Research on Classification and Application of Comprehensive Energy Load of Important Users

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Abstract. Important load users are the lifeline of urban development, and their energy security system is not yet complete. According to the existing power load classification guarantee principle, the comprehensive energy load classification and guarantee measures of important users are discussed. At the same time, it analyzes the characteristics of existing security resources, selects the semiconductor manufacturing industry as the application scenario, and explores more possibilities for flexible configuration of security resources for users with important loads. Finally, the distributed energy system is proposed as a security resource for semiconductor companies, and it is used as a backup with the mains, replacing conventional diesel generating sets, and switching from cold standby to hot standby. This will reduce the initial investment in enterprise construction, improve the utilization of security resources, and the reliability of energy supply for important load users.

1. Introduction

With the rapid development of the current national economy, the application of energy has penetrated all areas of society. Energy security has become an important factor related to a country's international status and social stability. The security of energy supply is related to the overall situation of China's modernization and development. Although the reliability of the current energy supply pipeline network is getting higher and higher, energy outage accidents caused by natural disasters, equipment failures, and other reasons still cannot be completely avoided.

The rapid development of my country's economy and society is inseparable from the contributions of important industries and users. Important load users are the main pillar of social and economic development. If an interruption occurs in the process of energy use by users of important loads, it may have a major hindrance to the development of the local economy. Important electricity users account for less than 1% of my country's electricity users, but their electricity consumption exceeds 70%, and their contribution to the national economic GDP exceeds 40%. Therefore, when energy supply is interrupted, priority should be given to ensuring the energy safety of important load users. To reduce the probability of energy supply accidents for important load users and reduce accident losses, it is necessary to formulate corresponding energy management measures according to the importance of user loads.

At present, the research on power load classification and power supply guarantee measures is the most complete. The interruption of cooling and heating loads can also cause serious casualties and economic losses. The importance classification and guarantee system of cooling and heating loads is still lacking. The current common solution is to convert the cooling and heating load demand into the electric load demand for electric refrigeration and electric heating regardless of the cascade utilization of energy is a great waste of resources. This paper analyzes the electric load classification and guarantee
principles against the standard and discusses the formulation of a comprehensive energy load classification and energy use guarantee system. The establishment of this system is conducive to ensuring the safety of energy consumption for important load users, and also conducive to improving energy efficiency.

2. Comprehensive energy load classification and guarantee

2.1. Comprehensive energy load classification principle

The traditional electrical load classification cannot fully reflect the reliability of the energy supply of common secondary energy sources including cold and hot electricity, and the method of converting high-grade energy to low-grade energy does not conform to the development trend of energy cascade utilization. Under the premise of ensuring the safety of energy supply for important load users, this paper adopts the method of benchmarking analysis and proposes a classification principle suitable for comprehensive energy loads. The classification results should meet the needs of daily production and life.

The standard "Code for Design of Power Supply and Distribution System" (GB50052-2009) [1] divides the electrical 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 electricity user itself. The specific classification principles are shown in the following table [2]. Therefore, this article refers to the principle of electrical load classification, selects three elements of personal injury, economic loss, and major political units for benchmarking analysis. Taking the casualties, economic losses, and the political and economic significance of the heat-using unit itself caused by the interruption of the comprehensive supply of energy including cold, heat, and electricity as grading elements, the following methods for grading the comprehensive energy load are proposed:

| Load level   | Classification principle                                                                 |
|--------------|------------------------------------------------------------------------------------------|
| Primary load | Interruption of energy supply will cause personal injury                                  |
|              | Interruption of energy supply will cause major economic losses                            |
|              | Interruption of energy supply will cause greater economic losses to units of major political and economic significance |
| Secondary load| Interruption of energy supply will cause greater economic losses                          |
|              | Interruption of energy supply will affect the normal work of units of major political and economic significance |
| Three-level load | Those who do not belong to the first and second load shall be the third load             |

2.2. Principles of Comprehensive Energy Load Guarantee

According to the importance of the load, formulating energy management measures that match it is an important means to reduce the probability of energy supply accidents and reduce energy supply accident losses [3]. Therefore, this article will formulate corresponding safeguard measures for different levels of load based on the classification results.

