Research on Dynamic Response Time Test System and Method of Reactive Power Compensation Device

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Abstract. In the actual enterprise production and inspection process, we found that there is a certain error in the dynamic response time detection method specified in the standard. For the fast response compensation device, the deviation is large, so it is urgent to study and improve the dynamic response test method. Especially for the dynamic reactive power compensation device with millisecond fast response, its input mode, the processing speed of the controller and the calculation method will affect the dynamic response time. In order to solve the shortcomings of the existing technology, this paper proposes a dynamic response time test system and method for reactive power compensation device. By introducing electronic load to generate periodic impulse current waveform, it can not only avoid the impact transient problem of inductive load, but also generate intermittent impulse current waveform, which is convenient to test the dynamic response time after switching off, which greatly improves the test accuracy. The simulation results show that the method can test the dynamic response time of tens of milliseconds more effectively and quickly.

Keywords: Dynamic response; Compensation device; Input mode; Electronic load; Inductive load.

1. Introduction
At this stage, most of China's power grid operation requires the power system to supply sufficient power load. In order to make the system more stable, be able to supply power continuously, reduce the wear of equipment in the power system, and improve the quality and efficiency of power supply, reactive power compensation devices will be installed in the power grid system, which is very important for the development and stability of the whole power grid [1].

For fast impact load equipment such as rolling mill, internal mixer and spot welder, compared with other loads, the power quality of such equipment is much more complex, mainly reflected in the aspects of fast reactive power change, low power factor and high harmonic content [2]. Reactive power compensation for this kind of equipment is easy to lead to over compensation or under compensation, which affects the safety of the equipment. Therefore, the requirement of dynamic response time test for this kind of equipment is relatively high.

At present, the research on reactive power compensation at home and abroad mainly focuses on the compensation configuration scheme, reactive power compensation device, calculation of reactive power compensation, reactive power compensation optimization and technology. Reference [3] introduces the
calculation of reactive power compensation through engineering design cases. According to the dynamic impedance matrix and power weight value, the passive / active impedance index considering power weight is derived and given in reference [4]. Finally, the reactive power compensation configuration scheme considering the dynamic characteristics of power grid is proposed. In reference [5], a simulation example of IEEE33 node distribution network is established, and compared with other optimization models and methods. Reference [6] briefly analyzes the application of various artificial intelligence algorithms in reactive power optimization, and proposes a new hybrid algorithm based on the advantages and disadvantages of genetic algorithm and artificial neural network algorithm. From literature [7] to literature [8], the reactive power compensation technology is analyzed and studied. Literatures [9] to [10] mainly study reactive power compensation device. Literature [11] studies the optimization of reactive power compensation method of distribution network, and constructs the mathematical model of reactive power compensation optimization. In reference [12], a novel STATCOM reactive power compensation strategy based on the front end current of compensation point is proposed. Reference [13] proposed that reactive power output and voltage quality of wind farm can be improved by optimization algorithm. In reference [14], according to the phase locked loop of power grid and the current mutation of DC bus, the dynamic reactive power compensation device is used to repair and optimize the detection of power grid line loss.

In order to solve the shortcomings of the existing technology, this paper proposes a reactive power compensation device dynamic response time test system and method. By introducing electronic load to generate periodic impulse current waveform, it can not only avoid the impact transient problem of inductive load, but also generate intermittent impulse current waveform, which is convenient for dynamic response time test after removal, and greatly improve the accuracy of the test.

2. Existing problems
At present, there is no universal IEC international standard for reactive power compensation devices. In China, GB/T 15576-2008 “Low voltage complete reactive power compensation device” is the national recommended standard for low voltage complete reactive power compensation device. At present, the standard is to use the low voltage complete set of reactive power compensation device as the complete set of equipment according to the requirements of GB/T 7251.1-2005, and stipulate the corresponding terms and definitions, technology and test requirements. In the actual production and inspection process of testing institutions, we find that there are some errors in the dynamic response time detection method specified in the standard. For the fast response compensation device, it is urgent to study and improve the dynamic response test and inspection method.

