Analysis and Design of a Novel Integrated Automatic Verification System Software Platform

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Abstract. In order to study the intelligent verification system of microprocessor-based relay protection tester, a novel software platform of integrated automatic verification system is designed in this paper. First of all, the composition and principle of the verification system are introduced, and then the communication between the relay protection tester and high precision AC-DC meter whose entire closed-loop system is completed theoretically. The software platform adopts the design concept of layering and modularization. Through the program generation platform layer, the verification schemes of relay protection tester under tested with different voltage and current output channels are completed to edit and design. Through the hardware interface layer, the communication modules of driver module and verification system of relay protection tester under tested are complete to design. Through drive modules of tester, analog voltage and current output are completed. Through communicating with high-precision meter, the reading of measurement is completed. And also, the calculation and result judgment of measurement error and test report generation are intelligently completed. The designed platform implements to automatically verify microprocessor-based relay protection tester, which greatly improves the efficiency of the verification system.

Introduction

The microprocessor-based relay protection tester is vital to the stable operation of the power system, whose application improves the level and efficiency of the relay protection equipment greatly. To clear whether the accuracy of the tester meets the requirements of the site tests, the tester should be tested regularly. However, the domestic tests for the microprocessor-based relay protection tester still remaining in the manual testing stage presently, the testing members control the testers to output results manually, read and record the results from the standard meters, calculate measurement error, judge whether the results are qualified, and then sort out test reports. The quality of testing can be influenced by the different software operations of the testers, fussy manual testing process, great work intensity, low work efficiency, and human factors, because the types of the microprocessor-based relay protection tester are too many, which are produced by manufacturers.

So it’s in need of studying and developing the automatic verification system to solve the questions what the tester exists presently. Pointing at the verification system of microprocessor-based relay protection tester in power system, a novel software platform is designed in this paper which can automatically verify steady parameters and transient parameters of microprocessor-based relay protection tester in one. The software platform solves the problem of inspecting equipment detecting automatically, and improves the inspection rate of the meter, the inspection level of the inspection department, and the application level of the users’ automation meter, thus indirectly improves the reliability of the field automatic equipment and the safe and stable operation level of the power grid.

The Principle and Composition of the System
The Principle of the Verification System

According to “DL/T 624-2010 Technical specifications of test equipment based on micro-computer for relaying protection” and “Q/GDW1153-2012 calibration specification of relay protection testers based on micro-computer”, the relevant performance parameters of the test content designed for the microcomputer-based relay protection tester by the system can be divided into the following three categories:

(1) Steady-state parameters: it mainly includes the output voltage, the accuracy of the current, total harmonic distortion, DC component, phase-shifting range, amplitude-frequency characteristic of the tested microprocessor-based relay protection tester, etc [1-3].

(2) Transient parameters: it includes response speed and synchronism of the voltage and current, etc.

(3) The accuracy of time measurement: it includes the response time of the input and output contacts, and test-time accuracy of the operation time of protection.

According to the verification requirements, the basic principle of the test system is:

(1) The tested microcomputer-based relay protection tester connects with an automatic verification hardware platform by the lines of voltage and current.

(2) The tested microcomputer-based relay protection tester connects with hardware platform and test lead PC by HUB to test the web environment.

(3) According to the specific verification function, the switching device can switch the load, the verification device measuring system of the microcomputer-based relay protection tester and the high precision AC-DC meter.

The Composition of the Verification System

The automatic verification system of the relay protection tester is shown in Figure 1. The automatic verification system consists of four parts: automatic verification hardware platform, automatic verification software system, the tested microcomputer-based relay protection tester, and verification program library. According to the test task, the automatic verification system can achieve all the technical parameters of the tester test automatically one-time, and output a verification report in the standard format automatically.

Design Principles and Realization of the Verification System Hardware Platform

The hardware platform is shown in Figure 2. The automatic verification hardware platform consists of three parts, they are the automatic verification device of microprocessor-based relay protection tester, COM3003 high precision AC-DC meter and automatically adjustable load.
The automatic verification device of microprocessor-based relay protection tester can achieve the periodic verification and performance evaluation for microprocessor-based relay protection tester, recording and analysis of the test data and test report generation, etc. The accuracy requirement of microprocessor-based relay protection tester is 0.2%, so the accuracy of the automatic verification device must be more than 0.05%. High-precision standard transformer is the key to this system design\cite{1-4}. Therefore the high-precision AC-DC meter with no less than 30ppm of the meter accuracy should be chosen to achieve the verification of the AC-DC output accuracy and harmonic accuracy, etc, to meet the verification requirements, such as COM3003. At the same time, owing to voltage measurement of the high-precision standard meter being limited by a range, for example, the voltage of COM3003 is 30 ~ 500V, for the voltage measured by below 30V, a voltage amplifying device should be developed to measure after small signal being amplified to a range which can be measured. Rationally distributing error ratio of the error source can effectively reduce the total error of the system\cite{2-5}. Automatically adjustable load can be controlled automatically, automatically adjust the load, and fully automatically complete the test of the load capacity by the host computer.

