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Notice.High-voltage line clips are forbidden to be clamped on the red outer sheath.

The high voltage cable clip is connected correctly

UST(As shown Figure1)

GST (As shown Figure2)



Figure1



Figure2

I. Overview

Intelligent $\tan \delta$ Meter is a kind of instrument with high precision fully automatic measuring the dielectric loss tangent and capacitance of various high voltage electrical equipments in the power plants and substations. The adoption of frequency conversion technology could ensure the accurate measurement in the interference of strong electric field.

The operation instruction of the instrument is English. The whole process is measured automatically through microcomputer.

The instrument also applies to the measurement of $\tan \delta$ and electrical capacity of high voltage electrical equipments in the workshops, laboratories and research institutes.

It could measure non-grounded or grounded high voltage equipments adopting positive and negative connection method. Besides, it could measure the $\tan \delta$ of capacitor voltage transformer and capacitance of main capacitor C1 and C2.

The instrument is equipped with high voltage step-up transformer. Besides, it takes security measures like zero-cross closing, lightning protection, etc. During the experiment, different levels of high voltage ranging from 0.5KV to 10kV are outputted. The instrument has the advantages of convenient and safe operation.

Under the circumstance of oil dielectric loss $\geq 0.01\%$, with oil cup, positive wiring can be used to measure the dielectric loss of oil.

This following protection features are included in this instrument:

- High voltage short-circuit protection
- CVT over-voltage protection
- Poor grounding protection

II. Operating principle

Under the AC voltage, the dielectric would consume a part of electrical energy that would be converted to heat energy leading to loss. This kind of energy loss is called the dielectric loss. When AC voltage is applied to the dielectric, phase-angle difference Ψ exist between the voltage and current of dielectric. The δ which is the complementary angle of Ψ is the dielectric loss angle. The $\tan \delta$ which is the tangent of δ is dielectric loss tangent. The value of $\tan \delta$ is the parameter for measuring the dielectric loss. The measuring circuit of the instrument includes a standard loop (C_n) and a tested loop is (C_x) which is shown in Figure 1. Standard loop is

composed of built-in high stable standard capacitor and measurement circuit. The tested loop is composed of specimen and measurement circuit. The measurement circuit is composed by sampling resistance, pre-amplifier and A/D converter. The current amplitude and phase of standard loop and tested loop can be measured by the measurement circuit and be collected real-time digitally by single-chip computer. The capacitance value and dielectric loss tangent of the specimen could be obtained through vector operation. Anti-interference measures are adopted by the instrument so as to make accurate measurement in the interference of external electric field.

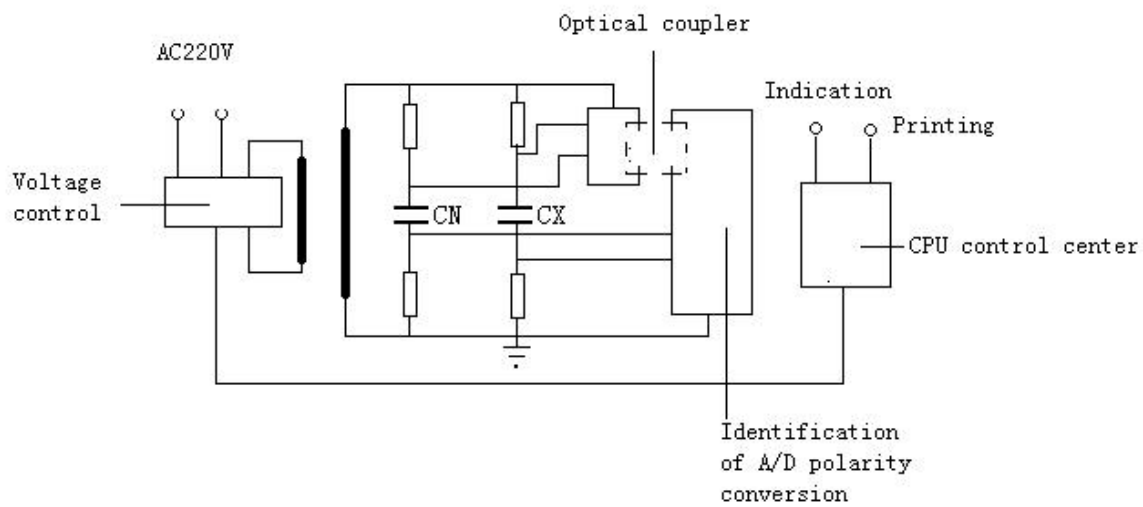
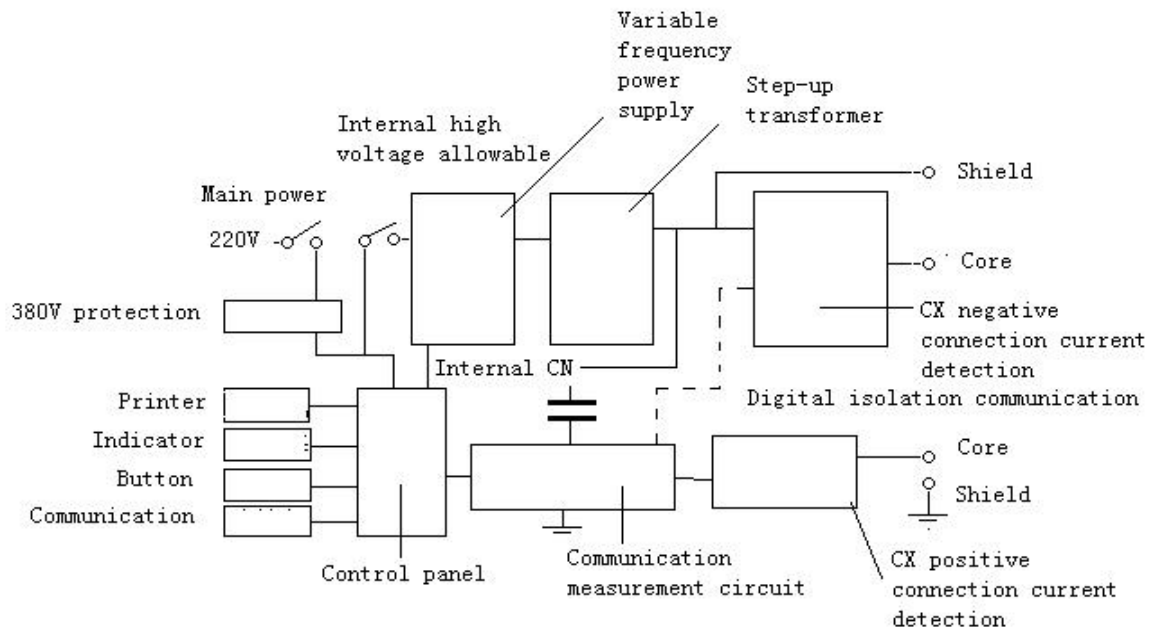


