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Research On Periodic Oscillation Test Equipment for TCR Thyristor Valves

by

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SUMMARY

With the development of smart grid, power electronics technology is focused and applied more and more in power system. As the important part of FACTs, SVC product is widely used in power system and industrial load. As the core component of SVC system, the reliability and stability of TCR thyristor valve is the key part which will result in whether SVC system can be used in power system.

The main test item of TCR thyristor valve is cyclic triggering and blanking test which is used to verify the consistency of cyclic cut-over and shutoff of thyristor valves, to ensure the valve can bear the maximum of voltage, current, thermal intensity etc., and simultaneously, to examine the voltage wave when thyristor valve is triggered uniformly and the voltage wave when BOD works because of triggering inactivation.

This paper provides a simple and practical solution to research the Periodic Oscillation Test Equipment, thus, it can meet the requirements of cyclic triggering and blanking test under the simple test condition. The paper analyses the security of service to thyristor valve in theory, and determines the minimum voltage, current, the interval time of triggering between positive and inverse group of valve, etc. And some matters need attention is also mentioned.

According to the calculation of parameters of equipment, the real equipment is produced which also test the 10kV thyristor valve. The solution is verified as reasonable through the theoretical analyse and real test. Thus, it can implement the corresponding equivalent test.

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1 Introduction

With the development of smart grid, power electronics technology is focused and applied more and more in power system. As the important part of FACTs, SVC product is widely used in power system and industrial load.

SVC device has some advantages. For example, it can be adjusted continuously and switched frequently, it has fast response, it can track and compensate reactive power dynamically, it can regulate voltage, increase power factor and balance three phase system etc. Generally, SVC is used to compensate reactive power of non-linear and irregular load in distribution network. But it is also installed in low-voltage side of the transformer system for compensating reactive power of high-voltage lines, thus, it can plays an important role in regulating voltage and expanding the stability limit.

As the core component of SVC system, the reliability and stability of TCR thyristor valve is the key part which will result in whether SVC system can be used in power system.

2 Equivalent Test Situation

Thyristor valve is the most important part of the TCR device, but also the most vulnerable sector. Its performance and security and stability have an extremely important influence to the whole SVC system.

The TCR valve operation test is designed to test the ability that the valve withstands actual complicated working conditions and harsh strength, so it is inevitable to study the valve operation test and completion of the trial test device.

TCR valve needs some tests before putting into operation. These tests include some conventional high-voltage test, such as withstanding voltage test, impulse test etc. In addition, it should also do some specific test for the TCR valve. To TCR valve, the important data includes di/dt, dv/dt, voltage-sharing during steady state and transient state. To make the valve run in actual conditions, the equivalent test should be done which should reflect the actual running condition.

Equivalent test can be understood from two sides. One is, to some test items, the test of basically basic unit can be used to instead the entire test. The other is to use equivalent test device which can get the corresponding voltage, current, thermal stress etc. to simulate the actual situation. Such equivalent test device is worthy of study in the aspects of circuit structure, equivalence and economic efficiency.

To the valve test, the ultimate target is the valve will not be damaged and no false triggering even in the severest situation during operation. And it should maintain a good economic efficiency to the extent possible.

The equivalence of valve test requires to be analysed from the following aspects, including voltage and current strength, dv/dt strength, di/dt strength, the dynamic voltage-sharing during opening process, the reverse dynamic voltage-sharing during shutdown, heat intensity.

(1) Voltage strength equivalence

Voltage strength is mainly to check electrical insulation and voltage withstand capability of valve and accessories. In actual situation, the steady voltage waveform valve withstands is a part of sinusoidal voltage which uses the voltage peak as the axis of symmetry (as the following figure shows), and its maximum value is the actual peak value.

Figure 1 The steady voltage waveform

According to the standard, the test strength should be harsher than the actual strength, so as long as the test voltage is not less than the actual operating voltage peak, the equivalent requirements of steady voltage strength can be met.

(2) Current strength equivalence

The equivalence of current strength reflects the equivalence of RMS current, thyristor conduction losses, switching losses and junction temperature. Because the operation test of TCR valve uses 50Hz current source, the current waveform under test conditions is the same as the current waveform under actual conditions. Therefore, the equivalent of current intensity is relatively easy to achieve. We just need determine the RMS of test current, the adjustment range of triggering angle, and making proper cooling, then the test can be implemented.

