Research on thermal load classification and safeguard implementation

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Abstract. Under the current economic development, the contradiction between the shortage of energy and the increasing energy demand of the society becomes more and more prominent, which brings great hidden danger to the energy security of our country. In order to reduce the loss caused by the interruption of power supply, energy management measures corresponding to the importance of user load need to be developed. However, the existing load classification system only involves electric power and does not clearly distinguish the importance of thermal and cooling loads, making it difficult to guarantee the safety of power supply of important cooling and thermal loads in emergency situations. With reference to the principle of classified safeguard of electric load, this paper proposed the idea of thermal load classification with the analysis of the personal injury, economic loss and political significance. It provides important ideas and methods for the construction of comprehensive classification and classification of energy and complete standard system of energy security.

1. Introduction

With the increasing dependence of China's development on energy, energy security has become an important factor related to international status, economic structure and social stability. Energy supply security is a key issue in energy security, which bears on China's overall modernization and development. On the one hand, China's energy consumption is huge, energy resources are poor, and the international political and economic environment formed which relate to energy is very complex, the amount of energy supply is often unable to meet the needs of social development, resulting in the energy supply accidents occur from time to time. On the other hand, the energy system is becoming more and more complex in structure and scale. Although the reliability of the power supply network is becoming higher and higher, the power outage accidents caused by extreme weather, natural disasters, equipment failures and other reasons cannot be completely avoided. In order to reduce the probability of power supply accidents and reduce the loss caused by accidents, energy management measures corresponding to the importance of user load should be formulated.

Cooling, thermal, electricity and gas are the secondary energy frequently used in people's daily life, among which electricity is the most widely used, most convenient and cleanest of the secondary energy. Therefore, the research on power load classification and power supply guarantee measures is the most perfect system at present. The standard "Specific configuration of power supply and self-
emergency power supply for important power users” (GB/T 29328-2018) [1] stipulates the configuration principles and main technical conditions of power supply and self-provided emergency power supply. The standard “code for design electric power supply systems” (GB50052-2009) [2] divided the power load into three levels according to the requirements for power supply reliability and the political and economic losses caused by the interruption of power supply. The standard “code for electrical design of machine factory” (JB/J 6-1996) [3] specifies in detail the load levels and support principles of important electrical equipment commonly used in mechanical plants. The standard "code for electrical design of civil buildings" (JBJ 16-2008) [4] specifies in detail the classification and guarantee principle of main power load and fire power load of various types of buildings in civil buildings. The above electrical load classification standard system reflects the requirements of different levels of load on the reliability of power supply, provides a sound theoretical guidance on how to choose the power supply mode in line with the actual level, and is of great significance to improving the security of energy supply in China.

In addition to the electrical load, the interruption of cold and hot load will also cause serious casualties and economic losses. It is regrettable that there is no classification and safeguard system for the importance of cold and hot loads. It is regrettable that there is no classification and safeguard system for the importance of cold and hot loads. The important cold and hot load can be divided into two categories: the cold region or the need to strictly control the temperature of the building heating, cooling and high risk production enterprises required cold and hot load. The data show that the interruption of the anti-freezing heat load in the shaft of coal mining enterprises will cause the well head to freeze. Data center cold supply interruption, will make the server due to high temperature damage and shutdown, resulting in huge economic losses; important departments in general hospitals have strict requirements on temperature. For example, the temperature of intensive care unit is 24±1.5℃. If there is a temporary interruption of heating or cooling, it is likely to cause casualties. It can be seen that the emergency protection of various cold and hot loads is also an important part of improving the safety of energy supply.

At present, although the detailed classification and classification of cold and hot load and the guarantee system have not been established, some important cold and hot load has attracted the attention of the society. For example, in the standard "Specific configuration of power supply and self-emergency power supply for important power users" (GB/Z 29328-2018) [1], the air-conditioning load is included in the primary power load of the electronics and manufacturing industries. On the one hand, this reflects the importance of cold and hot load guarantee in production and life, there is a need for important cold and hot load guarantee in production enterprises. On the other hand, it just reflects that due to the lack of classification and guarantee system of cold and heat load, the demand of cold and heat load can only be converted into the demand of electric refrigeration and electric heating. Unfortunately, the energy conversion without considering the cascade utilization of energy is also a waste of energy.

To sum up, the following two major problems of the current load classification system deserve special attention:

1. The classification and guarantee system of electric load is perfect, but there is no study on the importance classification and guarantee of other secondary energy. Only considering the electric load cannot meet the actual demand of energy security supply.

