Research of Portable Insulation Detecting Device which Based on for Electric Equipment

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***Abstract*—The insulating state detection of capacitive equipment has been a long time, but the actual effect is not satisfactory. It mainly because low-precision measurement and cannot overcome the location interference which can cause mutation of measured data. The reliability of the device is low. This has seriously affected the popularization and application of the state detection technology. According to current situation of capacitive equipment insulation monitoring, a kind of portable distributed charged detection device prototype of capacitive equipment dielectric loss and capacitance detection is developed, which based on high precision GPS synchronous sampling technology and the Internet of wireless sensor network technology. And it uses the relative comparison method of dielectric loss analysis algorithm to overcome data fluctuation caused by factors such as the current leakage along the surface. Experiments show that the devices realize high precise collection of the state data. It has widely application prospect.**

Keywords-GPS synchronization technology; Distributed System; Wireless Sensor Technology; capacitive equipment; Charged detection; relative comparison method

I. INTRODUCTION

With the construction of smart grid and the construction of "large maintenance" system of State Grid Corporation of China, the requirements of the state detection technology are becoming more and more urgent. Capacitive equipment is an important power transmission equipment, including high voltage capacitive bushing, current transformer (CT), capacitive voltage transformer (CVT or PT), a coupling capacitor (OY) and zinc oxide arrester (MOA), accounting for about of the total number of substation equipment 40%-50%[1-2]. These equipment insulation fault not only influence the safe operation of the substation, but also endanger the safety of other equipment and personal, and thus the insulation condition monitoring has important significance.

Capacitive Equipment dielectric loss tangent tan δ is the most important of online monitoring. Generally, the dielectric loss of capacitive equipment is proportional to the equivalent capacitance of the medium and tan δ when the applied voltage and frequency are constant. Tan δ is the fixed value of the dielectric, which is related to the nature of the insulation material, and has nothing to do with the size and shape of the insulating material. Therefore, the insulation condition can be judged by measuring the capacitance value (C) and tan δ of capacitive equipment [3-6].

At present, the on-line monitoring system uses the distributed monitoring system. Literature [7] proposed a distributed monitoring system solves the problem of long-distance transmission of the signal, but did not specify synchronous sampling control technology, which may not be able to keep synchronous acquisition of current and voltage signals and cause greater error. In the normal operation of capacitive equipment, the general insulation damage has a development process. Regular testing can find most of the insulation damage and other issues, and then develop a maintenance plan to ensure the safe and stable operation of power system. In the literature [8] synchronization technology is used to ensure the high synchronization of the sampling signal, and the ZigBee wireless communication technology is used to realize the wireless transmission of data. The use of high precision hardware equipment to real-time online monitoring is not only measured redundant data, but also a large investment in equipment, which is not conducive to the promotion of online monitoring. Therefore, this paper, by using high precision GPS hardware synchronization control of distributed data acquisition technology and the network technology of wireless sensor network, carries out the pressure vessel equipment charged detection technology research, researches and develops a portable and efficient detection device. Device for obtaining equipment dielectric loss, insulation resistance current data, which ensures high precision line detection, reduces the workload, improves work efficiency, reduces the economic cost of running the equipment, has high practicability.

II. THE MEASURING PRINCIPLE AND SYSTEM STRUCTURE

A. *The Measuring Principle*

When measure dielectric loss online, set up of the device under test leakage current is I and the voltage PT measured as U at simultaneously sampling. After phase calculation program calculates the δ and tan δ. When using relative method, selected a group of capacitive devices on one bus with 1 as the reference device, the relative dielectric loss as follows:

$$\tan\delta = \tan(\pi/2 - (\delta_i - \delta_1)) \tag{1}$$

Capacity is calculated as:

$$C = I / (2\pi \mathrm{fU}) \tag{2}$$

The relative dielectric loss comparison method to diagnose insulation condition of equipment, effectively weaken the influence of environment, interference, PT angle and other factors on the measurement of dielectric loss, improve the reliability of insulation condition diagnosis results[9].

B. System Structure

The system uses distributed measurement, and the monitoring unit is installed near the equipment. PP GPS pulse as the starting signal of synchronous acquisition. Zigbee wireless data transmission between the detection unit and the master station. Schematic diagram of the system is shown in figure 1.

