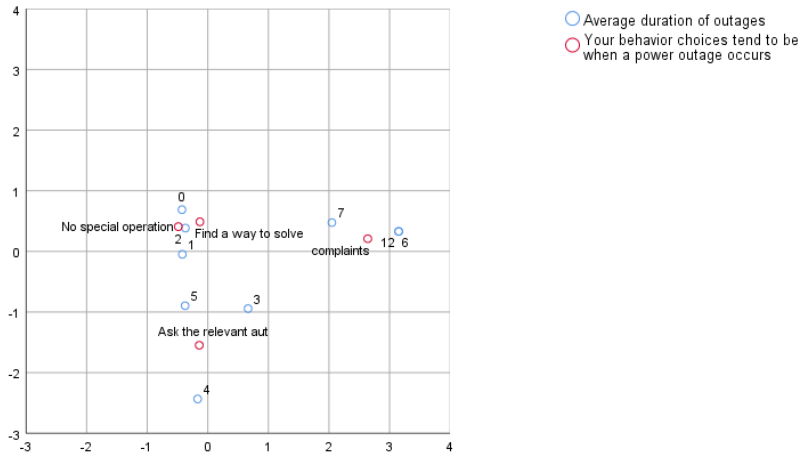

Fig. 4. Correspondence analysis of average duration of outages and behavioral tendency during power outage

4 Conclusions and policy implications

The public's psychological states and behavioral choices varied across outage durations, but the impact of average outage duration on them was significant. Longer outages led to increased anxiety and anger among the public, causing them to actively seek solutions from relevant authorities. This progression suggests that as power outages become more prolonged, the public's psychological state and behavior transition from anxiety to anger and a proactive approach towards seeking assistance.

Additionally, different educational groups exhibit varying psychological states and behaviors during power outages. Specifically, individuals with a college education or lower tend to complain, those with a bachelor's degree react neutrally, individuals with a master's degree seek help from relevant departments, while those with a doctoral degree attempt to solve the issue independently and consult the government collectively.

During emergency management, it is crucial to plan for various stages of power outages. When an outage occurs, providing psychological reassurance and emotional guidance to the affected public is essential. Failure to alleviate panic, anxiety, anger, and other negative emotions during this period can amplify the negative social impact of the outage and potentially lead to severe societal issues. Once power supply is restored, it becomes necessary to guide and redirect groups experiencing negative emotions towards effective diversion and pacification efforts.

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