

DEVELOPMENT OF HIGH-POWER, HIGH-FREQUENCY AND HIGH-VOLTAGE POWER SUPPLY SYSTEM FOR ELECTROSTATIC PRECIPITATOR

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ABSTRACT

In this document, the design principle is analyzed for the new type of high-power, high-frequency and high-voltage power supply system for ESP which is developed independently by Longking; the advantages of using the technical solution of series resonance soft switching are explained; the experience in developing power supply for ESP for many years is applied to resolve various key technical issues; all kinds of functions to improve the dust collection efficiency are designed completely. On-site application conditions are discussed preliminarily in this document.

1. FOREWORD

As the state's new effluent standard of environmental protection is implemented and people's demands on the environmental protection increase further, the environmental protection technology faces more and more serious challenges. As a dedusting equipment manufacturer in the front line of the drive of air pollution prevention, we bear historical responsibilities. It is a major task before us to develop a new generation of good products, to improve the dust collection efficiency and to guarantee that the fume effluent meets the environmental protection standard.

In modern times, high-voltage transformer rectifier (T/R) which was controlled by thyristor was mainly used as the power supply devices for the ESP. The basic working frequency of this installation was electric grid frequency (50 or 60Hz). At the end of 1990s, the electro-dedusting industry started to research in and to develop a new kind of power supply based on high-frequency switching technology. As a kind of grid frequency independent integrated high-frequency switching power supply, this new power supply solution provided various voltage waveforms from almost fully direct current to wide pulse range. During application, the most appropriate voltage waveform may be selected according to varied specific work conditions, which can improve the dust collection efficiency. Meanwhile, the high-frequency power supply has advantages such as small volume, lightweight, integration of complete set of equipment, high switching efficiency and high power factors, and little influence of three-phase power supply on the electric grid. With development and maturity of the technology, the product performance will be improved stably. Bearing a good market prospective and economic and social benefits, this product will become a revolutionary substitute for the traditional thyristor power supply.

With many years of experience in power supply equipment for ESP, our company has taken the leading position in technology at home. As an important project of our company, the high-frequency power supply development is also recognized as a major technical project of Fujian Province. In 2004, the newly developed high-frequency power supply prototype passed the authentication at factory level of our company. In early 2005, this machine passed various tests of the provincial Central Inspection Institute. In April 2005, this machine was put into industrial test run ESP of a domestic factory. Up to now, it has run stably and efficiently. Our company has own intellectual property of this high-frequency power supply equipment. Next we will continue in-depth research in and batch production of the new products in industry, making them become new key and leading products.

2. TECHNICAL SOLUTION OF THE HIGH-FREQUENCY POWER SUPPLY

As to the technical solution of the high-frequency power supply, based on introduction to relative technical documents, there are two main kinds of technical solutions, namely series resonance soft switching technology and PWM hard switching technology. PWM hard switching technology is weaker in restraining the instant short-circuit overflowing, which results in greater switching losses. And so it cannot suit the special requirements of the work conditions of ESP. We adopt the high-frequency power supply with series resonance topology structure; its constant current characteristic can restrain the current impact of the electric field spark effectively, quench the spark more quickly, and fast restore the electric field energy. The basic structure of this power supply is the series resonance converter, whose switching

device is null-current switching-on and null-current/null-voltage switching-off. Inverse-parallel diode is natural switching-on and switching-off with little switching loss.

The high-frequency power supply principle is shown in Figure 1.

