How to Discharge a Capacitor?

Author: Apogeeweb **Date:** 10 Sep 2020 3368

Introduction

Many people who are often engaged in maintenance work have experienced electrical shocks after being turned off. Obviously, the "culprit" causing this phenomenon is the capacitor.

From power capacitors to filter capacitors to the graphite coating of old-fashioned televisions' picture tubes, a large amount of charge will be stored in a short period of time after power failure. If the maintenance personnel accidentally touch it, there will be a strong sense of electric shock. Although it is generally not fatal, it can easily cause secondary injuries. Such as bumps, falls, or contact with other live points. Therefore, the capacitor must be discharged after power failure and before maintenance.

This article will mainly introduce the methods of safe discharge of capacitors and related knowledge, also involving working principles of several capacitors.

If you need to calculate the discharge rate of a capacitor under a known capacitance and charge it through a fixed value resistor, we recommend you to use Apogeeweb's Capacitor Safety Discharge Calculator.

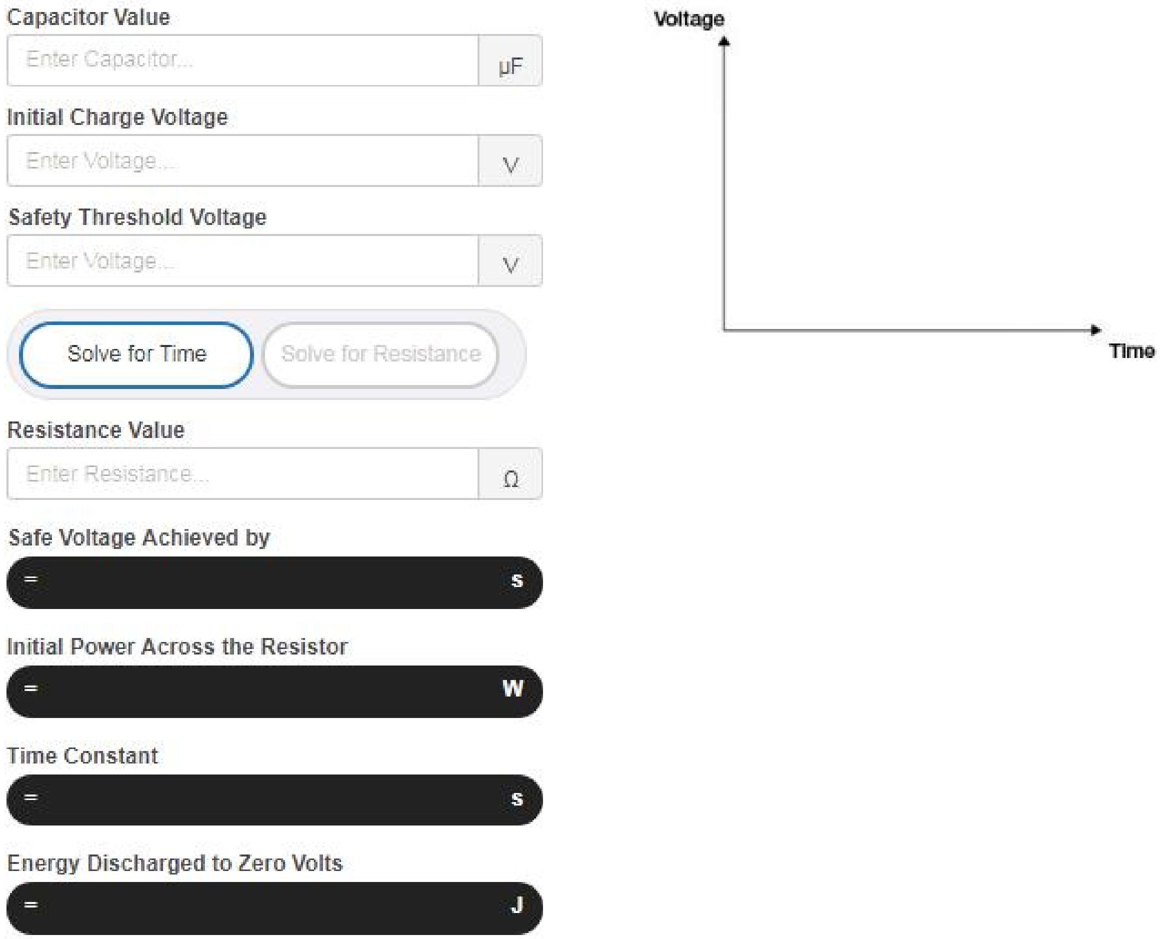

Figure1. Apogeeweb's Capacitor Safety Discharge Calculator

Catalog

I What Happens When a Capacitor is Charging or Discharging?

A capacitor is a passive device that stores energy in the form of an electric field. When needed, the capacitor can release the stored energy to the circuit. The capacitor is composed of two conductive parallel plates, and an insulating material or a dielectric material is filled between the plates.

