Data Processing and Research on Priority Strategy of Overhaul without Power Interruption Based on User Outage Loss Assessment

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Abstract. At present, overhaul without interruption is widely used at home and abroad to improve power supply reliability, reducing power outage time and improving labour efficiency. How to determine the priority of overhaul without power interruption in the case of limited resources is the key problem faced by the explosive growth of the number of overhaul without power interruption. In this paper, based on the construction of the user outage loss model, using the method of questionnaire survey, for different types of users to carry out research, using Tobit model truncation idea, pre-processing, and then from the qualitative analysis and quantitative calculation of two aspects of in-depth analysis and research, draw up the outage loss general function formula that can be used by evaluating the outage loss of users in the planned work order, and the priority of overhaul without power outage is determined according to the importance of users.

1. Introduction
At home and abroad generally use live working, bypass working, switching the power supply in a closed loop, emergency power generation vehicle and other technical means of uninterrupted power supply to reduce customer interruption duration. It is the most direct and effective measure to improve the reliability of power supply to carry out uninterrupted working. It not only reduces the power outage time of users, greatly improves the labour efficiency, but also improves service efficiency and quality, and establishes a good corporate image. At the same time, it also promotes the improvement of maintenance methods and better ensures the safety of the power grid.

At present, researches on improving power supply reliability through uninterrupted working mostly focus on uninterrupted working technology or net-working strategy of onsite uninterrupted operation [1-4]. In the case of limited equipment and personnel for uninterrupted operation, priority is simply deter-mined mainly according to the importance of users, interruption duration and other factors. Although it has strong operability, it can not minimize the loss of users caused by power interruption. In addition, priority is determined according to the power shortage, but it is not associated with the loss of users, so the loss of users caused by power interruption can not be evaluated [5-8].

In this paper, based on the construction of user outage loss model, without taking the means of non outage working, the loss of users caused by planned outage is evaluated, and then the loss degree of users in different planned outages is compared. Combined with the user's important level, the priority of uninterrupted working of each project is determined.
2. Customer Outage Costs Model

2.1. Modelling Ideas

Outage costs, also known as power shortage costs, refers to all the economic losses that the society will bear when the power supply is not completely reliable (that is, when the power is cut off or limited due to the interruption or shortage of power supply) or when it is expected to be not completely reliable. According to the research experience at home and abroad, the outage costs of different types of users presents different characteristics, but the trend and range of outage costs of the same type of users with time are similar. Therefore, in the process of modelling, we use classification modelling method to analyse and construct outage costs evaluation models for different categories of users.

In the process of data processing and modelling, Tobit model is used to process the original data [9-10]. The standard form of Tobit model is as follows:

\[ Y_i = \begin{cases} \beta^T X_i + e_i, & \beta^T X_i + e_i > 0 \\ 0, & \text{others} \end{cases} \]  

(1)

Where, \( e_i \sim N(0, \sigma^2) \), \( X_i \) is the explanatory variable of \((K + 1)\) dimension, \( \beta^T \) is the position parameter vector of \((K + 1)\) dimension, and the parameters to be estimated are \( \beta \) and \( \delta^2 \).

2.2. Modelling of Customer Outage Costs Model

Referring to the foreign classification modeling analysis method of customer outage costs, according to the influencing factors of outage costs, such as user (load) type, users load, blackout period, interruption duration, blackout date and whether to notify in advance. This paper focuses on the analysis of outage costs components of industrial users, commercial users, warehousing and logistics users and residents and their classification groups in different situations. Finally, the key influencing factors of outage costs are screened out and the model structure is simplified.

2.2.1. Industrial Users. When constructing the outage costs function for industrial users, the following outage costs are mainly considered:

1) Base value outage costs function for industrial users

1) Planned interruption costs

The outage costs are mainly composed of production and operation profit, workers' wages, recovery and start-up cost, and adjustment of production plan to reduce the loss.