When measuring, the control host sends a "readiness" command through the wireless network to the monitoring unit, and the monitoring unit receives the command and enters the "ready" state. Each monitoring unit is to enter the acquisition state after the arrival of the GPS pulse. After the acquisition is complete, the leakage current monitoring unit calculates the current value of the measured current signal and phase angle δi, system voltage monitoring unit calculates the voltage signal voltage and phase angle δu. All monitoring units will be transmitted to the host after the completion of calculation. The host calculates dielectric loss and capacitance.

III. SYSTEM SPECIFIC PROGRAM

A. Signal Sampling Plan

Leakage current of capacitive equipment is usually very small (MA level), while the field interference is serious, and the measurement of diagonal deviation is more stringent, so the choice of single core type active zero flux sensor. With its metal shield, 5V output AC signal, angular difference within the range of 40C-65C <1 ' , ratio difference <0.5%, with the ability to reliably anti 2kA / 2ms square wave impulse current exchange, it can meet the measurement accuracy requirements .

On site monitoring of the leakage current of capacitive equipment, using capacitive equipment monitoring unit wiring box installed in equipment nearby, with equipment through the end screen grounding wire string into the CT sensor to obtain casing leakage current, measure leakage current and phase angle.After the junction box is installed, the main line is not affected. When a device is required to detect the device, insert a portable measurement terminal to measure, and then take away.

System voltage monitoring unit wiring box installed in the vicinity of the PT/CVT terminal box, through the terminal PT/CVT acquisition system three-phase voltage value, through a protective resistance box partial pressure, and the three-phase voltage loop and current protection, to measure three-phase system voltage and phase angle. Also, when necessary to detect equipment, measurement is inserted into the measuring terminal. After the end of the measurement take terminal away.

B. GPS Synchronous Data Acquisition System

Distributed measurement systems, each measuring system has a separate ADC, a different collection terminal with the same sampling rate, start time of collection must ensure that no more than 1us, or different sample obtained from the terminal "phase" can not be compared.The monitoring system using GPS as a synchronization start signal acquisition, which is locked after high stability output PP second pulse (absolute error <1us).

GPS precision timing of the phase angle measurements provide a solution. Phasor measurement unit (PMU) clock within the device to sync once per second by the GPS receiver is generated by means of high-stability internal oscillator within one second intervals, so installed in different power plant within the power system PMU Sampling time error within a few microseconds, corresponding phase angle error does not exceed 0.1 ° , to meet the phase angle measurement. In this system, each collection terminal starting in rising or falling edge of the seconds pulse, the control of the clock signal AD, ensure that when the GPS second pulse arrives, begin the collection, thus ensuring the start of the sample collection terminal between different time error <1us. Because the data processing time is relatively long (> 1s) after each sample completed, to ensure that each terminal will be able to start collecting samples on the edge of the second pulse of the same without the occurrence of dislocation, GPS PP seconds before each pulse arrives needed by the control panel sends a wireless network via ZigBee "Ready" command. Upon receipt of this command, all collection terminal into the "ready" state, and then wait for the respective GPS PP second pulse, the initiative to enter the collection status.

C. Communication Scheme

The system uses a Zigbee wireless sensor network transmission technology of distributed measurement systems. Zigbee technology is an emerging wireless networking technology, which takes all the advantages of a powerful wireless IEEE802.15.4 physical layer specified: energy saving, simple, low cost and specifications, the rate at 20kb / s-250kb / s of Rooms, transmission distance up to 200 meters.

Monitoring unit through the ZigBee module, can be transmitted between the master station system or other test instrument. The ZigBee module is connected with the DSP through the asynchronous serial interface. Because the serial interface of the ZigBee module is TTL level, it can be directly connected with the SCI interface of DSP, and it is not necessary to carry on the level conversion. DSP sends the data to the ZigBee module in the specified format, and then sends it to the ZigBee module, which is then converted to a signal in the wireless network by the SCI interface. If the ZigBee module receives the data, it will be sent to the DSP via the serial interface.

Communication between ZigBee module and monitoring unit through USB port, the master station system and each monitoring unit adopt a master to communicate with each other. The number of the monitoring unit can be up to 255, which is used to communicate with the MODBUS protocol.

IV. SYSTEM HARDWARE AND SOFTWARE DESIGN

Measuring terminal access only when the test connection box test points, using high-performance lithium battery-powered, no external power supply, ADC, CPU, high-precision small current sensors, GPS receivers with a separate, ZigBee radio devices. The measuring terminal completes the data acquisition, the current amplitude and phase of the data acquisition, and transmits to the control host through the wireless communication network.

