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Feasibility Study on DC Power Supply System Scheme of Civil Buildings

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Abstract: At present, in the interior of electrical equipment in civil construction sites, most of them have adopted the conversion of AC to DC power supply. If the low-voltage AC power supply for such loads is changed to low-voltage DC power supply, it can not only reduce the cost of conductor materials of transmission lines, but also reduce the consumption of insulating materials, improve the safety level, and well suppress the electromagnetic radiation and interference caused by high-frequency harmonics in the power grid. This paper discusses this problem.

Keywords: DC power supply Single-phase load Electromagnetic radiation Line loss

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1.Introduction

Electricity consumption in civil buildings is a very important part of power load, which has the characteristics of wide distribution and single-phase load. In order to balance the three-phase load, TN-C-S system is generally adopted for the power supply of the whole building. In fact, it is a three-phase four wire power transmission and three-phase five wire power supply mode. This power supply mode makes the transmission cost high, energy consumption large and the structure complex.

Electrical equipment in civil construction sites is divided into electric, lighting, electric heating, electronic equipment and devices. With the continuous improvement of people's living standards, the domestic power load is rising. Mainly due to the increase of power load of household air conditioning equipment and kitchen equipment, the power supply for life and office is changed from single-phase power supply to three-phase power supply. Due to the wide distribution of living and lighting power, the three-phase four wire power supply mode is adopted, resulting in the high cost of transmission line. Due to the power frequency current transmission, it is more dangerous than DC at the same voltage level.

2. Defects of AC power supply in civil construction sites

2.1. Electromagnetic radiation of transmission line

Because some electrical equipment work in the state of pulse discharge or high-frequency oscillation, the power frequency power supply line contains high-frequency harmonics. These high-frequency harmonics are easy to cause interference to communication and broadcast receiving equipment, increase the reactive power index of the power grid, thus increasing the power grid loss. At the same time, they also produce electromagnetic radiation to people's work and living environment, causing certain harm to people's health.

If DC power supply is adopted, these high-frequency harmonics can be completely filtered, and the reuse of harmonic electric energy can be realized, so as to eliminate the interference to communication and broadcasting equipment and electromagnetic pollution to people's working and living environment.

2.2. The loss of AC transmission line is large

In the AC power supply line, due to the widespread existence of inductive load, in order to avoid resonance overvoltage, the power factor of local power consumption system is generally below 0.85. The transmission line should transmit both functional and reactive energy, resulting in the increase of line loss. DC power supply only transmits active energy, not reactive energy, so the line loss is relatively reduced.

In the process of AC energy transmission, there is an AC magnetic field around the conductor. When there is a conductor around the conductor, there is a vortex current inside the conductor, resulting in energy loss. If DC transmission, the above problems do not exist.

Due to the skin effect of AC, the effective conductive area of the line is reduced, which increases the line loss.

2.3. Overvoltage easily generated in power grid

Due to the sudden change of current in the load, it is easy to cause operating overvoltage in AC network; Induced

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lightning overvoltage often occurs in power grid due to electrical discharge; Due to the existence of distributed capacitance and compensation capacitance in the power grid, it is easy to produce resonant overvoltage in the power grid. These overvoltages are harmful but not beneficial in the AC network. However, if low-voltage DC power supply is used, the energy storage capacitor in the power network can effectively suppress these overvoltages and store and use these overvoltage energy.

2.4. High cost of AC power supply line

When the power of electrical equipment is required to be large, the three-phase three wire system needs to be used for power supply. Compared with the two-wire low-voltage DC transmission, it increases the consumption of insulating materials. Using DC transmission requires two-wire system, so the cost of transmission line can be reduced.

AC power supply wire is mainly copper and aluminum. Due to skin tendency, iron can not be used as wire. If DC power supply is adopted, iron wire can be used. Iron is easy to be plated and welded, the joint is easy to handle, and the cost is much lower than that of aluminum and copper.

2.5. Waste insulating materials

For AC transmission with the same voltage level, the withstand voltage level of the outer insulating material of the line is higher than that of DC transmission, because the peak voltage of sinusoidal AC is 1.4 times of DC voltage.