Figure 1 Schematic Diagram of Measurement Principle

1. Structure



Block diagram of instrument structure

Measurement circuit: Fourier transform, complex arithmetic, and all other calculations and range switching, variable frequency power control, etc.

Control panel: printer, keyboard, indicator and communication transferring.

Variable frequency power supply: SPWM switching circuit is adopted to generate and output high-power sine wave stable voltage.

Step-up transformer: the output of variable frequency power supply is stepped up to the measuring voltage. The maximum reactive power output is 2KVA/one minute.

Standard capacitor: internal Cn. It is the measuring basis.

Cn current detection: it is used to detect the internal standard capacitor current, $10\mu\text{A} \sim 1\text{A}$. The input resistance is $<2\Omega$.

Cx positive connection current detection: it is only used for the measurement of positive connection, $10\mu\text{A} \sim 1\text{A}$. The input resistance is $<2\Omega$.

Cx negative connection current detection: it is only used for the measurement of negative connection, $10\mu\text{A} \sim 1\text{A}$. The input resistance is $<2\Omega$.

Negative connection digital isolation communication: precision MPPM digital modem is adopted to transmit the current signal of negative connection to the low voltage side. The isolation voltage is 20KV.

2. Operating principle

After the measuring is started, the high voltage setting value would be transmitted to the variable frequency power supply that would adjust the output to the setting value by the algorithm of PID. The measurement circuit would send the actual measured high voltage to the variable frequency power, finely adjust the low voltage and realize the accurate high-voltage output. According to the setting of positive and negative connection, the measurement circuit would automatic select the input and switch the range based on testing current. Fourier transform is adopted for filtering out interference so as to separate the fundamental wave of signal, make vector operations of the standard current and specimen current, and calculate the capacitance and the $\text{tg}\delta$. After repeated measurements, the intermediate result would be selected. After the completion of measurement, the measurement circuit would send step-down instruction to make the voltage of variable frequency power to be reduced to 0 slowly.

III. Main technical parameters

1. High voltage output: 0.5~10kV

Increasing by 500V for each level, a total of 20 levels, capacity: 1500VA

2. Accuracy: $\text{tg}\delta$: $\pm (\text{reading} * 1.5\% + 0.06\%)$

Cx: $\pm (\text{reading} * 1.5\% + 5 \text{ PF})$

3. Resolution: $\text{tg}\delta$: 0.001% Cx: 0.001pF

4. Measuring range: $0.001\% < \text{tg}\delta < 100\%$

Internal high pressure : 3PF ~60000PF/10KV 60PF~1 μ F/0.5KV

External high pressure: 3PF ~1.5 μ F/10KV 60PF~30 μ F/0.5KV

5. CVT Variable ratio test: Variation ratio measurement accuracy: $\pm \text{reading} * 1\%$

The range of the measurement: 10~99999

Phase measurement accuracy: $\pm 0.1^\circ$

Phase measurement range: 0~359.9 $^\circ$

6. Power supply: AC 220V $\pm 10\%$ 50/60 $\pm 1\text{Hz}$

7. Measuring method: a.single frequency: 45(45Hz measuring)、50(50Hz measuring)、55(55Hz measuring)、60(60Hz measuring)、65(65Hz measuring) b.different frequency: 50D(45Hz/55Hz measure each time) 60D(55Hz/65Hz measure each time) Automatic frequency conversion

