Design and application of the automatic AC voltage test device for smart electricity meters and data acquire terminal of the special transformer

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Abstract: The AC voltage test is an important means to effectively detect the insulation defects of the equipment. The problems of low efficiency, poor safety, and poor compatibility of the AC voltage test for smart electricity meters and data acquire terminal of the special transformer are realised, which makes many problems of the existing test equipment to be effectively solved. Thus, the efficiency, compatibility, safety and reliability of the test are improved.

1 Introduction
Under the target of full coverage, full acquisition, and full cost-control, the smart electricity meters, data acquire terminal of the special transformer and centralised meter reading terminal have been popularised on a large scale, the safety and reliability of its operation have a, particularly, important influence on the common interests of power supply and consumption, even the personal and property safety [1]. Therefore, according to the requirements of the verification regulations, the electric power industry, manufacturers and technical supervision departments usually carry out AC voltage tests on energy metering products, such as smart electricity meters, data acquire terminal of the special transformer, centralised meter reading terminal and other electrical products, so as to meet users’ safety requirements [2].

The AC voltage test is a destructive test, which effectively finds the defects of local ionisation and the weakness of insulation aging and the insulation defects of the equipment can be exposed by the AC voltage test. It is not only the most effective and direct method to identify the insulation strength of the electric power equipment, but also an important part of the preventive test [3].

However, the problems of the long test time and low efficiency of the traditional AC voltage test device are becoming more and more prominent [4]. At the same time, the multi-station automatic AC voltage test device for electricity meters also has a high recoil voltage phenomenon when the equipment under test (EUT) is punctured [5–9].

In this study, the AC voltage test for smart electricity meters, data acquire terminal of the special transformer, and centralised meter reading terminal is studied, the testing difficulties and the common features of the EUT are summarised, the related automatic test methods are put forward, and finally the automatic AC voltage test device is designed, so as to make it automatically complete the AC test for the smart electricity meters, data acquire terminal of the special transformer, and centralised meter reading terminal, thereby improving the safety and efficiency of the test.

2 Test methods and requirements
According to the electrical meters for measuring alternating current electrical energy, technical specification for single phase static multi-rate electricity meters, triphase smart electricity meters, and power user electric energy data acquire system, the requirements for the AC voltage test are: between, on the one hand, all the current and voltage circuits as well as the auxiliary circuits whose reference voltage is >40 V, connected together, and, on the other hand, earth. The test voltage is 4 kV and the test time is 1 min. During these tests, no flash-over, disruptive discharge, or puncture shall occur. After the test, the instrument should have no mechanical damage and must work normally [10–16].

3 Test scheme
According to the requirements of the relevant standards, the test voltage and test point of smart electricity meters, data acquire terminal of the special transformer, centralised meter reading terminal are sorted out whose related characteristics are summarised. The test scheme include: one kind of single phase smart electricity meter, one kind of three-phase direct connected meter, three kinds of three-phase transformer operated meter, seven kinds of data acquire terminal of the special transformer, three kinds of centralised meter reading terminal (type II), and six kinds of centralised meter reading terminals (type I). Therefore, there are 21 kinds of test schemes. At the same time, the test voltage is different, and the wiring is complex.

In the traditional mode of operation, the test depends on manual wiring; hence the experimenter must be familiar with the testing standard and connection mode. Considering full performance test and sampling acceptance test as examples, the 21 test schemes are a batch, and there are 50 batches, so the average time of the manual test is ~15 min, and it will take ~33 working days to complete the full tests with an uninterrupted test of 8 h a day. The test time is not only far more than the limit but also there are dangerous situations such as electric shock and wrong wiring.

In order to find out the commonalities and summarise the test scheme, these 21 schemes are integrated and shown in Table 1, the connection mode is reduced to eight types from the original 21 types. Therefore, the number of test items has been greatly reduced, which effectively improves the efficiency.

In order to match the scheme of Table 1, the automatic AC voltage test device is designed, so as to improve the test efficiency and ensure the test safety.
4 System development

4.1 System

The system is mainly composed of test host, AC voltage tester, and AC voltage test device. Through the network cable, the test host is connected with the AC voltage test device. The AC voltage tester and AC voltage test device are connected through RS232. The test voltage of the AC voltage tester is output to the AC voltage test device through the power line (Fig. 1).

4.2 Test host

The test host is made up of the computer with the test software; the control command is transmitted to the AC voltage test device through the network cable. The test plan is selected by the experimenter through the software system, and the test for the equipment under test (ETU) is started. After the start of the test, all kinds of parameters of the AC voltage test device are monitored by the test host in real time through the network cable.

4.3 AC voltage tester

The AC voltage tester provides the required high voltage for the test. In order to simplify the follow-up calibration of the equipment, the AC voltage tester is designed as a separate device.

4.4 AC voltage test device

The AC voltage test device receives control commands from the test host, according to the scheme determined by the experimenter, and the point of application of test voltage for the EUT is selected. The control command of test voltage is transmitted to the AC voltage tester through RS232, the test voltage outputted by the AC voltage tester is applied to the test point which is selected by the AC voltage test device. So as to complete the automated test, the leakage current is monitored in real time by the test host and the quality of the tested product is automatically judged.