A. *Measuring Terminal Hardware Design*

Measuring terminal with the design of three analog input channel in the hardware structure, can simultaneously collect three current signal. For three phase distance of the equipment, the three-phase can use a test connection box and measuring terminal. For a device with a distance of three phases, each phase is fitted with a test terminal and a measuring terminal. The system voltage monitoring unit is used to measure the ABC three-phase voltage signal at the same time using the three way. Hardware components are shown in Figure 2:

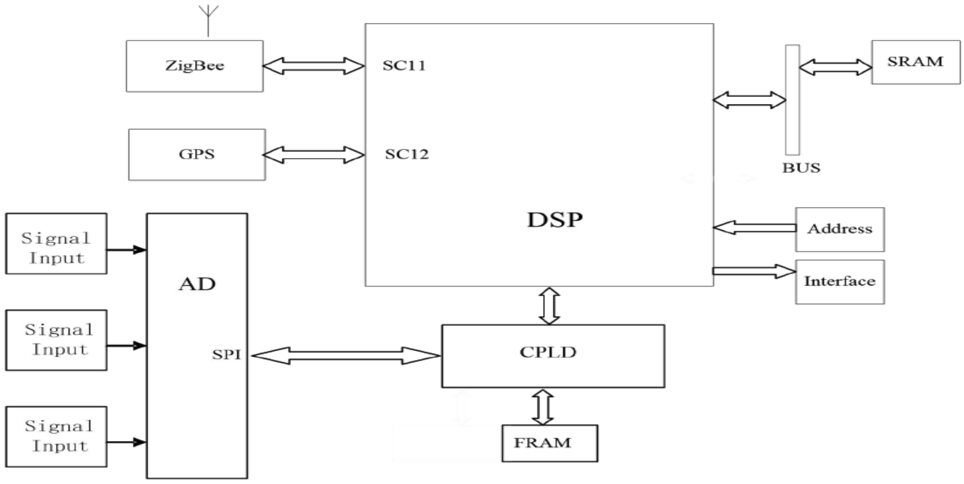

Figure 2. Measurement block diagram of terminal hardware

Comprehensive consideration of capacitive equipment insulation online monitoring system data and computing speed requirement higher characteristic, the digital signal processor of the system using TMS320F2812 of TI company, high frequency of 150MHz, using multi-bus Harvard architecture and pipeline structure instruction mode of operation, dedicated hardware multiplier and the fast DSP instruction, with processing speed, universal interface, peripheral rich and good stability.

The main function of this system is to measure the capacitive device capacitance and dielectric loss, with high accuracy requirements, so the analog to digital converter used is AD73360. AD73360 for the six-channel simultaneous sampling 16 AD, the maximum sampling rate per channel 64K, each channel has a programmable from 1 to 80 times the pre-amplifier PGA. Hardware circuit amplifying circuit magnification is not adjusted by PGA, do not have the hardware circuit design amplifier circuit for signal strength can, by software selection of different magnifications. In this system, through software programming, different for each phase signal amplitude, determine different magnifications, each phase signal amplitude less integrated into the signal, which can greatly improve the measurement accuracy. In addition, AD73360 uses Σ-Δ structure and the internal digital low-pass filter, it has a good anti-jamming capability, but also to avoid the additional analog filter circuit adversely affect the sampling signal phase.

AD73360 bidirectional interface for synchronous serial port (SPORT), and F2407 SPI port differ in the agreement, it can not be connected directly. To be able to read and write AD73360, must be implemented by CPLD necessary conversion, the system is done directly from the serial to parallel converter CPLD, implementation is as follows: To conserve resources, using half-duplex mode, namely: the first is configured to transmit mode, be AD73360 configuration and start the conversion. Then configured to receive mode to receive data AD acquisition.

B. *Software Design of Acquisition Terminal*

The system includes a system voltage monitoring unit and several leakage current monitoring units. System voltage monitoring unit is mainly responsible for the calculation and the system voltage of ABC three-phase voltage magnitude and phase angle. The leakage current monitoring unit is mainly responsible for the calculation and leakage current amplitude and phase. Monitoring unit and control host communication network for ZigBee wireless network, using MODBUS protocol. The hardware of the system voltage monitoring unit and the monitoring unit of the casing is identical, and the software is the same. This design adopts MODBUS protocol, the acquisition terminal constantly monitor control host command to complete the task: ad adjustment of magnification, ad data synchronous acquisition and RMS value and phase angle calculation, data reading and writing etc. task. Software main program flow chart is as shown in Figure 3:

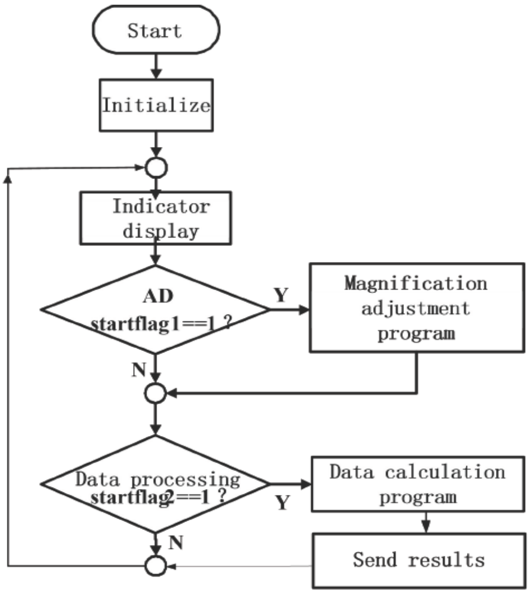

Figure 3. Software mainstream

V. LABORATORY VERIFICATION

In order to verify the performance of the portable capacitive equipment insulation detection device, we build a simulation test system in the laboratory, which can simulate the dielectric loss of 0.1-20. The schematic diagram of a capacitive apparatus is as shown in Figure 4. Where the Xu file is the system voltage, and the X1-X6 is the capacitance leakage current profile with different dielectric loss values.

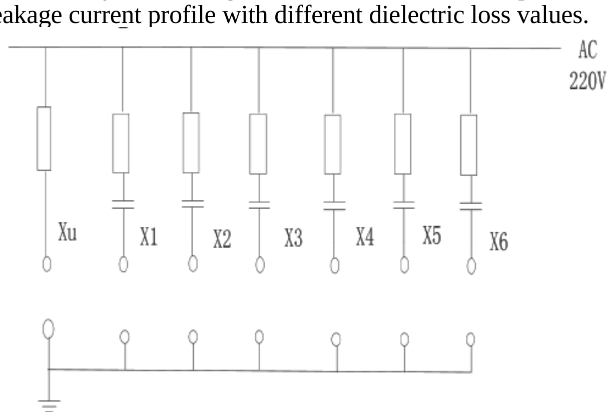

Figure 4. Simulation test system schematic

Analog sources can be used as the source of the system voltage analog field devices and capacitive devices. By adjusting the gear switch, it can simulate different values of dielectric loss.

Table 1 shows the measured data to a portable detection device X2 gear (dielectric loss of 0.3) .

TABLE I. LABORATORY SIMULATION SYSTEMS MEASURED DATA

No.	Current(mA)	Voltage(V)	Dielectric loss
1	1.053574	223.1976	0.30012
2	1.055568	223.4986	0.30015
3	1.053528	223.1276	0.30017
4	1.050565	223.3307	0.29883
5	1.050012	222.8882	0.29786
6	1.05092	223.0054	0.30042
7	1.055628	224.5003	0.29891
8	1.05808	224.8356	0.30001

Its intermediary loss curve is as shown in Figure 5.

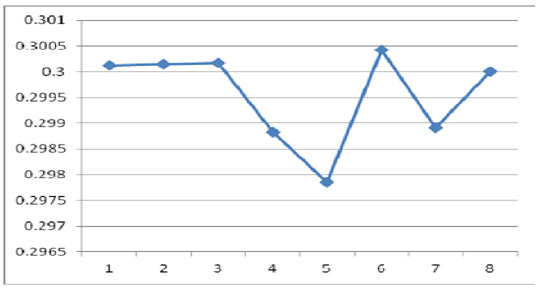

Figure 5. Dielectric loss curve

As can be seen by the above data, the error range of dielectric loss measurement within ± 0.1%, far less than the standard error of the on-line monitoring device dielectric loss factor error does not exceed ± (standard reading × 1% + 0.001) requirements, and the data fluctuation small[10]. So the device to meet the measurement accuracy requirements.

VI. CONCLUSION

1) R & D and efficient portable detection devices, accessing devices dielectric loss, capacitance, improving the accuracy of the charged detection, reducing field workload, cost-effective, have broad application prospects.

2) the use of wireless communications technology, get rid of the shackles of cable, testing without wire, and simultaneously measuring with more than one (up to 255) equipment, greatly improving test efficiency.