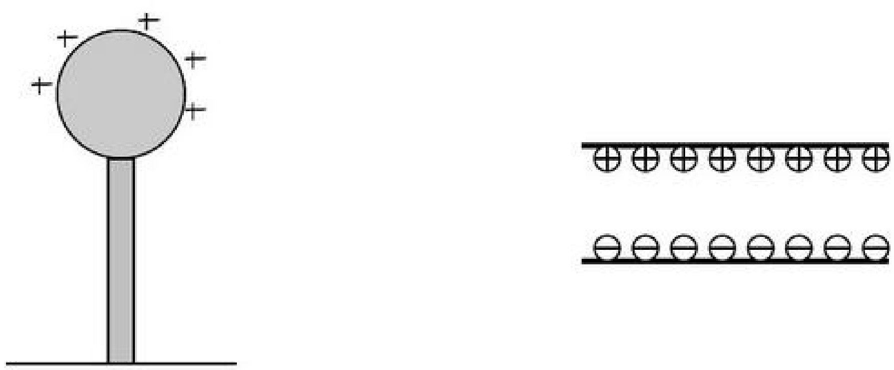

Figure2. The Function of Capacitors

The principle of the capacitor charging process is that the power supply moves through the charged particles in the charging circuit to make the potential difference between the two plates of the capacitor gradually approach, so as to reach the same voltage (potential difference) as the power supply. In the end, the two kinds of charges with opposite polarities stay on the capacitor plates as bound charges and store the electric energy provided by the power supply in the form of the electrostatic field formed by them.

The principle of the capacitor discharge process is that the capacitor moves the charged particles in the discharge circuit to make the potential difference between the two plates of the capacitor gradually approach, so as to achieve the same voltage (potential difference) as the two ends of the consumer. Eventually, the bound charge accumulated on the two plates of the capacitor is released, and the electrostatic field energy stored in the capacitor becomes the work consumed by the electrical appliance.

II How to Discharge the Capacitor?

We can watch this video first:

A nice capacitor lesson along with some fireworks.

2.1 Discharge Method After the Capacitor is Cut Off

When the capacitor is interrupted in the energized circuit, the capacitor stores a certain amount of voltage. When there are other loads or components in the circuit, it will discharge slowly, or it can be discharged quickly by artificially short-circuiting with small resistors or wires (at low voltage).

When the capacitor is discharged, the two poles of the capacitor carry a certain amount of charge, and the outside world and the capacitor form a closed loop (generally, the closed loop does not include the power supply). The two poles of the capacitor are in the closed loop to force themselves to achieve electrostatic balance to form an electric field. Excess electrons (negative charges) approach the positive electrode of the capacitor to form a current, which neutralizes the charges on both ends of the capacitor. After the neutralization is completed, the electric field between the two electrodes of the capacitor disappears. However, in the ideal situation, there is always resistance in the closed loop in reality, so the amount of charge at both ends of the capacitor is exponentially neutral, and it has been trending towards zero, but it will not be zero.

Figure3. Discharge Tools

2.2 Notes for Capacitor Discharge

(1) After the capacitor is disconnected from the bus, it must be discharged through a discharge resistor or a special voltage transformer.

(2) Discharge between the lead wires of the capacitor and between the lead wires and the casing.

(3) The capacitor can be grounded after the capacitor is discharged.

(4) Before working on the capacitor, a test discharge must be carried out. This kind of discharge is to place the discharge rod on the lead terminal of the capacitor for a period of time.
(5) Even if both sides of the capacitor device are grounded, in order to prevent the residual charge on the capacitor, a test discharge must be performed. Each group of capacitors connected in parallel must be discharged.
(6) Particular care should be taken when inspecting discharge of capacitors removed due to faults. Due to the damaged capacitor, the total grounding device may not be able to discharge the ground due to a certain part of the disconnection.
(7) If the capacitor device has an interlocking device, it should be considered that the small door of the capacitor bank protective fence can only be opened after the entire device is grounded.

2.3 The Charging and Discharging Process of the Capacitor

Suppose a capacitor has upper and lower plates, the upper plate is connected to the positive electrode, and the lower plate is connected to the negative electrode. After connecting to the power supply, a potential difference will be formed between the two plates, and the potential difference is equal to the power supply. Therefore, the upper plate is positively charged. The bottom plate is negatively charged, so that a potential difference can be formed between the two poles. The positive charge will not move, only the negative charge—electrons will move, so the electrons on the top plate move along the wire through the positive-negative pole of the power supply to the bottom plate. So that the two-electrode plates will be charged with different kinds of charges. As the electrons move, the two-electrode plates have more and more charges, and the voltage will become larger and larger, until the potential difference with the power supply is equal, it is fully charged.
After disconnecting the power, the charge will not disappear, nor will it be neutralized (after all, the two plates are insulated, and the positive and negative charges can only attract each other, but cannot be combined). In this way, the potential difference will always exist until we discharge the capacitor, connect the two plates with wires, and electrons will move from the lower plate to the upper plate along the wires, and the potential difference disappears.

