Research on Dynamic Response Time Test Method for Reactive Power Compensation Device

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Abstract. With a large number of applications of fast impact load equipment, the power quality of power grid is increasingly affected. During the actual inspection process of enterprise production and inspection organization, we find that there are still shortcomings in GB/T15576-2008 standard, so we need to study and perfect the dynamic response time test method of reactive power compensation device. In this paper, the input mode of switching switch, the processing speed of controller and the effect of operation method on the dynamic response time are analyzed, and a new dynamic response time test method is proposed. The application of electronic load in the dynamic response time test can greatly improve the accuracy of the test.

Key words: Power quality; reactive power compensation; dynamic response; Switching switch; electronic load.

1. Introduction
In the power system, power quality is related to the interests of power generation, power supply and power consumption, and the input of a large number of inductive loads has an impact on the operation and power quality of the power grid, so the reactive power compensation of the power grid is particularly important [1]. With the rapid impact load equipment such as rolling mill, internal mixer and spot welding machine, the demand for dynamic reactive power compensation device with response of tens of milliseconds becomes more and more large [2]. The dynamic response time of this kind of compensation device needs to reach 20ms, which is the time from the change of active and reactive load to the total input of the required compensation channels. If the compensation response is slow and the required capacity is not put into operation or cut off in time, problems such as under compensation, over compensation and voltage drop will be caused. Therefore, the response time test requirements of this kind of dynamic reactive power compensation device with tens of milliseconds response are relatively high.

At present, there are many researches on reactive power compensation at home and abroad, but they mainly focus on compensation technology, compensation model, optimal control and compensation device. Literature [3] mainly studies the problems of dynamic reactive power compensation technology in distribution system. In reference [4], the calculation model of active power loss caused by reactive power transmission of each component in distribution network is established, and the loss reduction sensitivity analysis is carried out. At the same time, the investment benefit model of reactive power compensation is established to optimize the reactive power compensation principle of substation and
distribution transformer. Reference [5] proposed a scheme of reactive power optimization control using magnetic energy regenerative switch technology. References [6] to [13] provide a composite reactive power compensation device for distribution network, which can continuously and dynamically compensate the reactive power of the power grid; discuss how to improve the reliability of the reactive power compensation device and realize the optimization of compensation; introduce the test method and principle according to GB / T15576-2008 standard; analyze the principle and practical significance of reactive power compensation in power supply and distribution system Research on compensation technology. Reference [14] gives a nine domain control method based on fuzzy control theory, and designs a set of medium and high voltage TSC reactive power compensation device based on DSP. In the actual enterprise production and inspection process, we found that the GB / T 15576-2008 standard still has the following shortcomings: there is a certain error in the dynamic response time detection method specified in the standard, and there is a large deviation for the quick response compensation device, so it is urgent to study and improve the dynamic response test and inspection method. For the dynamic reactive power compensation device with millisecond fast response, the response time reaches 20 milliseconds. By analyzing the influence factors of dynamic response time, a new dynamic response time test method is proposed, that is, using electronic load (electronic load is a kind of electronic energy feedback load, which can be programmed to generate the required reactive power, harmonic and other current waveforms) It can not only avoid the transient problem of the inductive load, but also generate the intermittent impulse current waveform, which is convenient to test the dynamic response time after switching off.

2. Standard test method
The reactive power compensation devices are divided into three categories according to the types of components for switching capacitors: 1) electromechanical switches (such as Contactors); 2) semiconductor electronic switches (such as thyristors); 3) composite switches (the combination of semiconductor electronic switches and electromechanical switches in parallel). For devices with semiconductor electronic switch or compound switch, the dynamic response time should not be greater than 1s.

The dynamic response time detection method specified in article 7.14 of GB/T 15576-2008: put the device in the automatic working state, apply the rated voltage to the device, input the inductive load greater than the set value in the main circuit, detect the change of the inductive load voltage, and record the time as T1, simultaneously detect the current change of the capacitor input, and record the change of the output current of the compensation capacitor Time T2, then t2-t1 is the dynamic response time t of the device. The test was carried out three times and the longest time t value was taken. The dynamic response time of the device, i.e. the time difference between voltage change and current change [15].