**Design Principle and Achievement of Verification System Software Platform**

The design ideas and purposes of this platform are reducing or avoiding manual interference in the verification process, visualization of the verification process, real-time outputting the test port, system having good scalability and compatibility\cite{6}. The system adopts the modular and hierarchical design method of the system architecture, which can simplify measurement software design\cite{7}.

**Overall Structure of the Software System**

Integrated intelligent automatic verification software is installed in the test terminal. As shown in Figure 3, in the software architecture of this automatic test system, using modular and structural hierarchical design ideas, the overall software architecture is divided into the system program generation platform layer, automatic test layer and hardware interface layer in the hierarchical structure.
The program generation platform layer is secondary development system of the relay protection tester test program, which achieves secondly develop according to the verification procedures and standards of the relay protection tester, edit the test program; The hardware interface layer includes driver modules of microprocessor-based relay protection tester, the communication modules of microprocessor-based relay protection tester verification device and the communication modules of high-precision meter. Automatic test layer includes automatic verification control program.

**The Program Generation Platform Layer**

According to verification procedures and standards of microprocessor-based relay protection tester, test program generation platform can edit verification program. The verification program file includes two parts: the verification template file and the report template file. The verification template file delimits tester verification items and verification circuits. The report template file delimits the verification report with automatically generating standard format. They are edited and generated by verifying template editing program.

As shown in Figure 4, the verification program generation platform has smart generation function.

The smart generation of verification template is designed as fellow:

1. For the types and channel composition of relay protection tester, for groups of tester output channels, 3I basic verification program, 3U basic verification program, 4U basic verification program, output basic verification program, input basic verification program and etc are developed. According to the verification type, basic verification program opens the data interface of parameters, such as the maximum current, the maximum voltage, the number of digital outputs, the number of digital inputs, the maximum DC voltage, etc;
(2) Provide the tester’s attribute data when generating, such as the tester’s type, the number of tester’s voltage paths, the number of tester’s current paths, the number of digital outputs, the number of digital inputs, the maximum current, the maximum voltage and the maximum DC voltage, etc.

(3) According to the number of tester’s voltage paths, the number of tester’s current paths, the number of digital outputs and the number of digital inputs, the system selects appropriate template. According to the number of voltage groups and current groups, and the number of outputs and inputs, the system splices intelligently basic verification program, transfers corresponding the maximum current, the maximum voltage and the maximum DC voltage, etc into basic verification program, and generates tested tester verification program with instantiation.

The Hardware Interface Layer

The hardware interface layer includes the tester’s driver module, the communication modules of relay protection tester’s verification device, the communication modules of high-precision meters.

The Drive Modules of Relay Protection Tester. The drive modules of relay protection tester opens standard interface (COM interface or DLL interface) to drive tester output, which is provided to use by automatic verification program. According to tester communication statute, the drive modules of relay protection tester develops, and also becomes the drive module which is opened by relay protection tester manufacturers.

In this paper, basing on the structure of the automatic verification system, the tester’s drive the external interface, the tester’s output function and their parameters are standardized. The system schematic diagram of the tester drive module standardization is shown in Figure 5.

![Figure 5. Architecture schematic diagram of the tester’s drive module.](image)

The tester’s drive module is designed for three parts, the output control module, the external interface module and standard files of the tester’s output function.

(1) Standard files of the tester’s output function: the tester’s output function and its parameters should be standardized, including steady-state parameters (such as output voltage of microprocessor-based relay protection tester, current accuracy, total harmonics distortion, DC component, phase shift range, amplitude-frequency characteristic, etc.), transient parameters (such as response speed and synchronization of voltage and current) and time measurement accuracy (relay protection tester testing the tested relay, action time accuracy of protection and safety automatic device) and so on, the file is saved in XML format.

(2) The output control module is the core module of the tester’s driver module, which achieves the functions of defining and describing in the "output function standard file". Output control module and the tester communicate with each other, control the output of the tester and read the digital input switch variable bit of the tester.

