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# An Improved Precision Measuring Method for Chemical Instrument Based on High-voltage Charging and Low-voltage Measurement

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The improved precision measurement method of high voltage charging low voltage measurement is discussed. Based on the theory of high-voltage charging and low-voltage measurement, through constant-current source test mode, the related fast measurement methods are analysed, and the advantages and disadvantages of different algorithms are compared. The practical application scope of different algorithms is determined in order to find the improved precision measurement method. The results show that the combination of saturated magnetic circuit method and constant current source device method can improve the actual measurement accuracy and expand the application scope of high voltage charging low voltage measurement. Therefore, the saturated magnetic circuit method and the constant current source device method are improved precision measurement method, which improves the measurement precision of high voltage charging low voltage through the DC resistance testing device of power transformer.

## 1. Introduction

The use of improved precision measurement methods is the main experimental item for substation equipment such as transformers etc. During the experiment, the results of handover test, preventive test or fault diagnosis are all very important, e.g., in the load experiment of power transformer, more accurate measurement results should be provided. Therefore, based on various literatures, this paper aims to find a significant improvement program, and make rational design of hardware and software.

## 2. Literature review

The traditional high voltage charging power supply adopts power frequency resonant charging mode, and its charging voltage decreases with the increase of laser working frequency, which affects the stability of laser output and beam quality. The volume and weight of the power supply are huge, which is not conducive to the miniaturization and lightweight of the device. The traditional switch trigger system adopts single-pulse trigger mode and trigger system. The trigger system has low efficiency, high loss and severe fever, and the breakdown probability decreases with the increase of operating frequency and switching pressure. With the development of high-frequency and high-voltage switching devices, magnetic materials and high-voltage insulation materials, high-frequency and high-voltage technology research is carried out, which is applied to high-voltage charging power supply and switching trigger system. It has important engineering application value in improving the reliability and stability of the laser, reducing the volume and weight of the laser and the development of the laser towards high-power and high-repetition frequency and it is of great significance for improving the overall technical level of laser.

In recent years, with the rapid development of high-frequency power electronic devices and magnetic materials, the switching power supply topology and control theory has become gradually mature; the volume of transformer core transmitting the same energy is inversely proportional to the working frequency, and the volume of high-frequency transformer is much smaller than that of power frequency transformer; in the field of low-voltage power supply, high-frequency switching power supply has replaced power frequency power supply. The adoption of high frequency power electronic devices greatly improves the accuracy, stability and

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controllability of high frequency switching power supply, and the design technology of high voltage insulation materials and high voltage insulation is developing continuously. At the same time, the application of soft-switching technology reduces the switching loss and electromagnetic interference of high-frequency power electronic devices, and the high-voltage power supply gradually develops to high-frequency. The high-frequency power supply system develops to the high frequency. The main high-voltage charging power supply for lasers includes direct high-voltage charging of power frequency transformer, resonant high-voltage charging of power frequency L-C high-frequency charging, and high frequency and high voltage switching power supply charging switching three charging modes. The direct high voltage charging mode of power frequency transformer is that power frequency power supply charges the high voltage charging capacitor directly after boosting and rectifying. Because the capacitor load current is very large at the initial stage of charging, it needs to increase current limiting resistance, which affects the power consumption and charging time of power supply. In the meanwhile, it works in power frequency, with large volume and weight, low charging accuracy and repeatability, and severe common mode interference. In order to meet the requirement of high efficiency and high reliability of laser, the power frequency L-C resonant charging mode is proposed. The power frequency L-C resonant charging circuit does not need current limiting resistance, has less energy consumption, high utilization rate of power supply, mature manufacturing technology of power frequency high voltage transformer and high reliability. There are still disadvantages of large volume, heavy weight and serious interference of working mode, as well as low charging accuracy and low repeatability. With the progress of power electronics technology and the development of power switching devices, high voltage switching power supply technology develops rapidly. Charging power supply based on series resonant converter in different kinds of switching power supply converters has the advantages of constant current charging characteristics and strong resistance to short circuit load. Therefore, it is suitable for being used as the circuit topology of high voltage charging power supply of laser.

In the theoretical research of series resonant charging power supply, Lee and Lee compared the charging characteristics of power frequency resonant charging power supply and series resonant charging power supply, and pointed out the advantages of series resonant charging power supply (Lee and Lee, 2018). Li et al. established the equivalent circuit of series resonant charging power supply with constant current load, and deduced the mathematical equation of reactive charging characteristics (Li et al., 2015). Liu and Dai deduced the voltage and current formulas of four operating modes of series resonant power supply, and explained the constant current charging characteristics of series resonant power supply (Liu and Dai, 2016).