Especially, the input mode, the processing speed and the operation method of the controller will affect the dynamic response time of the dynamic reactive power compensation device with millisecond response.

3. Dynamic response time test system and method
The dynamic response time test system of reactive power compensation device includes test power supply, electronic load and data acquisition module. The electronic load is respectively connected with the corresponding phase lines of the test power supply and the reactive power compensation device; the data acquisition module respectively collects the three-phase current of the electronic load and the three-phase compensation current output by the reactive power compensation device in real time, and takes the time when the electronic load current of at least one phase starts to suddenly change to the preset proportion when the compensation current of the reactive power compensation device reaches the target value as the dynamic response time of reactive power compensation device.

The dynamic response time of the reactive power compensation device is the time when the electronic load current of at least one phase starts to suddenly change to the preset proportion when the compensation current of the reactive power compensation device reaches the target value.

The simulation method for dynamic response time test of reactive power compensation device is as follows: the electronic load is simulated connected with the corresponding phase lines of test power
supply and reactive power compensation device in the virtual interface; the electronic load generates reactive power step according to the preset parameters, which is in line with the periodic change of response time; the reactive power compensation starts the automatic compensation mode; the three-phase current waveform of load and reactive power compensation are tested at the same time. The output compensation current waveform of the device changes suddenly from the reactive load of the electronic load to the preset proportion of the output of the reactive power compensation device reaching the target value, and the dynamic response time is obtained. The wiring diagram of dynamic response time test is shown in Figure 1.

Through the electronic load to achieve the entire range of capacity changes, and can produce changes step by step, can test the effect of switching and then switching, so as to achieve the real dynamic response time test. As long as the processor speed is fast enough, there is no delay, only the time between switching points, no impulse current and no impulse process. The detection method finds the time of no inrush current input through phase-locked. There is no inrush current when input, and no impulse current when transient input.

4. Simulation Verification
The simulation schematic diagram of the test system is shown in Figure 2.
The electronic load can be programmed to output the step reactive power required for the test. The step time, interval, and reactive power generated can be set by parameters. The reactive power compensation device is composed of an electronic switch or a composite switch. A dynamic compensation device with fast switching response. The reactive power compensation device quickly switches the internal capacitive reactance group by detecting the reactive power of the load (or system) to achieve the purpose of rapid compensation.

The specific structure is divided into main circuit, step time and reactive power control circuit, command generation and triangle carrier comparison circuit and dead time generation circuit. The step reactive power required for test can be output by programming, and the step time, interval and reactive power can be set by parameters.

The internal main circuit simulation schematic diagram of step reactive power electronic load is shown in Figure 3.

![Figure 3. Internal simulation schematic diagram of step reactive power electronic load](image)

The main circuit in the picture is composed of I-type three-level IGBT, and the output adopts LCL-type carrier filter. The step time and reactive power are generated by the control circuit to generate current commands, while the Ica, Icb and Icc in the main loop generate reactive currents required for compensation.

In the DQ coordinate system, by controlling the occurrence time and size of Iq, and then through DQ inverse transformation and two three inverse transformation, the required current command can be generated, and then the internal control circuit can control the power device to generate the required reactive current.

The simulation schematic diagram of internal command generation and triangular carrier comparison circuit of step reactive power electronic load is shown in Figure 4. There are six comparators in the circuit, and there are two triangle carrier generators in each phase of A, B and C to generate triangle carrier signal. Comparator front-end will give a modulation signal and triangle carrier for comparison, higher than the triangle carrier appear high level, lower than the triangle carrier appear low level, finally produce high and low level, form the corresponding switch
signal, control the current generator to produce the required target current, this is a controller automatic control circuit.

The simulation schematic diagram of internal dead time generation circuit of step reactive power electronic load is shown in Figure 5.