2.2.1 Principles of Electric Load Guarantee. The standard "Code for Design of Power Supply and Distribution System" (GB50052-2009) stipulates the protection principle of electric load, and the user load is guaranteed in strict accordance with the guarantee principle in the specification.

2.2.2 Principles of cooling and heating load guarantee. Heating methods can generally be divided into four types: urban centralized, regional, building and terminal. When formulating heat load guarantee principles, different methods should be adopted according to the different heating methods. Regardless of the method of supply, the primary load should be connected to the urban high-temperature heating pipe network with two independent heating pipe networks, and equipped with electric heating equipment,
gas boilers, oil boilers, and electric heating boilers according to actual production needs. Water source heat pump, air source heat pump, CCHP and other emergency supplementary measures; for the secondary load, two independent heating pipe networks are used to connect to the urban high temperature heating pipe network for heating; the third level is determined by itself according to the production situation.

3. Classification and characteristics of conventional security resources

3.1. Emergency power supply equipment

Emergency power supply equipment is mainly divided into static energy storage devices, dynamic energy storage devices, engine-driven generator sets, and mobile power generation equipment. Among them, static energy storage devices include UPS, EPS, and batteries; dynamic energy storage mainly refers to flywheel energy storage; engine-driven generators mainly refer to diesel power generation systems, internal combustion engines, and gas turbines; mobile power generation equipment is currently electric vehicles. This article mainly introduces static energy storage and engine-driven generator sets.

3.1.1 Static energy storage. (1) UPS is a kind of uninterrupted power supply equipment, it connects the battery (mostly lead-acid maintenance-free battery) with the host, and converts the direct current into mains power through the inverter. Has been widely used in industry, communications, national defense, hospitals, radio and television, and other fields. The reliability of its UPS [4] is shown in the following table:

Table 2 UPS reliability data

| Sample time/year | Failure rate (times/year) | Mean time between failures /MTBF (h) | Mean repair time /MTTM (h) | Average downtime /MDT (h) |
|------------------|--------------------------|-------------------------------------|---------------------------|--------------------------|
| 553.1            | 0.00092                  | 9499764.7                           | 3.8                       | 3.688                    |

(2) Fire emergency power supply (EPS) refers to the power supply that can continue to supply emergency fire equipment when the mains power fails. EPS is widely used in the field of building electrical and emergency lighting, fire protection, and other occasions that require an emergency power supply, and is called an important part of the "urban lifeline system".

The performance comparison between EPS and UPS is shown in the following table:

Table 3 EPS and UPS performance comparison table

| Index             | EPS                                          | UPS                                          |
|-------------------|----------------------------------------------|----------------------------------------------|
| Structure         | Inverter redundancy                          | Inverter redundancy is small                  |
|                   | Sleep state when the grid power supply is normal, power consumption is less than 0.1% | It also works when the grid power supply is normal, and its efficiency is only 80% to 90% |
| Power saving      | Sleep state when the grid power supply is normal, and there is no noise | Working noise is generally 55~65dB |
| Noise             | About 60% of UPS of the same capacity        | More expensive                               |
| Price             | Generally more than 20 years                 | Generally more than 8 years.                |
| Life              | Inductance, resistive load                   | Computer capacitive load                     |
| Target load       | Strong adaptability to load                  | Adapt to single load                         |

(3) A battery is a device that directly converts chemical energy into electrical energy. It is a battery designed for rechargeability. The main types of batteries include lead-acid batteries, nickel-hydrogen batteries, and lithium-ion batteries. The advantages and disadvantages of different batteries are as follows as shown in the table.