8. Harmonic adaptation: $\leq 3\%$

9. Application condition: -15 °C — 50 °C Relative humidity <80%

10. Dimension: 460 (L) × 345 (W) × 345 (H)

11. Weight: 35 kg

IV. Instrument panel

1. The diagram for control panel (Figure 2) and high voltage backplane (Figure 3)

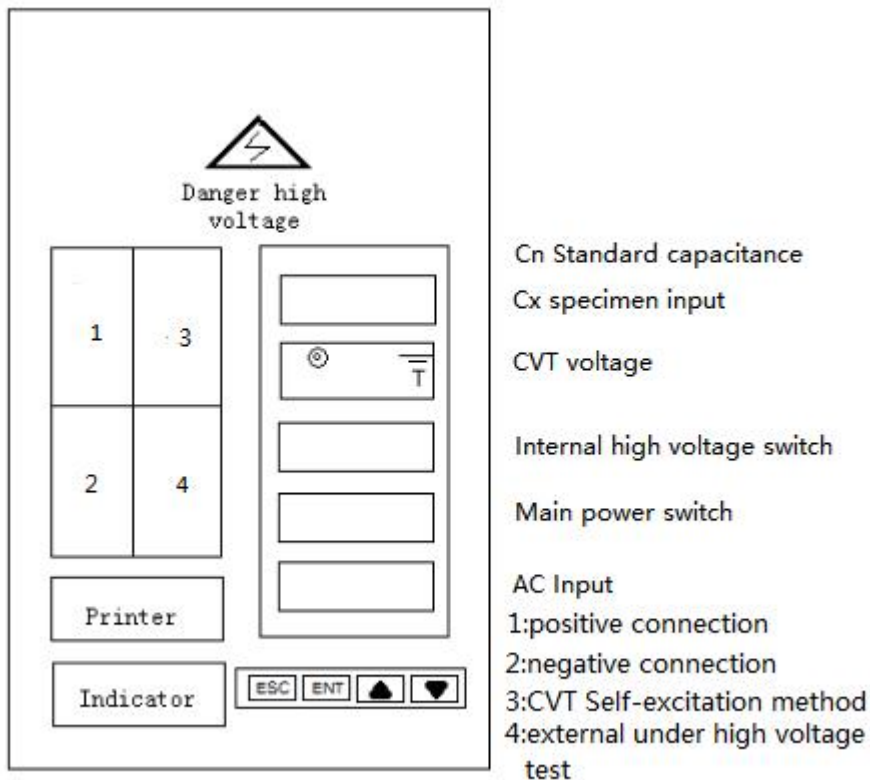


Figure 2

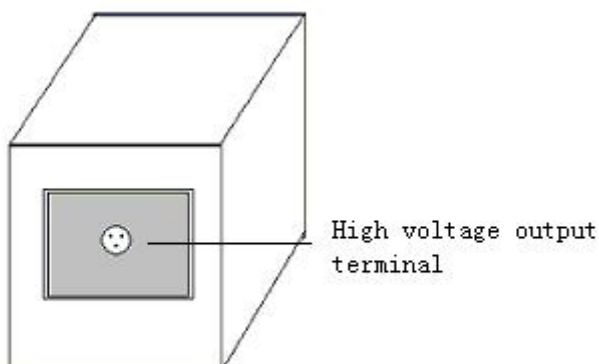


Figure 3

Cx specimen input: The specimen current should be inputted when it is positive connected. The core (red clip) should be connected with low voltage terminal of specimen when it is

positive connected. If the shielding electrode is available in the low voltage terminal, the shielded cable (black clip) could be connected; otherwise, it could be hung. When it is negative connection, Cx specimen input wire could be unconnected or hung.

Earth connection measurement: it is connected with the shell. In the positive and negative measurements, the instrument could be reliably and independently grounded. The grounding conductor cannot be painted or rusty. It should be wiped clean and make sure zero-resistance grounding. Poor grounding could cause errors or data fluctuation. If it is severe, it may cause danger.

Internal high-voltage allowable: Turning on this switch, high voltage would be outputted. Turning off the switch, high voltage will not be generated in the inner and will not be outputted.

Main power switch: Turning on this switch and the indicator would display the measuring content.

Keyboard: "ESC", "ENT", "▲", "▼"

"ESC": denial of the content where the cursor is located or the content has been completed.

"ENT": Once recognition of the content where the cursor is located, you can press this key to confirm and move the cursor to other place.

"▲", "▼": Changing the value or changing P(positive connection), N(negative connection), D(different frequency), S(single frequency) and other contents.

Indicator display: indicating menus, measurement information, measurement results. Sun exposure for long time should be avoided.

Brightness adjustment: adjusting the contrast degree of screen.

V. Operating instructions

The dielectric loss of high voltage winding for low-voltage winding and shell in the measurement of power transformers is an example. The negative connection should be adopted (see the diagram of negative connection method). After checking the proper connection of the instrument

with power transformer, D(different frequency) and 10KV voltage should be selected for measurement and the following operations should be made.

- ① Turn on the main power switch, the display of the screen of instrument is shown in Figure 4.

<input type="checkbox"/> Measuring method	50
Connecting mode	P
Measuring voltage	5KV
Start to measure	

Measuring method	50D
<input type="checkbox"/> Connection mode	P
Measuring voltage	5KV
Start to measure	

Measuring method	50D
Connection mode	N
<input type="checkbox"/> Measuring voltage	10kv
Start to measure	

Figure 4 Startup display

Figure 5 Connecting Mode

Figure 6 Voltage Measurement

- ② Pressing the "ENT", the cursor would go to the "Measuring method ☐ 50", pressing "▲", "▼", it could be adjusted among 50,50D,60,60D,45,55,65, pressing "ESC", the cursor would go to the first line, and then pressing "▼", it would be moved down to the "Connection mode" which is shown in Figure 5.(Measuring method: 45, 50, 55, 60 and 65 respectively represent 45Hz, 50Hz, 55Hz, 60Hz, 65Hz single-frequency measurement, 50D represents 45/55Hz Different frequency measurement,60D represents 55/65Hz Different frequency measurement)

- ③ Pressing the "ENT", the cursor would go to the "Connection mode ☐ P "▲", "▼", it could be adjusted among P,N,CVT,CN50,CN60,V1/V2", pressing "ESC", the cursor would go to the first line, and then pressing "▼", it would be moved down to the " Measuring voltage" which is shown in Figure 6. (Connection mode: P is for positive connection, N for reverse connection,CVT stands for CVT self-excitation measurement, CN50 represents external 50Hz high voltage test, CN60 represents external 60Hz high voltage test,V1/V2 represents the CVT ratio test)

- ④ Pressing the "ENT", the cursor would go to the "Measuring voltage ☐ 0.5KV", pressing "▲", "▼", the voltage could be adjusted among 0.5,1.0,1.5,2.0,2.5.....9.5~10KV, pressing "ESC", the cursor would go to the first line, and then pressing "▼", it would be moved down to the " ☐ Start to measure" which is shown in Figure 7.

Measuring method	50D
Connection mode	N
Measuring voltage	10KV
<input type="checkbox"/> Start to measure	

It is being measured,
please wait...

Dielectric loss: $\text{tg } \delta = 0.42\%$
Capacitance: 1000P

Frequency:	50
Connection mode:	N
Voltage:	10KV
Dielectric loss:	$\text{tg } \delta = 0.42\%$
Capacitance:	1000P

Figure 7 Start to measure Figure 8 Measuring Figure 9 Measurement Result Figure 10 Printing Results

⑤ Turning on the "high voltage allowable" switch, pressing "ENT", the instrument would begin to produce high voltage output accompanied by the hint sound of "beep", at this time, the screen would show "It is being measured, please wait..." which is shown in Figure 8.