(3) dv/dt strength equivalence

The ability of maximum dv/dt strength valve withstands can be tested through the protective trigger test methods. In other words, blocking the triggering pulse of a layer by artificially can test the reliability of the protective trigger circuit. In fact, the assessment to the dv/dt strength is mainly to check the trigger reliability of the protective trigger circuit.

(4) di/dt strength equivalence

① Steady di/dt strength equivalence

Steady di/dt strength means the periodically and stable di/dt strength valve withstands with periodically triggering and blocking in the actual operating conditions.

The di/dt strength during the opening time in actual conditions is mainly derived from the discharge of the damping circuit and the discharge of the parasitic capacitance in parallel with the valve. When the thyristor is triggered, the small area near the gate electrode is first conductive and expands, then results in higher current density in local area causing a large increase in temperature. If the instantaneous di/dt during opening process is too large, it will cause the temperature inside the device rise too high and damage the device. The di/dt strength during the closing process before current crosses zero determines the value of the reverse

recovery current Irr and reverse recovery charge Qrr, and thus determines the recovery characteristics of the valve's shutdown. Therefore, the equivalent of di/dt strength during opening and closing process is an important content.

To TCR valve, the di/dt strength used in operation test is mainly to simulate the steady di/dt strength of valve. The di/dt strength valve withstands will be maximum under the condition that the triggering angle is 90 degrees.

② Transient di/dt strength equivalence
Valve can be spontaneous conductive under the transient voltage, and the ability to withstand di/dt strength at this time will reduce too much.

In operation test, the performance that the valve withstands the transient strength can be checked by the non-periodic trigger test and the instantaneous forward voltage test during recovery.

To check this, the maximum transient voltage strength valve can withstand should be determined according to the system, and then combines the corresponding test circuit to complete the equivalent.

(5) Dynamic voltage-sharing test during opening process
In the cold state, valve is triggered to breakover under the lower voltage and the weakest triggering condition. At this time, the dispersion of thyristor's opening time will be maximum, and the voltage-sharing during opening is the worst.

(6) Reverse dynmic voltage-sharing test during shutdown
The reverse dynamic voltage-sharing of the thyristor components in valve is to check the voltage-sharing situation during shutdown crossing zero.

(7) Heat intensity equivalence
The equivalent of heat intensity can achieve equivalent test purpose by changing the test current and voltage, adjusting the tolerant heat intensity of each component etc.

Using simple periodic oscillation test device can implement most of the above tests.

3 Periodic oscillation circuit principle

The schematic diagram is shown below:

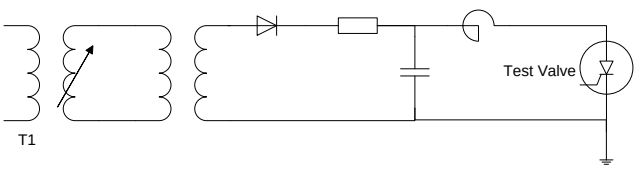

Figure 2 Periodic Oscillation Circuit

During testing, the TCR valve will run at high voltage through transformer and regulating transformer, and then uses the charge and discharge between capacitor and reactor to simulate the situation that large current flows thyristor valve.

Before testing, the thyristor valve and other components should be connected as shown in figure, and be sure to check whether the grounding is OK.

Raising the voltage of capacitor to 10kV by regulating the regulating transformer, and sending a triggering pulse signal to the thyristor valve by the console, then, the voltage waveform in the instant of thyristors' opening and closing can be measured via high-pressure probe. The triggering cycle of thyristors' can be set longer, for example, it can be set as 1Hz, thus, the capacity of the resistance and the reactor can be reduced.

Because laboratory capacity is limited, the triggering cycle generally uses 1Hz, 2.5Hz, etc. If a higher frequency is used, then the capacity of the system needs more.

