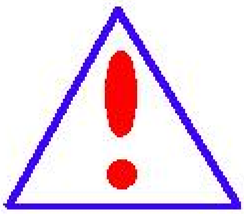
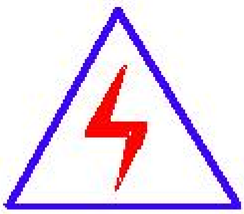
Dear Client,

Thank you for Purchasing our **Automatic Impulse Voltage Test System**. Please read the manual in detail prior to first use, which will help you operate the equipment skillfully.



Our aim is to continually improve and perfect the company's products, so there may be slight differences between your purchase equipment and its instruction manual. You can find the changes in the appendix. Sorry for the inconvenience. If you have further questions, welcome to contact with our service department.



The input/output terminals and the test column may bring voltage, when you plug in/pull out test line or power outlet, they will cause electric spark. PLEASE CAUTION RISK OF ELECTRIC SHOCK! To avoid risk of electric shock, be sure to follow the operating instructions!

◆ SERIOUS COMMITMENT

All products of our company carry one year limited warranty from the date of shipment. If any such product proves defective during this warranty period we will maintain it for free. Meanwhile we implement lifetime service. Except otherwise agreed by contract.

◆ SAFETY REQUIREMENTS

Please read the following safety precautions carefully to avoid personal injury and to prevent the product or any other attached products being damaged. In order to avoid possible danger, this product can only be used within the scope of the provision.

Only qualified technician can carry out maintenance or repair work.

--**To avoid fire hazard or personal injury**:

Use Proper Power Cord

Only use the power wire supplied by the product or meet the specifications of this product.

Connect and Disconnect Correctly

When the test wire is connected to the charged terminal, please do not connect or disconnect the test wire at will.

Grounding

The product is grounded through the power cord; besides, the ground pole of the shell must be grounded. To prevent electric shock, the grounding conductor must be connected to earth ground.

Before making connections to the input or output terminals of the product, please do check that the product is properly grounded.

Pay Attention to the Ratings of All Terminals

To prevent the fire hazard or electric shock, please be care of all ratings and labels/marks of this product. Before connecting, please read the instruction manual to acquire information about the ratings.

Do Not Operate without Covers

Do not operate this product when covers or panels removed.

Use Proper Fuse

Only use the fuse with type and rating specified for the product.

Avoid Touching Bare Wire and Charged Conductor

Do not touch the bare connection points and parts of energized equipment.

Do Not Operate with Suspicious Faults

If you encounter operating faults/suspect there is damage to this product, do not continue. Please contact with our maintenance staff.

Do Not Operate in Wet/Damp Conditions.

Do Not Operate in Explosive Atmospheres.

Ensure Product Surfaces Clean and Dry

一Security Terms

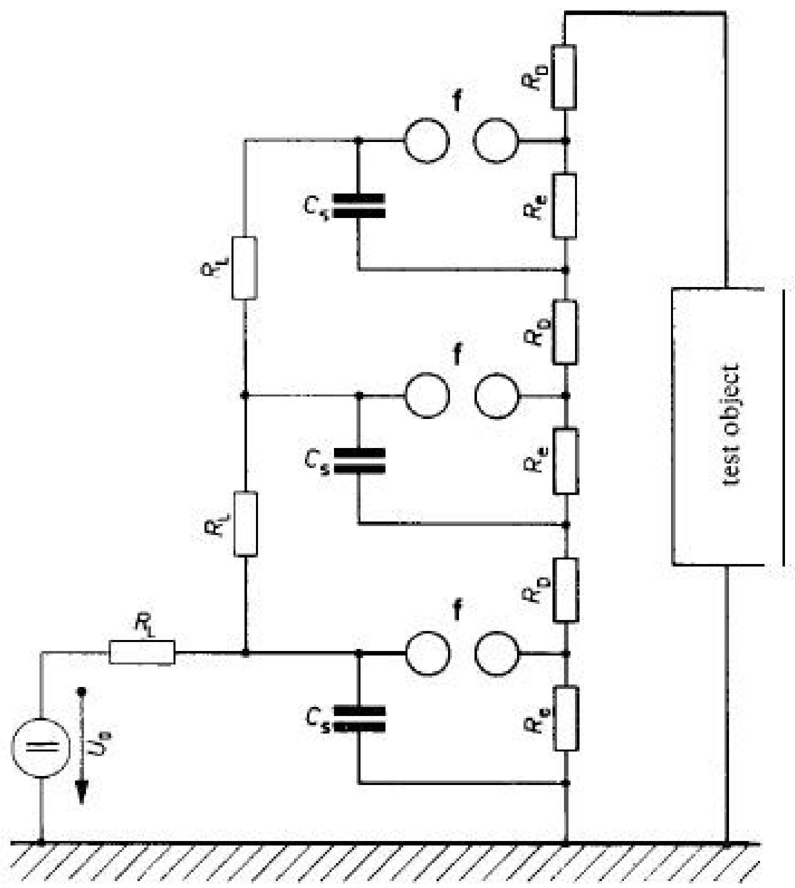
Warning: indicates that death or severe personal injury may result if proper precautions are not taken

Caution: indicates that property damage may result if proper precautions are not taken.

Contents

I. Overview

The impulse voltage test system is a testing equipment that simulates high pulse voltage. In real life, pulse high voltage is often encountered. For example, in natural lightning strikes, very high pulse currents and voltages will appear at the lightning location, and high pulse voltages will also be induced in the surrounding area; For example, the switching operation of switchgear in the power system can also cause transient pulse voltage. These transient pulse voltage amplitudes often exceed tens or hundreds of kilovolts, which can cause equipment damage and endanger personal safety. Therefore, it is necessary to conduct experimental research on impulse voltage. On the other hand, it is also meaningful to study the discharge mechanism by simulating natural lightning phenomena.



1. Marx electric circuit (3 stages) diagram

In order to generate high amplitude pulse voltages, the Marx multi-stage circuit invented in 1923 is still used, as shown in Figure 1. In this circuit, the three-stage capacitors are charged to voltage U_o by a DC voltage source through high resistance R_L in parallel, and then connected in series through synchronous discharge of the three-stage ball gap f, thereby obtaining a pulse voltage of nearly $3U_o$ on the test sample. Although there are multiple different circuit connections for Marx circuits in practical use, the basic principle is the same.

The impulse voltage test system can emit various shapes of pulse waveforms, but according to the needs of experimental research and relevant international and national standards, the following types of impulse voltage waveforms are mainly generated:

1. Standard lightning impulse waveform

2. Standard operating shock waveform

3. Other special impulse voltage waveforms, such as special operation impulse waves.

For the waveform of impulse voltage, three basic parameters are mainly defined to describe the shape of the waveform, namely peak voltage, wave head time, and wave tail time. The parameter definitions of the waveform are shown in Figure 2.

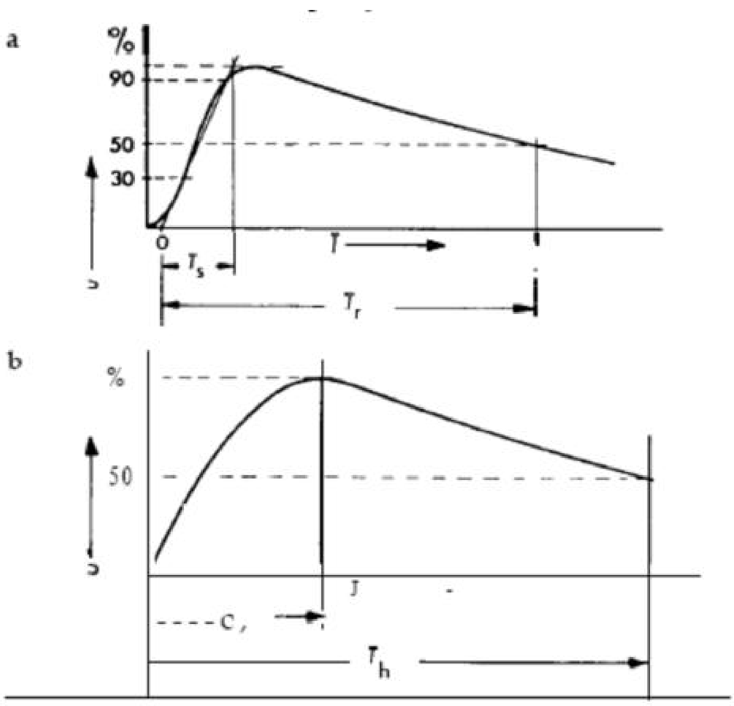


Fig. 2 Standardized test voltages
a Lightning impulse voltage 1.2/50
Front time: $T_s = 1.2 \pm 0.36$ μs
Time of half value: $T_r = 50 \pm 10$ μs
b Switching impulse voltage 250/2500
Front time: $T_{cr} = 250 \pm 50$ pa
Time of half value: $T_h = 2500 \pm 1500$ μs

The impulse voltage test is one of the basic items of high-voltage testing for power equipment. After the design, manufacturing, and repair of power equipment, impulse testing is required to verify or inspect. Common power equipment, including power transformers, power transformers, high-voltage switches, combination devices, lightning arresters, power cables and accessories, bushings and insulators, all require impact testing.