⑥ After about 40 seconds, the measurement would be completed. The high voltage would be cut off automatically and the screen would display the measurement results, which is shown in Figure 9.

If the results need to be printed out, you need to press "ENT". It is shown in Figure 10.

⑦ In the boot screen, pressing the "ESC" then 40 sets of historical data could be checked.

VI. Connection

Proper connection method should be selected in accordance with the grounding of tested equipment.

1. P(Positive connection)(UST)

If the low-voltage measuring terminal or secondary port of equipment under test is ground insulated, positive connection should be adopted.

The red special high-voltage cable should be led out from the HVx which is on the back of the instrument; the high-voltage shielded cable should be connected with the high-voltage terminal of equipment under test.

The black special low-voltage cable should be led out from Cx which is on the panel of instrument; the low-voltage core should be connected to the low-voltage terminal L of equipment under test (see Figure 11). The low-voltage shielded cable should be connected to the shielding terminal E of equipment under test. (If shielding terminal is unavailable, then it could be vacant)

The cores of HVx and Cx are not allowed to be shortened with the shielded cable. Otherwise, it

is impossible to sampling and to measure.

2. N(Negative connection)(GST)

If the low-voltage measuring terminal or secondary port of equipment under test is grounded directly, negative connection should be adopted.

The red special high-voltage cable should be led out from the HVx which is on the back of the instrument; the high-voltage core should be connected with the high-voltage terminal of equipment under test. The low-voltage terminal should be grounded (see Figure 12). At this time, the input line of Cx is vacant.

The core of HVx is not allowed to be shortened with the shielded cable. Otherwise, it is impossible to sampling and to measure.

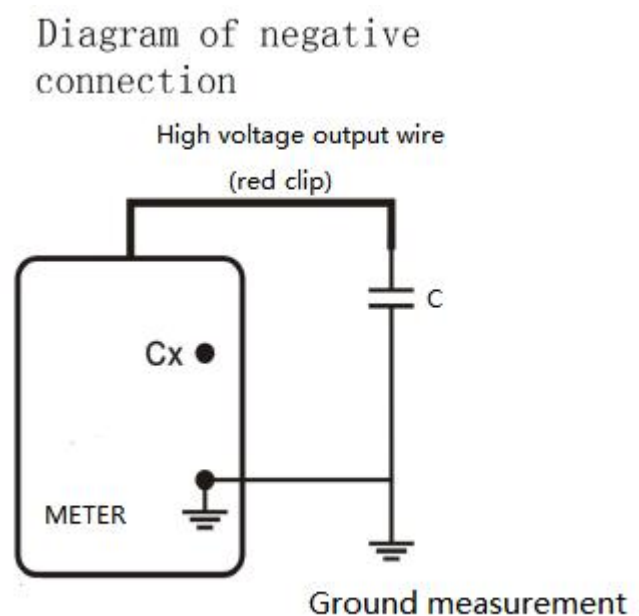
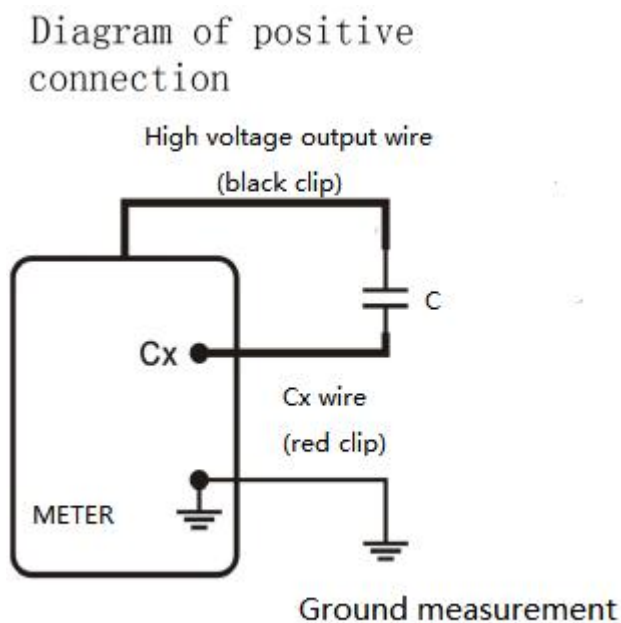


Figure 11 Positive Connection Method

Figure 12 Negative Connection Method

3. Cn(External high voltage test)

When using positive connection, outside the standard capacitance and with high pressure, by using this method.

External high voltage

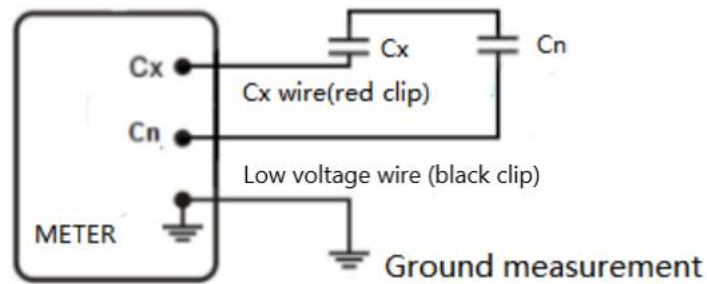
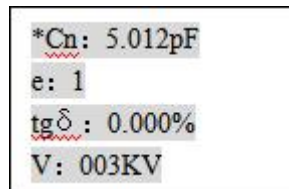


Figure 13

High voltage dielectric loss choose the "Cn50/Cn60" way, when choose the Cn50, select the measurement method 50, when choose the Cn60, select the measurement method 60, The external capacitance parameter must be put into instruments

