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Design of Substation and Distribution Station Monitoring System Based on DELPHI and Intelligent Modules

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Abstract. *It builds a kind of hierarchical distributed computer monitoring and control system through adding communication modules and intelligent acquisition modules without changing the primary equipment of 10 kV substation and distribution station. DELPHI is brought in the communication software which based on MODBUS-RTU protocol. And the problems of monitoring and control from distribution modules are solved. It also develops human-machine interface and realizes the monitoring of substation and distribution station. Therefore, the automation level of substation and distribution station is improved greatly.*
Keywords: Substation and distribution station; Monitoring system, Serial communications.

1. **Introduction.** As the terminal substation, impacts caused by the faults of 10 kv substation are relatively small. Because of lacking attention for a long time, the automaticity of 10 kv substation is very low, and makes its operation and maintenance difficult [4]. In recent years, with the development of society and economy, this situation has been changing because of the appearance and the implementation of the smart grid. In the new built substations, intelligent primary equipment, which contains communication interface, is increasingly used. Moreover, some reform solution for the old substations has been proposed [2] [5]. Ref.[2] focuses on the description of monitor and control software for each function module, but it lacks the specific design of monitor solution for the whole substation, and the method and protocol of communication are not considered. Ref. [5] focuses on the multithreading communication technology, but lacks the user interface for monitoring.

The monitoring system design of substation proposed in this paper can realize a layered and distributed computer monitoring system without changing the primary equipment of 10 kV substation. The problem of monitor and control for scattered module parameters is solved by the communications protocol software of MODBUS-RTU and the DELPHI-based monitoring interface. The approach proposed is proved to be effective for achieving the monitor of substation and improving the automaticity. Its low cost and high reliability overcome the drawbacks of the present communication configuration system, which is expensive and complex. For the substation with intelligent primary equipment, acquisition module is not needed by using the technology solution proposed. The system built has

been used in a 10 kV substation, and works well. It is proved to have good extensibility, flexible, strong real-time performance and a high cost-effectiveness.

2. **System composition.** As the scale of 10 kV substation and distribution station is not large and the monitoring distance is not long, RS485 is chosen for serial bus. Subordinate construction is used in the whole system. PC is the main control unit (upper-computer), the intelligent modules which have been added in the switch cabinet (lower computer) is the passivity performing unit and the switch cabinet is the monitoring object. The centralized management and optimization of monitored results can be realized through the computers powerful data process perform. RS232 serial port is changed to RS485 through HEXIN-III converter and then connects to intelligent collection modules. And then the control of several intelligence data acquisition models (lower computer) is realized. Each switching value and analog quantity is collected by corresponding intelligent modules. And then, it realizes the decentralized control of multiple parameters and remote communication. Figure 1 shows the overall structure of monitoring system.

2.1. **Chosen of intelligent acquisition module.** Considering the product maturity and develop speed, ADAM4050 of ADVANTECH is chosen as I/O collection module. The remote signaling and telecontrol can be realized based on RS-485 through the simple commands with the format of ASCII. As the install of ADAM400 serial modules is flexible and it fits for the hanging and guide way in industry field. It also supplies software package for the users and the develop period of the application system is decreased greatly.

EDA9033D of Shangdong Lichuang Science and Technology Corporation is chosen as analog quantity collection module. It is a kind of intelligent three phase parameters comprehensive collection module. And the update period of real-time data is 40mS-1000mS which can be set.

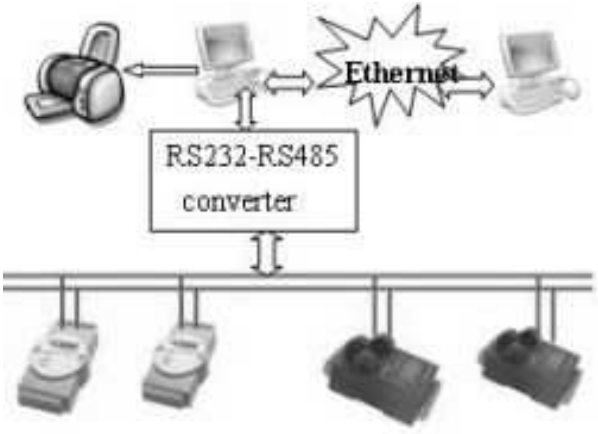

FIGURE 1. The overall structure of monitoring system

2.2. **Design of MODBUS communication.** MODBUS is a kind of common language which applied in electronic controller. It can realize the information change and data communication between EDA serial modules and PLC, RTU, DCS or the monitoring system which possess MODBUS compatibility. It has become a general industrial standard. Therefore, control equipment from different manufacturers can constitute industry network for centralized monitoring.

2.2.1. *Setting of MODBUS communication format.* MODBUS means that the most significant byte is stored at the lowest memory address which expresses address and data items. It means the most significant byte should be sent first when sending several bytes.