4.4.1 Automatic crimping technology:

To improve test efficiency and reduce the time lost by wiring, the base for testing and installation is studied and designed. The design of the test station for smart electricity meters, data acquire terminal of the special transformer, and centralised meter reading terminal is different. During the testing, the EUT is placed in the corresponding test station, the automatic crimping of the EUT is realised by the motor and the connecting terminal, thereby the wiring time is reduced and the work efficiency is improved. The connecting terminal is shown in Fig. 2. As shown in Table 1, the points of application of test voltage are different according to the test scheme, thus different test circuits are formed. In order to complete the test of different EUT, the test station whose design diagram is shown in Fig. 3 should be compatible with different test circuits. Each of the test stations has corresponding circuit switches, and different switches are selected through closing the switch.

4.4.2 Programmable controller (PLC) electrical design:

The PLC electrical schematics are shown in Fig. 4. As shown in Fig. 4, the PLC which controls the connection and motor movement of test station completes the automatic crimping and release of the EUT. The complexity and insecurity of manual wiring are effectively replaced, the work efficiency is greatly improved and most of the wiring time is saved.

Table 1 Integrated test scheme

| EUT                                    | Test voltage, kV | Point of application of test voltage                                      |
|----------------------------------------|------------------|--------------------------------------------------------------------------|
| single phase smart electricity meters  | 4                | between, on the one hand, terminals from 1 to 6 connected together, and, on the other hand, terminals 7 to 12 connected together |
| and centralised meter reading terminal (type II) |                  |                                                                           |
| three-phase direct connected meters     | 4                | between, on the one hand, terminals from 1 to 17 connected together, and, on the other hand, terminals 19 to 28 connected together |
| three-phase transformer operated meters | 4                | between, on the one hand, terminals from 1 to 17 connected together, and, on the other hand, terminals 19 to 28 connected together |
| centralised meter reading terminal (type I) and data acquire terminal of special transformer | 2                | between, on the one hand, terminals 1, 3, 4, 6, 7, and 9 connected together, and, on the other hand, terminals 2, 5, 8, and 10 connected together |
|                                        | 0.5              | between, on the one hand, terminals from 13 to 30, connected together, and, on the other hand, earth                        |

Fig. 1 System block diagram

![System block diagram](image-url)
The switches shown in Figs. 4b and c are in agreement with the switches shown in Fig. 4a. The PLC controls different switches, to close or disconnect, according to different options of the test scheme, which makes the test voltage to be effectively applied to the tested circuits.

4.4.3 Design of power supply: The AC voltage test device needs the power source to effectively supply the PLC and motor, and at the same time, the impact of the high voltage which is generated by the AC voltage tester must be effectively prevented. The AC voltage test device is powered by 220 V AC which is converted by the transformer to a suitable power supply for PLC and motor. In order to prevent interference, which is generated by high voltage experimentation area, from being applied to normal power supply system, the protection of strong and weak electrical isolation, interference filtering, and shell grounding must be done well. The power design diagram is shown in Fig. 5.

5 Test results and analysis

After the device is completed, according to Table 1, all kinds of smart electricity meters, data acquire terminal of the special transformer, and centralised meter reading terminal are tested. The flow chart of the test is shown in Fig. 6. First, the scheme determined by the experimenter and the point of application of test voltage for the EUT is selected. Second, the state of each device is monitored by the test host, if any errors exist, the experiment cannot start. Then, the leakage current is monitored in real time by the test host. Lastly, the quality of the tested product is automatically judged.

As shown in Fig. 8, the test time for the smart electricity meters, data acquire terminal of the special transformer, and centralised meter reading terminal is determined. By using the software programming, PLC control technology, and automatic crimping
Figs. 7 Test interface

Figs. 8 Comparison of test time

Figs. 9 Comparison of error rate

Figs. 10 Time used for training

As shown in Fig. 10, because of the manual operation of the wiring work, the experimenter must be familiar with all the test schemes and the wire connection mode; the time taken for training is long. By using the AC voltage test device, the experimenter should use the system skillfully and understand the safety precaution; the time used for training is significantly lower than that of the original.

6 Conclusion

In this study, the requirements of AC voltage test are discussed, the various testing schemes of the smart electricity meters, data acquire terminal of the special transformer, and centralised meter reading terminal are analysed. The reasons for low test efficiency are found out, according to the characteristics of different test schemes, and the technology of the test station and automatic crimping are designed and studied. In order to improve the essence of testing security, the compatibility automation test of smart electricity meters, data acquire terminal of the special transformer, and centralised meter reading terminal is realised. The test time is greatly reduced and the efficiency of the test is improved.

In this study, the problems of low efficiency, poor security, and poor compatibility of the AC voltage test are researched, an automatic AC voltage test device for smart electricity meters, data acquire terminal of the special transformer, and centralised meter reading terminal is studied and designed. The test efficiency is improved and the safety and effectiveness of the tested products are ensured.

7 References

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Owing to the automatic completion of the test, the error rate of the experiment has been greatly reduced. The statistical data is shown in Fig. 9. Owing to the manual operation of the wiring work, the error rate of the traditional test is high. The majority of the error rate is caused by wrong wiring, which may trigger the risk of an electric shock. The error rate of the test conducted by using the AC voltage test device is <1%, this rate is much less than the error rate of the traditional test.

technology, the time spent on the same test scheme was reduced to 3 min which was more than 15 min in the past. The test process does not need any personnel operation, which greatly reduces the failure rate and insecurity caused by personnel operation, and the quality and safety of testing are improved.

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