A New Dynamic Simulation Test Method of Intelligent Electricity Metering System

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ABSTRACT： Electricity metering is the core supporting technology for realizing accurate perception of electricity consumption, reasonable dispatching of power grids, rapid market response, diversified charging and new forms of electricity marketing. However, due to the significant differences in the actual metering environment, the operation of the electricity metering and information collection system is unstable, showing many problems such as unsuccessful parameter delivery and low acquisition success rate, which severely restricts the development of smart grid two-way interactive technology and the realization of smart electricity consumption in the last mile. There is an urgent need for a reliable and accurate dynamic simulation and systematic testing method to realize the reproduction and testing of various field faults. In this paper, we propose a new type of dynamic simulation test method for intelligent electricity metering system, which can realize the performance test, fault dynamic simulation, location and recovery of each functional unit of the master station, collection terminal and smart meter. Through experimental testing, our dynamic simulation test methods can realize the rapid recurrence of on-site problems, improve the high reliability and normal operation of the electric energy metering information collection system.

1. Introduction

With the construction of smart grids, power metering has become one of the most important components of energy big data [1-2]. The electricity consumption information collection system is a platform for information collection, analysis and data application that integrates energy measurement technology, power marketing technology and power load management technology. It is composed of master station, transmission channel, collection terminal and smart meter [3-4]. The realization of the two-way interaction of the smart grid puts forward more application requirements for the functions of the electricity information collection system, such as rapid market response, timely data collection and efficient services [5]. However, in the operation of the actual power metering system, it is affected by the complex electrical environment, often causes problems such as unstable communication, and unsuccessful parameter delivery, has a great impact on power marketing business functions such as electricity billing and line loss analysis [6-8]. When a problem occurs, it is impossible to quickly locate the fault point, resulting in a large workload and low efficiency. In order to achieve a more fine-grained panoramic information acquisition, it is necessary to study more accurate, reliable, and efficient dynamic simulation test methods for smart electricity metering systems. This paper tests, analyzes and verifies the system from physical layer for data transmission to application layer for business flow.

2. On-site problems of the electricity metering information collection system

Through the analysis of a large number of on-site carrier system faults, the operation faults of the low-

voltage carrier power information collection system are mostly concentrated in: (1) Software level: protocol analysis error, protocol conversion error, collection terminal system failure, etc; (2) Hardware level: hardware failure of carrier module, acquisition terminal, etc.

The collection terminal consists of three parts: uplink communication module, downlink communication module and data processing module. The collection terminal communicates with the main station and the electric meter through the uplink and downlink communication modules, realizing forward instructions and collect data [9]. If the above two communication modules fail, it may cause the command forwarding or data report error, which will affect the reliable operation of the electricity consumption information collection system.

The low-voltage carrier module is a functional module for two-way information transmission between the smart meter and the collection terminal [10]. Once the function is abnormal, result in impossible to complete parameters delivery and the data return.

3. Dynamic Simulation Test Method of Electricity Metering and Consumption Acquisition System

In order to solve the above-mentioned problems, we design a dynamic simulation test method for electricity consumption information acquisition system, it can realize multiple functions such as low-voltage carrier module detection and failure reproduction. The test system is designed according to the real electricity consumption information collection framework, consists of control machine, collection terminal, meter/carrier test module (including real smart meter) and communication channel.

Control machine includes analog master station, data forwarding module, monitoring module, analysis module and database. The analog master station is responsible for collecting instructions, issuing and receiving stopping information. The data forwarding module is used to forward the request of meter carrier module and forward the collected information of real meter. The monitoring module is responsible for monitoring the entire communication process, the analysis module is used to analyze the monitored data to obtain the test results. The meter/carrier test module is composed of real smart meter and multiple meter carrier modules. The system design capacity supports the access of 256 carrier virtual meters. The communication channel between master station and collection terminal includes wireless public network (GPRS/CDMA) and Ethernet, collection terminal and meter use low-voltage power line carrier mode. The analog master station issues meter reading commands to the collection terminal via Ethernet. According to the Q/GDW1376.1 protocol, instruction analysis content is shown in Table 1.

