Development of 25KV High Voltage Adjustable DC Generator

Abstract
This paper mainly introduces a kind of 25KV adjustable dc generators. This generator adopts the technology of linear regulator; voltage doubling rectifier technology produces the output voltage of the wide range of high stability. The generator has strong versatility, safety and economy. This paper expounds the function, use and design principle of the generator and the production process, and circuit diagram is given.

Key Words: High voltage; generator adjustable; high voltage table

1 Introduction

Dc high voltage generator is widely used in industry, agriculture, national defense, scientific research and other fields. Considered versatility and economical especially scientific research field: people usually require a dc high voltage generator with high stability, high reliability and output of wide range. In laboratory and industrial production, however, there are a lot of instruments and equipment with having high voltage dc voltage generator, some still require the output voltage generator that can be a wide-range and consecutive adjustment, in view of the current production of some small power dc high voltage generator bulky, heavy, too many and complicated components, only needs to be combined with the experiment, therefore designed and produced a 25KV continuous adjustable dc high voltage generator is designed and produced, through the laboratory test and the actual operation, proving that its work is reliable, various technical indicators have reached the original design requirements.

Technical indicators as shown below:
(1) DC voltage output of continuous adjustable is 0 to 25KV.
(2) The maximum power output is 12.5W.
(3) A set of high voltage output port can be connected dc high-voltage table.
(4) The volume is 400mm*200mm*300mm.
(5) The weight is about 3.5KG.

2 System scheme and working principle

The generator is fast silicon controlled rectifier as switching element, the power frequency of 50HZ is frequency doubling and booster rectifier, and then the generator
unit that is the high voltage dc voltage is produced by five times the voltage rectifier series of the middle of power supply.

The main loop of the dc high voltage generator is composed by three parts that concluding the input adjustment circuit changed, voltage doubling circuit and measurement display circuit. The principle block diagram of generator is shown in figure 1. The system adopts single-phase 220V ac commercial power supply, the 220 v ac voltage rectified through half controlled rectifier bridge of silicon controlled rectifier, filter and voltage regulator of adjusting the tube, the inverter is provided the dc voltage current of a high degree of stability and small ripple. The silicon controlled rectifier inverter transform dc voltage this as the intermediate frequency alternating current (ac), boosting through the intermediate frequency transformer booster, finally the dc high voltage is produced by variable voltage doublers rectifying voltage double.

![Figure 1: The principle block diagram of dc high voltage generator](image)

### 2.1 Adjustable dc voltage stabilized circuit

Adjustable dc voltage stabilized consists of circuit with AC-DC switching power supply and the silicon controlled rectifier ac regulator. It outputs 220V ac power frequency voltage after rectification, filtering and linear regulator, and outputting continuous adjustable high voltage stability dc voltage, in order to provide protection for the wide range of high and stable output voltage.

Using silicon controlled rectifier as ac switch, through properly changing synchronous trigger pulse time on silicon controlled rectifier control electrode to change the size of the conduction angles, can non-contact continuously adjust the size of voltage effective value, and it can be showed by figure 2 and the following formula:
To set the input sine wave voltage $U_d = \sqrt{2}U \sin \omega t$ $\tilde{U}$ is virtual value, control angle of silicon controlled rectifier is $\alpha$, so voltage effective value is

$$\tilde{U}_0 = \frac{1}{\sqrt{2\pi}} \cdot 2 \int_0^{\alpha} (\sqrt{2}U \sin \omega t)^2 d(\omega t) = \tilde{U} \frac{1}{\sqrt{2\pi}} \sin \frac{2\alpha}{\pi} + \frac{\pi - \alpha}{\pi}$$

(1)

On the type, when the control angle $\alpha$ changes, the output voltage changes. When $\alpha$ increases, $\tilde{U}_0$ decreases, and on the other hand, $\tilde{U}_0$ increases, so we can continuously adjust the size of the output voltage by adjusting the size of the control angle. The input ac voltage boost in transformer, then rectified through bridge of high voltage silicon pile, divider, we can get continuously adjustable dc high voltage output.