3. Factors influencing dynamic response time
The test method specified in the standard is not clear about the response time of all inputs. The actual test mostly adopts the response of one branch, and the response time of all input may be long, which is not suitable for the compensation device with quick response. The standard recording the starting time by measuring the inductive voltage will lead to the current lagging voltage of 90 degrees, which will bring about Test error: when the inductive load is put into operation, there will be transient current when switching on, which will make the waveform of recording time chaotic and bring detection error; some compensation devices are put into operation quickly for the first time, but they can only be put into operation again after discharge. If the compensation device with quick response needs to verify the response time test of quick compensation after removal.

There are two main factors affecting the dynamic response time of the dynamic reactive power compensation device with millisecond fast response: one is the input mode; the other is the processing speed and operation method of the controller. The input mode is divided into zero voltage input and phase-locked trigger.
3.1. Input Mode

3.1.1. Zero Voltage Input. Zero voltage switching capacitor switch is a kind of switch that can be used when the voltage at both ends of thyristor is zero. In the single-phase circuit without series reactor, it can realize fast switching. After series reactor, the voltage when the capacitor is cut off is higher than the grid voltage, and the voltage zero crossing at both ends of the thyristor can only appear after the capacitor is discharged for a period of time. Therefore, even if the controller sends the input command signal within a period of time after the capacitor is cut off, the voltage at both ends of the main circuit thyristor will not appear until the capacitor is discharged. If the voltage has not reached zero voltage and can not trigger the thyristor, the capacitor can not be put into operation. It needs a period of time for the capacitor to discharge to reach the voltage zero crossing point of the thyristor, which results in the delay of response time. In this paper, the capacitor switching switch of single-phase circuit, three-phase common compensation circuit (without series reactor) and three-phase common compensation circuit (charged reactance) is simulated, and the influence of zero voltage input on dynamic response time is analyzed.

1. Single-phase circuit

The simulation schematic diagram and waveform diagram of zero voltage input capacitor switching switch applied in single-phase circuit are as follows:

Fig 1. Simulation schematic diagram of zero voltage switching capacitor switch applied in single phase circuit

Fig 2. Simulation waveform of capacitor switching switch with zero voltage input applied in single phase circuit
From the above simulation waveform, it can be seen that the response time of the first capacitor input is very fast and there is no delay. However, if the capacitor is switched on again after being cut off, the response time is relatively long and cannot be put into operation immediately. In this case, if the original detection method is used, the response time test result will be very fast if the capacitor is switched on again after the capacitor is discharged, but this can not represent the actual response time. Therefore, it is necessary to send the input command again to test the response time immediately after the removal.

2. Three phase common compensation circuit (without series reactor)

In the three-phase common compensation circuit, the general design of zero voltage input capacitor switching switch is that two-phase thyristor is used and one phase is through. See the circuit schematic diagram below for details:

![Fig 3. Schematic diagram of application of zero voltage input capacitor switching switch in three-phase common compensation circuit (without series reactor)](image)

![Fig 4. Schematic diagram (without series reactor) simulation waveform of zero voltage input capacitor switching switch applied in three-phase common compensation circuit](image)
From the above simulation waveform, it can be seen that there is no delay in the initial operation, but it will be put into operation immediately after the cut-off. The reason is that the residual voltage after the capacitor is cut off is not uniform. After one thyristor meets the zero voltage on, the other does not meet the zero voltage and needs to wait for the capacitor to discharge. Therefore, one phase of thyristor is connected while the other phase is The phenomenon of no phase operation. If according to the previous test method, it is also considered that the compensator has made a faster response, but it is unreasonable to run without phase. The test should be carried out according to the whole working time of three phases.

3. Three phase common compensation circuit (live reactance)

The simulation schematic diagram and waveform diagram of capacitor switching switch with zero voltage input applied in three-phase common compensation circuit (live reactance) are as follows:

![Fig 5. Application of zero voltage input capacitor switching switch in three-phase common circuit
Schematic diagram of compensation circuit (live reactance)](image)