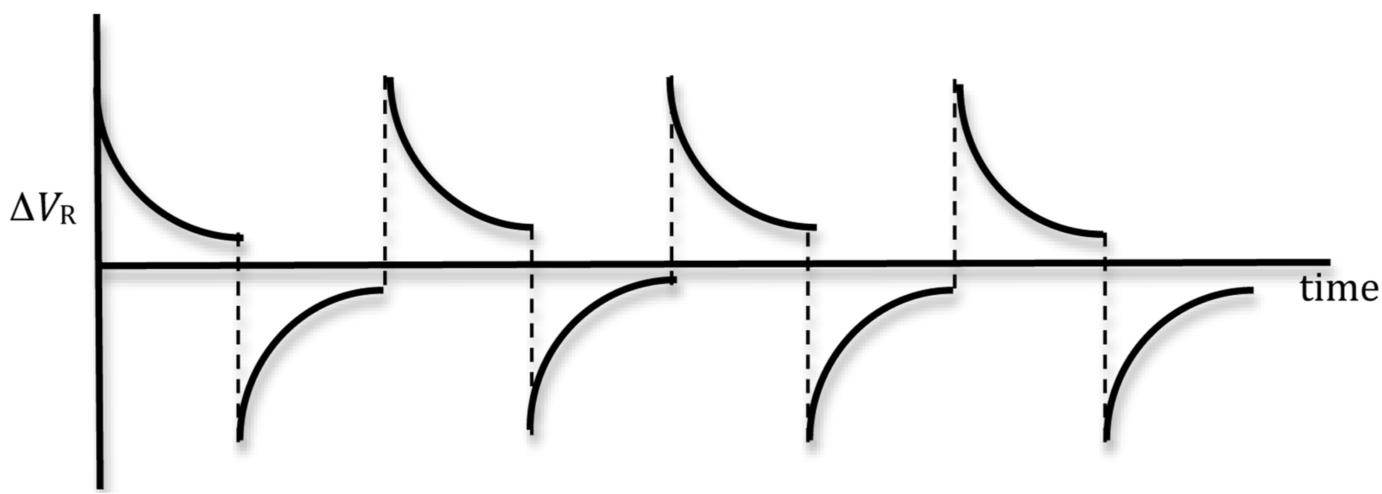

Figure4. Charge and Discharge

III Three Discharge Methods of High Voltage Capacitors

3.1 What is High Voltage Capacitor?

High-voltage capacitors refer to a type of capacitors mainly composed of outlet porcelain bushings, capacitive element groups and shells. High-voltage capacitors have the characteristics of low loss and light weight. Its shell is sealed and welded by thin steel plates, the outlet porcelain sleeve is welded on the shell, and the terminal is led out from the outlet porcelain sleeve. The capacitor element group (also called the core) in the housing is formed by connecting several capacitor elements. The capacitor element is made of capacitor paper, film-paper composite or pure film as the working medium and aluminum platinum as the pole plate.

In order to meet the withstand voltage requirements of capacitors of various voltage levels, capacitive elements can be connected in series or in parallel. The capacitive element group of a single three-phase capacitor is connected to form a triangle inside the shell. In high-voltage capacitors with a voltage of 10kV and below, a fuse is connected in series on each capacitive element, which serves as the internal short-circuit protection of the capacitor. Some capacitors are equipped with discharge resistors. When the capacitor is disconnected from the grid, it can be discharged through them. Generally, the residual voltage of the capacitor can be reduced to below 75V after 10 minutes.

Figure5. Microwave High Voltage Capacitor

3.2 How to Discharge High Voltage Capacitors?

The reason for discharging the capacitor is that the capacitor will store electricity inside after it is powered off, so we must discharge, otherwise it is prone to electric shock. How to discharge commonly used high-voltage capacitors? Three methods will be shared below.

The discharge of high-voltage capacitors is different from that of general capacitors. Generally, the capacitor discharge only needs to short the positive and negative poles of the capacitor. High-voltage capacitors are generally not to be short-circuited and discharged directly to avoid burning the capacitor's contacts. (At the same time, the sound is also chilling). You can choose an appropriate resistor or use a table lamp, an electric soldering iron, or the relevant voltage range of a multimeter. The discharge time can be a little longer, and this treatment can be performed many times until the discharge is over.

The specific steps of discharging high voltage capacitor are as follows:

● Method 1:

First unplug the electrical power.

Using a 20,000 ohm, 2 watt resistor, this kind of wiring part can be bought in most electronics stores at a very cheap price. Connect the probe of the resistor and the terminal of the capacitor together to discharge the high voltage capacitor.

