Evaluation of HV Power Source for ESP

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Abstract: Since the formal application of industrial ESP, our country has got great breakthrough in technology and wide application of it. As an important part of ESPs, High-voltage power source has gone through procedures as simulative control single-phase power source, constant-current power source, pulsed power source, three-phase HV power source, high frequency switch power source and HV contravene DC power source. For single field, one type of power source was used in the past. A few ESP manufactures begin to apply various types of HV power source on the same ESP in recent years. This article will analyze the advantages and drawbacks of HV power sources of ESP, give theoretic analysis and research for comprehensive use of various HV power source on the same ESPs.

Keywords: ESP, High-voltage power source, Comprehensive use

1 INTRODUCTION

As internationally recognized high efficiency dust removal equipment, ESP has been playing an important historic role in flue gas cleaning, dust collection, and environmental protection for about 100 years. In terms of the structure, ESP can be divided into main body and power source. The performance of high-voltage power source has a greater impact on the dust collection efficiency. Traditionally, high-voltage power sources are mostly Silicon Controlled Rectifier (SCR) at line frequency phased controlled power source with two-phase input. With the continuous improve-ment and increasing stringency of relative environmental policies and regulations, power source used for ESP has greatly improved. For example, SCR industrial frequency phased power sources with three-phase input, amplitude modulation (AM) LC constant current sources and high frequency power sources are developed. However most researches are only focused on its own technology development of single product, but ignored the applications of a variety of products in same ESP. For one type of power source, its technique parameters has reached top level in accordance with the present standard, but the results in practical application are not perfect as expected. The collecting efficiency of ESP which only uses one type of high-voltage power source usually cannot meet the requirement. So the applications of various types of power sources with different characteristics on the same ESP will be discussed in this paper.

2 SINGLE-PHASE LOW-FREQUENCY RECTIFIER POWER SOURCE

Single-phase Low-frequency rectifier power source laid a solid foundation for domestic ESP technology development. Because of its stable performance, advanced control technology, low cost and convenient maintenance, single-phase power source dominated the domestic market of ESP power source for a long period. However, with the continuous development of ESP power source technology and increasing stringency of national environmental policy, disadvantages of single-phase power source were exposed: First, low working efficiency, the power conversion efficiency is less than 75%, and it causes a serious waste of energy. Second, low working frequency, transformers and filters with huge volume and heavy weight cost a lot of steel and copper, doesn't meet the requirements of sustainable development; Third, the AC line frequency power source with input of two-phase 380 V, coupled with the line frequency phase modulation, cause a low power input, strong electromagnetic interference to the power grids and poor electromagnetic compatibility. Fourth, massive structure costs much space and more construction expense. Besides, single industrial frequency output with high ripple voltage leads a lower corona voltage, which can not adapt to the high-resistance condition, and can not reach the requirements of new dust emission standards.

3 THREE-PHASE HV POWER SOURCE

Compared to the traditional single-phase power source, new-style three-phase power source can adapt to different dust characteristics and operation conditions, and it can supply higher and more stable operation voltage to ESP. The outstanding characteristics of three-phase balance, efficiency enhancing and high power output, not only accord with the national energy saving and pollution reduction policy, but also improve the economic efficiency and social benefits of enterprises.

The working principle is illustrated in Fig.1. Line frequency power supply with three phase input is regulated by three pairs of two-way reverse paralleled SCR module after breakers and contactors of main circuit, and then transported to the transformer and rectifier (Δ-connect for input and Y-connect for output), and to the load at last. When flashover (spark discharge) happens in positive half-wave of phase A, SCR of phase B is conducted. Blockade signal is outputted at the zero-crossing and phase changing point of positive half-wave of phase A, can turn off the negative half-wave of phase A and phase C, but cannot turn off the conducted signal of phase B in time until at the zero-crossing point. The flashover impact current is 1.5-2.5 times of the transient conducted

current. But phase B is continually conducted under the condition of dielectric breakdown of phase A with strong fundamental wave, and it has greatly strengthened the breakdown in substance. So the practical impact current generated under the flashover is 3-5 times of the transient conducted current, and cause strong interference to the control and rectifier transformer system.