![Fig 6. Simulation waveform of capacitor switching switch with zero voltage input applied in three-phase common compensation circuit (live reactance)](image)
From the above simulation waveform, it can be seen that there is no delay in the initial input, but it will also appear the phenomenon of phase loss when it is put into operation immediately after the removal. The reason is that the residual voltage after the capacitor is cut off is not uniform. After one thyristor meets the zero voltage on, the other does not meet the zero voltage and needs to wait for the capacitor to discharge. Therefore, one phase of thyristor is connected while the other phase is the phenomenon of no phase operation. There is no response for a long time after the third input command is sent out. This is because with different cut-off points, the SCR terminal voltage caused by the residual voltage of the capacitor after adding reactor is below zero crossing point. Therefore, no thyristor meets the zero voltage condition and can not trigger the switch on. Only after the capacitor is discharged for a period of time, the zero crossing will appear before it can be put into operation again. If according to the previous test method, it is also considered that the compensator has made a fast response at first, but the subsequent operation without phase or no response is unreasonable, so the test should be conducted according to the whole working time of three phases.

3.1.2. Phase Locked Trigger. The phase-locked trigger capacitor dynamic switching switch is triggered in the corresponding grid voltage fixed-point time point according to the phase-locked mode. It does not need to detect the voltage at both ends of the thyristor, so there is no need to wait for the discharge process of the capacitor, and the response time is fast. The trigger schematic diagram is as follows:

![Fig 7. Simulation schematic diagram of phase locked trigger capacitor dynamic switching switch](image-url)
3.2. Processing Speed and Operation Method of Controller

The delay caused by the processing speed and operation method of the controller is a fixed delay, which is not affected by the test method and the response time of the switching switch. In order to achieve the dynamic response of tens of milliseconds, the detection speed of the controller should be fast enough to meet the requirements.

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4. Test method of dynamic response time

To sum up, for the capacitors switched on and off by thyristor, some switches judge the zero voltage of the switch before putting them into operation again. When the residual voltage of the capacitor is cut off, the condition of zero voltage opening of the switching switch can only be reached when the residual voltage of the capacitor is consistent with the grid voltage. However, when the compensation circuit is
connected with reactors in series, the residual voltage of the capacitor is higher than that of the grid voltage and needs to be longer Therefore, even if the controller sends a command to the switch, the compensation branch can not be put into operation again immediately after it is cut off. However, some switching switches adopt phase-locked trigger mode, and the switching response time is fast. In view of this reason, it is necessary to study the response time of all the dynamic reactive power compensation devices, instead of testing the time of putting into one branch, and also need to test the response time of switching on again, which is not specified in the original standard.

The test method in the standard is to input inductive load, which will produce transient current and introduce test error; the standard adopts detecting the change of inductive load voltage to record time, which is not suitable for dynamic compensation device test, because the load current is lag VOLTAGE 90 degrees (5ms for 50 Hz), and the compensation device is the sampled current 0 Hz system will inevitably lead to 5ms test error, which is very large for the dynamic compensation device of tens of milliseconds. By analyzing the influence factors of dynamic response time, it is necessary to study new dynamic response time testing methods.

In this paper, the electronic load is applied to the dynamic response time test. Test steps:

a. Firstly, the electronic load generates the periodic reactive load in accordance with the response time by programming, and the maximum reactive power of the reactive step should be greater than the output capacity of the compensation device.

b. Reactive power compensation starts automatic compensation mode operation.

c. On the one hand, the oscillograph tests the three-phase current waveform of the load, on the other hand, tests the compensation current waveform at the inlet of the compensation cabinet. From the beginning of the compensation object to the device output reaching 90% of the target value, the oscilloscope is used to measure the current waveform data and measure the response time.

d. According to the recorded data, the response time of reactive power compensation device should meet the requirements of response time.

Through the step load to achieve the entire range of capacity change, and can step change, can test the effect of switching on again, so that we can achieve the real dynamic response time test.

5. Conclusion

The innovation of this paper is to analyze the influence factors of dynamic response time, and then propose a new dynamic response time test method. By introducing the electronic load to generate periodic impulse current waveform, it can not only avoid the transient impact of inductive load, but also produce intermittent impulse current waveform, which is convenient for dynamic response time test after switching off The accuracy of the test is improved.

With a large number of applications of fast impact load equipment, the impact on power quality of power grid is becoming more and more serious. In this paper, aiming at the dynamic reactive power compensation device with millisecond level fast response, the influencing factors of dynamic response time are analyzed, which can further improve the technical ability and product quality of compensation device products, promote the healthy development of the industry, and have significant economic benefits and important significance.

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