- ① Open the total power switch (note: the high voltage switch don't open, don't answer the high tension line)
- ② Press "ENT" button, the cursor into the "connection mode ☐ P", then press "▲" 、 "▼" button and select "connection mode ☐ Cn", press "ESC" key to exit, and then press "☐ start measuring", appeared the following interface:



Cn adopting scientific notation, such as:

$5.000e1 = 5.000 \times 10^1 = 50.00$, $1.000e2 = 1.000 \times 10^2 = 100.0$, etc,

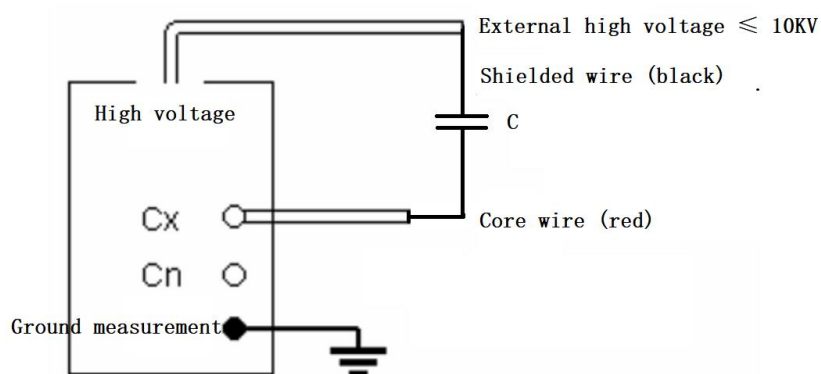
Range: $0.000e0 \sim 9.999e5$ ($0 \sim 999900pF$). $tg \delta$ Set Range $0 \sim 9.999\%$.

Press "▲"、 "▼" button can change the value.

- ③ After the completion of the set press "ESC" key, then press the "ESC" key, start measuring and display the results after coming out, if need to print the results, press the "ENT" button.

4. the external high pressure internal standard connection test

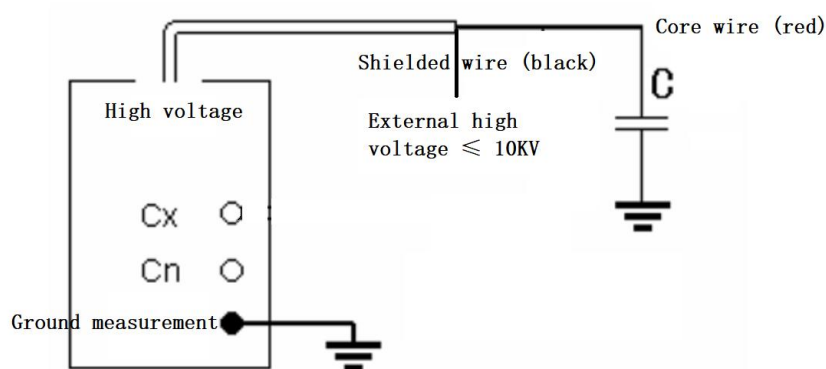
This method is used when using direct connection method, internal standard capacitance, and external high voltage.



The measurement mode is 50, the connection mode is CXP, the voltage is corresponding to the external voltage, and the $> 10\text{KV}$ cannot be selected.

5. Reverse connection test of external high voltage and internal standard

This method is used when using reverse connection method, internal standard capacitance, and external high voltage.



The measurement mode is 50, the connection mode is CXN, the voltage is corresponding to the external voltage, and the $> 10\text{KV}$ cannot be selected.

6. CVT self-excitation measurement

CVT self-excitation method can be connected according to the following figure. If C1 is a single power saving capacity, the bus cannot be grounded. If C1 is multi-saving capacity, the bus can be grounded, C11 and C12 can be measured by conventional positive and negative wiring, and C13 and C2 can be measured by self-excitation method.

Key wiring diagram

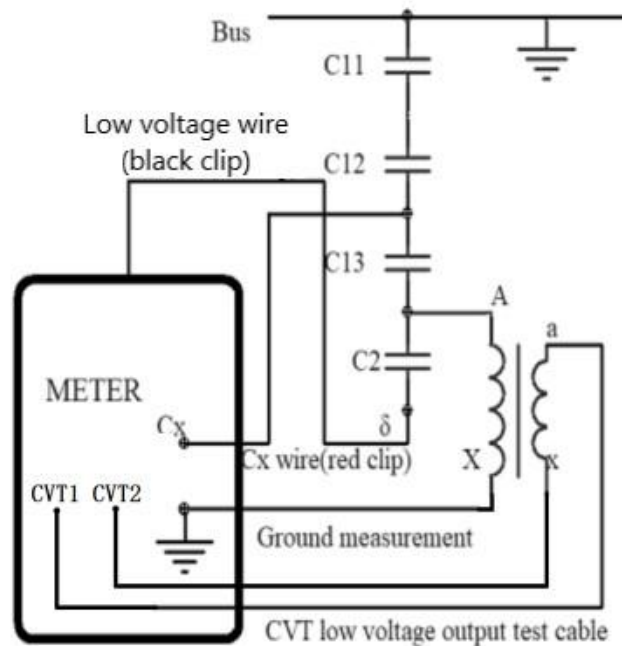


Figure 14

Actual wiring diagram

A. the end of junction box is opened to the ground and the secondary wirings are vacant. Record should be made so as to make it restored after the testing.

B. Turning on the switches of main power supply and internal high-voltage allowable of dielectric loss tester.

C. Moving the cursor to the "Connection mode" and pressing "ENT". Pressing "▲" or "▼", selecting "CV" and then pressing "ESC"

D: Moving the cursor to "Measure voltage" and choosing 1KV and pressing "ESC"; moving the cursor to "Start to measure", pressing "ENT" and waiting for the display of results. If the results need to be printed out, pressing "ENT".

E: CVT self-excited measurement method, can be connected at the same time to measure

C1/C2, no need to change the line and any external accessories.