The impulse voltage test is also one of the basic projects in high-voltage testing research. It is necessary to conduct impulse voltage tests in many aspects such as insulation coordination research, electromagnetic compatibility research, and discharge mechanism research.

Therefore, impulse voltage testing equipment has a wide range of applications, and different specifications of impulse testing equipment can be seen in high-voltage testing laboratories in factories, research institutions, and universities.

II. Explanation of Lightning Impulse Voltage Test System

The complete impulse voltage test system is shown in the following figure, including the following parts:

Basic components:

- Impulse voltage generator body
- DC charging power supply
- Capacitive voltage divider (basic load)
- Control system

Extension component:

- chopped gap (single ball or multi-stage)
- Impact splitter
- Lighting Impulse Shock Measurement System

Other options:

- Resistive voltage divider

- Peak Voltage Meter
- Glaninger circuit accessories
- Load expansion compensation device
- Steep gap

1. Impulse voltage generator body and DC charging power supply

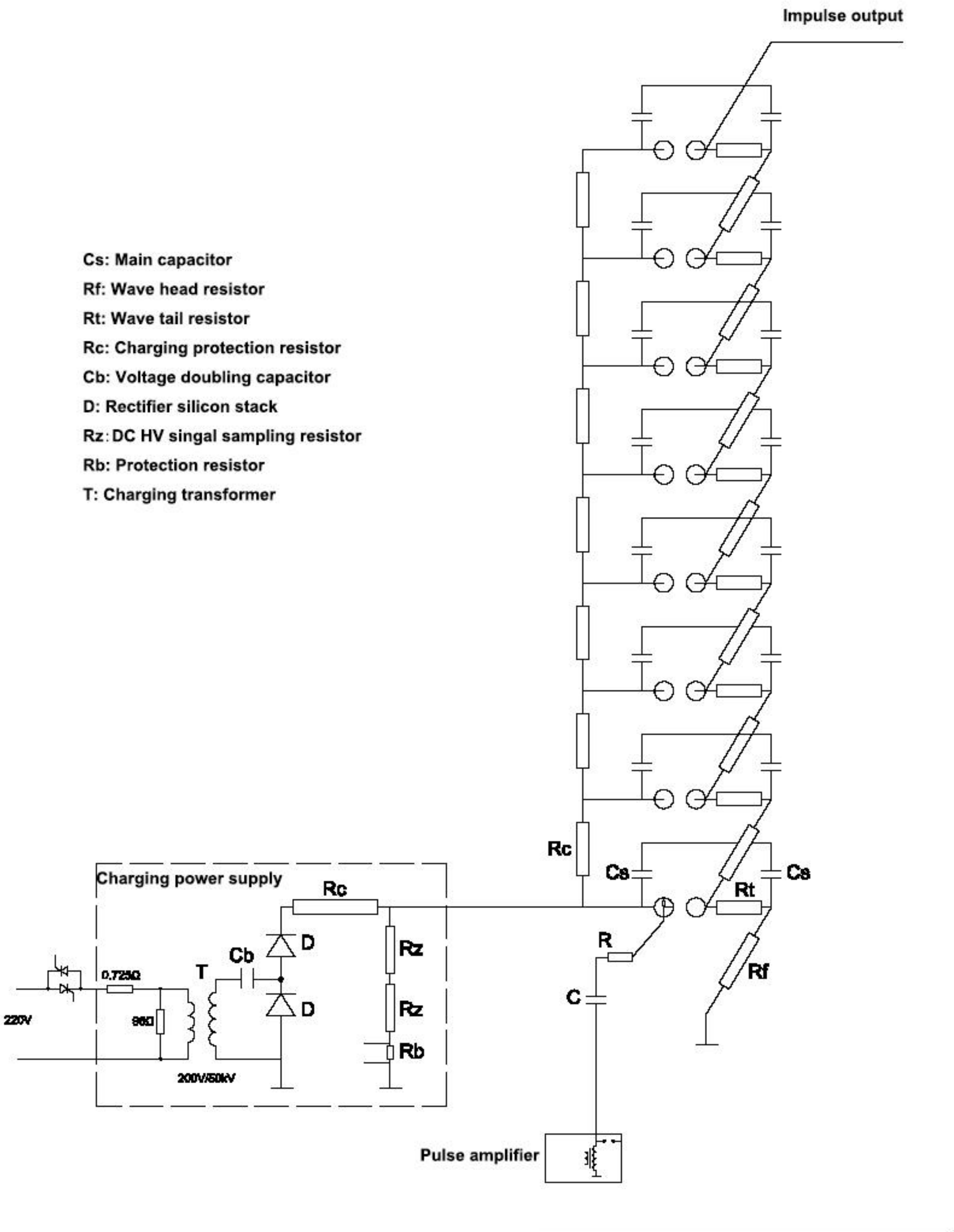
There are various structural forms of the impulse voltage generator body and DC charging power supply, and the basic principle is to use Marx multi-stage circuit, that is, capacitors at all levels are charged in parallel and then discharged in series to obtain pulse high voltage. The main technical parameters of the standard voltage generator body include:

Rated voltage: the sum of the maximum charging voltages at all stages of the generator.

Rated energy storage: the sum of the maximum energy stored by the capacitors at all stage of the generator.

For different structural forms of impulse voltage generators, the current adopted voltage levels mainly include 100kV, 150kV, 200kV, and 300kV, and the capacitance of each stage of the generator is reasonably selected according to experimental needs. The impulse voltage generator adopts 100kV stage voltage.

1.1 Circuit diagram of impulse voltage generator body and DC charging power supply principle



1.2 Description of the impulse voltage generator body structure

The impulse voltage generator is designed for indoor use and is supported by three insulated columns. Connect three columns reliably at each stage of the generator and form a stable structure with each other.

Each stage of the generator has a low inductance, large capacity surge capacitor placed in the center of the surge voltage generator structure. This capacitor adopts high-density solid capacitors, which have the characteristics of light weight and small volume. Even when operated continuously under rated conditions, they have sufficient service life.

All resistors used on the generator are plug-in wire wound resistors. The surge resistor for lightning waves is made of non inductive winding and has a very small inductance. The wave head resistor and wave tail resistor are installed between the two columns of the generator. The charging resistor is installed on one side of the ignition ball gap.

The DC charging power supply (consisting of a high-voltage transformer, a voltage doubling capacitor, and a high-voltage silicon stack) adopts a voltage doubling rectification method. The high-voltage silicon stack is installed on an insulating support plate, and its direction can be manually changed through a simple spring crimping mechanism. The DC high voltage is output to the first stage capacitor of the impulse voltage generator through a protective resistor. The high voltage and high resistance used to measure the charging voltage are also installed on this insulation support plate.