2. The conversion of high grade energy to low grade energy inevitably leads to a large amount of unnecessary energy consumption, which is not in line with the development trend of energy cascade utilization and cannot meet the requirements of energy conservation and emission reduction.

Therefore, the current single power load grading system can no longer meet the needs of social development, so it is urgent to consider the load grading and guarantee system of comprehensive energy supply to ensure energy security and standardize production.

In view of the perfect power load classification system, the classification method is in line with the actual demand. Therefore, this paper takes thermal load as the research object, adopts the method of benchmarking analysis, and puts forward the idea of thermal load classification and safeguard method by referring to the existing principles of electrical load classification and safeguard. In this paper, the
study on the classification of heat load and the method of safeguard is helpful for the thermal units to respond quickly in the case of interruption of heat supply, give priority to the protection of important heat load, and reduce the accident loss. It provides important ideas and methods for further ensuring the security of energy supply, constructing the comprehensive classification and classification of energy and guaranteeing the complete standard system.

2. Thermal load classification method

2.1. Load classification principle reference

(1) Electrical load classification principle reference in China

The standard “code for design electric power supply systems” (GB50052-2009) [2] divides the power load into three levels according to the consequences of personal injury and economic loss caused by the interruption of power supply and the political significance of the power unit itself. Therefore, this paper refers to the classification principle of electrical load, and selects three elements of personal injury, economic loss and significant political unit for comparative analysis.

Although the power load classification principle divides the power load into three levels through the consequences caused by the interruption of power supply, the loss has not been clearly quantified. For example, there is a definition of casualties caused by the particularly important load in the first-level load, and there is also a definition of personal injury caused by the first-level load. The distinction between the two is not described in detail. In the principle of first-grade load classification: the interruption of power supply will cause great political and economic losses; In the principle of secondary load classification: the interruption of power supply will cause a large economic loss, but there is no specific parameter to measure what is a major economic loss and what is a large economic loss. Therefore, in addition to the electrical load classification system, this paper will also refer to other classification methods.

(2) Electrical load classification principle reference in foreign countries

In western countries, there is no regulation on load grading according to the consequences of power outages. Because in a market economy, projects are funded by business owners and do not require government approval. The way for western countries to determine power supply guarantee is to compare the economic loss caused by power failure every year with the increased investment to reduce power failure loss and improve power supply reliability [9]. If the power failure loss is greater than the investment to improve power supply reliability, the power supply system shall be improved for this load and emergency power supply equipment shall be equipped.

IEC 60364-7-710-2002 [9] classified loads into 5 grades according to the interruptable time: 0s, less than 0.15s, 0.5s, 15s and greater than 15s, not according to the consequences of a load interruption.

(3) China's safety accident classification standards

According to the regulations on the “report and investigation of production safety accidents issued” [10] by the state council, production safety accidents are divided into four levels according to the casualties and economic losses caused by them: especially serious accidents, major accidents, major accidents and general accidents. According to the classification standard, the number of people killed, the number of people seriously injured and the number of economic losses are specified in detail.

The standard "classification standard of enterprise employee casualty accidents” [14] uses the working days of personnel loss to make detailed provisions on the definition of death, serious injury and minor injury of personnel.

2.2. Thermal load classification method and calibration analysis

The heating project provides the power support for the production of industrial enterprises, and provides the appropriate temperature for the social service industry, business and residential users. Once the heating is interrupted, it will lead to frostbite; Social production activities cannot be carried out normally, bringing property losses to enterprises; High risk industrial enterprises may cause a
series of serious consequences such as fire, explosion and other major accidents due to uncontrolled reaction.

Based on the previous load grading standards and other grading principles, taking the casualties and economic losses caused by the interruption of heating and the political and economic significance of the thermal unit itself as the grading factors, the following classification methods of thermal load are proposed:

Table 1. Thermal load classification principles

| Load level     | Classification principles                                                                 |
|----------------|------------------------------------------------------------------------------------------|
| First order load | The interruption of heating will cause personal injury                                    |
|                | The interruption of heating will cause significant economic losses                        |
|                | The interruption of heating will cause great economic loss to enterprises of great political and economic significance |
| Second order load | The interruption of heating will cause great economic loss                                |
|                | The interruption of heating will affect the normal work of enterprises of great political and economic significance |
| Third order load | Those who do not belong to the first and second order load shall be the third order load |

2.2.1. Comparative analysis of personal injury elements

(1) Personal injury measurement standards

China is a socialist country, the government must be involved in personal and production safety issues to take mandatory provisions. Personal injury means a situation in which three or more persons are killed or more than ten persons are seriously injured. Death of personnel refers to the situation where the working days of personnel lost due to interruption load are more than 6000 working days (including 6000 working days), serious injury of personnel refers to the situation where the working days of personnel lost due to interruption load are more than 105 working days (including 105 working days) and less than 6000 working days [14].