When collection terminal receives command, according to the Q/GDW1376.1 protocol and obtain the actual forwarding content. In order to detect return channel and function of carrier module, system adopts the real meter calibration method. After carrier module receives the collection instruction forwarded by collection terminal, it sends a request for obtaining real meter data directly to the data forwarding module of control machine through the RS232 serial port. After receiving the request of carrier module, controller collects the current positive active energy data block of real meter, and sends data back to carrier module under test through data forwarding module. The carrier module encapsulates power data according to protocol and reports it back to control machine through collection terminal. The analog master station judges the correctness of each function by comparing the data of real electricity meter retained locally with the data reported by carrier module under test.

Table.1 Analysis of commands issued by the control machine

Frame format description	Code	Meaning
Frame start symbol	68	Frame start indicator.
Length	f2 00 f2 00	“f2 00” means use the Q/GDW 1376.1 protocol. The user data length is 60 bytes, is the total bytes of control domain, address domain, and link user data.
Control domain	4b	Master station downlink message, request level 2 data
Address domain	00 12 f3 8d 02	“00 12” is administrative division code. “f3 8d” is terminal address. “02” is master and terminal address identification. Here it means there is only one master station address, and terminal address is single address.
Application layer function code	10	“10” means data forwarding
Frame sequence field	Ed	“ed” means have time stamp, single frame, no need to confirm the frame, start frame number is 13.
Unit ID	00 00 01 00	“00 00” means terminal information. “01 00” means informational ID

Data unit	1f 6b c8 64 14 00 fe fe fe fe ……	Data organized by data unit identification, including parameters, commands, etc. The four 'fe' are the preamble, followed by a valid data frame
Event counter	00 00	Count of important events and general events
Time stamp	5d 35 30 14 13 00	"5d" means start frame counter value 84. "35 30 14 13"is send time stamp. "00"means allow transmission delay to be 0.
Frame checksum	cc	Checksum.
End of frame	16	End of Frame marker.

In order to realize module detection and fault location of power metering information collection system, we provide an experimental method use meter carrier module to reproduce the actual meter for systematic verification. It can detect, analyze and locate fault points on the functions of analog master station, acquisition terminal and multiple meter carrier modules. The process is shown in Figure 1.

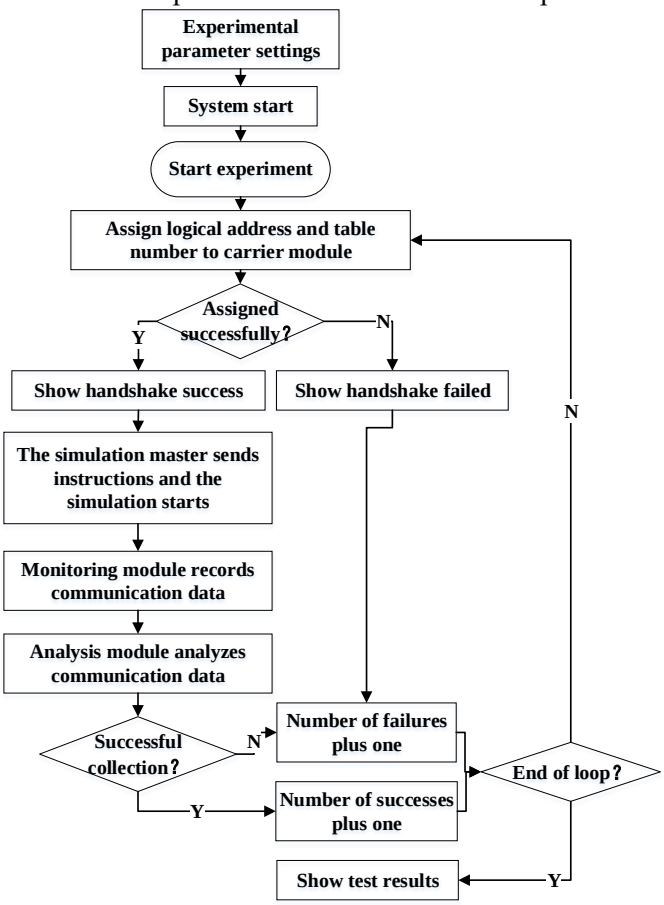

Fig.1 Flow chart of simulation test of electric energy meter

1) Experimental parameter settings: At the beginning of the test, we need to configure the experimental parameters first, set and issue instructions. Table 2 shows commonly used signs.

Table.2 Common data identification use cases

Data labeling	Command meaning
0001FF.00	Collect the current positive active energy data block.
001500.00	Collect the current phase A positive active energy.
01.010000	Collect the current total maximum demand and occurrence time of positive active power.