If the capacitor has three terminals, connect the resistor to one of the outer terminals and the center terminal, and then connect to the remaining outer terminals and the center terminal.

● Method 2:

Connect one end of the resistor to a test lead and the other end to an alligator clip, and wrap the connector with insulating tape.

The alligator clip is clamped to the ground wire, and the test lead is used to connect the other pole of the capacitor, so that there will be no sparks during discharge.

It should be noted that if a lot of capacitors are discharged continuously, the resistors will heat up. You can choose a larger wattage.

● Method Three:

bulb discharge, similar to method two, use a 100-200 watt bulb.

Use a 60-80W soldering iron to discharge, the method is similar.

Insulate ground discharge.

In daily maintenance, we must consider the discharge of high-voltage capacitors. If the discharge is not complete during maintenance, electric shock accidents are likely to occur. After the capacitor is powered off, it is recommended to use the alligator clip to discharge. Not only is it safe and there is no spark, the speed of choosing the alligator clip with larger resistance is fast and good, of course, the smaller resistance can also be discharged, and the time is longer.

IV How to Discharge Low Voltage Capacitors?

4.1 Short-circuiting with Wires

For capacitors that work below 50V or whose capacity is below 1μF, they can be directly discharged by short-circuiting the two poles of the capacitor. Of course, a screwdriver can also be used, but sometimes it will leave traces of electric burn. This discharge is the fastest and most effective. If the high-voltage and large-capacity capacitors can only be discharged slowly with a resistor, or discharged with a 100w incandescent lamp and electric furnace wire, it is also okay in water (but not recommended, too much energy will cause water explosion.) Never directly short-circuit the discharge, otherwise it will produce a lot of sparks and noise, which will damage the discharge or the conductor.

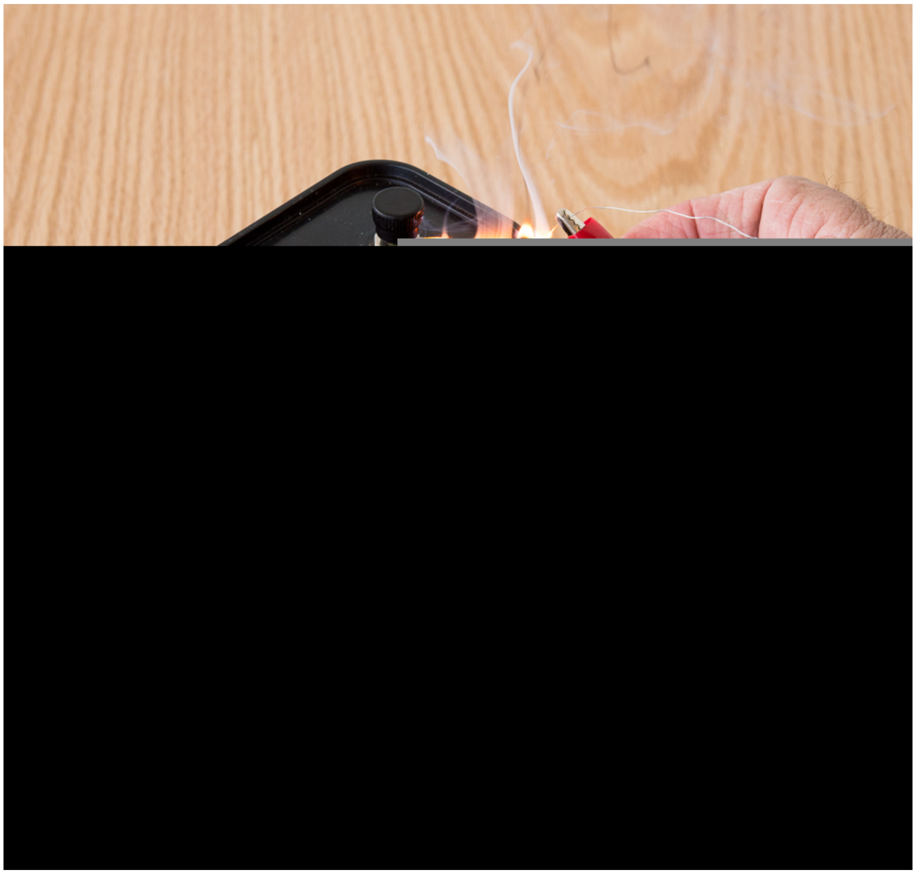

Figure6. Shortcircuit

4.2 Use a Multimeter

Discharge with the resistance file of the multimeter. If the capacity is large, first use a large-scale connection capacitor such as 100K/200K to discharge. You will see that the number or pointer keeps dropping until 0, and the discharge is complete. Generally, it only takes a few seconds, and the test leads will be disconnected immediately after the discharge is completed, otherwise it will be reversely charged; 10K/20K gears can be used for small capacity, and the discharge speed is faster.