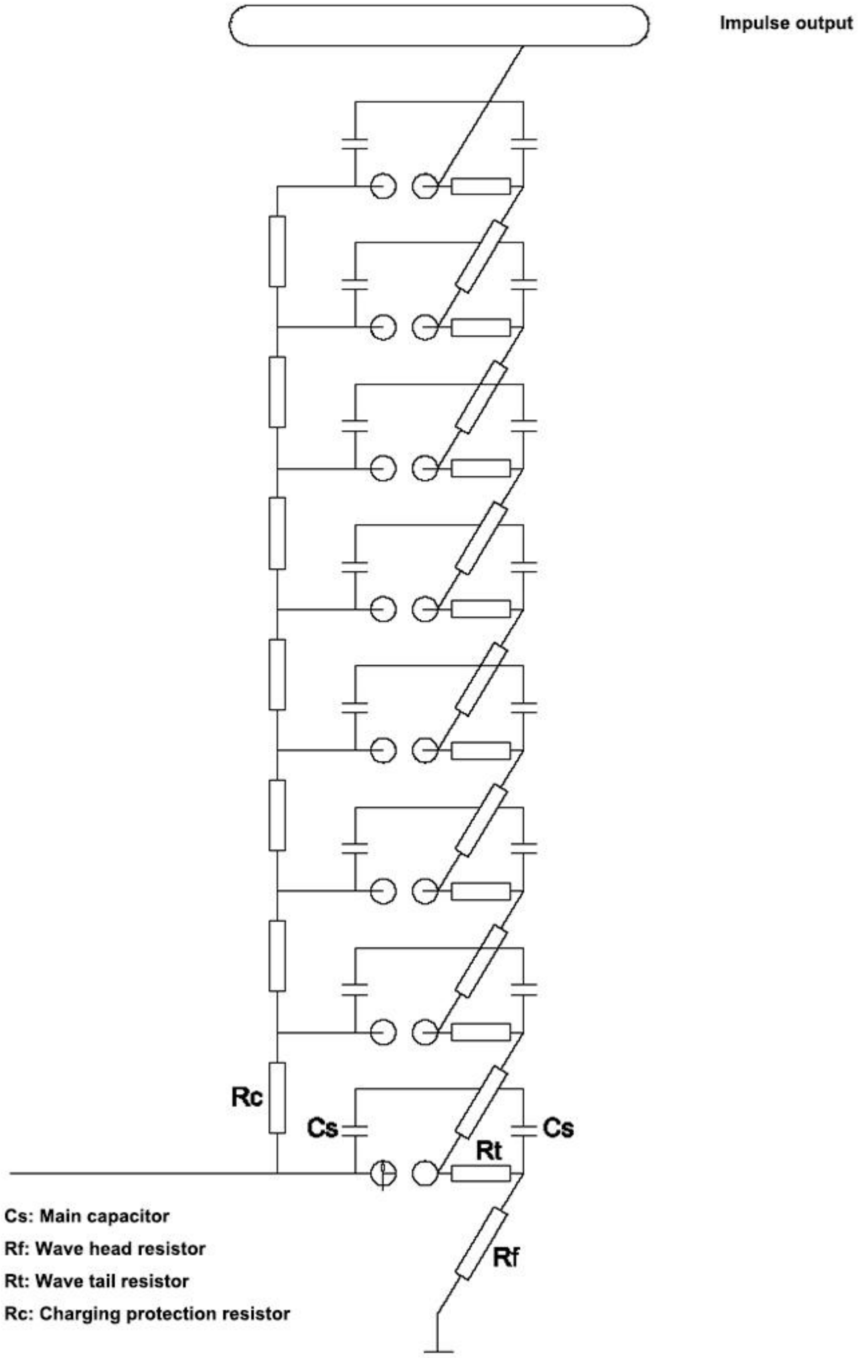
The ignition trigger of the generator is achieved by triggering the ball gap at the lowest level to discharge it. Therefore, the ball gap at the bottom level is designed as a three gap structure. The trigger pulse is a high level, rapidly changing pulse voltage. It is generated by an ignition pulse amplifier. A coupling capacitor for detecting the ignition pulse of the generator is installed on the base of the generator.

To ensure the safe operation of the generator, the system provides a grounding mechanism. Once an abnormality occurs in the generator, the grounding discharge switch will automatically ground after the first charging resistor, resulting in all surge capacitors being discharged through the lowest level resistor.

1.3 Operation mode of impulse voltage generator

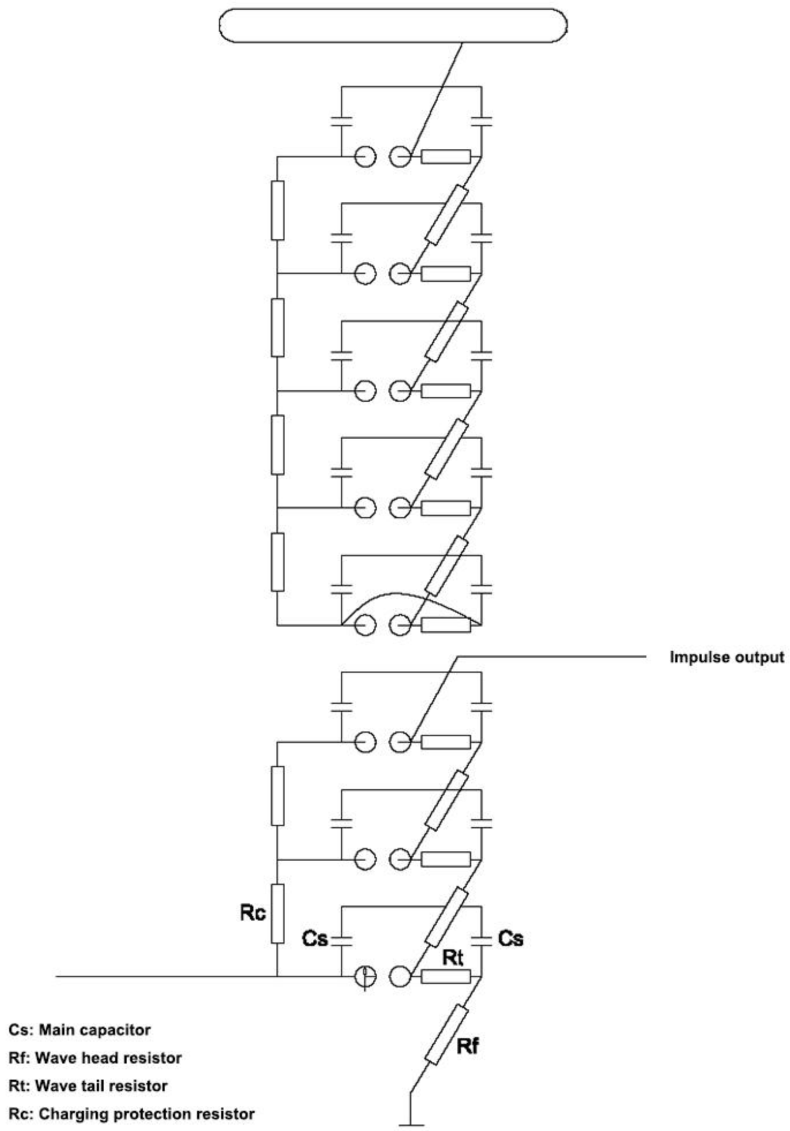
a. Series connection

All n-stages of the impact generator are connected in series at the moment of ignition, and in this wiring method, the maximum output voltage can be obtained. The circuit wiring is shown below.



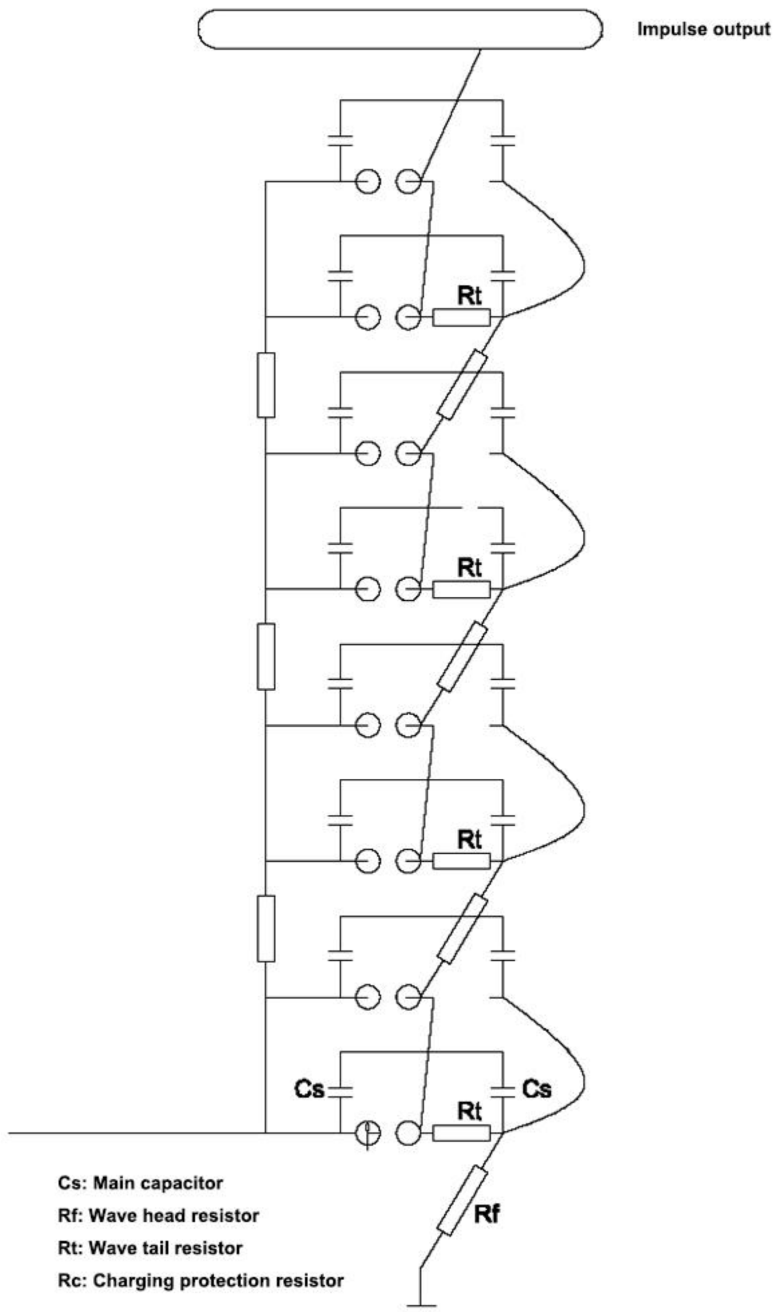
b. Reduce the stage numbers of series connections