3. Power supply demand of electrical equipment in civil construction sites

If the structure and principle of living and office power supply equipment are slightly analyzed, it will be better to use DC power supply. The electrical equipment in common civil construction sites is divided into four categories: electronic devices, lighting devices, electric equipment and electric heating equipment. The current power supply is as follows.

3.1. Electronic device

Such devices are actually powered by low-voltage DC power supply, and now switching power supply is widely used. Rectifier and filter circuits are set inside these devices, which are used to convert AC into relatively stable DC. If DC voltage is used for power supply, the cost of switching power supply can be reduced. Since the AC power grid supplies power, the harmonics in the power grid are difficult to filter out. Therefore, mutual inductance filters must be installed inside these electronic devices, which further increases the production cost of the equipment.

3.2. Lighting device

There are three types of lighting devices used now and in the future: one is incandescent lamp, which uses DC or AC without conversion. One is the fluorescent light source. Now the fluorescent light source has generally adopted electronic ballast. The use of DC power supply can save its rectifier circuit and reduce the requirements for filtering. Most of these lighting devices are not equipped with mutual inductance filter due to the consideration of price factors by manufacturers, resulting in great pollution to the power grid. The other is semiconductor lighting source, which is suitable for DC constant current source. If DC power supply is adopted, its conversion is easier than AC power supply.

3.3. Electric equipment

There are three kinds of electric equipment commonly used in families: one is single-phase AC asynchronous motor, which is used for high-power electrical devices. One is series excited motor, which is used for electric tools. The other is DC permanent magnet micromotor, which is used for electric equipment with small load.

For electrical equipment using series motor, such as electric drill, electric sewing machine, beating machine, etc., series motor has the advantages of AC and DC, so it can directly use DC power supply for power supply。

DC permanent magnet micromotors generally use DC motors with low-voltage DC power supply, such as hair dryers and cooling fans inside electrical equipment. As long as the chopper for step-down and voltage regulation is added.

Single phase AC asynchronous motor is adopted, such as washing machine, electric fan, refrigerator, air conditioner, etc. The mechanical and electrical performance of this kind of motor is significantly lower than that of three-phase AC motor, and its advantage lies in the use of single-phase power supply.

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Compared with three-phase AC synchronous motor, single-phase AC asynchronous induction motor has the defects of low efficiency, high operating noise and low power factor. If these electrical equipment are powered by frequency conversion device and replace single-phase AC asynchronous motor with permanent magnet three-phase synchronous AC motor, it can not only improve its service performance, but also reduce energy consumption and improve efficiency. For example, in the washing process, the washing machine is directly started and operated intermittently. If the frequency converter is used to drive the three-phase synchronous motor, the smooth start and program variable speed control can be realized, which is very beneficial to improve the washing effect and save electric energy. If the electric fan is driven by the frequency converter, the three-phase AC synchronous electric drive fan will also obtain better use effect. Even low-cost electrical devices such as electric fans can be regulated by choppers and driven by DC brushless motors, which is much cheaper than using frequency converters. As for refrigeration equipment such as refrigerators and air conditioners, double position control is generally adopted. If PID vector frequency conversion control is adopted, better use effect will be obtained.

3.4. Electrothermal equipment

Common electric heating equipment include electric heating tube, induction heating device, microwave heating device, etc. electric heating tube heating device uses resistance to convert electric energy into heat energy, and the effect of DC and power frequency AC power supply is basically the same. The working power supply inside the induction and microwave heating device is actually DC power supply. Therefore, the electric heating equipment can be directly powered by DC power supply.

