A Portable Test Device for Smart Substation Based on PXI Bus

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Abstract: In debugging and testing process of the intelligent substation process level intelligence unit ,it need to build multiple sets of test environments, with the wiring complexity and low efficiency. For this case, we design of a portable intelligent substation testing device based on PXI bus, describe the system architecture and software system implementations, focusing on the hardware configuration and the main board of the device works, describe the configuration type test software implementation and testing process, introduces the test purpose and implementation of each test item. The device implements the automatic testing of the intelligent unit, reducing the number of supporting test equipment. Practical application shows that the test device based on intelligent unit operation PXI bus is good, it meets the design requirements and the testing needs of the scene.

Introduction

Currently the field testing device has capacity to test secondary equipments in intelligent substation, such as merge units, intelligent terminal or spacer monomers. Aiming at different item in test process, it needs the cooperation of multiple sets of testing device. At the same time, there are still some problems existing in debugging process, for example complex device wiring, low efficiency, long time for devices debugging, and overall effectiveness and accuracy of that intelligent substation is still unknown[1-5].

PXI bus technology has been the mainstream design scheme in automatic testing system which widely used in recent years. Compared with traditional automatic testing systems, PXI technology combines PC technology, instrument technology and abides Oka mechanical specifications. Moreover it provides high-performance I/O slot with high-speed data transmission and dedicated 10MHz oscillator clock. Consequently it has following advantages: the reliability, modularization, structural normalization that makes it easier to upgrade and maintain. In addition, testing system based on PXI bus technology also has other advantages such as low cost, low technology risk, shorter development cycle. Overall, it is ideal for development of testing instrument use in intelligent substation [6-7].

The control technology of configuration software has characters of opening, easy using and generality which via hardware configuration, data configuration, screen configuration to complete development work of testing software. It effectively improve the testing work efficiency and reduce the workload of testers and suitable to function integration of multiple sets of independent software. Therefore, a new design of portable testing device used in intelligent substation based on PXI bus is presented in paper, and testing items and methods can be performed by the device are also presented at the same time. The device combines the PXI bus technology and configuration software technology, it meets the testing demand of secondary equipment in intelligent substation, the configuration method is easy and suitable to on-site test application and accords with the development trend of intelligent testing device in intelligent substation.

System Architecture

With the application and promotion of intelligent substation, merge unit, intelligent terminal as bridge between transformers, switch and spacer layer devices have become important devices for

information sampling and command execution. Therefore the accuracy and reliable of merge unit and intelligent terminal must to be validated by test[1]. The test item of intelligent terminal include: test of merging unit and intelligent terminal. The test item of merge unit include: analog precision test, error and alarm functional test; test item of intelligent terminal include: input and output test.

Miniaturized and portable PXI chassis is selected which make testing device easier to carry, and it is reinforced with strong resistance to shock and impact and good thermal performance [1-4].

The overall architecture of portable testing device is shown in Figure 1. Hardware system provides various functions such as analog signal sampling, input and output, GPS signal and alarm signal transmission, reception and control though PXI module. Software system is designed based on Labview virtual instrument platform, various testing functions can be configured flexible which meets the debugging demands of intelligent substation. All functional tests can be performed automatically as preset script, test result can be displayed on screen. Test interface can be connected though PC display or LCD screen that device carrying. Test results can be output through the printer when test is completed.