The (n-x) stages of the impulse generator are connected in series at the moment of ignition, and the x-stage is short circuited. This connection method can vary between series connections and minimal parallel connections. In this case, the output energy of the generator decreases proportionally by x: n, and the output voltage can be obtained from the highest stage used. The circuit wiring is shown below.



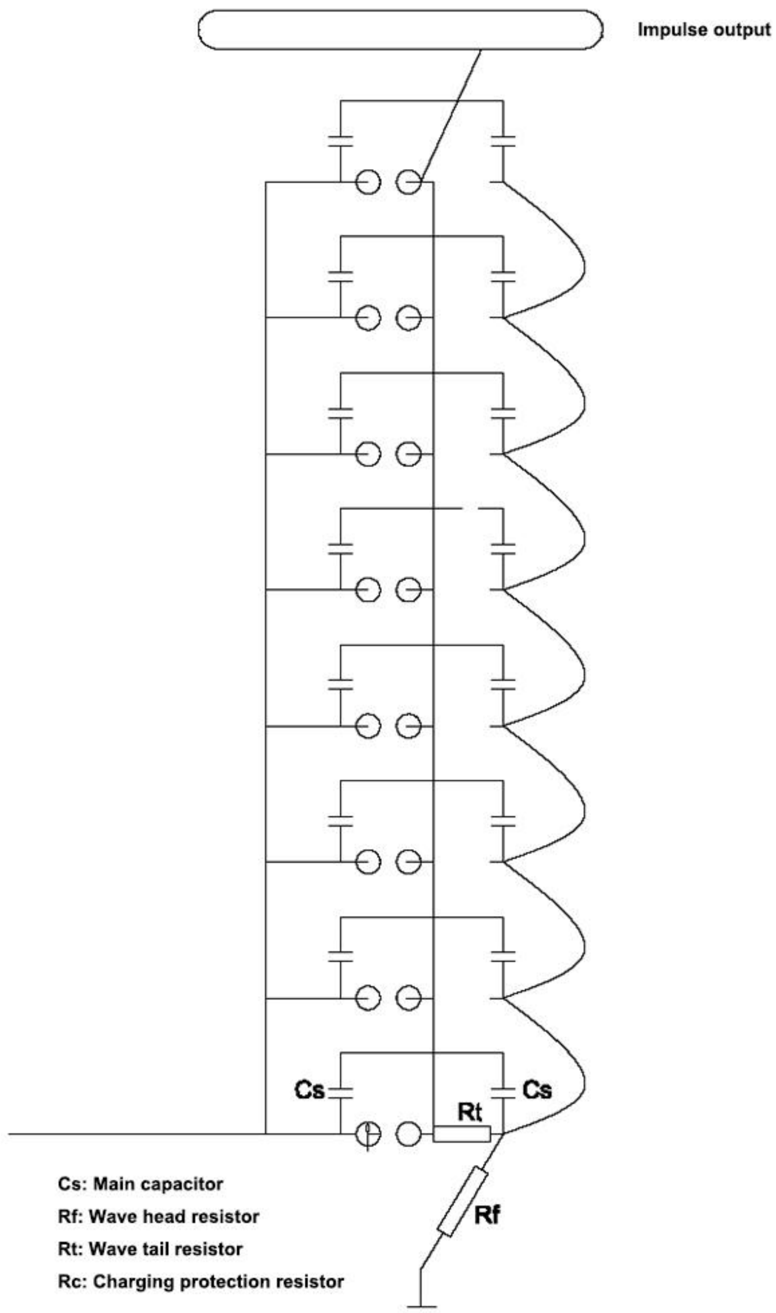
C. Series parallel connection

The s-stage of the impact generator is connected in series, and the p-stage is connected in parallel. In this case, the total charging voltage of the generator is s times the charging voltage of the s-stage. The circuit wiring is shown below.



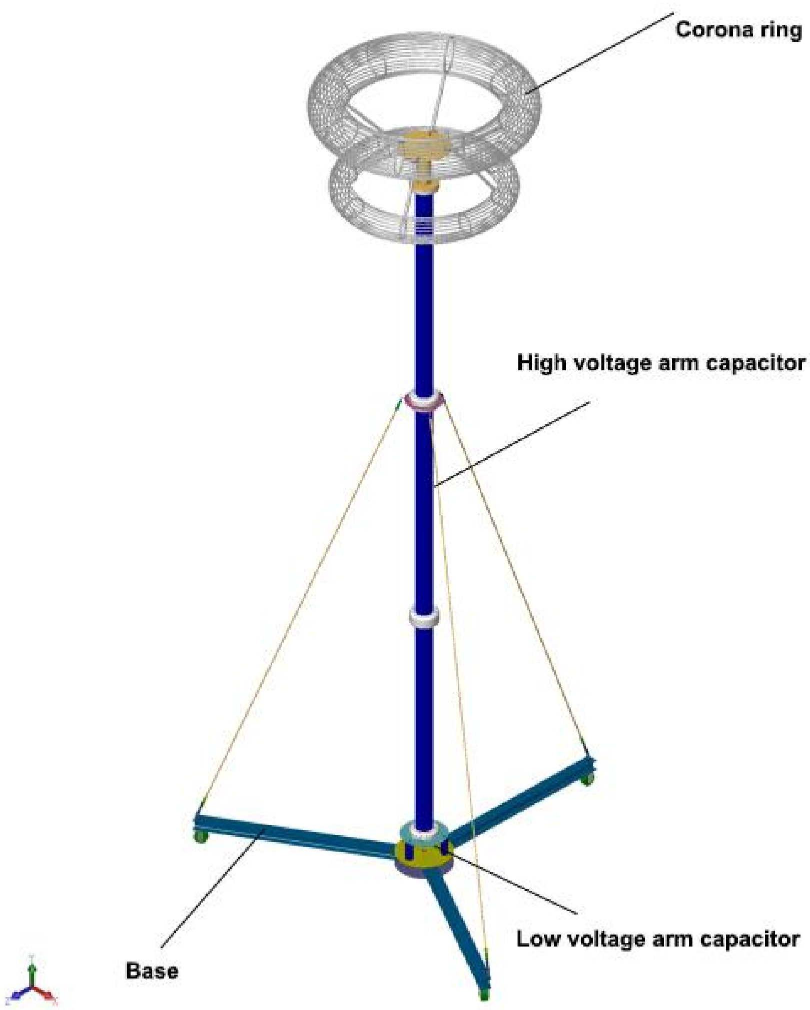
D. Multi Stage parallel connection

This connection method is generally used in the impulse test of transformers and reactors, because the tail time of this test is only determined by the impedance of the test sample. In this connection method, the generator can generate the maximum output energy. The circuit wiring is shown below.