① Continuous production

\[ C_{I\, n}(t) = \left( \sum_{k=1}^{m} \frac{C_{I\, prod\, n\, k}(t) + C_{I\, pay\, n\, k}(t)}{8760} \times t + C_{I\, prem\, n\, k}(t) \right) / m \times R_n \]  

(2)

Where, \( k \) is the \( k \)-th user of the \( n \)-th sub category of industrial user, and \( m \) is the number of surveys of the \( n \)-th sub category of industrial user. \( R_n \) is the maximum load.

② Discontinuous production

With production plan adjustment:

\[ C_{I\, n}(t) = \left( \sum_{k=1}^{m} \frac{C_{I\, pay\, n\, k}(t)}{Working hours per day\times Annual working days} \times t + C_{I\, prem\, n\, k}(t) \right) / m \times R_n \]  

(3)

No production plan adjustment:

\[ C_{I\, n}(t) = \left( \sum_{k=1}^{m} \frac{C_{I\, prod\, n\, k}(t) + C_{I\, pay\, n\, k}(t)}{Working hours per day\times Annual working days} \times t + C_{I\, prem\, n\, k}(t) \right) / m \times R_n \]  

(4)

2) Failure interruption costs

The outage costs are mainly composed of production and operation profit, workers' wages, waste loss, recovery and start-up cost, and adjustment of production plan to reduce the loss.

① Continuous production
Where, \( t_1, t_2 \) represents the start and end time of waste respectively.

2. Discontinuous production
With production plan adjustment:

\[
C_{I_n}(t) = \left\{ \begin{array}{ll}
0, & t < t_1 \\
\frac{C_{I_waste\ n\ k}(t)}{t_2-t_1} \times (t - t_1), & t_1 \leq t \leq t_2 + C_{I\ prem\ n\ k}(t) \\
C_{I_waste\ n\ k}(t), & t > t_2 
\end{array} \right\} / m \times R_n
\] 

No production plan adjustment:

\[
C_{I_n}(t) = \left\{ \begin{array}{ll}
0, & t < t_1 \\
\frac{C_{I_waste\ n\ k}(t)}{t_2-t_1} \times (t - t_1), & t_1 \leq t \leq t_2 + C_{I\ prem\ n\ k}(t) \\
C_{I_waste\ n\ k}(t), & t > t_2 
\end{array} \right\} / m \times R_n
\]

(2) Outage costs function fitting for industrial users
Firstly, when fitting the outage costs of industrial users, the fitting proportion of planned interruption and fault interruption is the ratio of average outage time length of planned interruption and fault interruption. Secondly, when fitting the functions of planned interruption and fault interruption, the load proportion of continuous and discontinuous production enterprises is taken as the addition coefficient. Finally, when fitting the outage costs function of discontinuous production outage (including plan and fault), whether there is production plan adjustment is classified and calculated according to the actual production survey.

Therefore, the outage costs function of industrial users is as follows:

\[
C_I(t) = \sum_{n=1}^{m} R_n \times (C_{I_n}(t) \times k_1 + C_{I_n}(t) \times k_2)
\]

Where, \( K_{I_n} \) denotes the proportion coefficient of the \( n \)-th sub category of industrial users in the whole industrial user category; \( C_{I_n} \) is the outage costs of the \( n \)-th sub category of industrial users; \( k_1, k_2 \) refers to the proportion of planned interruption and fault interruption.

2.2.2. Commercial Users. When constructing the outage costs function for commercial users, the following outage costs are mainly considered:

(1) Base value outage costs function for commercial users
\[ C_{C_n}(t) = \left( \sum_{k=1}^{m} \frac{C_{C\text{merch }n \_k}(t) + C_{C\text{pay }n \_k}(t)}{\text{Annual working days} \times \text{Daily business hours}} \times t + \begin{cases} C_{C\text{damage }n \_k}(t), & t \geq t_{\text{Loss}} \\ 0, & t < t_{\text{Loss}} \end{cases} \right) / m \times R_n \]  

(9)

Where, \( k \) is the \( k \)-th user of the \( n \)-th class of commercial user, \( m \) is the number of surveys of the \( n \)-th sub category of commercial user. \( t_{\text{Loss}} \) is the time when the goods begin to deteriorate.