Through adjusting the testing parameters, the voltage and the current can be got as close as possible with the actual operation of the waveforms, and the stress of the valve can be correspond to the actual operation of the valve. The test can show the switch capacity of the valve during the periodically opening and closing, and reproduce the transient stress caused by the combined intensity of voltage and current during switching process. In addition, it also can verify the backup triggering which is BOD.

When the parameters of circuit selected are in accordance with the system operating conditions, the test circuit can reproduce correctly the electrical stress of valve in severe situation, that is the electrical stress during the opening and closing process of the valve.

4 Periodic oscillation circuit design

(1) Parameter calculation

① Determine the maximum values of voltage and current

To the equivalent test of valve, because the step-up transformer has been determined and the rated voltage in the secondary side is 10kV, then, U_{DRM} of positive group equals 14.14kV before the discharging, and U_{DRM} of anti-group should be considerable before the discharging.

The amplitude of oscillation current is not isolated, but proportional to the wave impedance. Wave impedance has relationship with LC parameters.

Here, oscillating current bottom width is —, the wave impedance during discharging is – and the peak current during discharging is — .

If the peak current during discharging is determined, then, the wave impedance is determined. In fact, if the bottom width of oscillating current and the peak current during discharging are fixed, then L, C values can be got according to linear equations.

② Determine the bottom width of oscillation current
According to the above analysis, if the bottom width is narrow, then the peak current during discharging Im can be transferred large. If the bottom width is wide, then he peak current during discharging Im can be transferred small.

③ Determine the time interval between positive and anti-group
Periodic oscillation test device uses the capacitor to store energy and to exchange energy with the reactor to form the oscillating current and voltage. Therefore, the energy is limited, not inexhaustible.

Each time supplied by the power should supplement the energy, thus, the oscillation can continue without decaying. Especially the voltage during opening in anti-group is obtained from anti-vibration by positive group, and this time will not last very long which will be decayed after 1ms to 2ms. This is because the oscillation circuit is not lossless circuit. The oscillation circuit has constant loss of partial media or parallel branch's leakage, so it is better to trigger anti-group after the positive group withstands the reverse voltage for 1ms. Sure, the time interval of triggering front edge between positive group and anti-group can be set to be adjustable. It can be adjusted from 0.5ms to 2ms to observe their relationship.

For example, if the parameters are selected as following: L=1.33mH, C=60μF. Then, the bottom width is 1ms, the wave resistance is 4.71Ω, and the peak current Im is 3000A.

(2) Control Analysis
Control schematic diagram is shown below.

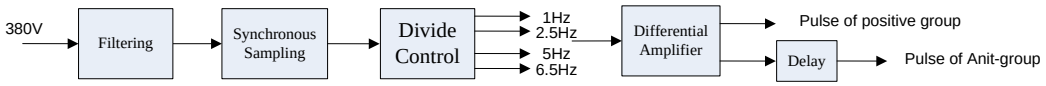

Figure 3 Periodic Oscillation Pulse Control Diagram

Here, 380V voltage should come from one source with the primary side of regulating voltage used for periodic oscillation circuit.

(3) Matters need attention

① The pulses of triggering positive group and anti-group are got in the negative half-cycle which means the power stops charging. One reason is to avoid accidental short circuit of power, and the other reason is to avoid the test in the charging process so that the measurement error will be caused by uncertain magnitude.

② After the triggering of positive group, the reverse voltage during shutdown is formed. The triggering of anti-group should avoid the transient peak voltage, so the triggering should be delayed for 0.5ms to 2ms. Thus, positive group and anti-group are both tested, and the reverse voltage after the oscillating current occurred in anti-group is completed can connect

the next positive half-cycle energy.

Actually, the capacitor energy during triggering in anti-group is certainly less than the capacitor energy during triggering in positive group

5 Periodic oscillation circuit test situation analysis

According to the test circuit shown in Figure 2, the peak current and the wave impendance can be different by adjusting the L value and C value. The test is mainly to observe the dynamic voltage-sharing during opening and closing.