New information always begins with quiescent times which less than 3.5 bytes in RTU pattern. And then, the first domain (device address) is sent next. The whole information of frame should be transferred in the form of continuous data flow. It will make an error. If the interval time is over 1.5 bytes before the end of information. Standard structure of MODBUS-RTU frame information as seen in Tab 1.

Table 1. Standard structure of MODBUS frame information

Begin	Address domain	Function domain	Data domain	CRC check-ing	End
T1-T2-T3-T4	8 bit	8 bit	n*8 bit	16 bit	T1-T2-T3-T4

2.2.2. *MODBUS function code.* Function code 01 (0x01): reading the output state of one or multiplex switch signal.

Function code 02 (0x02): reading the input state of one or multiplex switch signal (DI).

Function code 03 (0x03): reading multiplex registers.

Function code 05 (0x05): writing the output state of one switch signal (remote control).

Function code 06 (0x06): writing one register.

Function code 0F (0x0F): writing the output multiplex switch signal (remote control).

Function code 10 (0x10): writing multiplex registers.

2.2.3. *CRC code.* The host or slave can judge the information through CRC code. It will make an error in the transfer process for electronic noise or the other disturbance. CRC can check in the data communication process from the host or slave. The wrong data can be abandoned. And the system reliability and communication efficient will be improved.

CRC domain contains two bytes which includes binary value with 16 bits. It will be added into the information after being calculated by transmission equipment. The receiving equipment calculates the received CRC again and then checks the value. If the CRC values are different, it means something is wrong. It only uses 8 data bits when calculating CRC. It means the begin, the end and the parity bit will not be calculated in CRC calculation.

Calculation of CRC code:

1) CRC register with 16 bits are preset all "1" (0xFFFF);

2) XOR calculation between the first binary data with 8 bits (the first byte of the information frame) and the lower 8 bits in the CRC register. And the result is stored in the lower 8 bits CRC register;

3) The content of the CRC register should be right shifted (to the lower bit) and the higher bit is filled with 0. And then check the shifted bit;

4) If the shifted bit is 1, and then XOR should be calculated between CRC register and A001 (1010 0000 0000 0001) which is preset. If the shifted bit is 0, then do nothing;

5) Repeat the step 3 and 4 about 8 times and then the 8 bit data will be handled;

6) Repeat the step 2 to 5 and then handle the next byte of the information frame;

7) The 16 bits CRC can be gotten through the steps above;

8) The CRC will be added into the information begins with lower byte and then higher byte.

3. **Monitoring software design of the upper computer.** Delphi is selected as developing tool. The monitoring software is designed in modular. There are ten function modules: the main interface of monitoring system, database operation, communication test interface, data inquire and export, real-time display, running protection, real-time trend curve display, history trend curve display, alarm display and record module, Web browsers.

3.1. **Communication program of upper computer.** The system can realize the communication between upper computer and ADAM4050 intelligent module through third-party control of MSCOMM. It can build the connection between application program and serial port. And most of the underlying operations can be packaged in the controls. Therefore, there is no need for the programmers to spend time understanding the complicated API function. They just need to set and keep watch on the property of MSComm and event. And then asynchronous serial communication can be realized and the program operation is simplified greatly. MSComm owns many properties. Some need to be set and the other takes the default value. Since there have been many materials introduced, There is no need to introduce the detailed setting method [2].

As EDA9033D intelligent module takes MODBUS-RTU communication protocol [6], and the commands are agile. However, it needs to calculate the checking value of CRC16, and it is difficult to realize using MSCOMM controls. Therefore, it uses the third controls of Teda9033D to realize the communication with EDA9033D intelligent module. The control is developed for the user to use EDA9033D module conveniently. It packages all the electrical parameters collecting, control commands and response in the inner function. And then all the response result will reflect to the user in the form of control parameters.

The third-party control of Teda9033D includes control functions and parameters. The command communication of module can be realized through calling control function. The result can be gotten through calling control parameter after calling control function.

3.2. **Design of monitoring interface.** The wiring diagram of main circuit should be written by AutoCAD. And then the picture is exported as the background of the main interface. The menu bar can be generated through adding Main Menu control. After adding Sharp control, the control will become red when the breaker closes and it will become green when the breaker breaks. The operation record can be written into XML document through loading XML Document control. Figure 2 shows the main monitoring interface.

System displays the main wiring diagram and the switch state of each circuit breaker in real time. If necessary, the circuit breakers can be switched quickly and directly by a mouse click on the switching control of corresponding circuit breaker, and the operation record is generated automatically at the same time. The three phase current and voltage of busbar, three phase current, active power, reactive power of each circuit and other electrical parameters display at the corresponding position of the main wiring diagram. When the abnormal conditions occur or the electricity parameters beyond their limits, corresponding alarm signals will be sent by the system monitoring interface, and circuit breaker will disconnect automatically if necessary.