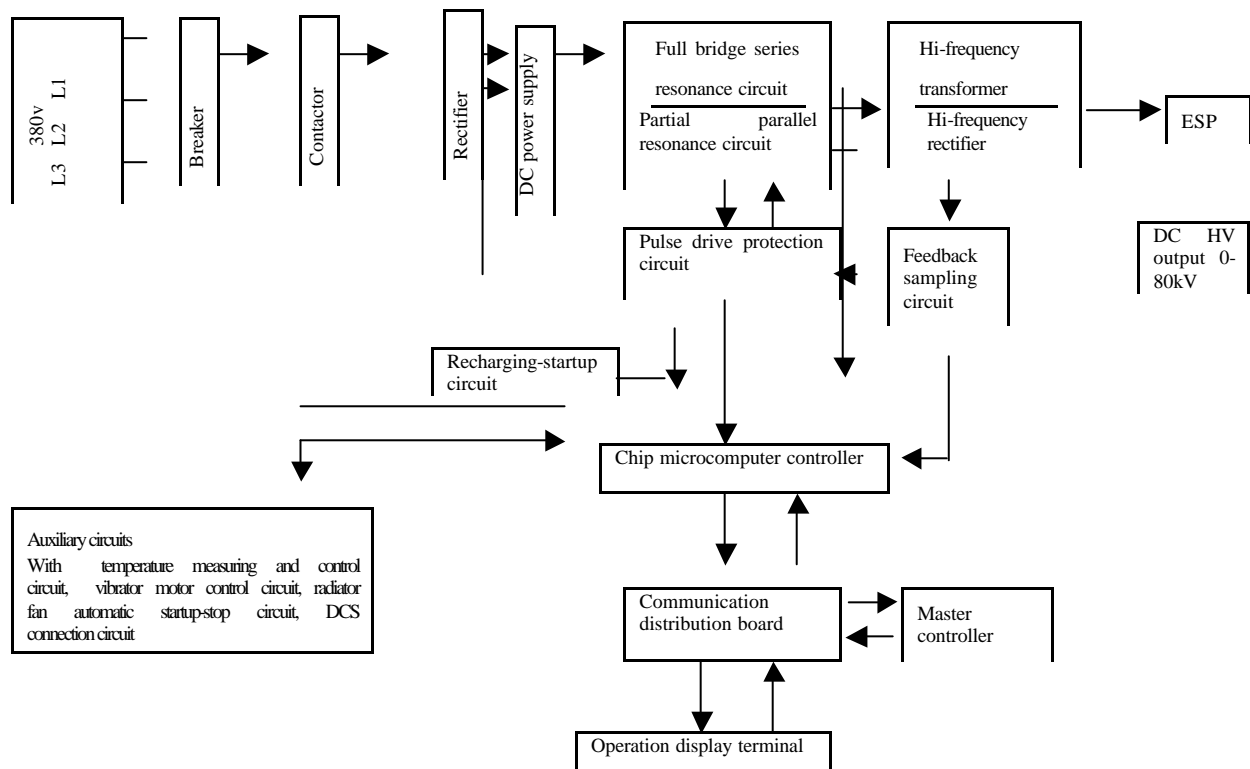


Figure 1 Diagram of High-Frequency Power Supply Principle

Mainly the high-frequency power supply consists of three parts: converter, high-frequency transformer and controller. The three-phase AC power becomes DC power after its impact into the rectification. Then DC power becomes high-frequency AC current after inversion. In the end the direct current high voltage is emitted after rectification. The converter is used for conversion from direct current to high-frequency alternating current, while the high-frequency transformer/ high-frequency rectifier is for output of boosting rectification and supplies power to ESP.

3.KEY POINTS OF THE HIGH-FREQUENCY POWER SUPPLY AND SOLUTIONS

3.1 High-power converter

The topology structure of the converter is the whole-bridge series resonance which consists of IGBT switching device, series resonance inductance and resonance capacitance. Its main features are as follows: ? The power device has few switching-on and switching-off losses; the device produces little switching-off impact; the electromagnetic interference is reduced. The well-designed series resonance inverter has strong current-limiting ability during side short-circuit output. In particular, this feature is fit for frequent spark impact and high short

circuit ratio of the ESP under site work conditions. Moreover, the feature of its constant current has obvious spark restraining effect, and the critical voltage at the spark breakdown increases greatly. There are strict requirements for the high-frequency transformer parameters, which affect the transformer resonance directly. During dedusting, quick output voltage boosting rate is required for the power supply equipment; the characteristic resistance value of the resonance loop should be small; more requirements are raised for the converter design and the selected type of the main parts.

In the converter design, the inductance of the loop bus bar and leading wire is reduced; the loop's overshoot voltage is quickly absorbed; the series resonance frequency improves; transmission and conversion of the high-capacity power is realized; the power supply conversion efficiency is increased.

Although the constant current characteristic of the series resonance circuit bears many advantages suitable for the ESP's load feature, it has some difficulties in running under the conditions of light load or quasi open circuit. For this reason, we have designed local parallel resonance circuit, which is helpful for stable running under light load conditions, stable current waveform during power supply period under the intermittent energization conditions, improvement of the secondary current waveform, and for the enhancement of the equipment efficiency.

Furthermore, since our system makes demands on full direct-current continuous energization and intermittent energization, the special triggering control drive system which is designed by ourselves is used in the IGBT drive system instead of the existing integration trigger. As the impulse drive armour plate which is designed by us is linked directly with the output signals from the microcomputer controller, it has functions such as multiple protections. These functions ensure the drive and protection of IGBT devices and avoid wrong triggering and switching-off, and so the converter may be guaranteed to work normally.