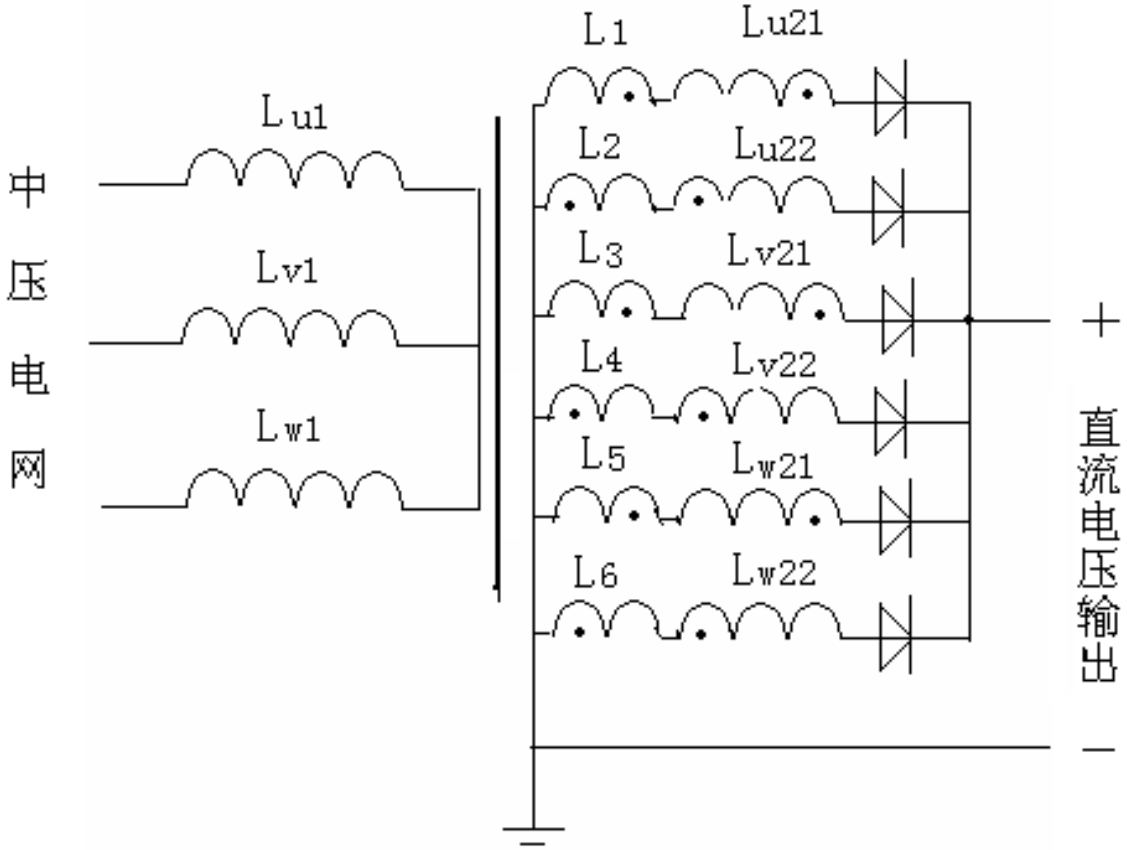

图 1 低压直流供电电源原理图

Figure 1 Schematic diagram of low voltage DC power supply

4. Advantages of low voltage DC power supply system

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If the low-voltage DC power supply system is adopted, it can overcome the defects of the above low-voltage AC power supply system, such as complex transmission lines, skin effect, eddy current loss of single line string pipes and so on.

Compared with AC asynchronous motor, traditional DC motor has the defects of complex structure and high cost of use and maintenance. Therefore, AC asynchronous motor is generally used when there is no speed regulation requirement. In the past, due to the underdevelopment of electronic technology, AC motors can only use AC power supply directly, which makes single-phase AC asynchronous motors with simple structure, low cost and simple use and maintenance used in civil construction sites. With the development of electronic technology and power electronic technology, the wide application of Brushless DC motor has a great trend to replace the traditional DC motor. With the improvement of frequency conversion technology, the cost performance of DC frequency conversion control of AC motor has exceeded that of direct AC power supply control. Frequency conversion air conditioner, frequency conversion refrigerator and frequency conversion washing machine are developing rapidly, which has a great tendency to replace traditional technology. Moreover, with the discovery of new permanent magnet materials, the speed stability, efficiency and power factor of permanent magnet AC synchronous motor driven by frequency converter are higher than that of AC asynchronous motor. To sum up, the low-power electrical equipment in civil construction sites is gradually converted from AC power supply to indirect DC power supply from AC to DC. Now the AC power supply in civil construction sites has shown signs that it is not suitable for the application of electrical equipment.

Using DC power supply, it is convenient to use lead-acid battery as backup power supply. In the case of high power requirements, the required DC voltage can be generated directly in series through the battery pack, and in the case of low power requirements, the required DC working voltage can be generated through boost conversion. Compared with the ups backup power supply in the AC system, it reduces the inverter link, improves the conversion efficiency and greatly reduces the cost.