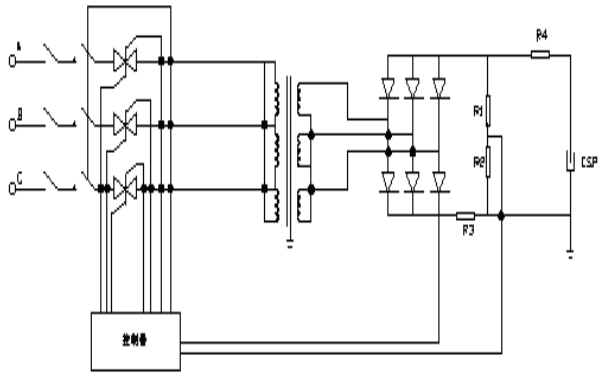

Fig. 1 Principle Schematic Diagram of Three-phase HV Power Source

The voltage, current and magnetic flux of three-phase HV power source are equal to every phase which phasic discrepancy of 120° in turn, so the grid is always balanced and in the most scientific. Compared to the current unbalance of single-phase power source, three-phase HV power source has done an excellent contribution to the quality of electric grid.

Three-phase HV power source which uses three-phase voltage regulating, three-phase voltage rising and three-phase rectifying, with power factor≥0.95 and low power grid loss, can efficiently overcome shortcomings of present single-phase power source, such as low power factor, high open-phase loss and low utilization. In comparison to the power factor of high frequency power source (almost 0.9) which is still in single phase condition at high-frequency inversion, three-phase HV power source still has certain advantages, and its utilization (conversion) ratio is approximate to high frequency power source.

Although three-phase power source has merits of balance of power supply, little damage to power grid and super power output, in comparison to single-phase power source, it has disadvantages such as stronger flashover impact, more serious partial electric erosion of electrode, high raw material quantity and grade, larger volume and more difficult to package, transport and hoisting.

All in all, development of three-phase power source needs further technical perfection and to solve technical problems below:

(1) Three-phase time sequence: solve three-phase synchronization problem, otherwise the unbalanced output waves will be misjudged as flashover by the control system.

(2) Interference problem: strong flashover impact and interference make the devices can not work stably in bad condition. It is necessary to use control circuit with strong anti-interference ability and fast processing speed. So that the advanced and reliable technology need to be applied for power source controller.

(3) Spark check: in order to make reliable turn-off without arc, suitable and efficient spark control technique is necessary, and special turn-off technique and protection action are needed.

4 LC CONSTANT CURRENT SOURCE

In 1980s, constant current source started to be applied on ESPs. Although using a lot of passive components such as reactors and capacitors to compose LC conversion network, it adopted current source and changed power supply mode. As a circuit it is often composed of power supply and load, it has three tokens: voltage, current and impedance. No matter earlier saturated magnetic amplifier power source or present SCR power source, they are both voltage power sources. “Constant voltage” or “constant current” working can be obtained by changing impedance to limit current or changing average voltage output (waveforms), but they are both by controlling and regulating the voltage. Their main variable value which can be directly controlled and regulated is voltage (u), as indicated in Fig.2: $i=f(u)$. And the main variable value of constant current source is current (i), as indicated in Fig.3: $u=f(i)$. It works under the condition of “constant voltage”, “constant current” and “optimum spark rate” by controlling and regulating current.

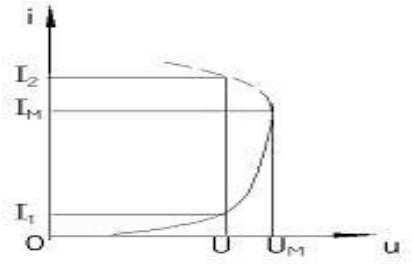

Fig. 2 Voltage Source Power Supply $i=f(u)$

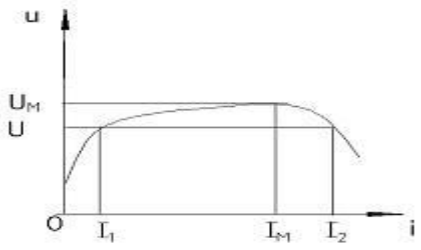

Fig. 3 Current Source Power Supply $u=f(i)$

Time and power consumption are needed from partial corona discharge to spark breakdown in ESPs. Regardless of whichever power sources, the current of power source is corona current under the condition of corona discharge and the current is spark current under the condition of spark discharge. When using constant current source, equivalent resistance of discharge channel decreases with the increase of ionization strengthen in the process of corona turns to spark, so the injected power into the discharge channel has decreased, and holes back more discharge. It is a physical process of negative feedback. Thus the breakdown critical voltage