3.2 Rectifier with high power, high frequency and high voltage

As the core part of the high-frequency power supply, the high-frequency transformer has high working frequency, small volume, leaky inductance and strict demands on the distributed capacitance. Meanwhile, it need meet the demands on high voltage grades, high power output and rectification output with high frequency and high voltage. In order to improve cost efficiency of the equipment, the home-made ultracrystalline is adopted in the iron core in the design. And many special design methods are used for structure and winding design. The iron and copper losses of the transformer are restricted within the design value via strict tests, while the temperature rise at the oil top during long-term running of the transformer is controlled within 40k. The transformer leaky inductance and the distributed capacitance are contrary to each other. Rational design and calculation is the core content of the transformer design and concern the normal and reliable running of the transformer.

As another key technology for the high-frequency transformer, high-frequency and high-voltage silicon stack is difficult to realize by general manufacturing technique owing to the high working frequency, high standards for pressurization, high working current peak, great

high-frequency losses, and tolerance for impact. We have asked the domestic specialized manufacturers to develop the high-frequency and high-voltage silicon stack, but the provided silicon stack cannot meet the application requirements. With thirty years of experience in making conventional silicon stack, our company has invested in basic research and practised in many kinds of technologies. We have high standards for independent research in and production of high-frequency silicon stack. Through many attempts and tests, we have fully mastered the key technologies in making high-frequency silicon stack. Our self-made high-frequency and high-voltage silicon stack has passed many type approval tests and other trials such as long-time full power running and different impacts.

3.3 Microcomputer control system

The key technologies of the high-frequency power supply control system are as follows:

3.3.1 The system has two power supply modes, namely the full direct-current and the intermittent impulse. As for the full direct-current, the output voltage is like a straight line. The peak-to-peak value percent ripple is within 5%, while conventional power supply peak-to-peak value percent ripple is about 35%-40%. The guiding idea of the full direct-current design is to increase the average voltage and average current for ESP running as high as possible before the Spark in the electric field. And therefore, this design is applicable to the fume work condition with medium-ratio resistance. The full direct-current is people's ideal pursuit under specific work conditions. Full direct-current power supply tests and research have been conducted in conventional working frequency rectification power supply, but they have been given up due to difficulty in resolving the spark control problem. However, the mentioned problem is solved under the high-frequency condition. This ideal power supply creates good conditions for improving the dust collected efficiency with specific factors. Another new kind of power supply under the high-frequency condition, the intermittent impulse mode looks like the conventional intermittent power supply, but they have essential differences. Firstly, unlike the working frequency period restriction on conventional power supply, the Pon and Poff time of the intermittent impulse can be adjusted freely. Secondly, compared with conventional intermittent power supply, the high-frequency intermittent power supply can select broader impulse width and frequency freely and has steeper voltage rise ratio. For this reason, it may play a more important role under high-ratio resistance work conditions, and thus the dedusting efficiency can be improved more than the conventional intermittent power supply.

3.3.2 Flexible and reliable spark check and response control are key technologies in all kinds of electro-dedusting power supply. The spark discharge characteristic of the high-frequency power supply is obviously different from conventional power supply. According to our analysis and tracking of the high-frequency spark discharge characteristic, the specially designed spark check technical solution is adopted in this high-frequency power supply. This solution is very effective for the high-frequency spark detect and can also capture any weak spark. The current has no impact wave during flashover control. The output to the ESP may be switched off quickly within over ten microseconds. During flashover, only several electric charges continue to be emitted to the electric field, and the spark energy is controlled effectively. Therefore, after the spark goes out, the electric field energy may be fast

recovered, and the electric field voltage is restored quickly with few losses. At the same time, the following can be set: the spark post-recovery curve, initial and final value of spark fast rise, increment and slow rise increment, constant spark ratio, etc.

3.3.3 Intelligent control strategy. This machine has functions of intelligent inverse corona detect and back corona automatic control. It is well-known that the back corona is one of the major reasons for great reduction in dedusting efficiency. When back corona occurs, the equipment emits higher power, but the secondary voltage is not increased consequently. Sometimes, the secondary voltage goes down a little. Based on our many-year experience in the back corona detect technology, we have developed a special back corona detect method under high-frequency power supply application conditions. According to the checked back corona index, the equipment may mitigate the back corona effect by timely power output reduction. If the back corona is serious, the equipment will enter into the intermittent impulse power supply status and start seeking and tracking the best impulse width and frequency automatically so as to obtain the best dedusting effect.