(2) Personal injury calculation method

The personal injury caused by interruption load can be divided into death, serious injury and minor injury. With reference to the calculation model of casualties in earthquake disasters [15] and the expected model of casualties in power failure [16], the casualty model of interruption load is proposed:

\[
N_d = p_h \rho S_d
\]

\[
N_j = p_h \rho S_j
\]

\[
N_k = p_h \rho S_k
\]

Where: \(N_d, N_j\) and \(N_k\) are the number of deaths, serious injuries and minor injuries in the evaluation area respectively; \(p_h\) is the probability of the accident after the interruption of load, \(\rho\) is the personnel density of the evaluation area. \(S_d, S_j\) and \(S_m\) are the area of death injury, serious injury and minor injury in the event of an accident.

1) Accident probability

The probability of accidents caused by interrupted energy supply is usually related to the time of energy interruption. The longer the energy interruption, the greater the probability of accidents.

\[
p_h = \frac{E}{r_i}
\]
Where, $T_2$ is the interruption time of power supply, and $T'_2$ is the interruption time of load

2) Personnel density

Refer to “hvac design manual” [17], and select the personnel density of typical buildings as shown in the table below:

| Building type | office | school | hospital | factory | market | theater |
|---------------|--------|--------|----------|---------|--------|---------|
| Personnel density (number/m²) | 0.1 | 0.5 | 0.1 | 0.3 | 0.5 | 1 |

3) Area of personal injury

According to the interruption of heating users, the resulting personal injury accident is different. The calculation of the area of personal injury with different heat units should be based on the actual production situation.

2.2.2. Benchmarking analysis of economic loss factors

(1) Economic loss measurement standard

Significant economic loss is defined as the sum of production loss and equipment loss caused by the interruption of the load heating is greater than the increase in the cost of improving the reliability of heating for the load.

Large economic loss is defined as the sum of production loss and equipment loss caused by the interruption of the load heating is more than 10 million yuan but less than the increase in the cost of improving the reliability of heating.

The influence of normal work is defined as the sum of production loss and equipment loss caused by the interruption of the load heating is less than 10 million yuan.

(2) Calculation method of economic loss

There are many factors influencing the economic loss, the calculation is complicated, and there are strong personalized differences according to the different units of energy use. Different types of energy use unit load characteristics are different, resulting in different economic losses. Therefore, the user survey method is adopted to calculate the economic loss of users.

2.2.3. Comparative analysis of units of great political significance

Political and economic significance is an important factor to measure the consequences of the interruption of heat supply, and there are many influencing factors, complex contents and lack of relevant systematic research, so it is difficult to assess whether the relevant units have significant political and economic significance in a short period of time. The identification of power supply units of great political significance is carried out by power supply enterprises and users organized by relevant governments under the leadership of provincial government departments. Its classification is more reliable and has reference value. Therefore, this paper temporarily quotes the list of units of great political significance listed in the electric load classification principle.

The unit which has significant political, economic meaning including large financial center, a large computing center, large communication/broadcasting center, important transport hub, important communication hub, the guesthouse, the frequently used in international activities of large Numbers of people concentrated in public places, stadium, a museum and national hall/state guesthouse/conference center, administrative center/disaster prevention center, the party and the judicial organ, national defense, international organizations, such as all kinds of emergency command center.
3. Important heat load assurance

3.1. Important heat load guarantee principle
Heating can be divided into urban central heating, district heating, building heating and end heating. According to the characteristics of different heating methods, the load guarantee principles are as follows:

| Load level | heating mode          | guarantee principle                                                                 |
|------------|-----------------------|-------------------------------------------------------------------------------------|
|            |                       | design of pipe system                                                               |
| First order load | urban central heating | Two independent heating pipe networks are connected to urban high temperature heating pipe networks |
| district heating |                       | If there are two or more independent heat sources, two independent heating pipe networks are used to connect the two independent heat sources for heating. If there is only one heat source in district heating, two independent pipe networks are used to connect the heat source for heating |
| building heating |                       | Same as the principle of regional heating                                             |
| end heating |                       | none                                                                                |
| Second order load | urban central heating | Same as the principle of first order load guarantee                                 |
| district heating |                       |                                                                                     |
| building heating |                       |                                                                                     |
| end heating |                       |                                                                                     |
| Third order load | urban central heating | Depending on the production conditions                                             |
| district heating |                       |                                                                                     |
| building heating |                       |                                                                                     |
| end heating |                       |                                                                                     |