2. Weekly damped capacitive voltage divider

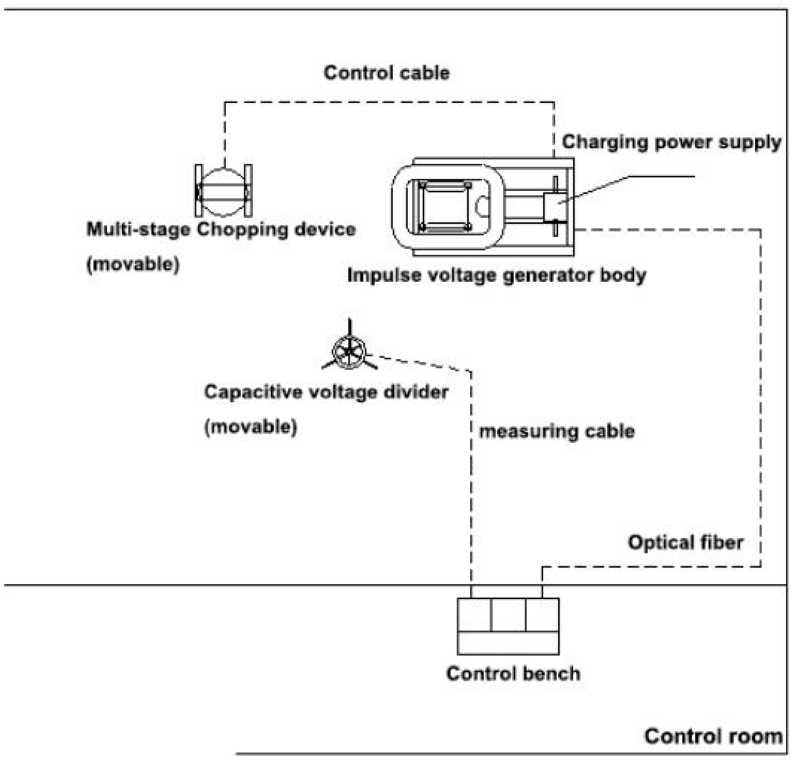
The resistive capacitive voltage divider consists of high voltage arm capacitors and low voltage arm capacitors. As the basic load of the impulse voltage generator, it is a necessary equipment for generating impulse voltage waveforms. At the same time, it proportionally reduces the impulse high voltage to a low voltage signal, which can be measured using a peak voltmeter and waveform measuring instrument. The structural diagram is as follows:



3. Control system

The control system based on PLC technology is used to provide various controls for the impulse voltage generator, fully meeting the various control functions of the impulse test. The control system consists of two parts: the control cabinet (with auxiliary operating unit) and the main operating unit. The control cabinet is installed next to the DC charging power supply at the bottom of the generator, and the main operating unit is installed in the control room. The two are connected by two core optical cables, and their control connections are shown in the following figure.

System Layout Diagram



3.1 System configuration table

Item	Function	Location
Control bench	Provide control command	On the base of generator main body
Pulse amplifier 1	Generator body ball gap trigger	On the base of generator main body
DC blocking capacitor	Isolate the DC high voltage of triggering pulses	Near the 1st ball gap of generator main body
Ignition feedback voltage divider	Detect the triggering status of the generator ball gap	On the base of generator main body
DC voltage divider	Measure the charging voltage of the generator	On the base of generator main body
Pulse amplifier 2	chopped device ball gap trigger	On the base of chopped device
Secondary operating unit	Input and status display of various control commands and parameters	On the control cabinet
Primary operating unit	Input and status display of various control commands and parameters	On the control bench of control room
2-core multimode fiber	Connect the control cabinet and the main operating unit	

3.2 Technical parameters of control system

Charging voltage:

Setting range 0~100.0kV

Working range 10.0~100.0kV

Setting deviation ≤± 1%

Instability ≤ ± 1%

Setting resolution of 0.1kV

Charging time:

Setting range 30-180s

Set resolution for 1 second

Alarm delay of 2s

Applied voltage times: setting range 1~999

Protection setting: overcurrent protection value，settable

Overvoltage protection value，settable

Dynamic charging protection，settable

Output shock stability: ＞ 99%

3.3 The main measurement and control functions of the control system are as follows:

Measurement display:

DC charging voltage

Transformer primary current

Generator body ball gap distance

Status display:

The Switch on-off status of the main power contactor

The Switch on-off status of grounding device

Trigger state of generator ball gap

Polarity status of Generator charging voltage

Control:

The control function has manual, automatic, and program control functions, and each level of function is relatively independent. Adopting thyristor voltage regulation method and equipped with charging voltage feedback measurement system.

The distance between the ignition ball gap and the chopped off ball gap can be manually and automatically adjusted, and displayed on the LCD panel. A truncated trigger pulse with adjustable delay and a feedback system triggered by generator ignition. By using a function controlled constant current charging method, the stability of the charging voltage can reach 0.5%.

The LCD panel can indicate the charging voltage and charging process of the impulse generator, with an accuracy of 1%. The charging voltage and charging time can be directly input from the panel. Equipped with abnormal charging protection function, it can automatically or manually trigger ignition pulses

Indication of the working status of the impact generator, such as self ignition, non triggering, abnormal charging, stable charging, etc.

Grounding and grounding release control of the equipment body and charging part.

It can automatically or manually control the charging process of charging voltage and sound an alarm bell.

Protection and interlocking:

Overcurrent protection

Overvoltage protection

Abnormal charging protection

Door switch interlock

Grounding organization interlock

Polarity conversion interlock

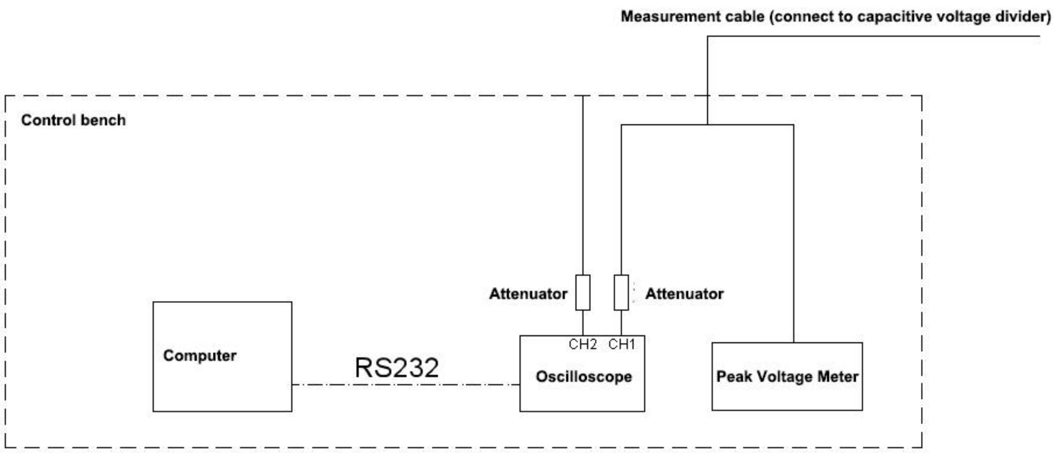
Operation tips:

Equipped with various operation prompts, corresponding prompt screens will pop up when the system encounters errors or improper operations.

4. Impulse voltage measuring instrument

The measurement of impulse voltage uses a peak voltmeter to measure the amplitude of the impulse waveform, or a digital oscilloscope/acquisition card combined with a dedicated measurement software package to measure the impulse waveform. The measurement signal is led out from the low-voltage arm capacitor of the voltage divider by the measurement cable, connected to the input terminal of the peak voltage meter, and also connected to the input attenuator of the digital oscilloscope/acquisition card.

The measurement signal of the other channel of the dual channel digital oscilloscope/acquisition card can be connected to another voltage divider or to a shunt to measure the impulse current signal.