obviously increases, it means that positive resistance region of ESP's V-I characteristics has been extended greatly, and the extension amplitude depends on ESP's running status and operation condition. Generally, the amplitude is larger under the condition of high dust concentration, high resistance dust and mechanical shortcomings, and the extension is near $r=du/di\rightarrow 0$, that means current increases several times when the voltage increases several thousands voltage. In Fig. 2 and Fig. 3, ESP has a non-linear characteristic about gaseous discharge, especially negative resistance characteristic in the rear half curves. It is possible that several values correspond to one voltage, but voltage is single value for one current value, it means that the operation voltage is a single-value function of current. Thus simply regarded the stability of non-linear circuit balance, the voltage will not jump and can work stably near $r=du/di\rightarrow 0$ when it is given by constant current power supply. This stability doesn't need feedback control circuit support; it exists in the circuit itself. The principle of LC power source is indicated in Fig. 4.

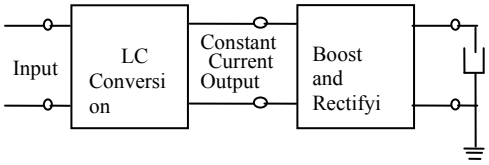

Fig. 4 Principle Schematic Diagram of LC Power Source

AC sinusoidal voltage source of the power gird input is conversed to AC sinusoidal current source by LC constant current convertor, and then to constant HV DC source supplied to field. It has technical features below:

(1) Stability, reliability, can maintain collecting efficiency for long-time and bear transient & steady short circuit.
(2) Adapting to variational condition, preventing dust re-entrainment, and ability of inhibiting corona-block and cathode hypertrophy.
(3) High work voltage, inhibiting discharge, and it is non-sensitivity to mechanical structure shortcomings.
(4) Simple structure, parallel modular design, convenient maintenance and few failure.
(5) High power factor (≥ 0.9), and it doesn't change with operating power, obvious energy-saving .
(6) Input and output waveforms are full sinusoidal waves, noninterference to the power grid.

In the practical application of ESPs, unpredictability of operating condition makes the V-I characteristics of the 'heating state' operating deviate from designed value, such as high voltage, low current and frequent flashover, low operating voltage, etc. ESPs' performance can be changed by constant current power source to attain optimum control effect.

5 HIGH FREQUENCY SWITCH POWER SOURCE

High frequency switch power source (full name: high frequency switch integrated rectifying power source) is a new tendency of ESPs' HV power supply. It has merits of slight weight, small volume, compact structure, three-phase symmetry, high power factor and possibly high collecting efficiency, and it will become attractive substitute of traditional SCR voltage regulating and rectifying power sources.

High frequency switch power source has begun to commercialize since 1990s. Now power source adopts 20 kHz-50 kHz frequency which is higher than that time's. With three-phase charge, the voltage injected into ESPs is almost constant DC. So it brings some features and advantages which the single-phase power source doesn't have.