Miniaturized high-power high-frequency high-voltage series resonant charging power supply has become more mature, and many companies have formed related products. Jackson said that the product had parallel current sharing technology, and multiple parallel could achieve maximum power 1MJ/s (Jackson, 2016). Morshead et al. successfully developed 25kV, 35 kJ/s capacitor charging power supply, and used series resonant charging technology with switching frequency of 20 kHz (Morshead et al., 2017).

Domestic high-power laser charging power supply is mainly power-frequency L-C resonant high-voltage charging power supply. In China's representative Shenguang and Xingguang laser nuclear fusion devices, power-frequency L-C resonant charging power supply is used. The high-power laser of Institute of Electronics of Chinese Academy of Sciences also uses power-frequency L-C resonant charging power supply. Murasawa's high-frequency and high-voltage charging power supply used voltage doubling mode to make the charging voltage reach 50kV and the average charging power was less than 2kW. It could be used as a single laser debugging test and it needed to limit the current of high-voltage discharge (Murasawa, 2017). At present, Naderi and Shiri are engaged in the research of high-power, high-frequency and high-voltage charging power supply, and they are still in the experimental research. The technology is not mature enough to form the related shaped products (Naderi and Shiri, 2017). The leading technology is mainly the Huazhong University of Science and Technology and the Institute of Electrical Engineering of the Chinese Academy of Sciences. The output voltage of the charging power supply developed by Pritchard et al. is continuously adjustable from 0 to 25kV. The rated charging voltage is 23kV, the average charging power is 1 kJ/s, the peak power is 25kW, the load capacitance is 2420uF, and the charging efficiency is more than 85%. The series resonant charging technology with fixed pulse width of 16.3us and switching frequency control was used (Pritchard et al., 2016). Salazar et al. developed a series resonant charging power supply operating in the current continuous mode, with a switching frequency of 25kHz, a resonant frequency of 42.5kHz, a charging voltage of 10kV, and an average charging power of 20kJ/s (Salazar et al., 2015). Zhou et al. developed a series resonant charging power supply operating in the current continuous mode with full digital control, whose switching frequency was 21kHz, resonant frequency was 37kHz, charging voltage was 10kV, average charging power was 20kJ/s, peak power was 43kW, and overall size was 500 *450 *350mm (Zhou et al., 2017).

In summary, the above research work mainly carries on the thorough analysis to the high frequency electronic appliances in the measurement aspect. It is possible to carry on the mutual assistance according to the high voltage and the low voltage two forms to carry on the implementation, which will make the device voltage in the balanced state. The volume of transformer cores transmitting the same energy is inversely proportional to the working frequency, and the volume of high frequency transformer is much smaller than that of power frequency transformer. In the field of low voltage power supply, high frequency switching power supply has replaced power frequency power supply. Therefore, based on the above research status, an improved precision measurement method based on high voltage charging low voltage measurement is mainly analysed and studied, and the appropriate measurement form is found out to play a promoting role in the subsequent implementation.

## 3. Method

### 3.1 Analysis of measurement methods

Various rapid measurement methods are based on one certain model; the measurement time is shortened and the measurement speed is improved by various means. Despite their own advantages and disadvantages, the basic requirements for the measurement method in the actual test are consistent. Figure 1 shows the specific requirements.

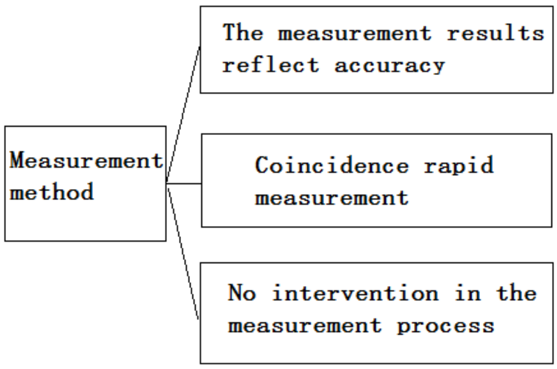


*Figure 1: Basic requirements for measurement methods*

The measurement process of all methods requires manual intervention. The control switch is also required to change the measurement circuit. The time when the switch is disconnected has a great influence on the overall measurement effect; the specific manual operation time cannot be easily grasped, and the operation engineering is also complicated, which cannot meet the automation of the operation process. The circuit abrupt method of increasing the loop resistance needs to select the resistance value of the series according to the capacity of the power transformer; the high-voltage charging and low-voltage measurement method should also determine the power needed according to the capacity of the transformer; the operation in the magnetic flux pump measurement process is complicated. These problems above limit their application. In order to improve the measurement accuracy, the above four static measurement methods should be combined with bridge measurement. Under the condition of maintaining its measurement accuracy and sensitivity, the bridge must flow a certain test current, and its size is related to that of the measured resistance. Its inductance L is expressed as shown in Figure 2.