III. Guidelines for the Use of Impulse Voltage Test System

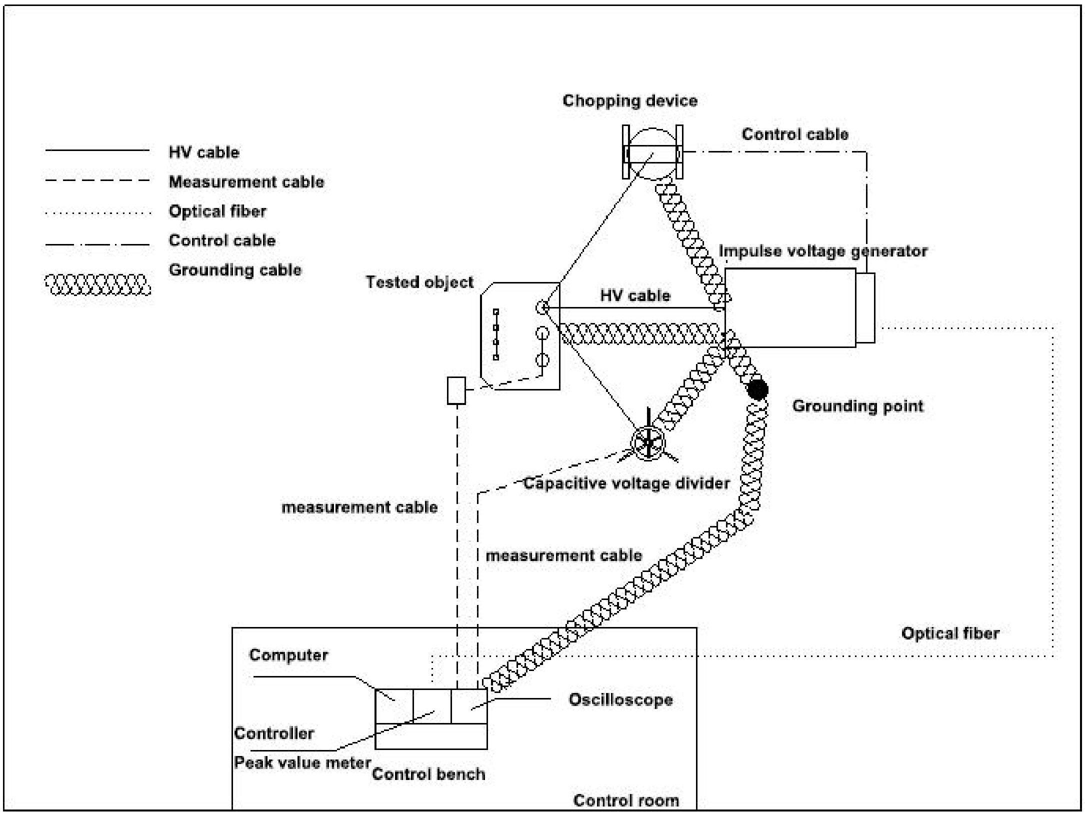
The normal use of the impulse voltage test system includes three aspects: correct wiring, understanding of the test procedure, and proficient operation of the equipment.

1. Wiring of impulse voltage test system

The wiring of the impulse voltage testing system includes the positioning and arrangement of equipment and test objects, the connection of high-voltage leads, the connection of ground wires, and the connection of control and measurement cables. Due to the fact that the impulse voltage testing system includes multiple equipment components, the types of test samples and testing requirements are also different. Therefore, a reasonable test layout is the key to successfully conducting impulse voltage testing. Inappropriate layout and wiring can cause equipment damage.

1.1 Equipment layout and wiring instructions for impulse voltage testing of transformer inductive loads:

Transformer Impulse Voltage Test System wiring diagram



Applicable test samples: transformers, reactors, voltage transformers

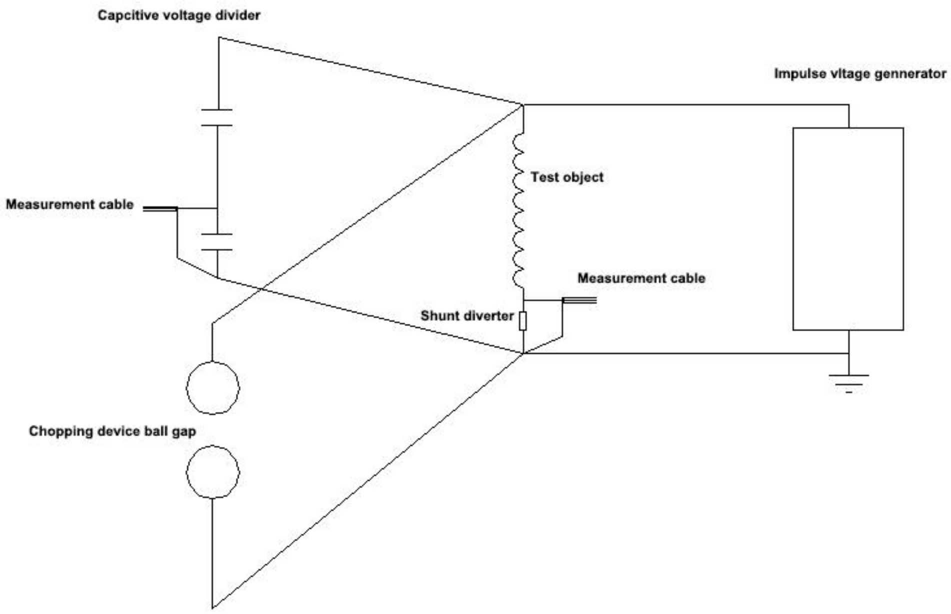
Note:

1. Bare copper wire can be used for high-voltage leads, and sufficient insulation distance should be reserved during connection;

2. It is best to use 150mm width copper foil for the grounding wire.

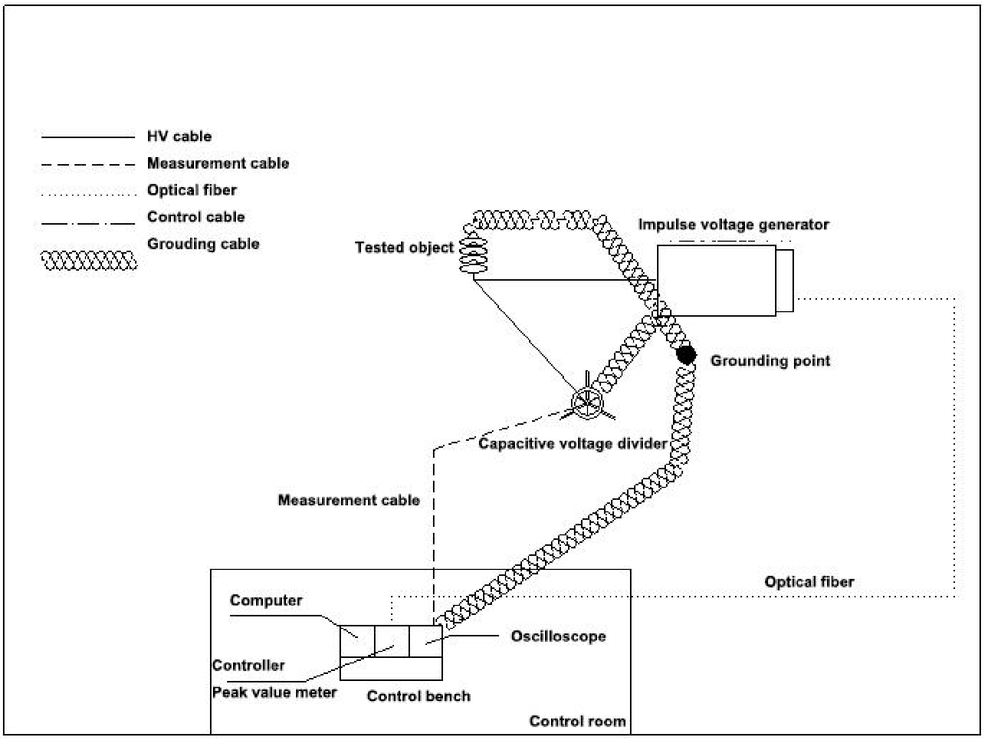
3. Measure cables using RF coaxial cables with specified impedance.