CVT self-excitation measurement (see Figure 16)

Note: The C1 and C2 can only be measured under the testing mode of CVT; **CVT would be damaged in the methods of positive connection and negative connection!!!**

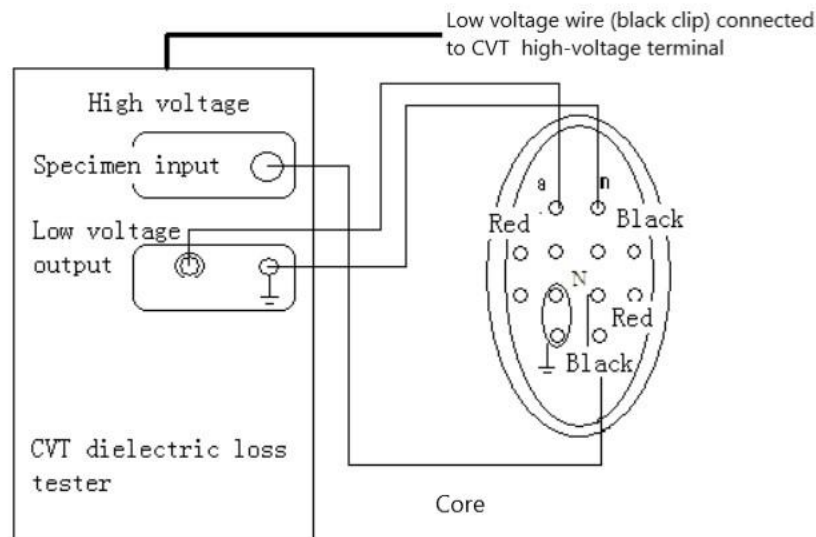
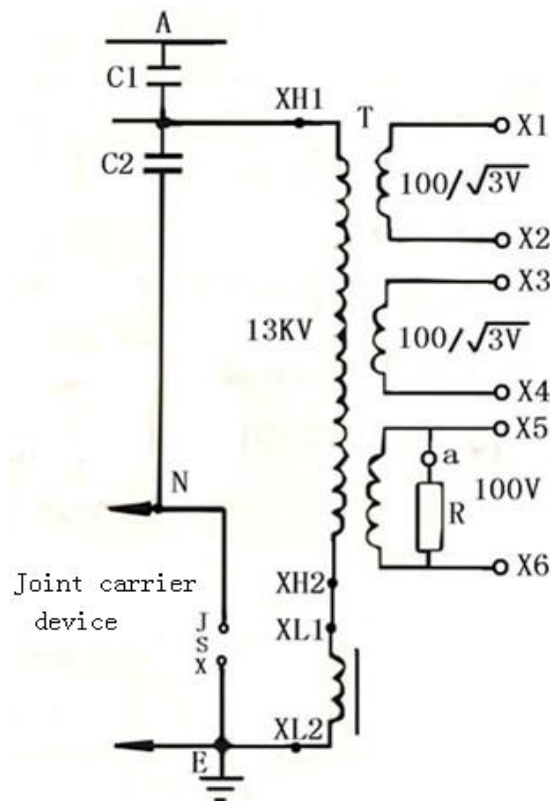


Figure 15 measuring C1/C2

The HVx should be suspended without contacting the ground. Otherwise, the dielectric loss of high-voltage line to the ground would cause error. Thin cable should be used to connect high-voltage outlet with CVT specimen and should be hung. **It is strongly recommended to use black Cx wire for high voltage outlets.**



C1、C2- Partial pressure capacitor
S- Discharge gap

Figure 16 Structure diagram of CVT principle

7. CVT Variable ratio test

The upper end of the CVT with the conductor of the high voltage line. The lower end of the CVT is grounded, and the low-voltage red black clip is connected to the secondary windings. Note: if the test Angle is close to 180 degrees, the red black clamp should be reversed. (see figure 17)

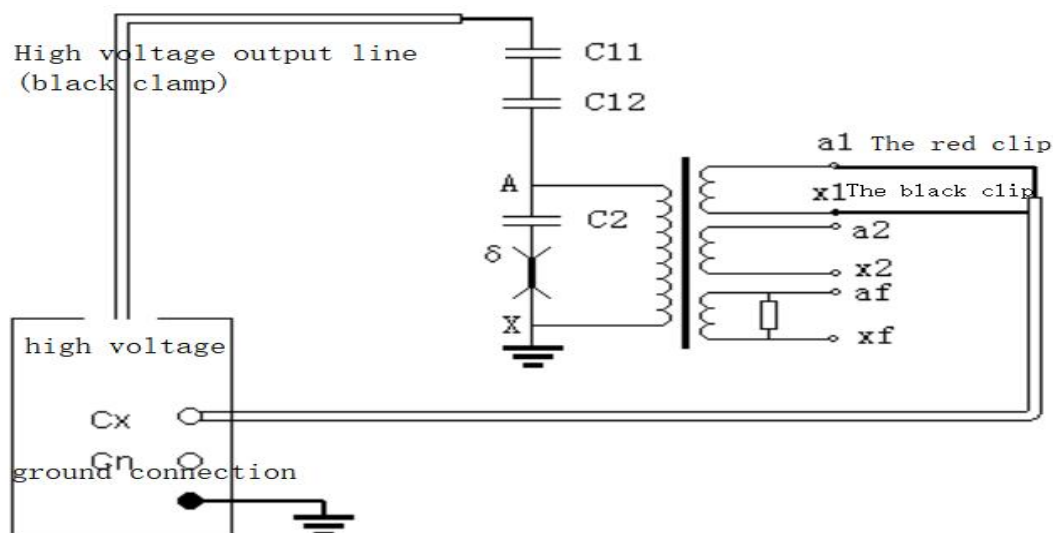


Figure 17

8.Measurement of low-voltage shield of reverse connection(GSTG) (see Figure 18)

Select "M" for measurement.