3.1.2 Engine driven generator set. (1) Emergency diesel generators can provide power resources after an emergency power failure. They are mainly used in important load locations, such as systems with precision equipment, meters, and computer systems. They are usually combined with batteries or UPS to provide emergency power.
Emergency diesel generators mainly have two working characteristics: emergency and standby. Therefore, it is usually in a shutdown waiting for the state. The emergency diesel generator will only start after the main power supply is cut off, and the continuous working time is usually less than or equal to 12h. When the main power supply is restored, the emergency diesel generator will stop working immediately.

(2) The internal combustion engine is a heat engine that burns fuel inside the machine and directly converts the heat energy it emits into power. Commonly used diesel engines and gasoline engines. After the diesel internal combustion engine is started, it should be operated at low speed for a few minutes, and then gradually increase the throttle to the rated value. After everything is running normally, it can be operated with the load. Emergency and backup power sources are generally calibrated to 12h power, and basic power sources should be calibrated to continuous power.

(3) In the case of emergency energy supply, general gas turbines need black start diesel generators to provide power to auxiliary electrical equipment when the external black grid is used to ensure the smooth start of the gas turbine. It needs to be pointed out that the 6B series gas turbine equipped with a diesel engine as a starting device does not require a black start diesel engine, which makes the black start scheme more economical and convenient. When necessary, this type of gas turbine can also be used as a black-start power source for black-start power plants to replace large-capacity black-start diesel generators.

3.2. Emergency heating equipment

3.2.1. Boiler. Common boilers include gas boilers, coal-fired boilers, and oil-fired boilers. The boiler start-up time is related to the pre-start state, capacity, fuel type, and other factors. Usually, the cold start time is 6~8h, the warm start time is 3~4h, and the hot start time is 1~2h.

3.2.2. Waste heat utilization. The waste heat boiler is a kind of auxiliary boiler, which is equipped with the exhaust pipe of the heat engine. It uses the waste heat from the exhaust gas, waste material, or waste liquid in various industrial processes and the heat generated by the combustion of combustible substances to heat water to a certain temperature. Because the upstream of the waste heat boiler is matched with the heat engine and the downstream heating or refrigeration equipment is matched, its parameters vary from project to project. The rated working condition of the waste heat boiler should match the rated working condition of the gas turbine and be in the best efficiency range.

3.3. Emergency cooling equipment

3.3.1. Water storage equipment. The cold water storage technology uses the peak-to-valley price difference to store cold in the water during the low electricity price period and uses the stored low-temperature chilled water to provide cold for air conditioning during the daytime peak electricity consumption. When encountering a short-term power drop, the refrigeration unit cannot operate in a short period, and the water storage system can immediately provide cold capacity until the refrigeration unit resumes normal operation[5]. The schematic diagram of the water storage system for emergency cooling is shown below.

Figure 1  Schematic diagram of emergency cooling for water storage equipment
3.3.2. Ice storage equipment. Ice storage is the use of the latent heat of phase change of ice for cold storage. Compared with water cold storage, storing the same amount of cold energy, the volume required for ice storage will be much smaller than that of water cold storage, which can save the volume of cold storage devices and system investment [6].

When the ice storage device is used as an emergency cold source, it is necessary to ensure that there is sufficient ice available under any circumstances. However, in actual use, the ice storage device may not be put into use for several months, and the ice stored in it is During the long-term standby process, it will slowly melt due to heat dissipation, resulting in loss of cooling capacity. It may also happen that the power supply problem occurs again during the cooling period after the cooling is completed, and emergency cooling is required again[7]. Therefore, it is necessary to consider a variety of situations when designing, and conduct data review for different working conditions to ensure that there is sufficient ice in the ice storage device at any time.