**Figure 4.** Schematic diagram of internal command generation and triangular carrier comparison circuit simulation of step reactive power electronic load

**Figure 5.** Simulation schematic diagram of internal dead time generation circuit of step reactive power electronic load
The so-called dead zone is that two tubes of the upper and lower tubes cannot be opened at the same time. There is a delay, that is, one tube is closed, and the other tube can be opened only after the delay. In order to achieve the delay, this circuit is added.

The device is composed of switching main circuit unit, reactive power detection unit, reactive power control unit and switching timing management unit.

The main circuit unit is composed of electronic switch (The SCR is used in the simulation), reactor and capacitor. Three switching branches are adopted in the simulation schematic diagram, which are 480V 120kvar capacitor, 480V 60kvar capacitor and 480V 30kvar capacitor. The actual output reactive power of the three branches after 6% reactance rate in 400V system is 88.65kvar (128A), 44.33kvar (64A) and 22.16kvar (32A) respectively. The switching of its electronic switch is controlled by reactive power control unit and switching timing management unit.

IA, IB and IC are the load current. Through matrix transformation, the three-phase current is finally converted into the instantaneous value of reactive current, and then multiplied by the corresponding coefficient to become the effective value, which is compared with the later control signal. For the problem of fast response, we use instantaneous reactive power detection algorithm, as long as the processor speed is fast enough, there is no delay, only the time between switching points, no impulse current, no impulse process. The detection speed is fast and the delay is small.

The simulation schematic diagram of reactive power control unit of high speed dynamic compensation device is shown in Figure 6.

The function of reactive power control unit is to select the required branch according to the reactive current detected by the system and the compensation reactive current of each branch.

The simulation principle of the switching time management unit of the high speed dynamic compensation device is shown in Figure 7.

The function of switching timing management unit is to find the time of no inrush current input through phase lock. When receiving the input command of reactive power control unit, the thyristor of corresponding branch is triggered to input the capacitor reactance group at the time of no inrush current input.

The system dynamic response time simulation principle waveform is shown in Figure 8.

After detecting the abrupt reactive power, it just missed the peak point of line voltage Vab, resulting in that the thyristor between AB lines could not be put into operation immediately. After a period of delay, the peak point of Vbc came. Firstly, the thyristor between BC lines was put into operation, and
then the thyristor between CA lines and AB lines was triggered successively. At this time, the response time was close to 20ms. If the reactive power was detected, it happened to be put into operation immediately. The shortest response time is about 13.33ms, which is related to the starting phase of the load.

Take 90% of the negative peak value of three-phase current as the dynamic response time, and the test diagram is as follows. In the diagram, take 90% of the negative peak value of C-phase current, and the response time test is 17ms.

In conclusion, the simulation analysis shows that the dynamic reactive compensation detection method proposed in this paper can test the dynamic response time of tens of milliseconds more effectively and quickly.

**Figure 7.** Simulation principle of switching time management unit of high speed dynamic compensation device

**Figure 8.** Simulation principle waveform of system dynamic response time
5. Conclusion
Compared with the existing technology, the innovation of this paper is as follows:

1). By introducing electronic load to generate periodic impulse current waveform, it can not only avoid the impact transient problem of inductive load, but also generate intermittent impulse current waveform, which is convenient for the dynamic response time test of switching on again after cutting off, and greatly improves the accuracy of the test.

2). Firstly, the electronic load generates the reactive load with periodic change 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. Through the step electronic load, the whole capacity change range can be realized, and the step change can be produced. The effect of switching and switching can be tested, and the real dynamic response time test can be realized.

3). Through the construction of simulation system including electronic load, reactive power compensation device and test power supply, the accuracy of the test method is verified, which proves that the proposed dynamic reactive power compensation detection method can test tens of milliseconds of dynamic response time.

The research results not only provide important technical requirements and standard support for the type test certification of the reactive power compensation device products by the third party testing institutions, but also further improve the technical capability and product quality of the compensation device products, promote the healthy development of the industry, and provide important reference for the customers of power system to select compensation devices, so it has a significant social significance economic performance.

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