This machine also has a special function of power reduction or power-off rapping. The power reduction or power-off rapping technology is a new successful one on electromechanical integration application by Longking. According to the mill dust with different stickiness, corresponding power-off rapping strategy will be used to gain obvious effect. We have transplanted the power-off rapping technology of the conventional power supply into the high-frequency power supply, and the high- and low-voltage joint control is fulfilled internally due to the integration design of the high-frequency power supply and the rapping control. The power-off rapping has an evident effect on improving dedusting efficiency, and substantial results have been achieved in much application. We believe that the high-frequency power supply application will be better.

3.3.4 Multiple-protection function This function provides protections of short circuit, open circuit, overload, and excess temperature on the site under bad work conditions. This multiple-protection function is by no means inferior to the conventional power supply and hardly has partial excitation without partial excitation protection needed.

3.3.5 This machine has functions of micro-terminal display operation, communication with the Master controller, and connection with DCS system. The Master controller and the micro terminal are joined to the single-chip machine controller via the communication distributing plate. The micro terminal includes configuration function, parameter display, setting function, graphical V/I curve, operational trend curve, etc. In addition to accepting the Master controller orders and transmitting various equipment parameters and conditions to the Master controller, the equipment has other functions such as distant soft startup and soft closing down.

3.4 Temperature rise control of the main parts of the system

The main parts of the system include IGBT temperature rise, series resonance inductance temperature rise and transformer temperature rise. The effective cooling system guarantees the reliable working of the high-frequency power supply powerfully. Forced air cooling is

adopted for heat elimination of the inversion loop, and all important heat devices are brought into the cooling system. Big radiator is used for heat elimination of the IGBT whole-bridge (four devices), and the wind resistance is as small as possible in the whole heat elimination channel during the structure design. The transformer is self-cooled by oil immersion. During design, the iron core material is used rationally to control iron losses. Reasonable layout of the installation structure of the transformer and silicon stack may improve heat elimination results effectively. The transformer oil temperature can also be controlled within rational range during full power running. In the whole transformer loop design, special attention is paid to avoiding local high temperature which results in losses caused by eddy and skin effects.

4. ON-SITE UTILIZATION

The full direct-current power supply is more applicable to the medium- and low-ratio resistance mill dust. For this reason, the power supply voltage fluctuation of the duster is very low, namely very few discrepancies between the output voltage arithmetic mean and the peak value and the valley. As for the conventional power supply, since the output voltage peak value is very different from the valley, the peak voltage has caused spark discharge at low average voltage, and the equipment working current is relatively small. The high-frequency power supply can increase the working current greatly and enhance the equipment output power. In particular, when the high-frequency power supply is applied in the first electric field, the dedusting effect is improved obviously and the mill dust load is reduced in the back electric field. Thus the whole dedusting effect of the duster is improved. The intermittent power supply is more applicable to the high-ratio resistance mill dust and it aims at decreasing occurrence of the inverse corona so as to improve dedusting efficiency. Undoubtedly, the intermittent power supply can save much energy.

In the industrial running trial, we applied a high-frequency power supply unit with 0.4A/80kV of capacity to replace the conventional power supply unit with 0.4A/80kV of capacity in the electric field of a power plant. During conventional power supply, the secondary current was about 200mA, and the secondary voltage was some 60kV. Flashover occurred frequently when the voltage exceeded 60kV. After the high-frequency power supply was used, the secondary current was increased to more than 300mA, and the secondary voltage rose over 72kV without flashover. The whole power supply is installed at the top of the duster; the site installation is very simple. The Master controller is installed inside the control room. The installation site is shown in Figure 2. The volume and floor area of the visible high-frequency power supply are obviously smaller than those of conventional power supply. The whole weight of the high-frequency power supply is only a percentage of that of conventional transformer. Since its test run, it has kept stable and reliable without any failure, and the dedusting efficiency has been improved.



Figure 2 High-frequency power supply in the site test

5. CONCLUDING REMARKS

Now the newly developed high-frequency power supply is at the site test run stage, and the manufactured system design and structure design are being modified further. The site control strategy needs to be improved. Although the high-frequency power supply cost is higher than that of conventional power supply, the factory cost will go down with batch production and generalization of the product. As the high-frequency power supply has relatively high efficiency and high power factor, its running cost is comparatively low. The existing practical experience has proven that the high-frequency power supply has superior performance to the conventional power supply. As for either the medium- and low-ratio resistance mill dust or the high-ratio resistance mill dust which has puzzled the dedusting industry for a long time, the high-frequency power supply will exhibit its prominent performance and become a new development trend of the duster power supply. And in the end it will turn into the leading product of a new generation.