3.2. Requirements for selection of emergency heating equipment
The primary goal of emergency heating is safety. In order to respond to the demand for emergency heating, the equipment selection should also consider the following factors in addition to meeting the basic requirements of heat temperature and heat pressure:
(1) Reliable equipment

The reliability of the equipment refers to the ability of the equipment to perform the specified function without failure in a certain period of time and under certain conditions. The commonly used device reliability calculation formula is as follows:

\[
R(t) = e^{-\lambda t}
\]  \hspace{1cm} (5)

Where, \( R(t) \) is the reliability of the equipment, \( \lambda \) is the failure rate of the equipment, and its value is the ratio of the failure times of the equipment to the sample time.

(2) Equipment available

Availability of equipment refers to the probability that the equipment will work properly at any time of operation, and is usually measured by the failure time of the equipment. IEEE STD 493-2007 defines device availability as follows:

\[
A = \frac{MTBF}{MTBF + MTTR}
\]  \hspace{1cm} (6)

Where, \( A \) is the availability of equipment, \( MTBF \) is the mean time between failures, and \( MTTR \) is the mean time to repair. Considering the actual situation of emergency heating, the failure time here should be the time when the equipment cannot meet the output requirements normally, including not only the equipment failure maintenance time, but also the time when the equipment cannot work normally due to the unstable heat source.

(3) Equipment response time

The response time of the equipment is the interval between the start of the equipment and the successful heating of the equipment under emergency circumstances. The response time of the equipment should be less than the interruption time of the heat load. Therefore, the response time of the equipment can be expressed as follows:

\[
t = LIT - ERT > 0
\]  \hspace{1cm} (7)

Where, \( LIT \) is the Load interruptible time; \( ERT \) is the Equipment response time.

(4) Safe use of fuel

The safety of fuel includes three aspects: ignitability, explosiveness and toxicity.

Flash point is a safety index to evaluate the ignitability of flammable liquids and a volatile index to evaluate the ignitability of flammable liquids. The flash point of combustible liquid is generally required to be 20 ~ 30℃ higher than the service temperature, so as to ensure the safety of use and reduce volatilization loss. The explosion concentration limit is a safety index to measure the explosivity of fuel. The explosion limit is not a fixed value, which is affected by ambient temperature, ambient pressure, container material size, and inert medium. Therefore, fuel needs to be selected according to the actual production. The toxicity of fuel mainly refers to whether a large amount of \( SO_2 \), \( NO_2 \), \( CO \) and other toxic substances will be produced during the use of fuel. In order to ensure the safety of personnel in the process of using emergency equipment, equipment selection should try to avoid the equipment that will produce a large number of toxic substances.

According to the above principles, several typical heating equipment are selected to explore whether they can be used as emergency equipment. The results are shown in the following table:
Table 4. Emergency equipment selection

| Heat source     | Equipment                  | Can be used as emergency heating equipment |
|-----------------|----------------------------|------------------------------------------|
| **Fuel combustion** | oil burning boiler         | Yes                                      |
|                 | Gas infrared radiator     | No, fire and carbon monoxide poisoning risk is great |
| **Electric heating** | Electric heater           | Yes                                      |
| **Waste heat**  | heat recovery boiler       | Yes                                      |
| **Heat pump**   | Air source heat pump      | The air source heat pump is suitable for hot users in central and southern regions, and the water source heat pump is suitable for areas with water resources |
|                 | Water source heat pump    | The air source heat pump is suitable for hot users in central and southern regions, and the water source heat pump is suitable for areas with water resources |
| **geotherm**    | geothermal heating        | Only areas with geothermal resources are available |
| **solar energy** | Solar water heater        | No, Solar water heater is greatly affected by the weather, and does not meet the requirements of equipment availability |

4. Conclusion

In view of the present important load ignore cold heat load problems in classification, combining the development trend of future energy of fine and professional supply, calls for energy conservation and emissions reduction, energy cascade utilization, this paper, based on the consequences of interrupt heating heat load classification principle is put forward, and then according to the load importance to set up the corresponding load security principle, and make constraints for heating appliances. The method of heat load classification and guarantee proposed in this paper is of great significance to improve the reliability of comprehensive energy supply, promote energy conservation and emission reduction, and also provides research ideas for perfecting the formulation of comprehensive energy classification and classification standards.