Using silicon controlled rectifier ac regulator, silicon controlled rectifier ac voltage regulator consists of two parts, including controlled rectifying circuit and trigger circuit, the circuit principle diagram 3 as shown in the figure below, it has small volume, light weight, high efficiency, long life, fast, and convenient to use.

From the figure, the diode D1-D4 constants of bridge rectifier circuit, base diode T1 forms relaxation oscillator which is regard as synchronization trigger circuit of silicon controlled rectifier. After the voltage regulator connected to mains, 220V ac rectified from the load resistance RL to diode D1-D4, forming a pulsating dc voltage on both ends of silicon controlled rectifier A, K, the voltage by the resistor R1 from reduction voltage dc power supply of as trigger circuit. In alternating current is half cycle, the rectifier voltage charges capacitance C through R4 and W1. When the charging voltage $U_s$ achieve peak voltage of the T1 pipe Up, T1 tube is from padlock to conduction, and the capacitance C discharges rapidly by T1 tube e, b1 and R2, the result obtains a spike in R2. Regarding the pulse as control signal is sent to control
cabinet of silicon controlled rectifier, making silicon controlled rectifier conduction. The pressure of the tube drops very low after silicon controlled rectifier is conducted, generally less than 1V, so relaxation oscillator stops working. When alternating current passes the zero point, silicon controlled rectifier shuts off automatically. When alternating current is in the negative half cycle, capacitance C is charged again... Such a cycle, we can adjust the load of power on the RL.

2.2 Booster circuit

A booster circuit consists of power frequency transformer, power frequency transformer is also known as low frequency transformer. Low frequency transformer used to diffuse the signal voltage and signal power, also can realize the impedance matching between circuit and the dc has isolation effect. The generator for low frequency transformer adopts EI type magnetic core of the silicon steel sheet; it has low cost, small volume, etc. In this paper, the switch frequency is 50HZ; step-up transformer is from 220V to 5000V.

2.3 Voltage doubling circuit

Voltage doubling circuit consists of high voltage rectifier diode and high-frequency rectifier capacitance. The parameters design of voltage doubling circuit directly affect the output voltage of generator, including the voltage ripple is an important index of generator. The voltage ripple is the peak of ripple voltage in the output voltage of double voltage rectification. The voltage doubling circuit diagram as shown in figure 3, the calculation formula of voltage ripple voltage of doubling circuit is:

\[ \Delta U_0 = \frac{I_{\text{out}}(n+1)}{2fC} \]  

(2)

Including the \( I_{\text{out}} \) is the output current; the \( U_0 \) is the output voltage; the \( f \) is generator frequency; the \( n \) is the order number, usually twice is regarded as 1 order; the \( C \) is the capacity value of capacitance

![Figure 3 voltage doubling circuit diagram](image)
2.4 Output circuit

The 25KV high voltage of the generator is received through 200MΩ voltage divider. We should consider the power efficiency comprehensively and the current output capacity to select the output value of resistance in the actual application. The generator is debugging for the first time, we can use organic glass rod and tube to fix and protect the voltage divider, the result is directly hit the voltage display from the current on both ends of the voltage divider, through analysis, the whole voltage divider is isolated with organic glass, then debugging again, the device is running well.

3 simulation experiment

The generator outputs the dc voltage amplitude of 25KV through the divider, maximum output power is 12.5W; the output resistance is 50MΩ by calculating. The simulation time is 0.1ms, we draw the response curve of output voltage, and the results of simulation are shown in figure 4. As can be seen from the figure 4, the output voltage fluctuations rise rapidly, finally held steady at about 25KV, the simulation results show that the circuit output can meet the design requirements.

![Voltage waveform graph over time](image)

Figure 4 Voltage waveform graph over time

4 Conclusion

Due to the highest output voltage of voltage doubling circuit of the generator is up to 25KV, mishandling prone will produce high voltage power phenomenon, and cause the damage of electric parts. The power frequency transformer, voltage doubling circuit and output circuit of the generator was fixed in a waterproof container, in order to reach the requirement of sealing and insulation. It has the advantage of the adjustable output voltage, high voltage stability, high reliability and low cost, etc. The generator begins to service the lab, it is being normal, reliable
operation, the operation of the instrument is flexible, and make convenient and effectively help experimenter work smoothly.

Reference