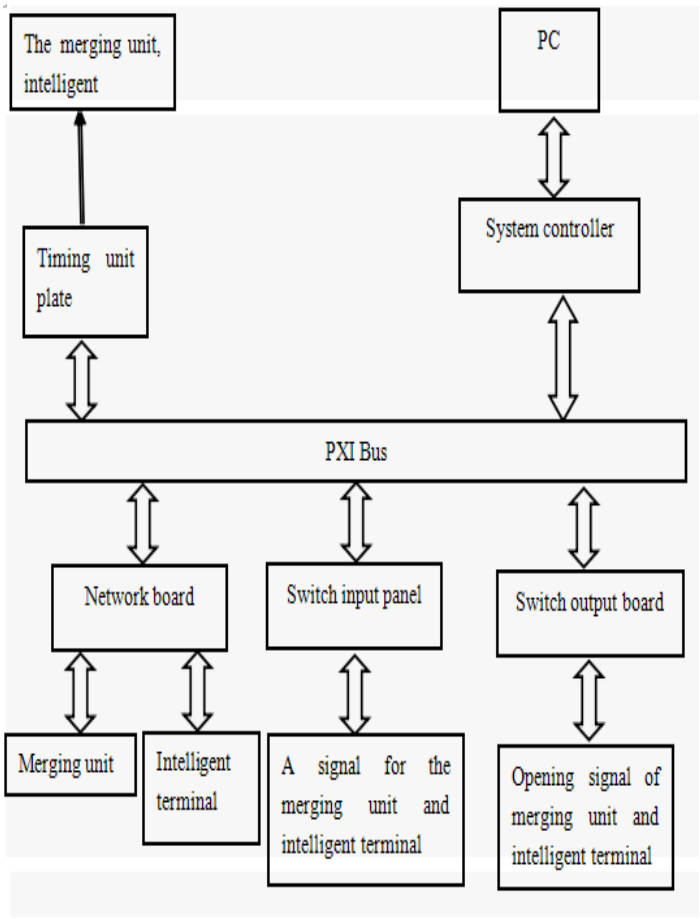

Fig 1. portable device debugging overall chart

Hardware Design

According to the field demands of the secondary equipment in intelligent substation, portable testing device consist of following modules: PXI platform, system controller, network interface board based on FPGA, timing unit board, digital I/O board, etc. All boards are designed based on modular principle and can be combined to build different testing system according to on-site application [9-10].

The 8 slot 3U size PXI chassis provided by United States NI company is chosen for PXI case, which complies with the PXI and Compact PCI standard specification. The chassis contains the system controller and power plug, is the main control part of the whole device.

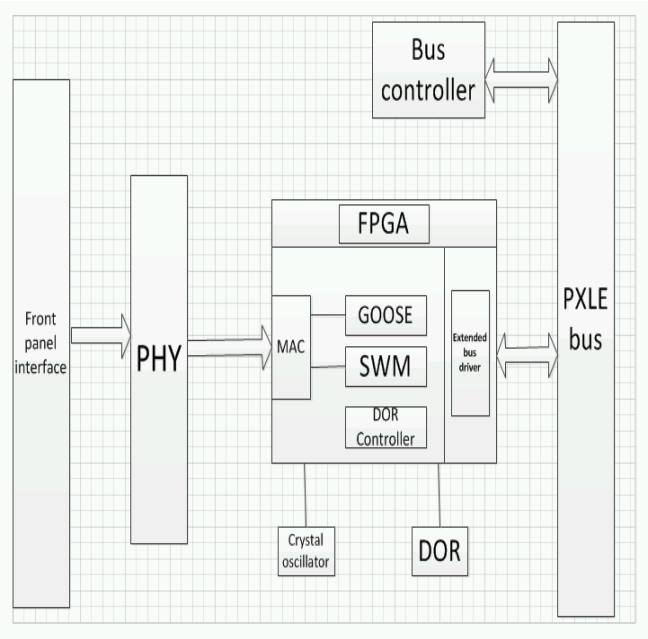

Fig. 2 Schematic diagram of network structure

The system controller board is the core part of the testing device which functional software runs on. It has the interface of GPIB, USB2.0, RS232 and Ethernet, which can communicate with the equipment to be tested and auxiliary equipment. The PXI module in system is controlled and switched though PXI bus. The majority of its tasks are receiving and parsing of goose message, logical judgment, I/O board driver, reading of I/O status information, control of network interface, collaboration of timing units.

The structure of the network board is shown in Figure 2. The network board is designed to transmit and receive SMV information and GOOSE message between test device with the merge unit and intelligent terminal through the PXI bus and the system controller board.