The schematic diagram is as follows:



1.2 Equipment layout and wiring instructions for impulse voltage testing of capacitive loads on insulators etc. :

Capacitive loads Impulse Voltage Test System wiring diagram



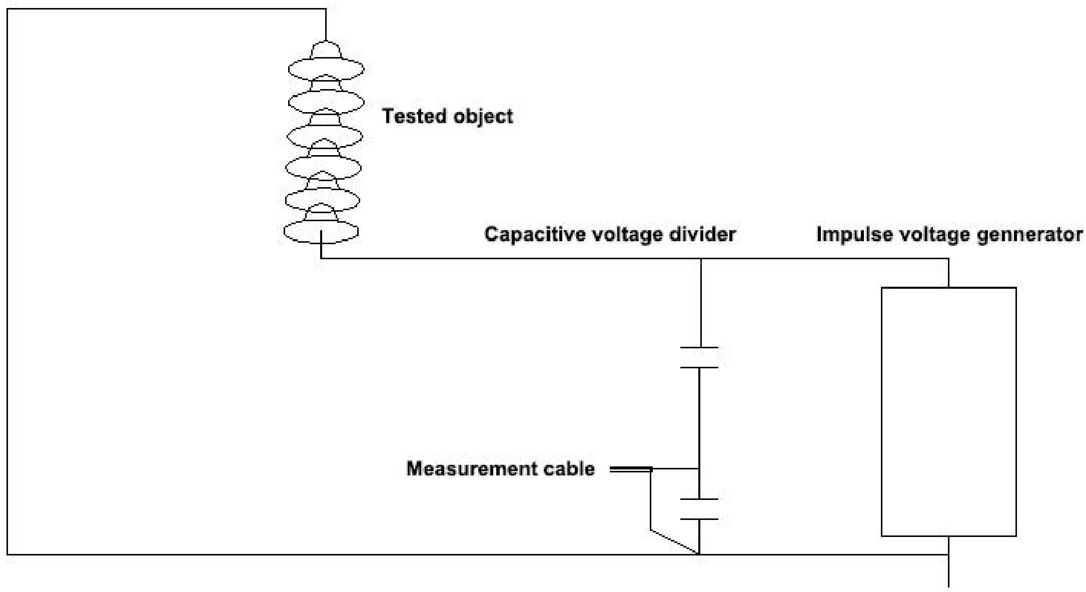
Applicable test samples: insulator strings, composite insulation products, switches, capacitors, power cables, etc

Note: 1. Bare copper wire can be used for high-voltage leads, and sufficient insulation distance should be reserved during connection;

2. It is best to use 150mm width copper foil for the grounding wire.

3. Measure cables using RF coaxial cables with specified impedance.

The wiring schematic is as follows:



2. Principle and Procedure of Impulse Voltage Test

The impulse voltage is a single transient process, so the impulse voltage test has different requirements for the three test quantities of voltage amplitude, voltage waveform, and voltage frequency.

2.1 Voltage amplitude:

For different samples and testing requirements, corresponding impulse voltage amplitudes should be applied. It is easy to understand that the amplitude of the impulse voltage can be adjusted by controlling the charging voltage of the impulse voltage generator. It should be noted that the corresponding relationship between the amplitude of the impulse voltage and the charging voltage is:

$$UP = UC * n * \eta$$

UP: Impulse voltage amplitude

UC: Charging voltage of impulse voltage generator (each stage) n: The stage qty used in the impulse voltage generator

η: Efficiency of impulse voltage generator

2.2 Voltage waveform:

The commonly used waveforms for impulse voltage testing include standard lightning impulse waveform, standard Chopped wave lightning impulse waveform, standard operating impulse waveform, steep wave waveform, and other waveforms with special requirements. The definition of waveform parameters can refer to the provisions of GB/T16927 "High Voltage Test Techniques".

It should be noted that the output waveform of the impulse voltage test circuit is closely related to the distance between the test sample, the components of the test equipment, and the surrounding grounding body. Therefore, the difficulty and most of the work in impulse testing is the wave adjustment work. The key to impact testing is to obtain an impact waveform that meets the standard requirements.

The waveform adjustment usually refers to adjusting the wave head time and wave tail time of the shock waveform. For the chopped test, it is also required to adjust the chopped time, and for the steep wave test, it is required to adjust the steepness of the waveform.

Using a capacitive load as an example to illustrate the steps of wave modulation:

Initial selection of wave modulation resistance value: To obtain the desired impulse waveform, it is necessary to adjust the resistance of the wave head and tail. Due to many influencing factors, the resistance value is difficult to determine in advance. The following formula can be used for initial selection:

$$R_1 = \frac{t_1(c_1 + c_2)}{2.2c_1 + c_2}$$

$$R_2 = \frac{t_2}{0.71(c_1 + c_2)}$$

In the formula:

R_1- wave head resistance value kΩ

R_2- Wave tail resistance value Ω

C_1- Main body impact capacitance μF

C_2- Load capacitance μF, including sample inlet capacitance, impulse voltage divider capacitance, and various parasitic capacitance

t_1- Shock wave head time μs

t_2- Shock wave tail time μs

Adjust the impact waveform and determine efficiency:

Connect the preliminary selected wave adjusting resistor, tested object, and impulse voltage divider, generate an impulse voltage of approximately 0.6 times the test voltage value using a generator, and adjust the resistor to achieve the required impulse waveform. Use an oscilloscope to capture waveforms, calculate efficiency, and determine the charging voltage value for formal testing.

In fact, for different tested object, especially small inductive loads, the tuning of the generator is very complex, and it may be necessary to change the connection method of the generator body, using multi-stage parallel and series connection methods. Therefore, it is necessary to accumulate experience in practical use.

2.3 Number of times of applied Voltage:

After determining the voltage amplitude and waveform, the remaining task is to determine the number of times to apply voltage as needed. It should be noted that the waveform of the impulse voltage has positive and negative polarities, and the number of applied voltages for each polarity should be clearly defined. The interval time between each application of voltage should also be considered.

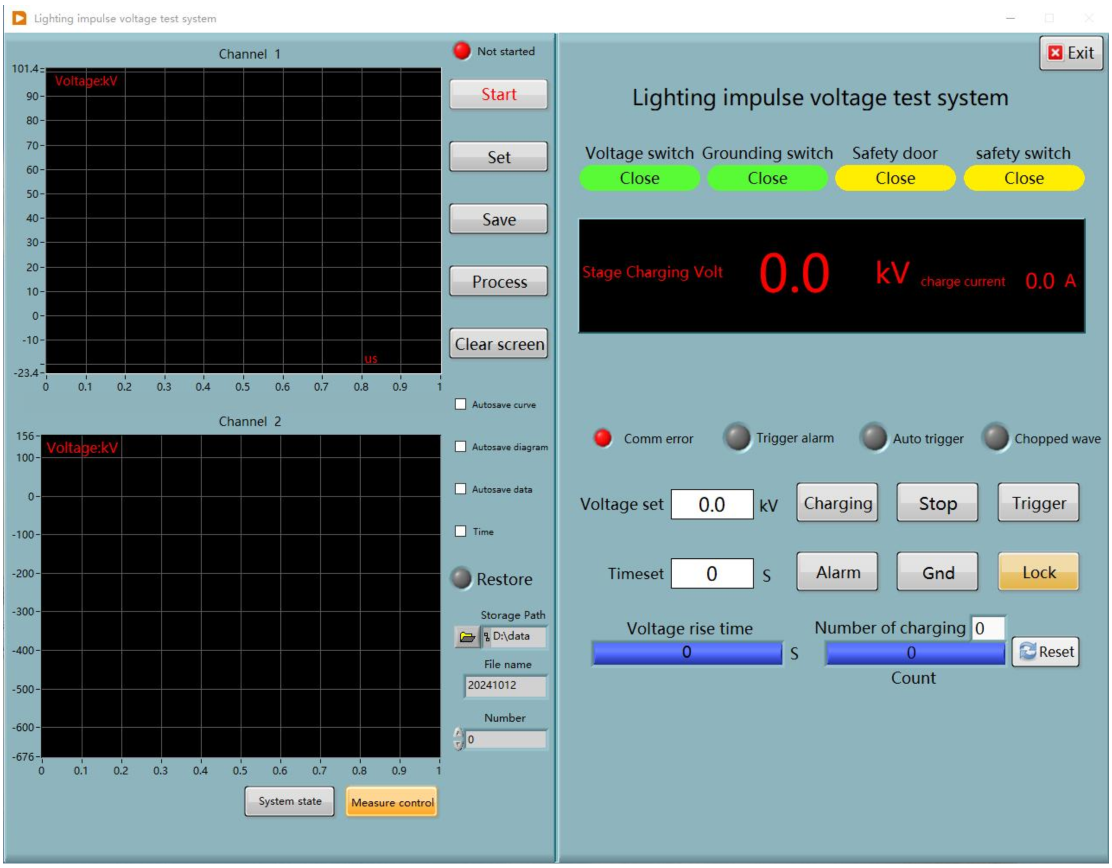
3. Operation brief Introduction of the Impulse Voltage Test System

The operation of the impulse voltage test system is achieved through two parts: the control system and the measurement system. The control system completes the charging, triggering, grounding and other control operations of the impulse voltage generator, and the measurement system completes the measurement of the impulse voltage signal.

After completing the wiring of the impulse voltage test system and clarifying the program requirements for the impulse test, the operation and control of the impulse voltage test system can be carried out.