$$L=\frac{\Phi}{I}=\frac{KIns}{lI}=\frac{Kns}{l}\mu$$

*Figure 2: Transformer winding formula*

### 2.2 Measurement method adjustment

Figure 1 shows that the inductance L of the power transformer winding is determined by the number of turns in the winding, the loop length of the core, and the magnetic permeability of the silicon steel sheet. For the measured power transformer, n, s, and l are known and determined, and only the magnetic permeability μ can be changed. The saturable magnetic circuit method is a fast measurement by reducing the inductance. This method is simple in measuring the front wiring, only by connecting the high and low voltage windings in series, with no need to connect the components such as resistors and capacitors. During the measurement process, the basic measurement loop is not changed, but only to improve the large inductance value L affecting the rapid measurement, so it is a practical method with limited side effect. The basic principle of the saturable magnetic circuit method is to use the high-voltage windings of the same phase and the same polarity to assist the magnetism. Since the number of turns in the high-voltage winding is much larger than those in the low-voltage winding. With the number of excitation ampere-turns in the high-voltage winding, the smaller current can ensure the core to be be saturated, so as to reduce the self-inductance effect, greatly decrease the winding inductance, and shorten the test time. Thus, the purpose of rapid measurement can be achieved. At present, the constant current source is widely used in the measurement of DC resistance. It cannot change the inductance and resistance parameters of the transformer winding, but the stable current value can be increased during the test, and then the test time can be shortened. Meanwhile, the simulation shows that the larger DC current is beneficial to the rapid measurement of the inductive load DC resistance; the DC current with high stability is beneficial to the accuracy of the inductive load DC resistance measurement. Therefore, it's the best choice of the high-current constant current source with high stability to be combined with saturable magnetic circuit method. Its technical advantages are reflected in Figure 3.

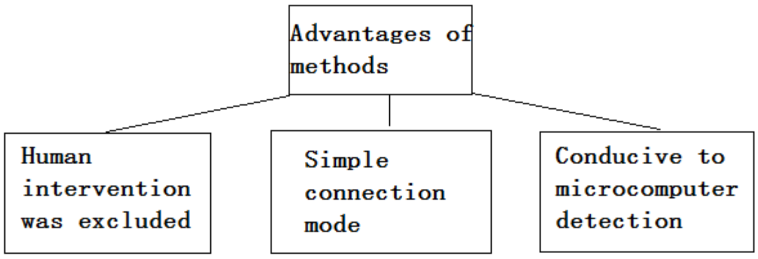


*Figure 3: Advantages of improved methods*

**2.3 Measurement experiment and design**

Firstly, the characteristics and performance of various constant current source circuits were briefly introduced according to the adjustment method. Then, in terms of different adjustment components used, they were discussed in detail. Specifically, the constant current source can be classified into the types as shown in Figure 4

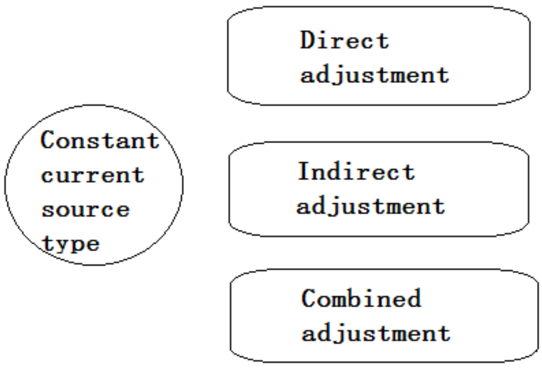


*Figure 4: Constant-current source classification*

With the rapid development of power electronics technology, high-frequency switching power supplies have received extensive attention due to their small size, light weight and high efficiency. However, its disadvantages such as large switch interference and complicated control lines, limit the application, e.g., the stabilized pressure source and steady current source needed by the measuring instrument require the power supply to be continuously adjustable within a certain range, high stability and good protection performance. If directly using the high-frequency switching power supply is directly used, it shall lead to great technical difficulty, high cost, and small practical value. The series DC regulated power supply has the characteristics of wide voltage regulation range, good stability and simple control circuit, but its power consumption of the voltage regulator is large, and the withstand voltage performance isn't high. Based on the characteristics of the high-frequency switching power supply and the series DC regulated power supply, the scheme shown below in Figure 5 is generally selected.