4. Innovative high-reliability hot backup security resources

Take an integrated circuit project in Lingang, Shanghai as an example, and conduct innovative research and analysis on its energy supply scheme from a design perspective. The original power supply plan of the project is as follows: the power supply is provided by the regional power grid, and the two 220kV power stations around the project each draw a 110kV loop power supply as a dual power supply to meet the power demand of the project. Diesel generator sets are set up in the factory as a backup power source to supply power for the first-class load and particularly important loads, and UPS power sources are set up to provide uninterrupted power supply for the control system, process cooling water, process exhaust, gas detection, and life safety systems, and IT systems to ensure Equipment power continuity and power quality stability requirements. For the demand for cold and heat load, the heat recovery system of the chiller is generally adopted, and the free heating is used in winter[8]. While the heat recovery chiller is working, the heat of the process equipment is recovered to produce medium-temperature hot water for air-conditioning fresh air heating, and pure water heating. The comprehensive energy classification results of the project are as follows:

Table 4 Electric load classification results

| Area                        | Main load                                                                                                                                 | Classification |
|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| Production process area     | Computer-aided control of electricity load, clean room lighting load, etc.                                                              | Level 1        |
|                             | FFU high efficiency filter equipment, etc.                                                                                               | Level 2        |
| Power Plant                 | Control equipment for water supply and drainage, waste gas treatment, circulating cooling water, special gas transportation, etc.        | Level 1        |
| Living office area          | Lighting and ventilation load, office equipment load                                                                                     | Level 2        |
| Fire and Security area      | Emergency lighting, electricity for fire fighting facilities, etc.                                                                        | Level 1        |

Table 5 Cooling and heating load classification results

| Area                        | Main load                                                                                                                                 | Classification |
|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| Production area process area| DCC cooling load of primary surface cooler and dry surface cooler of MAU in clean area                                                   | Level 1        |
|                             | Cooling load of fresh air unit in clean area                                                                                             | Level 2        |
| Power Plant                 | Air conditioning and process equipment cooling loads in distribution substations                                                          | Level 1        |
| Living office area          | Building heating/cooling load in office area                                                                                             | Level 2        |
| Logistics support facility area | Warehouse building heating/cooling load                                                                                                    | Level 3        |

In line with the principle of enhancing the safety and stability of the energy supply system in the plant area, a hot backup was added based on the two-circuit power supply and replaced the diesel
generator set to reduce the operating cost of the project. The first-level load of the project uses gas generators as the main power source, and the shortfall is supplemented by one line of mains power, and the other line is used as a backup power supply; for the second-level load, gas generator sets are used as the main power source at the same time, and the shortfall is from one line of mains power. Supplement; for the three-stage load, the power is supplied by the gas generator set. According to load requirements, grades, and classification requirements, this plan is to be equipped with 5 4.4MW internal combustion generators (4 used and 1 standby), which is larger than the installed capacity of the originally designed diesel power generation system by 14.4MW and can replace the originally designed diesel power generation system. From cold standby to hot standby. At the same time, 4 sets of 4MW flue gas hot water lithium bromide units are selected as the supplementary part of the original design of the cooling and heating system, and the energy production form of the cooling and heating system is increased, and 4 sets of 4.2MW electric refrigeration units are supplemented as standby.

5. Conclusion and prospects
The integrated circuit manufacturing industry is a precision manufacturing industry with a high degree of capital and technology-intensive, and because of its position in the industry, integrated circuits are always in the "spotlight". The “Overall Plan for the Lingang New Area of China (Shanghai) Pilot Free Trade Zone” issued by the State Council in 2019 clearly stated that the Lingang New Area will build a comprehensive integrated circuit industrial base to promote core chips, special processes, key equipment, and basic materials. This paper takes an integrated circuit project in Lingang, Shanghai as the background, and conducts innovative research and analysis on its security system from a design perspective. At present, relevant solutions are still being discussed and explored, but from the perspective of the development trend of the entire energy industry, under the premise of improving the comprehensive energy load classification and guarantee system, the future distributed energy system is feasible as an innovative supplement to safety guarantee resources.

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