(1) The average values of Voltage and current of pure DC supply are higher than that of the conventional power source, which is beneficial to improve the collecting efficiency about medium and low resistivity dust. Generally, it can make dust emission decreased by 30%.
(2) When spark discharge, the conventional power source needs to turn off a semiwave, that is 10ms, and the high frequency power source can quench the spark within 2 ms-5 ms, recover full power within 5 ms-15 ms. There is no HV decreasing evidence at the spark rate of 100 times per minute.
(3) Rectifying transformer (T/R) has obviously lightened at weight and minified at volume, with lower cost and higher price-performance ratio than conventional T/R. A 70 kV/800 mA power source (includes input T/R, control console and high frequency switch, etc) is only 200 kg but the conventional T/R is as heavy as 700 kg-1700kg, even it is lighter than a control console of conventional power source. It is easy and economical to install. Oil pan, oil drain pipe and oil storage tank are not been required due to little oil is need to use.
(4) High integration. All of the wirings, input power, high frequency switch, T/R, high voltage/low voltage/ rapping/heat control are integrated in a small box, and it has high modularity.
(5) High power conversion rate. The total power loss is less than 3 kW for a rating 600 kW power source.
(6) Three phases are balanced, symmetry, and they have no interference to the power grid.
(7) Like the conventional power source, "intermittent charge" (likes pulse style) is available to high resistivity dust, with a higher degree of freedom and better effect. Intermittent power pulse of switch power supply hasn't been restricted by half-wave width of conventional power supply (10 ms). Its best wave width and amplitude of optimal power supply, and optimal period (charge ratio) are optional. At the same input power of ESPs, switch power source can provide higher current, narrower pulse width than conventional power source, and it is more beneficial to the collection of high resistivity dust.

Switch power source is developed on the basis of high frequency conversion technology, its structure is indicated in Fig. 5. Voltage supplied by three-phase power grid, rectified by three-phase rectifier bridge and filtered by filter with buffer capacitor. DC voltage is transmitted to series resonant convertor which is connected with HV transformer, the

secondary voltage is rectified by single-phase rectifier bridge, and applied to the discharge electrode of ESPs at last.

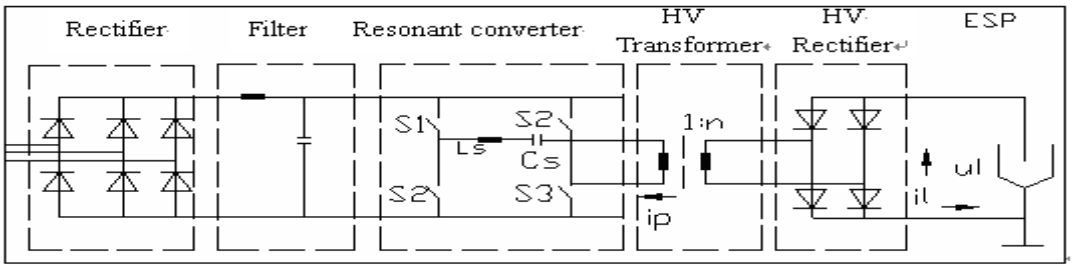

Fig. 5 Principle schematic Diagram of High Frequency Switch Power Source

6 CONCLUSIONS

This paper outlined several mainstream kinds of HV power supplies for ESP in present market, and briefly summarized their respective advantages and disadvantages. Usually, domestic selection of ESP power source is mainly concerned about one kind of HV power source. Comprehensive usage of a variety of HV power sources hasn't been fully understood. It is fortunate that some environmental enterprises and factories have begun to discuss and study these subjects.

Through decades of field application, and plus increasingly stringent environmental standards, we progressively realize that new-style high efficiency HV power source has a great effect on collecting efficiency of ESPs, at the same time we have known the most shortages of single-style power source in the practical projects. The selection of power source can't limited on specification, it should combine several kinds of power sources to maximize respective advantages and optimize integral performance according to different field conditions such as dust components, climate, and regional differences. For instance, generally speaking, ESP has problems such as corona-block in the first field because of high concentration dust, re-entrainment in the rear field and back-corona, etc. We can select tree-phase HV power source or high frequency power source in the first field, use constant current power source in the rear field and common single-phase power source in the rest fields, thus it can solve the problem mentioned above and play a role in energy-saving and emission reduction.

Integral match of various types of power sources which depends on practical condition, it should fully be considered about energy-saving, emission reduction, cost and installation. Choose different power sources according to different condition. It is only theoretically analyzed due to complicated operating conditions and few available sample projects, and its practical effect is needed to be gradually verified by applications in future.

REFERENCES

1. Guoshan TANG. Application Technology of Industrial ESP, Chemical Industry Press, Beijing, China, 2005.
2. Zaishi LI. Selection Installation and Performance Manage of ESP, Chemical Industry Press, Beijing, China, 2005.
3. New three-phase high voltage power supply for ESP collected papers (1), Doway, Jinhua. 2007.