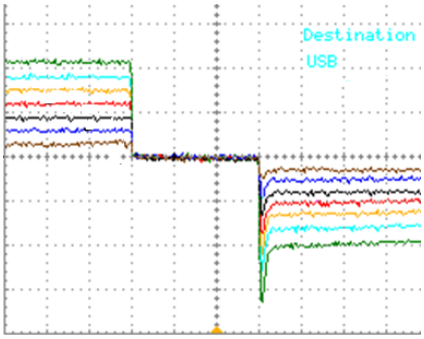

Figure 4 Voltage Waveform of turn-on and turn-off thyristor

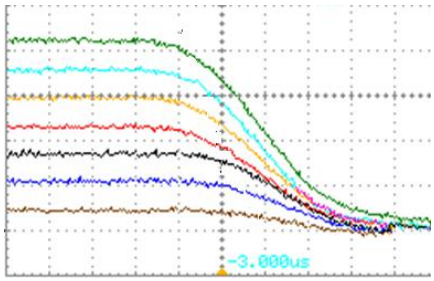

Figure 5 Instantaneous Voltage Waveform of turn-on thyristor

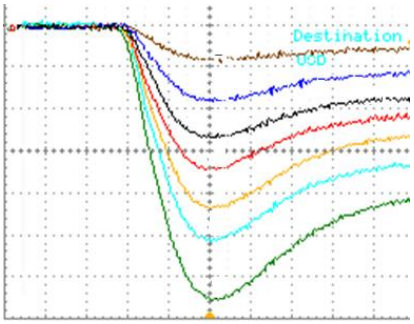

Figure 6 Instantaneous Voltage Waveform of turn-off thyristor

To a thyristor valve, if a handful of thyristors can't be triggered normally, these thyristors will withstand full voltage. If measures will not be taken to protect the single thyristor's over-voltage, then the blocking thyristors will be damaged by over-voltage successively.

If the design allows the over-voltage protection act periodically, then after triggered thyristors conducted, the voltage crossing the thyristors not be triggered normally increases, and the formatted current will charge the damping capacitor through the damping resistance. When the voltage crossing the thyristors not be triggered normally reaches the voltage threshold value, the corresponding thyristor is triggered.
However, this protective triggering will bring additional losses to thyristor.

Test conditions: Positive opening 10kV voltage, the current peak after the thyrisor is opened Ip≥500A, the width of current ≥2ms, the triggering frequency f=6.25Hz.

During testing, one or two thyristors' pulse is removed and BOD will act to trigger the corresponding thyristors. The test lasts 30 minutes, and no thyristor should be damaged or downgraded. Under this situation, the dv/dt parameter of BOD is also tested.

Test analyses are as the following shows.

(1) The voltage-sharing during opening process
The voltage-sharing distribution test of valve is done according to the circuit in Figure 2, if the thyristors are conducted under the triggering conditions of low voltage and harsh triggering angle, then the inhomogeneity of voltage distribution is more serious.

The test shows that, in general, to the thyristors, the dispersity of opening time and triggering time should be restricted more strictly.

(2) Overshoot factor test during shutdown
The actual measurement result shows the overshoot factor K ≈ 1.21, so it is generally able to meet the design requirements.

(3) BOD test
After simulation test, the parameters required by BOD protection are determined. The test and analysis shows the BOD has some impact to trigger thyristors mistakenly when the junction capacitance of BOD is impacted by steep wave.

6 Conclusion

This paper introduces the operation equivalent test of the thyristor valve, describes the periodic oscillations test circuit of the thyristor valve, and analyses the work process in detail.

Test methods presented in this paper for periodic triggering and extinguish test of valve verify the dynamic voltage-sharing during the opening process and shutdown of valve. The results show the dynamic voltage-sharing can reach 90 percent, and the basic performance of valve meets the design requirements.

The above tests show that to use periodic oscillation test circuit to test valve under limited testing conditions has some advantages.

(1) Test circuit consumes little energy, thus simple laboratory can implement it.

(2) Energy-saving effect is remarkable. The test has no disturbance to the grid, and it can save space and money, thus has good economic result.

(3) Test items and parameters can be easily configured without a lot of changes. The test is more flexible.

(4) The test circuit is simple, and the test component also has high security and is not easy to be damaged due to the failure of the test circuit.

(5) The valve after testing via the periodic oscillation device generally has no problem in system test.

7 BIBLIOGRAPHY

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