Determine the scope to be tested: number of smart meter carrier modules connected to the system and starting table number, set the test timeout time t_o, test retries γ_c and cycles g. t_o is the maximum allowable delay from when collecting terminal sends reading instruction to a certain carrier module to be tested until the module reports meter data. Set t_o <50s. If a module under test does not return correct meter data after t_o, it is deemed that the meter reading has failed, and the module is revisited until the number of retries γ_c is reached, this module is marked as abnormal and test the next module. The completion of the test for all N modules to be tested means the completion of a round of testing.

2) System initialization: It mainly completes the power-on of meter module, power-on of collection terminal, self-checking of collection terminal, self-learning to match the uplink and downlink protocols, and the establishment of a communication link with power meter and control machine.

3) Address allocation: The control host allocates a 10-bit logical address/meter number to each meter. After each meter confirms the logical address, reply "fe fe 68 logical address 68 9f 00 XX 16". If the control host does not receive reply message, it will mark the logical address error and re-allocate it, indicating the handshake has failed.

4) Data acquisition: After all meters are allocated, the analog master station issues various meter reading instructions to the meter under test through acquisition terminal, and communicates through low-voltage carrier two-way channel. The data monitoring module monitors and records each message between each communication point (carrier module, measurement collection terminal, control machine) in real time, and stores it in the database as the original record data for detection and verification.

5) Test result analysis: call the data analysis module to analyze and judge the monitoring record data. If the control machine receives meter data from metering collection terminal and the local retained data collation is consistent, it means achieve a correct collection and transmission test; otherwise, it is based on history return the message to reproduce fault and locate the fault point.

4. Simulation test system experiment

In order to prevent carrier interference, noise and harmonics in the mains from being connected to the system, and to ensure the purity of the low-voltage power carrier test channel, use three-phase isolation transformer to filter the mains in the front-stage power supply of the system, connect meter carrier module, single-phase and the collection terminal uses threat Type I. The carrier module and the acquisition terminal are low-voltage carrier communication, the acquisition terminal and the control machine are connected via Ethernet.

First, set initial test parameters: the number of meter carrier modules N=24, the starting meter number address is 2013121011, the issued command is the current positive active energy data block collection, the timeout time is 20s, the number of retry and cycles are respectively 0 and 3, the number of address allocation retries is 2 times, “receive" and "send" in the experiment record indicate the actions of control machine. Four sub-experiments are carried out: (1) the correctness test of address allocation of meter; (2) the correctness test of the command issued by control machine; (3) the correctness test of the actual data of meter; (4) the failure recurrence test.

The system starts, power on all carrier modules, control machine starts to assign logical addresses to carrier modules and issue logical address commands. Check whether the logical address is correctly configured through the monitoring channel. Figure 2 shows the recorded serial communication data between controller and meter, the direction represents the action direction of controller. If any message is missing, or the actual channel transmission message is inconsistent with the control machine monitoring message, the location address allocation fails.

The actual smart meter interface is reserved in test system, by connecting the smart meter to detect the correctness of various instruction sets received by the meter, and to complete actual copy experiment.

When the real meter receives collection, request forwarded by data forwarding module, it performs meter data collection or cost control operations, and sends the result back to control machine via reliable RS232 serial line. At the same time, the system adds test operation of power meter under test: the control machine reliably sends the meter data to power meter under test via RS232 serial port, finally sends the meter data back to analog master station via collection terminal according to low-voltage carrier channel. Obtain the entire process of data interaction through monitoring module, compare it with the real meter data. If they are the same, it indicates that the meter reading is successful, otherwise record a fault.