(2) Fitting of outage costs function for commercial users

Since the advance notice has little influence on the business operation of commercial users, the difference between planned interruption and fault interruption is not considered, so the outage costs function of commercial users is as follows:

\[ C_C(t) = \sum_{n=1}^{11} K_{C\_n} \times C_{C\_n}(t) \]  

(10)

Where, \( K_{C\_n} \) denotes the proportion coefficient of the \( n \)-th sub category of business users in the whole business user category; \( C_{C\_n} \) denotes the outage costs of \( n \)-th sub category of commercial users.

2.2.3. Warehousing and logistics users. When constructing the outage costs function of warehousing and logistics users, the following outage costs are mainly considered:

(1) Base value outage costs function of warehouse logistics users

1) Planned interruption costs

When calculating the costs of planned interruption, the enterprise should be informed in advance and deal with sensitive items in advance, so the cost of leakage or damage of items is not considered.

\[ C_{WL\_n}(t) = \left( \sum_{k=1}^{m} \frac{C_{WL\text{prod }n \_k}(t) + C_{WL\text{pay }n \_k}(t)}{\text{Annual working hours} \times \text{hours}} \times t + C_{WL\text{prem }n \_k}(t) \right) / m \times R_n \]  

(11)

Where, \( k \) is the \( k \)-th user of the \( n \)-th category of warehousing and logistics user, and \( m \) is the number of surveys of the \( n \)-th sub category of warehousing and logistics user.

2) Failure interruption costs

When calculating the costs of failure interruption, the enterprise can not predict the information of failure interruption, so the cost of leakage or damage is considered.

\[ C_{WL\_n}(t) = \left( \sum_{k=1}^{m} \frac{C_{WL\text{prod }n \_k}(t) + C_{WL\text{pay }n \_k}(t)}{\text{Annual working hours} \times \text{hours}} \times t + \begin{cases} C_{WL\text{waste }n \_k}(t), & t \geq t_{\text{Damage}} \\ 0, & t < t_{\text{Damage}} \end{cases} \right) / m \times R_n \]  

(12)

(2) Fitting of customer outage costs function in warehousing and logistics

The outage costs of warehousing and logistics users is similar to that of industrial users. Therefore, the customer outage costs function of warehousing logistics is as follows:

\[ C_{WL}(t) = \sum_{n=1}^{3} k_{WL\_n} \times (C_{W\_n}(t) \times k_1 + C_{W\_n}(t) \times k_2) \]  

(13)

Where, \( k_{WL\_n} \) denotes the proportion coefficient of the \( n \)-th sub category of warehousing and logistics users in the whole warehousing and logistics user category; \( C_{W\_n} \) is the outage costs of the \( n \)-th class of
warehousing and logistics users; \( k_1, k_2 \) is the proportion coefficient of planned interruption and fault interruption.

2.2.4. Residential users. When constructing the outage costs function for residents, the following outage costs are mainly considered:

(1) Basic outage costs function for residents

\[
C_R(t) = \left( \sum_{k=1}^{m} C_{R\_damage\_k}(t) + C_{R\_daily\_k}(t) + C_{R\_potential\_k}(t) \right) / m \times R_n \tag{14}
\]

Where, \( k \) is the \( k \)-th user, \( m \) is the number of resident users investigated.

(2) Fitting of outage costs function for residents

In the process of fitting calculation of outage costs function for residents, it is necessary to consider the different living conditions of residents in normal working days, weekends and holidays, and take them for calculation and fitting respectively.

Therefore, the outage costs function of residents is as follows:

\[
C_R(t) = D_{WD} \times C_R(t)_{WD} + D_{HD} \times C_R(t)_{HD} \tag{15}
\]

Where, \( C_R \) is the outage costs of residents; \( D_{WD}, D_{HD} \) are the proportion of working days and holidays.