The structure of the board timing unit is shown in Figure 3 schematic. The role of timing unit playing in device is to provide timing reference for whole device and also export standard timing signal (including B code, SEC pulse, SNTP) to equipment to be tested. The output of B code can provide the timing reference signal for the merge unit, intelligent terminal. For the convenience of field wiring, it offers standard ST optical fiber interface and RS485 interface. At the same time, timing signal generated by timing unit can be sent to each slot as synchronous pulse interval through PXI trigger bus, interval of each pulse is 1ms.

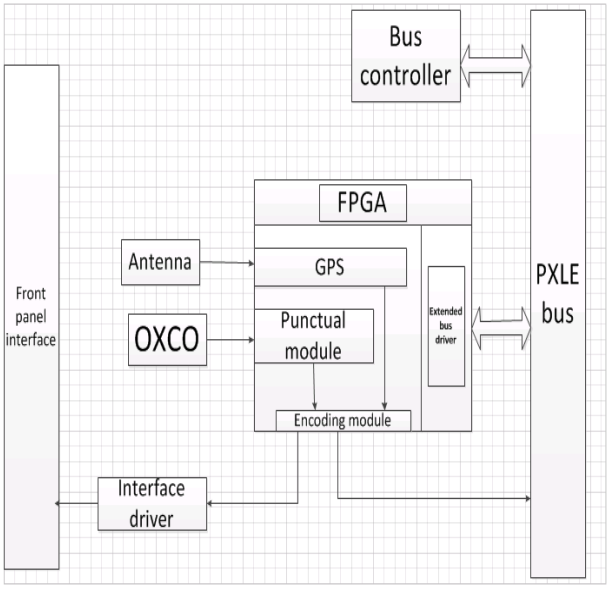

Figure 3 Schematic diagram of timing unit plate structure

I/O board is composed of several components including: signal conditioning circuit, isolation circuit and FPGA. The signal comes from external 16 channel in input board are transfer to SOE status information through isolation, shaping, denouncing by FPGA internal switch scanning module. And SOE status information will be sent to system controller module through PXI bus later. Output board receives command through PXI system controller and then drive corresponding relay in operation loop to control the switch on-off of breaker.

The signal switch operation of I/O board can be configured and controlled by the software to realize the centralized control of single device or multiple devices.

Software implementation

The test function implement by the system control software in the portable test device, the system control software is composed of several modules including: board identification, synchronization and trigger mechanism, communication specification, instrument driver, network configuration, function configuration.

Software design follows modular and open principle. Software control software runs on the system controller board and it comes with own database management module. The software configuration model of the portable debugging device is shown in figure 4.

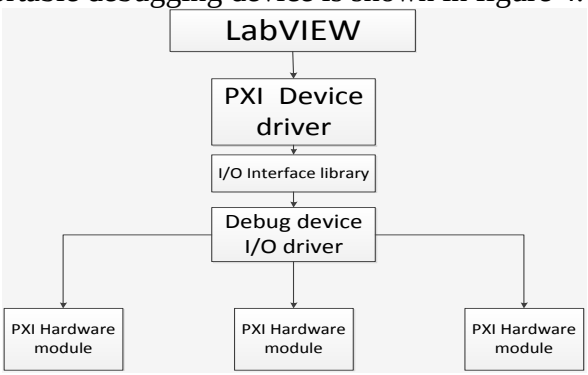

Figure 4 software configuration model of the test device

The realization of the system control software is based on PXI hardware board driver, I/O interface and PXI bus communication mechanism. PXI hardware board driver mainly includes testing system to support the various hardware boards. These communication between the upper computer and function software is realized by the I/O interface library. The design of the I/O interface library is platform portability and adapted to a wide variety of network mechanisms, which ensure system control software adapt for different hardware platforms and the future expansion of the software [10].