The thermal load classification and support principle proposed in this paper is limited by the research level and other factors, and there are still many problems that need to be further studied:

1. The next step should be put forward in this paper the heat load of classification and principles of security with thermal unit classification results are based on the actual application, according to the different types of industry classification research in hot demand, further verify the feasibility of this principle, and according to the actual production for further optimization, according to the load classification result to perfect the related industries with hot specification.

2. In the process of studying important load emergency support, this paper found that a large amount of equipment reliability data, equipment economic parameters, equipment response time and other data were needed as model selection support. Therefore, it is necessary to further establish and improve the database of emergency heating equipment so that users of different loads can choose suitable emergency heating equipment for production.

3. The thermal load classification principle proposed in this paper is conducive to the rapid response of thermal units in the case of interruption of heating, ensuring important thermal loads and reducing accident losses. However, when the interruption of heating accident expands to a certain area, or even the whole city, it is necessary to first select the important units of heating from the numerous units, and give priority to ensuring the heating safety of the important units. Therefore, the importance classification of heat units should be further studied.
Acknowledgments
This work was financially supported by scientific research program of Shanghai municipal science and technology commission (18DZ1203304) and National natural science foundation of China (71403162).

References
[1] GB/T 29328-2018. “Specific configuration of power supply and self-emergency power supply for important power users”.
[2] GB 50052-2009. “code for design electric power supply systems”.
[3] JBJ 6-1996. “code for electrical design of machine factory”.
[4] JGJ 16-2008. “code for electrical design of civil buildings”.
[5] Kai-le Zhou, Shan-lin Yang, Chao Shen. “A review of electric load classification in smart grid environment”. Renewable and Sustainable Energy Reviews, vol. 24, pp: 103 - 110, 2013.
[6] Rui Li, Yue Li, Jian Su, Xiande Bu, Yiming Hou. “Power Supply Interruption Cost of Important Power Consumers in Distribution Network and Its Emergency Management”. Power System Technology, vol. 35 (10), pp: 170 - 176, 2011.
[7] Kariuki, K.K., Allan, R. N. “Evaluation of reliability worth and value of lost load. Generation Transmission and Distribution”, IEEE Proceedings, vol. 143(02), pp:171-180, 1996.
[8] Houyu Wang. “Reviewing on Making of Load Grading Rules in Design Code”, Building Electricity, 2006 (05): 4 - 6.
[9] IEC 60364-7-710-2002.
[10] decree no. 493 of the state council of the People's Republic of China. report and investigation of production safety accidents issued.
[11] Zhifeng Liu. “The harm of mine shaft icing to mine and its preventive measures” Science & Technology Information, 2012 (13): 412.
[12] Yunjuan Hou. “Research on Risk Assessment and Layout Optimization of Heat Supply Engineering in Chemical Industry Park”, Beijing Institute of Technology, 2015.
[13] Litao Yan. “Effects of indoor air temperature and humidity on patients in intensive care unit”, Shanxi Medical Journal, vol. 41 (06), pp: 580 - 581, 2012.
[14] GB/T 6441-1986. Classification of casualties among employees.
[15] Shansuo Zheng, Ruiming Zhang, Fei cheng, Li Long, Yan Zhou, Jie Zheng. “World Earthquake Engineering”, World Earthquake Engineering, vol. 35 (01), pp: 87 - 96, 2019.
[16] Zifa Liu, Zaibao Zhang, Bin Yang, Zhidong Wang, Fang Qi. “Evaluation of Great Blackout Social Comprehensive Loss of Power Grid”. Power System Technology”, vol. 41 (09), pp: 2928 - 2940, 2017.
[17] hvac system design manual.
[18] Zhiyong Liu. “The research on pool fire model and injury characteristics”. Fire Science and Technology, vol. 28 (11), pp: 803 - 805, 2009.
[19] Tianyi Yang. “Discussion about the Electrical Load Classification and Power Supply”. Building Electricity, vol. 28 (09), pp: 7-11, 2009.
[20] Dr. Pé ter Ká dar, Mark Karacsi. “Emergency heat and power supply with mCHP device in global blackout”. 2015 IEEE 10th Jubilee International Symposium on Applied Computational Intelligence and Informatics, IEEE, 2015.