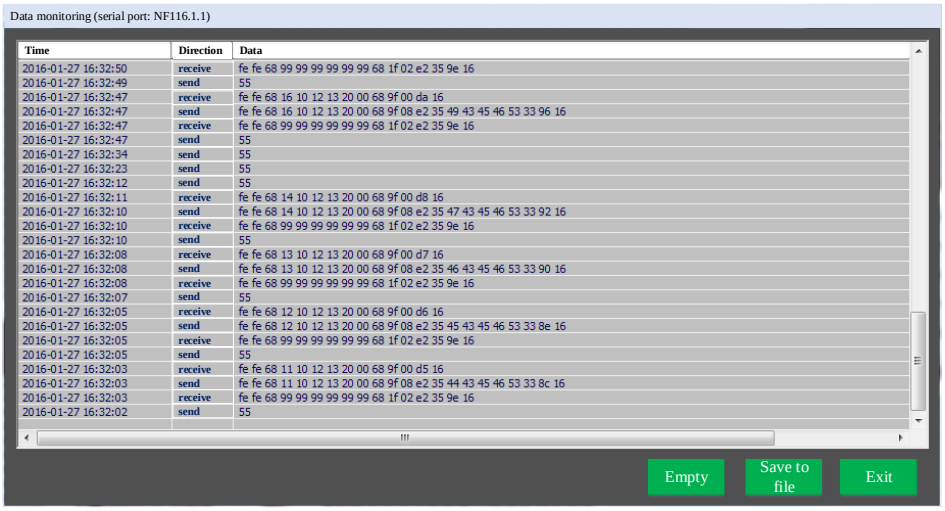

Fig.2 The address allocation process of the electric meter carrier module

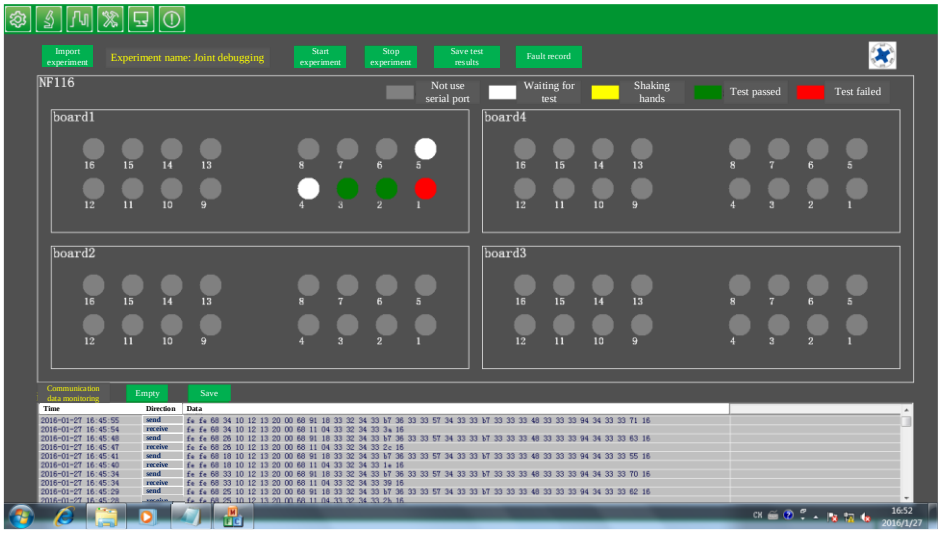

Fig.3 Dynamic simulation to simulate failure recurrence

We use visual marking and data analysis to realize dynamic simulation, reproduction, and analysis of failures. As shown in Figure 3.

I) Abnormal function of collection terminal: as shown in Figure 3, it is manifested as collection terminal failure. Analyze the fault, first, the monitoring module records show that the network port data between control machine and collection terminal is normal, means control machine issues collection command to collection terminal. According to the DL/T645 protocol, the address is resolved to "11 10 12 13 20 00", position the address of power meter. Because control machine and collection terminal are connected through reliable Ethernet, the faults of control machine and uplink channel can be eliminated. The record of missing collection terminal forwarding instructions to the table number 2013121011 is missing, and the fault type is temporary function abnormality.

II) Power meter login failure: It is manifested as handshake failure between power meter and control machine at a certain address, the record of "Time Send 55" appears in history record of its address allocation multiple times, reach the upper limit of retransmissions number, as shown in Table 3. If the control machine does not receive response from analog power meter at the corresponding point in time, it can be determined the power meter's handshake function is abnormal.

Table.3 Serial data record between control machine and meter

times	records
1	2021-03-27 16:32:12 send 55
2	2021-03-27 16:32:23 send 55
3	2021-03-27 16:32:34 send 55

5. Conclusion

Aiming at the problems of frequent faults, difficulty in locating and on-site analysis in actual application of electricity metering information collection system, we design a new type of dynamic simulation test method of intelligent electricity metering system. It can realize performance testing, fault location and reproduction functions of system master station, collection terminal and smart meter. Finally, we verify the accuracy and practicability of this system through experimental tests.

Acknowledgments

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