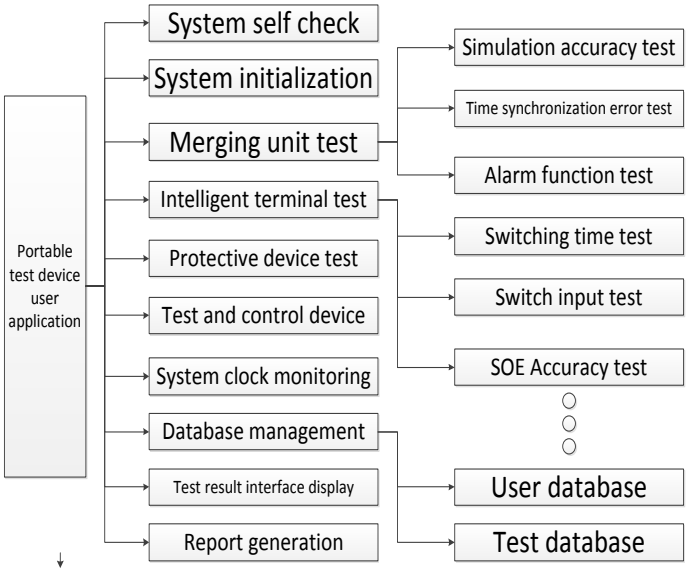

Figure 5 software configuration model of the test device

The application function of the system control software is realized by the user application software. The application software can be divided into several modules according to the on-site debugging demand as follow: the system self-test module, the functional test module, the database management module and the display output module, as shown in Figure 5. The application software can automatically identify the board configuration of the test device through the I/O interface library, so the testing items is identified that the device able to complete now. The application include multiple independent test functional modules. These modules not only can be used independently, but also used to configure and perform as a single device by the control interface.

The application software has the function of database management. It can record the configuration mode and test method which is used by the user in the process of testing, so as to make use of the following test, and the test data can be stored and managed in order to facilitate the test report's generation and test data.

The system control software has the external data communication interface, and the interface can communicate with the external device through the communication interface board. The data content of the external data communication interface can be configured according to the needs of a specific external device.

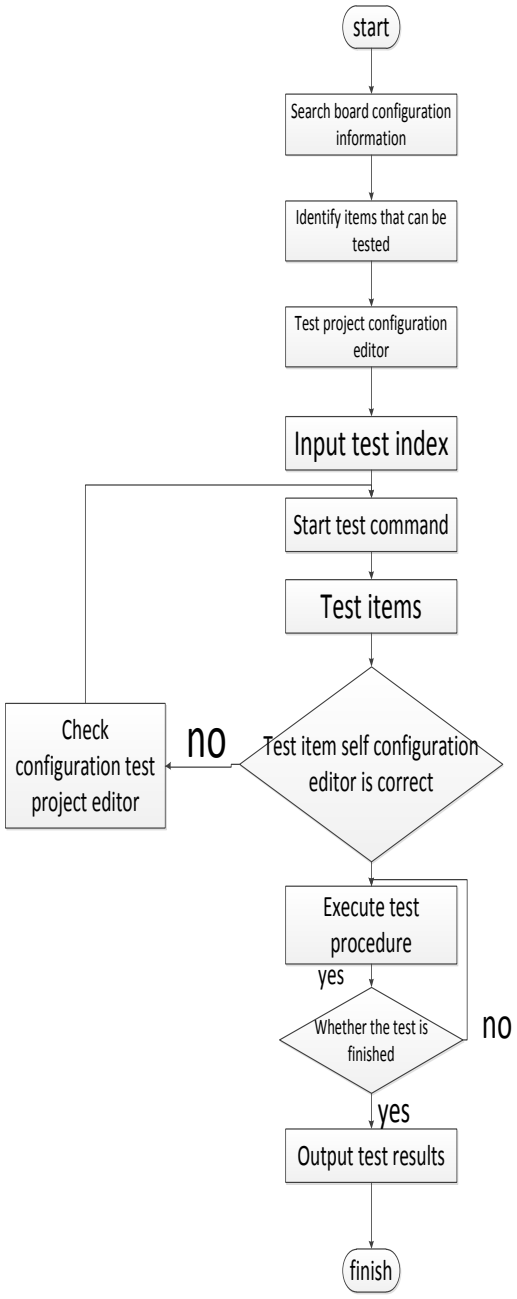

Figure 6 test procedure for testing device software

The test process of portable test device is shown in Figure 6. When the test starts, the test device begin to read configuration in chassis board, set the basic configuration information of the test items and device. The tester can edit the test items based on information promote by the interface, the test command will be sent after preparation is completed. After that, system will carry out self-examination process to ensure that no error during test and the test item execute automatically.