Figure7. Multimeter

4.3 Attention

Since the two poles of the capacitor have the characteristics of residual electric charge, first try to discharge its electric charge, otherwise electric shock accidents may easily occur. When handling a faulty capacitor, the circuit breaker of the capacitor bank and its upper and lower isolation switches should be opened first. If a fuse is used for protection, the fuse tube should be removed first. At this point, although the capacitor bank has self-discharged through the discharge resistance, there will still be some residual charges, so manual discharge must be performed.

When discharging, first fix the grounding end of the grounding wire with the grounding grid, and then use the grounding rod to discharge the capacitor several times until there is no spark or discharge sound, and finally fix the grounding wire. At the same time, it should also be noted that if the capacitor has internal disconnection, fuse blown or poor lead contact, there may be residual charges between its two poles, and these residual charges will not be discharged during automatic discharge or manual discharge. of. Wear insulating gloves and short-circuit the two poles of the faulty capacitor with a short-circuit wire to discharge it. In addition, the capacitors using series connection should also be discharged separately.

V Filter Capacitor

5.1 How to Discharge the Filter Capacitor?

The filter capacitor is an energy storage device installed at both ends of the rectifier circuit to reduce the ripple coefficient of AC pulsation and improve the efficient and smooth DC output.

The filter capacitor is generally connected to the output end of the bridge rectifier. If it is 220v rectifier, the voltage on the capacitor will reach 310v. At this time, the best discharge tools are electric soldering iron and resistor. Take 25w electric soldering iron as an example, its internal resistance is about 2.2KΩ. According to l=U/R, the maximum current at the

moment of discharge is 310v/2200Ω=140mA, and there will be no obvious sparks. A capacitor of several hundred microfarads can be discharged in a few seconds.
If the same 25w bulb is used for discharge, the filament may be burnt. Due to the large difference between the cold and hot resistance of the bulb, the cold resistance of the 25W filament is only 160Ω, and the instantaneous current when receiving 310v is close to two amperes, which is easy to damage. In addition, the low internal resistance of the analog multimeter can be used to discharge while measuring, but it takes a little longer.

Figure8. Filter Capacitors

5.2 What is the Charge and Discharge Time of the Filter Capacitor?

The charging and discharging time of the filter capacitor is actually related to the resistance of the circuit. Capacitor filtering actually uses the characteristics of capacitor charging and discharging to achieve DC voltage stability. In the AC to DC power conversion circuit, only pulsating DC power can be obtained after the AC power is rectified by the rectifier diode, and the fluctuation is still quite large. After the filter capacitor is added, the capacitor is charged during the voltage rise, and the capacitor is discharged during the voltage drop, thus achieving voltage stability. We can call the time required to charge the filter capacitor as the charging time constant, and the time required to discharge the filter capacitor as the discharge time constant. The size of the charging time constant and the discharging time constant is related to the capacitance of the resistance and capacitance of charging and discharging.
(1) Capacitor charging and discharging curve
The capacitor charging process is a process that is infinitely close to the maximum voltage. The time it takes for the voltage across the capacitor to reach 0.63 times the maximum voltage is called the charging time constant. After 5 times the charging time constant time of charging, we will treat the capacitor as fully charged. The discharging process is opposite to the charging process, and the discharging process is infinitely close to zero voltage.

Figure9. (a)Charging Curve (b)Discharging Curve

(2) Calculation of filter capacitor charging time constant

The charging time of the filter capacitor is related to the size of the charging resistance and the capacitance of the filter capacitor, Tc=RC. The larger the charging resistance, the longer the charging time, the larger the capacitance of the filter capacitor, and the longer the charging time.

It can be seen from the rectifier filter circuit in the figure below that after the AC power is rectified by the rectifier bridge, the filter capacitor C is directly charged. The internal resistance of the rectifier diode is very small when it is turned on. If the internal resistance of the rectifier diode is 30Ω when it is turned on, the capacity of the filter capacitor is 2200uf, Tc=30Ω x 2200uf=30Ω x 0.0022F=0.066S=66ms, and the charging is quite fast. It takes 66 milliseconds to charge the capacitor voltage to 63%.