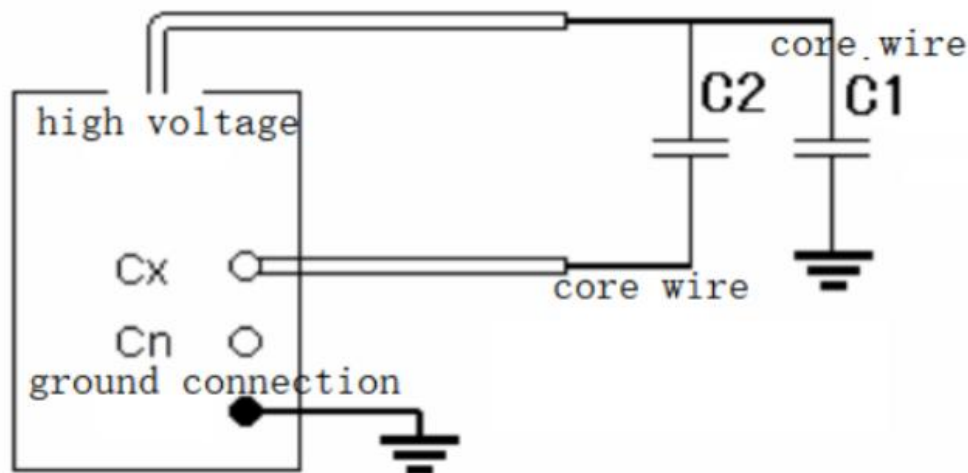


Figure 18

9. The wiring of specimen with small capacitor

For small capacitors, when the air humidity is large, the measured value of dielectric loss would be abnormal and unstable as its $\tan\delta$ is impacted by the surface state. At this time, the shielding ring could be adopted for absorbing the leakage current on the surface of the specimen. The shielding electrode is grounded when positive connected and is connected to the shielding layer of Cx when negative connected. This method may change the distribution of electric field in the internal equipment under test and then affect the $\tan\delta$. Both the standard capacitor and standard dielectric loss tester adopt this kind of connection method.

10. The connection method of some equipment can refer to Section IX "Reference of connection methods".

VII Precautions

1. The instrument is only used on power-off equipment. The grounding terminal should be connected to the grounding network reliably.

The instrument should be used in spacious, safe and reliable place.

2. The equipment under test is shifted to the maintenance state if the high-voltage lead is disconnected from operation state and could be cleaned. The instrument could be tested only

after good initial insulation test so as to avoid the poor insulation of equipment under test causing the damage of the instrument during the pressing process.

3. The connection mode should be based on the installation of equipment. Corresponding connection mode should be selected in the menu option.

4. The testing voltage level should be selected according to different equipment and the desired voltage should be selected in the corresponding menu option.

5. Under the special circumstances of endangering safety during the testing, the main power supply could be switched off.

6. The connection mode could be changed or the work is done after the power switch on the panel is switched off and the 220V test power is disconnected. If the equipment needs to be retested, you can press the “reset” or select repeat after the completion of previous testing.

7. In order to ensure the measurement accuracy, it is vital to guarantee the good insulation of low-voltage terminal (or secondary terminal) of the equipment and it should be tested in the environment with low relative humidity especially if the small loss of specimen with small capacitance.

8. When making the testing of specimen with large capacitance, the grounding of the instrument and the specimen should not be in the same place to prevent the reverse breakdown voltage or traveling waves which may affect the safety of the instrument.

9. The step-up device is available in the instrument. It is necessary to be careful about the insulation distance of high voltage lead and personnel safety.

10. The instrument must be grounded reliably. Poor grounding may cause danger.

11. After the starting of the instrument, except in special circumstances, the power is not allowed to be turned off suddenly to avoid the over-voltage which may destroy the equipment.

12. Although the HVx special high-voltage wire equipped with the instrument is made factory inspection, it still should be far away from human beings and low-voltage test line. Both the high-voltage core and high-voltage shielding cable are not allowed to be grounded and contact with the low potential of the testing circuit. The core and shielding cable of Cx input line are not allowed to contact with part with high-voltage.

13. The instrument should be protected from the moisture and excessive vibration.

14. The different frequency should be adopted for measuring if the result cannot be confirmed measured by Single frequency with too much interferences. Otherwise, Single frequency should be used for the measurement.

15. If the measurement result cannot be shown long time (1 min) after sending out the measurement instruction, it may be caused by large capacitance of the specimen or crashing of the instrument. You need to restart the instrument, reduce the measurement voltage and make measurement.

16. The instrument has automatic protection feature if it has short circuit.

17. If the paper is extended out from the paper exit on the top of the printer, you need to press the button to stop it. The printing paper could be pulled out.

VIII. Full set of instrument

1. Host	1
2. High-voltage HVx test cable (Red)	1
3. Cx-specific test cable (black)	1
4. Cn-specific (Low voltage wire) test cable (black)	1
5. Low-voltage output test cable (for CVT, dual-core)	1
6. 220 V power line	1
7. Ground wire	1
8. Instruction manual	1
9. Factory certification	1
10. Fuse, printing paper	for spare
11. Factory inspection report	1