Test project and its implementation

Multiple devices can be connected simultaneously to test the overall performance of the intelligent secondary equipment. As an example, the joint commission of merge unit and the intelligent terminal is described in paper. The connection diagram of the test device and merging unit and intelligent terminal is shown in Figure 7.

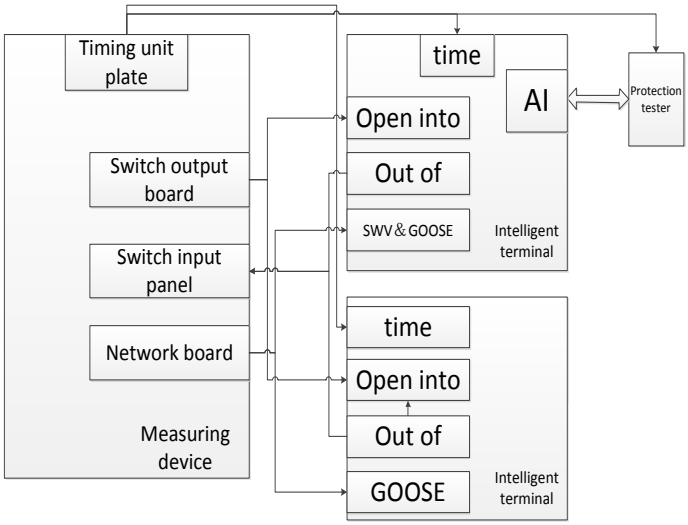

Figure 7 test wiring diagram

A Test items

Test items can be configured according to the requirements of the test, the hardware of test device can also be configured according to the test requirements. The test device can simulate several tests for example: the input and output test, message delivery and reception, timing, alarm reset etc. the overall performance and coordination of the secondary equipment in intelligent can be evaluated in test.

For example, the joint commission of the merge unit and intelligent terminal, test items include: simulation accuracy test of merge unit, synchronization error checking of merge unit, alarm function test of merge unit, input and output measurement of intelligent terminal and SOE precision test etc..

The test device can receive and parse the SMV packets of the merge unit to test the conversion error. And it judge whether or not merge unit can send proper alarm information under condition that abnormal of the power supply, voltage, acquisition unit, communication interruption happened by receiving and analyzing the GOOSE packet.

The test device of timing unit has the function of time comparison. The work principle is as follows: timing unit board output 1PPS standard pulse to the merge unit to be tested, the merge unit output synchronous sampling pulse /1PPS connect back to equipment to be test device. Compared with the standard 1PPS signal, pulse error of merge unit can be figure out. After that, synchronization error of the merging unit can be calculated by pulse counting method.

B Test method

A test template of device can be formed according to the test process. The test project, the setting value, the parameter and output result are defined in the test template, and the device will automatically complete the test items according to the template configuration.

If special module used to communication interface of external data is configured, the test device can also be used to control the other test instrument for on-site joint commission such as:

protection test instrument. During the test, the staff can check the test progress and the intermediate results through the man-machine interface. After test is comleted, the test device can be used to evaluate the test results, according to the relevant standards to determine whether the test results meet the requirements of the relevant standards.

Test templates and test results can be stored in the test device comes with a small database. In the mode of configuration test, the test template can be integrated with a number of test items, which can be used to test the personnel and save the time of the operation.

Concluding remarks

A design scheme of debugging device in intelligent substation based on PXI bus is present in this paper, and the implementation method and testing process of configuration test software is described. The device provides integrated test environment for on-site debugging of intelligent substation, makes debugging process independent from the timing unit, oscilloscope and other test instruments. The test application software come with debugging device can realize automatic test, which to avoid affect come from the man-made factors during testing process, and eases the workload of testers, improve the efficiency.

Test device based on PXI bus is proved to be running well in practice and test. The result shows the device reached its design requirements, and meet the on-site test demands. In addition, the design principle of device is convenient for expansion and upgrade of the system in future to avoid problem caused by upgrade ,having a good application prospect.

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