(3) External interface module opens standard interface function. By calling these interface functions, external automatic verification program uses the output control module to achieve all the functions. These interface functions include: the connect tester function Connect, configuring tester function Config, the output function StartTest, stopping output function StopTest, acquiring the test data of the tester function GetDatas, acquiring the abnormal information function GetErrorMsg, etc.
The overall principle procedure of the tester driver module in the system is as follow:

The first step: the tester drive module exports "the output function standard file";

The second step: According to the output function standard file, the editing program of verification program edits basic verification program, and according to the attribute parameters of the tested tester, the verification program file of tested tester is generated;

The third step: According to the verification item defined by the verification scheme file, the automatic verification program calls the external interface function of the tester drive module, and transmits the output function standard parameter data to the tester drive module;

The fourth step: According to the parameters passed from the interface, the tester driver module controls the tester output.

The procedure design in this paper is that the tester drive module, test program editing module, automatic verification module form closed-loop from the verification principle level.

The Communication Modules of Relay Protection Tester Verification Device. The communication modules of microprocessor-based relay protection tester verification device communicate with verification device of microprocessor-based relay protection tester. The communication modules open interface function to achieve the following functions:

1. Read the measurement of verification device of microprocessor-based relay protection tester;
2. Control verification device of microprocessor-based relay protection tester to switch microprocessor-based relay protection tester to achieve channel wiring;
3. Control verification device of microprocessor-based relay protection tester to achieve load switching control.

The Communication Modules of High-precision Meter. The communication modules of high-precision meter communicate with high-precision meter, the structure diagram of module frame is shown in Figure 6.

![Figure 6. The communication modules of high-precision meter.](image)

The data model file of high-precision meter defines the device data model of the meter, including the data modeling such as settings, measurements and so on. Data model module manages device data model.

Communication protocol thread module communicates with the international typical high-precision meter (COM3003, RD33), including the establishing communication connections, sending communication commands, resolving communication message and so on.

External interface module provides COM interface for automatic verification program to call, to achieve reading the settings, modifying the settings, switching the range, reading the measurements and other functions to be called.

Core management module manages and schedules the data management module, communication protocol thread module, and external interface module.

Automatic Test Layer

Automatic test layer is control procedures of automatic verification. According to the verification process defined by the verification program file, control program of automatic verification opens the verification program file and perform the verification of each test item in turn:

1. Automatically call the tester drive module and control the microprocessor-based relay protection test tester to output analog;
(2) Automatically communicate with automatic verification device of microprocessor-based relay protection tester and standard meter and read measurements;
(3) According to the output standard value and the measurements, automatically calculate the error and determine whether the test is qualified;
(4) Automatically fill the test results into the report and form the test report in the standard format.
(5) In the verification process, the automatic verification control program controls the automatic verification device the microprocessor-based relay protection tester to automatically switch wirings between the tester channel and the standard meter.

The Overall Verification Process

(1) The automatic verification control program loads the verification scheme file generated by the verification scheme generation platform.
(2) The automatic verification control program drives the tester driver module in the hardware interface layer, and drives the tester output measurements according to the test command and parameter issued by the automatic verification program.
(3) Automatic verification control program calls communication module of microprocessor-based relay protection tester verification device and communication module of standard meter to read the data of the measurement, calculates the error, judges the results, and fills the test results into the standard test report.

The Application Situation of the System

The integrated automatic verification system of microprocessor-based tester carried out the actual field application in 2017 in Hainan Electric Power Experimental Research Institute. High-precision standard meter uses COM3003, achieves automatic verification for the microprocessor-based relay protection tester in the application, and automatically generates a test report for the tested microprocessor-based relay protection tester. Application of system shows that: using previous manual test model, a single testing all the test items is up to 8 hours. After the using the method of fully automatic test in this system, testing all the test items needs only 2 hours. The test time is shortened 6 hours, the test efficiency increases by 4 times. The analysis of test efficiency is shown in Table 1.

<table>
<thead>
<tr>
<th>test mode</th>
<th>the number of tests</th>
<th>testing time</th>
<th>Efficiency analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>manual test</td>
<td>one</td>
<td>8 hours</td>
<td>test efficiency increased by 4 times</td>
</tr>
<tr>
<td>automatic test</td>
<td>one</td>
<td>2 hours</td>
<td></td>
</tr>
</tbody>
</table>

The application of this system improves the efficiency of the test, and solves the problem of long inspection period and low test efficiency to lay a good foundation for cycle verification and network detection in the future.

Concluding remarks

The design of a novel integrated automatic verification system software platform can realize the automatic verification of several technical parameters for microprocessor-based relay protection tester, realize the automatic generation and management of the test report, provide equipment protection for shortening the verification period of the inspection instrument, and solve the problem of long inspection instrument delaying time. At the same time, it reduces the testing cost of the inspection instrument, improves the inspection rate of the customer's instrument and the inspection level of the inspection department, thus improves indirectly the reliability of the on-site automation equipment.
References