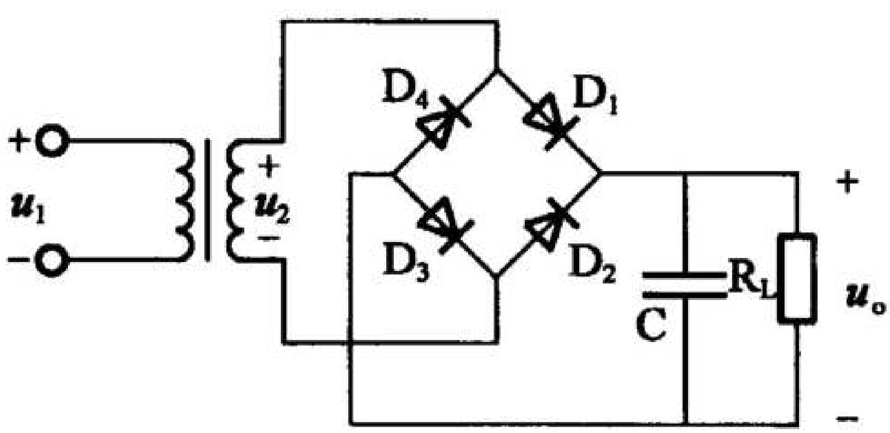

Figure10. Bridge rectifier circuit

(3) Calculation of filter capacitor discharge time constant

The discharge of the filter capacitor is carried out through the load. The load generally has a certain internal resistance. If the resistance of the load is RL=300Ω,

The same is the 2200uf filter capacitor, Tc=300Ω x 2200uf=300Ω x 0.0022F=0.66S=660ms, and the discharge time is 660ms. If the internal resistance of the load is greater, the discharge time will be longer.

Related recommendation: Apogeeweb's time constant calculator.

VI Fast Discharge Methods of Power Compensation Capacitor and Electrolytic Capacitor

(1) Power factor compensation capacitor

The unit of this kind of capacitance is generally expressed in KVar, which is mainly for the convenience of selection and use. The compensation capacitor is actually a special non-polar capacitor. If converted into a capacitance unit, there are generally several hundred microfarads. From a safety point of view, the compensation capacitors are equipped with a discharge resistance of several thousand ohms. You can put the power below the safety line soon after disconnecting from the power source. However, just in case, the capacitor must be discharged before maintenance. The discharge tool is also an electric soldering iron or high-power resistor. Because the compensation capacitors work at a high voltage above 220v, you must be careful when discharging.

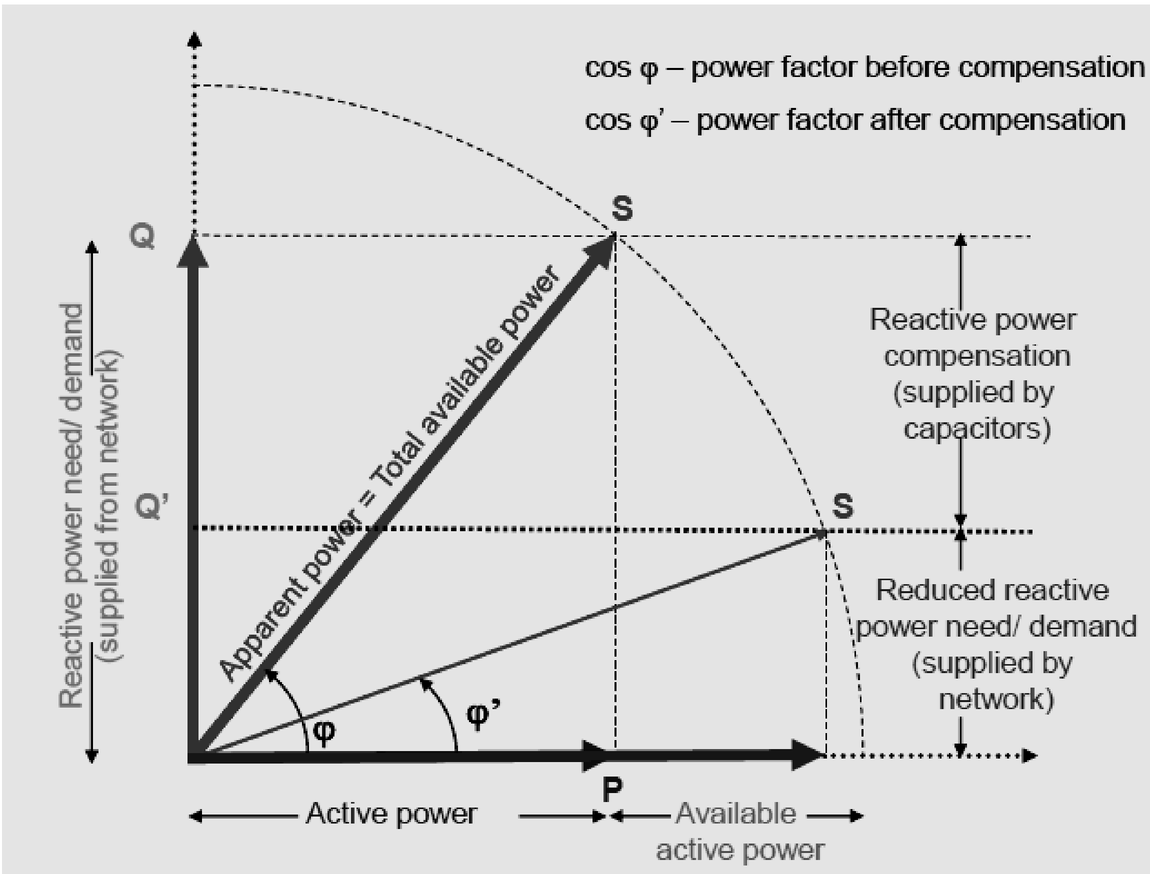

Figure11. Reactive Power Compensation Supplied by Capacitors

(2) Operating skills for short-circuit and fast discharge of non-polar electrolytic capacitors