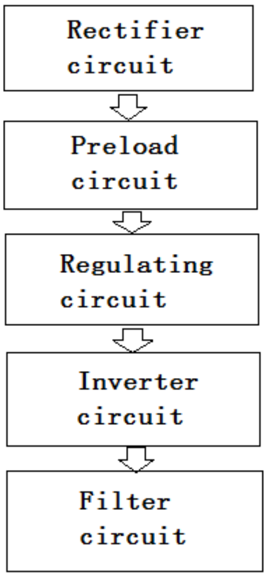


*Figure 5: Circuit composition scheme*

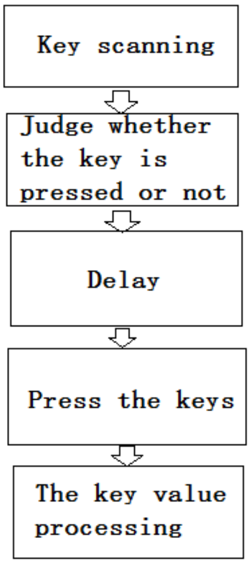


*Figure 6: Process flow chart*

The control circuit, based on the 80C196 single-chip microcomputer (SCM), includes sampling circuit, AC synchronous circuit, thyristor trigger drive circuit, high-frequency inverter circuit trigger drive and protection circuit. The voltage regulation process of this circuit consists of two parts: the series voltage regulator circuit and the thyristor pre-regulation circuit. The former is the same as the conventional voltage regulator circuit. By sampling the output voltage and feeding back the output voltage to the comparison circuit and comparing with the reference voltage, the series voltage regulator circuit makes adjustment according to the differences compared by the comparators to stabilize the output. The latter detects the input voltage of the adjustment tube and the output reference voltage of the system through the detection circuit to the SCM, which compares the difference between the two with the reference voltage; then, based on the difference compared, the single-chip microcomputer generates the trigger angle of the thyristor, to ensure the voltage across the regulator to be the set value and stabilize the input voltage of the regulator. Thus, the stability of the power supply is greatly improved by the two-step voltage regulation above. Overcurrent protection is achieved by the current commutation circuit. In case of overcurrent, the commutation circuit through the commutation can ensure that the thyristor pre-regulation circuit does not work, and cut off the input of the series regulator circuit, to reduce the current of the circuit. When the overcurrent is eliminated, the SCM restarts the pre-regulation circuit to protect the circuit from working.

## 4. Results and analysis

The start-up of the test program is controlled by the button. When the test button is pressed, the channel for the gates is controlled by the program, the preset magnification is selected, and then the power is turned on to start charging the transformer winding. During the charging process, the charging current is sampled at any time. When the charging current reaches a preset current value, the current speed drop in the winding is stabilized. In this process, the current value in the winding is sampled, and when the current is stable, the sampled current value is recorded and stored in the RAM. Then, another channel is gated to measure the voltage drop across the winding, and the winding resistance can be obtained by calculation. After completing the measurement, the winding must also be discharged to prevent the counter EMF from harming the device and the human body. All data within the interval, along with the latest data at the end, form the current queuing result. The data of each new sampling point that comes afterwards will be put back into the queued temporary storage area along with the latest data at the end, until the last set of positions in the data temporary storage area is occupied, and then the sequence re-starts from the beginning, as shown in Figure 6.

## 5. Conclusions

The high-voltage charging low-voltage measurement method, the magnetic flux pump method, and the circuit abrupt method for increasing the loop resistance all need to strictly control the switch off time in the measurement process, otherwise the measurement speed and accuracy are affected. The short-circuit demagnetization method must effectively achieve the effect of eliminating the influence of the current free component; the resistor R connected in series in the loop must generally be larger than several tens of ohms. But the heat dissipation power of the resistor is large and the utility is not large. The above methods are usually combined with bridge measurements, and measurement accuracy is affected. Through analytic research, this paper proposes an improved scheme combining the high- and low-voltage winding series saturable magnetic circuit method with the constant current source, which can effectively compensate for the defects of the commonly used measurement methods. It is a good method for rapid measurement of DC resistance. Besides, the measurement testing of the performance parameters was carried out, to find that the data results meet the requirements, and the software design is more perfect.

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