IX. Reference connection method

1. Voltage transformer

(1) : Primary side to secondary side

A. See Figure 6

B. Voltage: 2kV

C. Positive connection

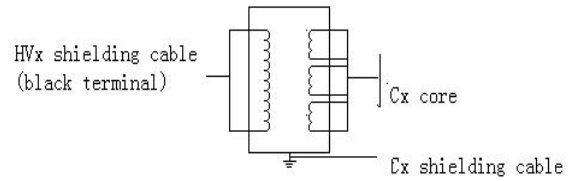


Figure 6

(2) : Primary side to secondary side and ground

A. See Figure 7

B. Voltage: 2kV

C. Negative connection

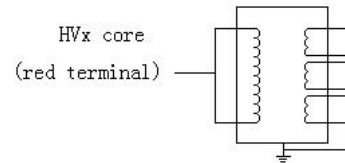


Figure 7 PT
connection

(3) : Secondary side to primary side and ground

A. See Figure 8

B. Voltage: 2kV

C. Negative connection

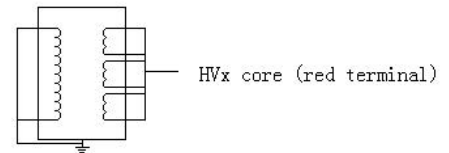


Figure 8 PT
connection

2. Current transformer

(1) : Primary side to secondary side

A. See Figure 9

B. Voltage: 10kV

C. Positive connection

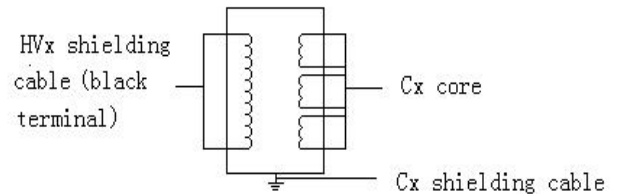


Figure 9 CT
connection

(2) : Primary side to end shield

A. See Figure 9(core connect to end shield)

B. Voltage: 10kV

C. Positive connection

(3) Primary side to secondary side and ground

A. See Figure 10

B. Voltage: 10kV

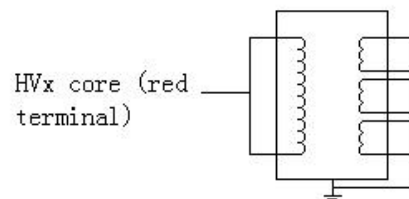


Figure 10 CT
connection

C. Negative connection

3. High-voltage wall bushings

(1) Core to end shield and ground

A. See Figure 11

B. Voltage: 10kV

C. Negative connection

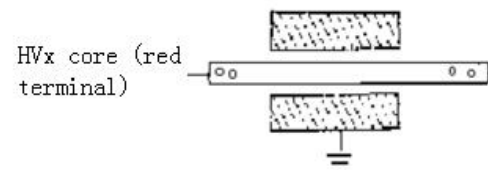


Figure 11 Connection of bushing

4. Power transformer

(1) Primary winding to secondary winding

(the neutrals are not grounded)

A. See Figure 12

B. Voltage: 10kV

C. Positive connection

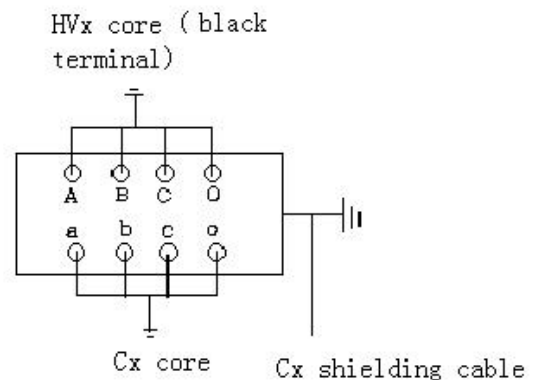


Figure 12 Connection of transformer

(2) Primary winding to secondary winding and ground

A. See Figure 13

B. Voltage: 10kV

C. Negative connection

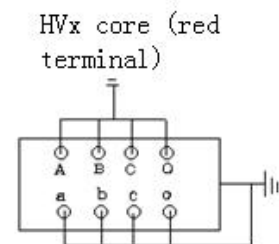


Figure 13 Connection of transformer

(3) Secondary winding to primary winding and ground

A. See Figure 14

B. Voltage: 10kV

C. Negative connection

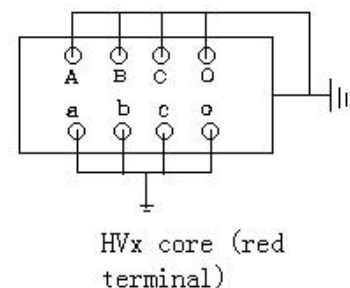


Figure 14 Connection of transformer

5. Dielectric loss of insulating oil

- A. Positive connection
- B. Lead See Figure 15
- C. Voltage: 2kV
- D. (C) connected to HVx shielding cable (Black terminal)
- E. (A) connected to Cx core
- F. (B) connected to Cx shielding cable and grounded
- G. The cup should be put on the insulating stand and distance of insulation should be kept

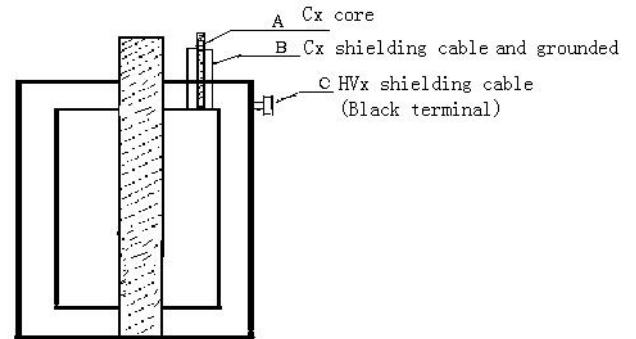


Figure 15 Connection of dielectric loss oil cup

6. Standard capacitor and dielectric loss tester

(1) . Positive connection

- A. "High voltage" connected to HVx shielding cable (Black terminal)
- B. "Low voltage" connected to Cx core
- C. "E" connected to Cx shielding cable and grounded
- D. See Figure 16

(2) . Negative connection

- A. "High voltage" is grounded
- B. "Low voltage" connected to HVx core (Red terminal)
- C. "E" connected to HVx shielding cable (Black terminal)
- D. See Figure 16
- E. Insulation is necessary

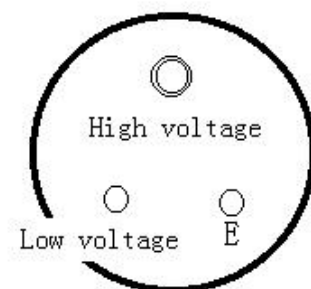


Figure 16 Connection of standard capacitor