① For lead-type small aluminum electrolytic capacitors, it is sufficient to directly short-circuit and discharge them, but generally we do not recommend them.

②The horn type electrolytic capacitor with a little larger capacity can be used to make a 220v/60-100w bulb or discharge slowly with a resistor.

③ Bolt-type high-voltage and large-capacity electrolytic capacitors are recommended to use discharge coils, which can not only discharge the electricity of all capacitors, but are also a good helper when repairing short-circuit faults.

We recommend that all capacitors use a discharge coil, which is safe and will neither hurt people nor equipment.

There is a very simple way. Find a short wire, about 5m or so, wind it up, use alligator clips on both ends, and connect them directly to the positive and negative poles of the capacitor to discharge. But remember one thing: one is that the wire should not be too short, and the other is that it must be wound up. Especially for high-voltage and large-capacity aluminum electrolytic capacitors, after discharging, you will find that the wires are hot.

VII How Does Capacitor Bank Discharge Coil Work?

The installation of discharge coils is now a necessary technical safety measure for parallel capacitors in substations. It can effectively prevent the capacitor bank from being charged again when the capacitor is still charged to produce closing overvoltage and overcurrent that endanger the safety of the equipment, and ensure Safety of maintenance personnel.

7.1 Principle of Capacitor Bank Discharge Coil

(1) The discharge coil is a commonly used discharge element for capacitor cabinets. The outlet end of the discharge coil is connected in parallel to the two outlet ends of the capacitor bank, and bears the voltage of the capacitor bank during normal operation. Its secondary winding reflects the primary transformation ratio. The accuracy is usually 50VA/0.5, and it can be used for a long time under 1.1 times the rated voltage. run. The secondary winding is generally connected to an open triangle or phase voltage differential to protect the internal fault of the capacitor bank (the PT on the bus cannot be used).
(2) The open delta voltage protection and unbalanced voltage protection of the capacitor bank are actually this kind of protection. According to the requirements of GB-50227, this kind of protection is widely used in 6kV~66kV single Y-connected capacitor banks.
(3) Sometimes the discharge coil will be replaced by a discharge PT. Whether the capacitor discharge uses a discharge coil or a voltage transformer mainly depends on the capacity of the capacitor. Generally, a voltage transformer for small capacity (<1.7Mvar) capacitor bank discharge is sufficient, and a large capacity capacitor bank (≥1.7Mvar) Discharge coil must be used, otherwise it will cause the voltage transformer to burn or explode.

7.2 Influence of Connection Mode

(1) When the discharge coil is also used for phase voltage differential protection, the jumper method is not applicable, unless the discharge coil is designed separately.
(2) When the discharge coil adopts a jumper connection method and also serves as an open delta voltage protection, only the rated phase voltage of the capacitor bank in the protection setting formula is changed to the average operating phase voltage of the bus bar where the capacitor device is connected, or the bus bar phase voltage based on the design is that can.
(3) When the discharge coil must be used to directly monitor the capacitor terminal voltage, the jumper method is not applicable.
The above is the principle of the capacitor bank discharge coil and the influence of the change of the connection method introduced for you today. I hope to have a little help for you. The discharge coil is suitable for 66kV and below power systems, and is connected in parallel with the high-voltage parallel capacitor bank, so that the residual charge after the capacitor is removed from the power system can be quickly discharged, which can be used for line monitoring.

VIII How to Use the Principle of Capacitor Discharge to Test Capacitors?

The common faults of fixed capacitors include breakdown, leakage and failure. The performance of the capacitor can be detected by the resistance of a multimeter. This detection method mainly uses the discharge principle of the capacitor. The specific detection method is as follows:
(1) When testing, use the pointer of the multimeter to swing and return to "∞" quickly, indicating that the capacitor performance is normal.
(2) The pointer of the multimeter cannot return to "∞" after swinging, but refers to a certain resistance value, indicating the leakage of the capacitor. This resistance is the leakage resistance of the capacitor. The leakage resistance of a normal

small-capacity capacitor is about tens to a few Hundreds of megaohms, weak capacitance leakage resistance, light rain a few megaohms, can not be used.