3) GPS synchronous sampling with time error <1us. Measuring range of dielectric loss tan δ = 0.1% -50%, the measurement accuracy of ± 0.1%. The precision of the GPS hardware synchronous sampling technology to detect live substation insulation products, improve the accuracy and effectiveness.

4) devices using anti-jamming measures, including the use of active zero flux current sensor and anti-interference ability of AD73360 chip, using relatively calculated dielectric loss. Tests show that the device has a stable measurement performance and high reliability.

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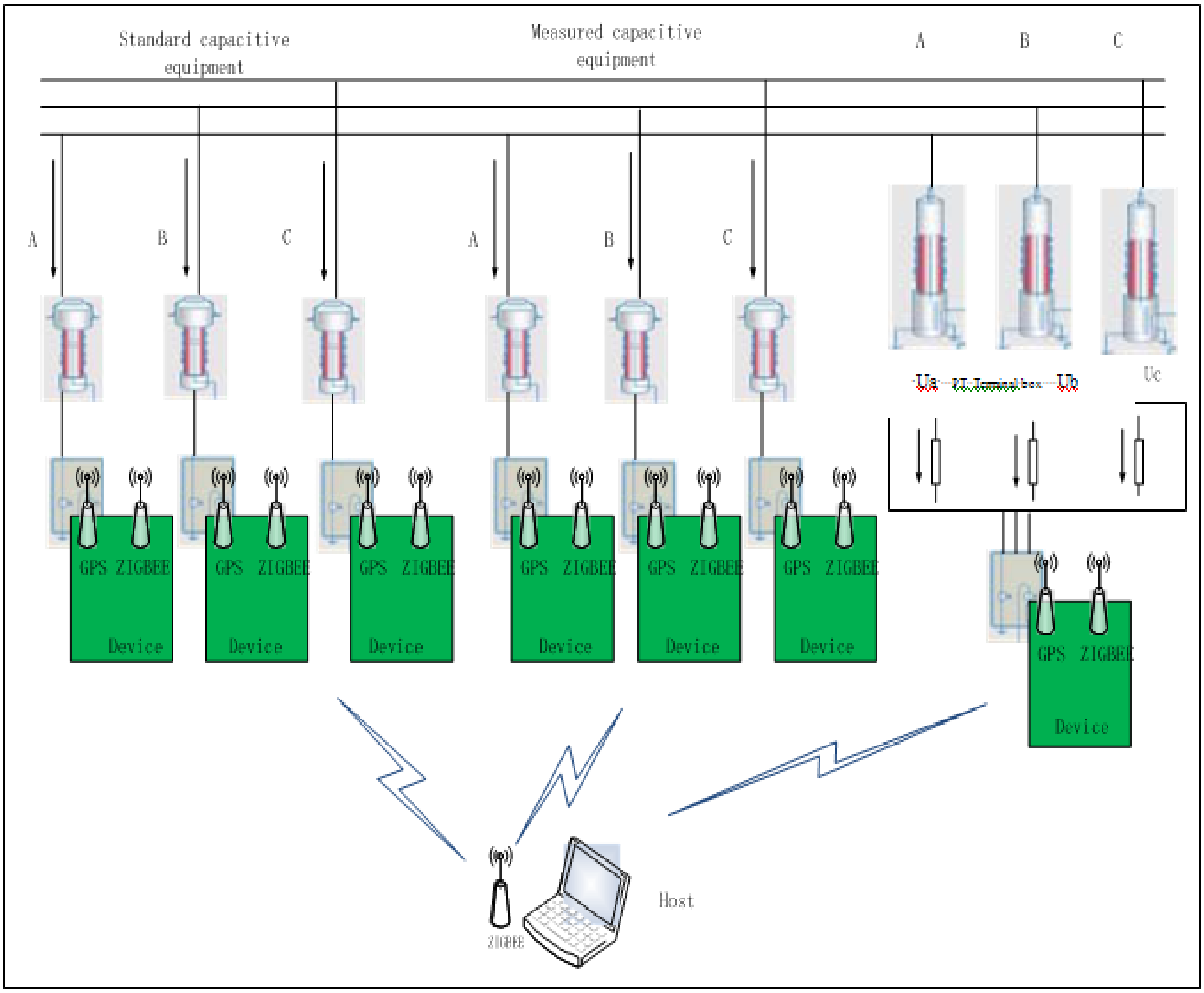

Figure 1. Capacitive equipment on-line detection system schematic