3.1 Control operation

Control operations are implemented on the operating interface of the control system. The control operation interface is a computer operation interface. The interface is as follows:



3.2 Operating Procedure Instructions

Here are the steps to follow:

3.2.1

Power on the control bench power supply and the impulse voltage generator control bench (next to the charging power supply of the impulse voltage generator) separately. At this point, it should be ensured that the emergency stop button (located next to the console operation interface) is locked, and the safety switch button (located next to the power switch in the main control cabinet) is locked and the generator grounding switch is grounded.

Due to the grounding and safety locking of the generator, the charging operation of the impulse voltage generator is prohibited. At this time, the impulse voltage generator system can be checked for wiring, equipment, and the replacement of the generator's wave head and tail resistors without the risk of high voltage shock.

3.2.2

After confirming that the equipment wiring is correct and there are no other personnel in the test area, the charging operation can begin:

Unlock the safety button and remove the grounding rod;

Reset emergency button

Enter the main control interface from the initial interface and unlock the charging.

Select automatic charging function, ball gap automatic tracking mode, and automatic triggering mode.

Set the charging voltage, charging time, counting times for each stage, and reset the counter.

Set the maximum protection voltage (which should be greater than the charging voltage setting) and the maximum protection charging current.

Press the charging button, and the system will automatically start charging

If the charging restriction is not lifted, the system will not charge and a corresponding prompt screen will pop up.

After the system reaches the set charging voltage, it automatically triggers discharge and continues with the next charging.

Press the grounding button, the system will automatically ground and stop charging

The system is in charging mode. Press the pause button to stop charging, but it is not grounded.

The system is in charging mode. Pressing the emergency button will stop charging and ground the system.

The system automatically counts and stops charging and grounding when the count setting is reached.

3.2.3

Manual control using physical buttons, operating instructions:

Release the charging lock on the main control interface.

Set the charging voltage for each level, count the number of times, and reset the counter.

Set the maximum protection voltage (should be greater than the charging voltage setting) and the maximum protection charging current

Press the close button on the physical button, wait for the light to turn on, press the boost button to start charging, and press the boost button to stop charging.

If the charging restriction is not lifted, the system will not close and a corresponding prompt screen will pop up.

After the system reaches the set charging voltage, it automatically triggers discharge and waits for the next charging. The system stops charging and is not grounded. Press the disconnect button, and the system will automatically ground and stop charging.

The system is in charging mode. Pressing the emergency button will stop charging and ground the system.

The system automatically counts and stops charging and grounding when the count setting is reached.

3.2.4

After completing the charging operation and grounding, the following operations should be confirmed:

Lock the charging button on the control interface

Press the emergency button on the console

Lock the safety button on the control cabinet (button light off)

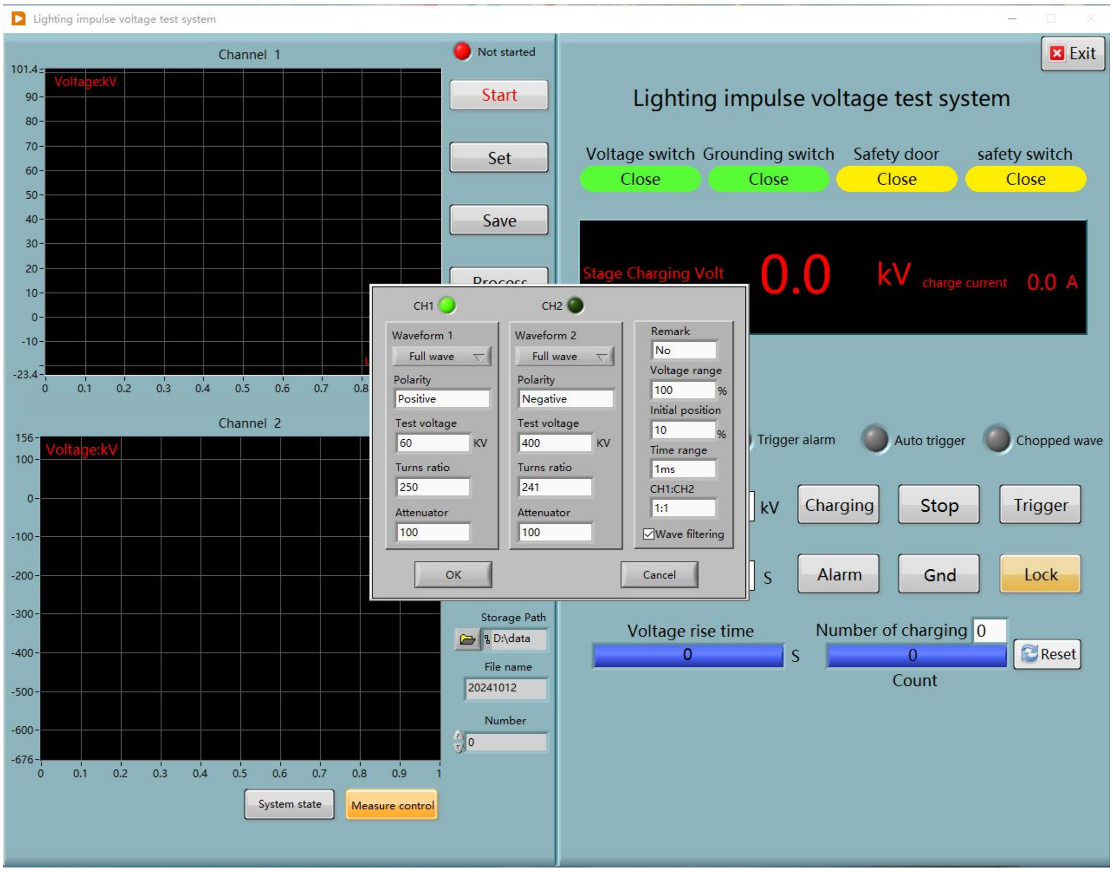
Hang the grounding rod on the first stage DC high voltage output line of the generator

4. Measurement operation

After each trigger of the impulse voltage generator, it will generate impulse high voltage pulses. After being divided by the voltage divider, they will be sent by the measuring cable to the peak voltage meter and oscilloscope on the control panel, which can display the pulse amplitude and waveform, and automatically measure the waveform parameters.

The measurement operation of an oscilloscope is completed by software. Through measurement and control software, the oscilloscope can be set up and the waveform data measured by the oscilloscope can be sent to a computer for display, parameter calculation, waveform analysis, and data storage.

The operation interface is as follows:



The operation steps are as follows:

4.1 Click to enter the main interface of the measurement control software operation

4.2 Click the parameter setting button to enter the parameter setting interface for necessary settings:

Select the measurement channel of the oscilloscope

Select the type of impact waveform to be measured

Select the polarity of the measured impact waveform

Select the maximum value of the measured voltage

Set the dividing ratio of the voltage divider (actual dividing ratio of the input voltage divider)

Set the attenuation ratio of the attenuator,

Select the time to record the waveform

After correctly setting the parameters of the oscilloscope, click the "Get Waveform" button, and the computer will set the oscilloscope and prepare to record the pulse waveform. After the generator is triggered, the oscilloscope will automatically record the waveform and transmit it to the computer screen for display, which can obtain waveform parameters such as pulse amplitude, wave head time, and wave tail time.

4.4 Click the Save Waveform button to save the displayed waveform to the computer's hard drive.

4.5 Click the waveform processing button to retrieve the saved waveforms, generate image files or print them out.

IV. Equipment Maintenance

1. To ensure personal and equipment safety, it is necessary to regularly maintain the generator. To avoid dust accumulation, the generator should be wiped regularly, especially the surfaces of the insulation platform, insulation rod, etc. should be kept clean.
2. During operation and idle, the generator should be protected from moisture. When the surrounding air humidity is too high for a long time, the cover plate of the body should be opened; When the condensation on the inner wall of the insulation cylinder affects its use, clean hot air should be blown into each ventilation hole on the bottom to dry it.
3. After a period of use, lubricating oil should be added to each mechanical transmission part.
4. The semiconductor paint on the surface of the upper ceramic bushing near the middle flange of the high-voltage rectifier transformer should be well protected; If there is strong corona due to wear or failure, semiconductor anti corona paint should be sprayed to make the corona basically disappear.
5. If there is oil leakage or abnormal noise in the components of the generator, it should be stopped from use. It can only be put back into use after repair and passing the test.

6. If the ignition pulse system is not working properly, check whether there are short circuits or open circuits in various parts of the ignition pulse system and solve them.