(3) The pointer of the multimeter does not understand and stays at "∞", indicating an internal open circuit of the capacitor, but small capacity capacitors with a capacity of <5000pF are caused by insignificant charging and discharging and cannot be regarded as an internal open circuit.

(4) The pointer of the multimeter swings to "0", indicating that the capacitor has been short-circuited and cannot be used.

(5) After the pointer of the multimeter swings to a certain position in the middle of the scale line, it stops. Exchange the meter pen and measure the hour hand is still at this value. When going to the toilet, there is resistance, indicating that the capacitor has failed.

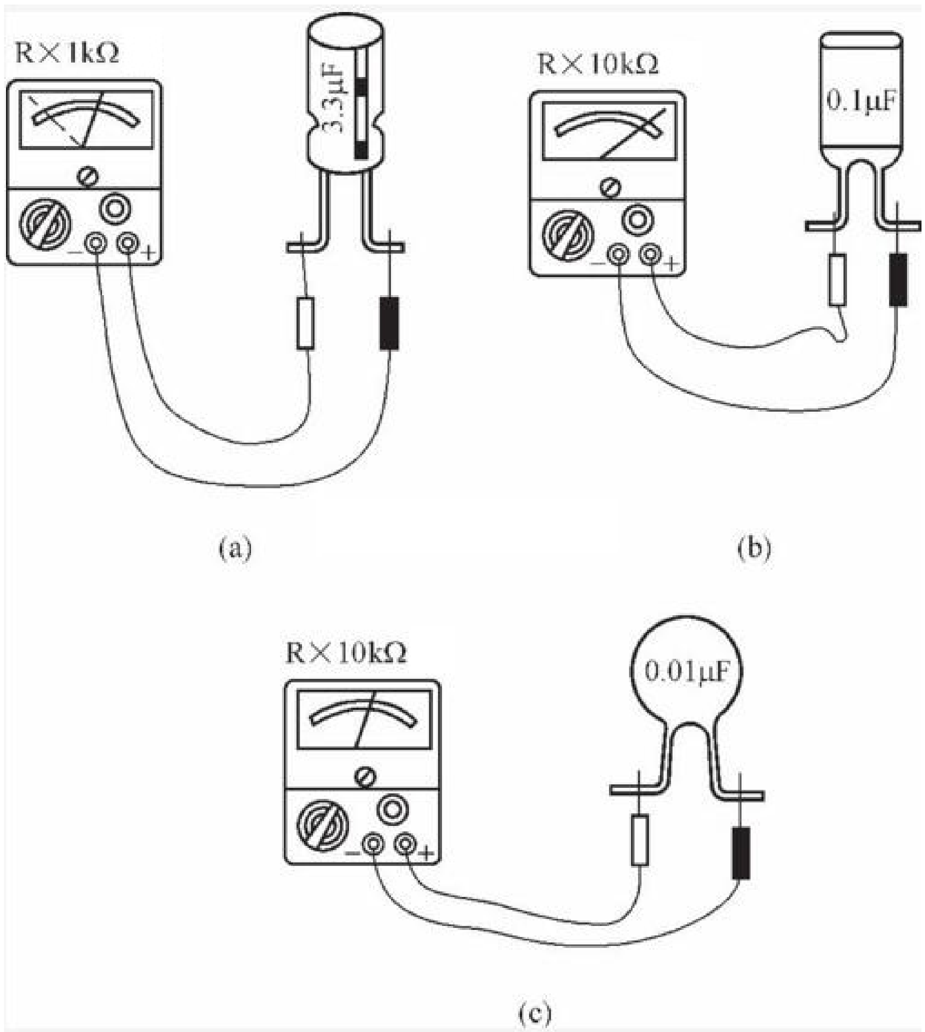

Figure12. (a) Normal; (b) Breakdown; (c) Failure

Notes:

(1) The capacity of a fixed capacitor of less than 10pF is too small, and an analog multimeter can only detect whether it has leakage, internal short circuit or breakdown.

(2) The pointer type multimeter with 10pF-0.01uF capacitor can only detect leakage and internal short circuit, but cannot detect whether there is charging or discharging.

(3) For capacitors larger than 0.01uF in one row, when measuring with a multimeter, a proper range must be selected for measurement according to the capacitance of the capacitor in order to give a correct judgment. To measure capacitors with a capacity above 300uF, you can choose R*100 ohm or R*1 ohm; for 10-300uF capacitors, you can choose R*100Ω; when measuring 0.47-10uF capacitors, you can choose R*1KΩ; measure 0.01- 0.47uF capacitor, R*10KΩ file can be used.

IX Quiz

Which of the following depends on charging and discharging rate of a capacitor?

a) Time constant

b) Current

c) Power

d) Voltage

Answer: a

Explanation: The time constant in a circuit consisting of a capacitor is the product of the resistance and the capacitance. Smaller the time constant, faster is the charging and discharging rate and vice versa.