2.2.5. Hybrid users. The outage costs of hybrid users also follows the principle of maximum costs, and the average outage costs of users under maximum load is calculated. In curve fitting, the weight of outage costs of various users is the proportion coefficient of maximum load.

According to the outage costs function of different types of users, the comprehensive outage costs function of mixed users can be fitted:

\[
C_{user}(t) = K_{UI} \times C_i(t) + K_{UC} \times C_c(t) + K_{UWL} \times C_{WL}(t) + K_{UR} \times C_R(t) \tag{16}
\]

Where, \( K_{UI}, K_{UC}, K_{UR}, K_{UWL} \) represents the load proportion coefficient of industrial users, commercial users, residential users and warehousing and logistics users in the whole user, namely the maximum load percentage.

3. The General Function of User Outage Costs

Based on the extensive questionnaire survey, this paper investigates the original data of different types of users, uses Tobit model truncation idea to preprocess them, and tries to trace the source of the data, so as to reflect the power consumption characteristics and outage costs variation law of various types of users more completely. The general function formula of outage costs corresponding to outage costs curve is fitted by using the original data of outage costs after preprocessing.

(1) Outage costs function of industrial users

\[
LP_1(t) = 0.4104t^3 - 16.4111t^2 + 321.2014t + 592.104 \tag{17}
\]

(2) Outage costs function for commercial users

\[
LP_2(t) = 107.3235t + 37.7347 \tag{18}
\]

(3) Outage costs function of warehousing and logistics users

\[
LP_3(t) = 0.035t^3 - 1.5282t^2 + 77.3265t + 238.3129 \tag{19}
\]

(4) Outage costs function of residential users

\[
LP_4(t) = 0.1598t^3 - 7.0465t^2 + 87.8882t - 31.4773 \tag{20}
\]

(5) Outage costs function of hybrid users
\[ LP_5(t) = 0.2741t^3 - 11.0695t^2 + 235.4732t + 355.96 \]  \hspace{1cm} (21)

4. Priority Strategy of Overhaul without Power Interruption

4.1. Priority Policy
(1) The user importance level of the planned work order, with the highest level as the user importance level of the planned work order.
(2) According to the general function of user outage costs, the comprehensive user outage costs of planned work order is calculated.
(3) For different planned interruption, the higher the importance level of users, the higher the priority of overhaul without power interruption; for users of the same importance level, the higher the outage costs, the higher the priority of overhaul without power interruption.

4.2. Case analysis
The basic information of the three planned work orders is shown in Table.1.

| Number | Outage Duration(h) | Number of users, outage power | User's importance level |
|--------|-------------------|-------------------------------|------------------------|
| 1      | 4                 | Industrial: 2 households, 1100kw; Commercial: 1 household, 400kW; Residential: 1 household, 200kW | second level |
| 2      | 12                | Industrial: 1 household, 600kW; Hybrid: 1 household, 400kW | No important users involved |
| 3      | 9                 | Industrial: 3 households, 1800kW; Warehousing and logistics: 1 household, 500kW | |

According to formula (17) to formula (21), the user outage costs of planned work orders 1 to 3 are calculated as follows: the user outage costs of work order 1 is 2.035 million yuan, the user outage loss of work order 2 is 2.024 million yuan, and the user outage costs of work order 3 is 3.6481 million yuan. According to the priority strategy of overhaul without power interruption, the priority of the three planned work orders in the example is: order 1 > order 3 > order 2.

5. Conclusion
In this paper, based on the construction of user outage costs model, by means of extensive questionnaire survey, different types of users are investigated. Using Tobit model truncation idea, the data is preprocessed, and then from the qualitative analysis and quantitative calculation, the general function formula of outage costs is fitted. By using the general function formula of outage costs, the outage costs of users in the planned work order can be evaluated, and the priority of overhaul without power interruption can be determined combine with the importance level of users.

Acknowledgments
This work was supported by the science and technology project of China Southern Power Grid Co., Ltd. The project’s name is “Research on all level and all service overhaul without power interruption technology of distribution network”. Project Number is 090000KK52180088.

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