Using DC power supply can also easily combine a variety of energy sources, such as solar photovoltaic cells, small wind power generation and so on.

5. Factors restricting DC power supply in civil construction sites

The main problem of replacing AC power supply with DC power supply in civil construction sites is the capital investment of equipment increased by replacing single-phase AC asynchronous motor with direct AC power supply with three-phase synchronous motor driven by frequency converter.

Frequency converters have been mentioned, which often makes people price problems. At present, the price of low-power IGBT has been very cheap, and the price of MCU and interface devices used to realize frequency conversion has also been reduced to hundreds of yuan. For example, the current price of induction cooker is only more than 300 yuan. Among them, the 40A IGBT used is only more than ten yuan. As for the frequency converter driving electric fan, it only needs less than 10A VDMOS tube, and its price is only about 3 yuan. With the development of electronic technology and power electronic technology, the above devices still have great room for price reduction. It is a general trend to use frequency converter to drive three-phase AC permanent magnet motor in civil construction places.

6. Acquisition of DC power supply

The DC power supply is depressurized by a three-phase power transformer, and the DC power supply voltage is generated by six phase half wave rectification with balance reactor or 12 phase rectification combined with YD. its pulsation is very small, so the filtering requirements of all electrical equipment are very low. In this way, the three-phase power transformer can output two voltages at the same time, one is the three-phase four wire AC used in industrial production and high-power electric field, and the other is the low-voltage DC used in civil construction sites.

Its typical circuit is shown in Figure 1: L1 ~ L6 in the circuit are balanced reactors, which not only play the role of smooth filtering, but also balance the conduction current of rectifier diodes. Lu21 and lu22 are two antisymmetric coils on u phase, which output sinusoidal AC voltage with opposite polarity and equal amplitude; Lv21 and lv22 are two antisymmetric coils on V phase, which output sinusoidal AC voltage with opposite polarity and equal amplitude. Lw21 and lw22 are two antisymmetric coils on W phase, which output sinusoidal AC voltage with opposite polarity and equal amplitude.

Due to the six phase rectifier technology with balanced reactor, the pulsation of the output current of the system is

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very small and almost stable. In each DC power load, whether to connect the filter capacitor at the input of the power supply can be determined according to its own characteristics.

The winding of the transformer used for low-voltage DC power supply must be an independent winding isolated from the line voltage 380V AC power supply winding.

7. Selection of DC supply voltage

From the perspective of household power load, two voltages of 110V and 220V can be selected. 110V is used for household appliances with small power, which can also improve the level of safe power consumption, and its harm is much lower than 220V AC voltage. 220V can be used for power supply of electric heating equipment, and the harm caused by electric shock is also lower than 220 AC voltage.

If 220V DC voltage output is selected, some electric heating devices with rated voltage of 220V, household appliances (such as color TV) with internal switching power supply for voltage conversion, office equipment (such as computer) can be used directly without modification. The number of turns of the secondary winding of the supporting power distribution transformer is 29% less than that of the secondary winding with the primary phase voltage of 220V, and the corresponding AC voltage output is 156v.

If 110V voltage output is selected, the current household appliances and office equipment cannot be used directly.

Direct lightning strike also has a good effect.

8. Measurement of DC power supply

After adopting low-voltage DC transmission, the traditional induction single-phase watt hour meter can not be used, just as the traditional single-phase AC induction asynchronous motor can not use DC voltage for power supply, but the electronic watt hour meter can be used for power measurement. At present, the price of electronic watt hour meter is equivalent to that of inductive watt hour meter. In fact, inductive watt hour meter has basically faded out of the market.

9.Conclusion

Through the above comparison, it is found that using low-voltage power supply for civil construction sites does have great advantages. We have simulated and compared the two power supply modes in the laboratory, which fully proves the above discussion. At present, the main problem is that there are a large number of single-phase AC motors with tens of watts of power, such as fans, which need to be replaced by cheap DC brushless motors. The development of such motors will affect the popularization and popularization of low-voltage DC power supply technology.

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Author introduction

Zhang Bin, male, born in 1981, majored in mechanical design and manufacturing, application of electrical and electronic technology, instrumentation and automation technology.

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