Part code of main interface:

```
begin
form3.eda9033D.ClosePort ();
MSComm1.CommPort:=3; //choose serial port 1
MSComm1.InputLen:=0; //read the whole content in the buffer
MSComm1.InBufferCount:=0; //clear the input buffer
MSComm1.OutBufferCount:=0; // clear the output buffer
```

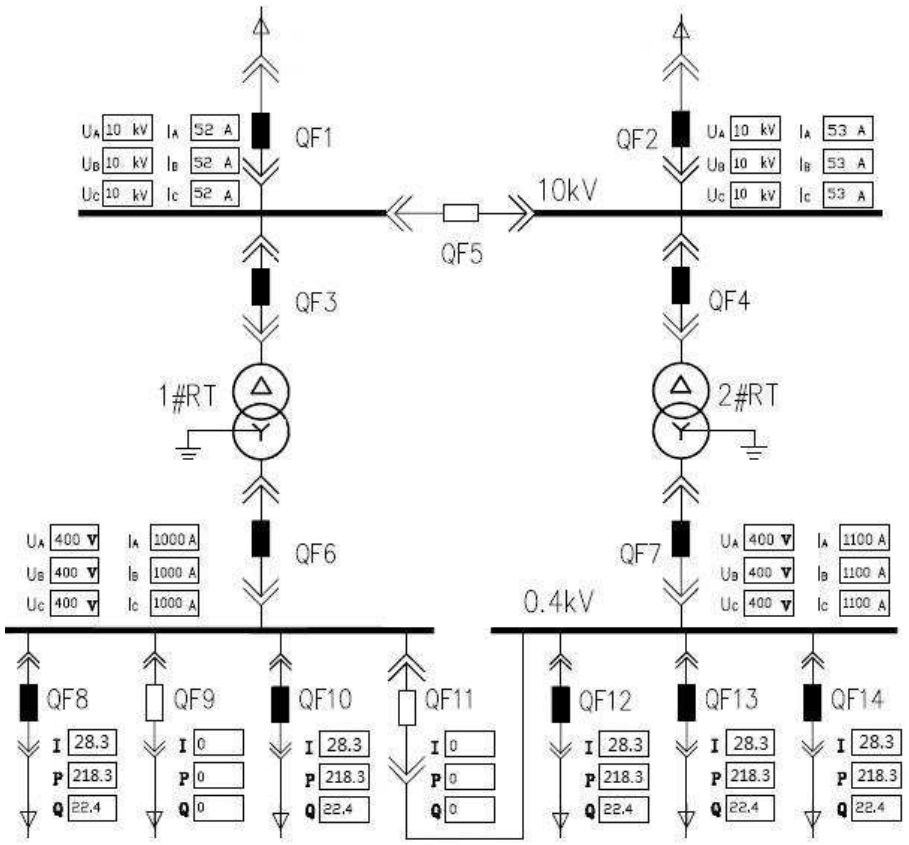

FIGURE 2. Monitoring main interface

```
MSComm1.Sthreshold:=0; //OnComm event will not happen when sending data
MSComm1.Rthreshold:=1; //OnComm event will be generated when receiving a byte
if mscomm1.PortOpen =true then
  MSComm1.PortOpen:=false;
MSComm1.PortOpen:=true; // open serial port
    Sbuf:=vararraycreate([0,7],varbyte);
    Sbuf[0]:=1;
    Sbuf[1]:=5;
    Sbuf[2]:=0;
    Sbuf[3]:=ionum;
  if ison= false then
    Sbuf[4]:=strtoint('$'+'ff')
  else
    Sbuf[4]:=0;
    Sbuf[5]:=0;
  if ison= false then
begin
    Sbuf[6]:=strtoint('$'+'8c');
    Sbuf[7]:=strtoint('$'+'3a');
end
  else
  begin
    Sbuf[6]:=strtoint('$'+'cd');
```

```
    Sbuf[7]:=strtoint('$'+'ca');
  end;
  BF:=Sbuf;
  mscomm1.Output:=bf; //send data
  MSComm1.PortOpen:=false; form3.eda9033D.OpenPort(3,'9600,n,8,1');
end;
```

3.3. **Monitoring interface design of inlet and outlet circuit.** Monitoring interface of inlet and outlet circuit mainly shows the three phase voltage, current balance and every electrical parameters: active power, reactive power, power factor, frequency and so on. It also can show the state of the breaker and they can control it by opening or closing it through the system.

Three phase voltage and current balance can be shown in the form of histogram through Bar of TeeChart. The problem of showing several parameters can be solved through using PageControl control for supplying multiple pages showing in a window. Module communication signal can be realized through the Shape control. The message window should update data regularly which is completed by timer control. The monitoring interface of loop is shown in Figure 3.

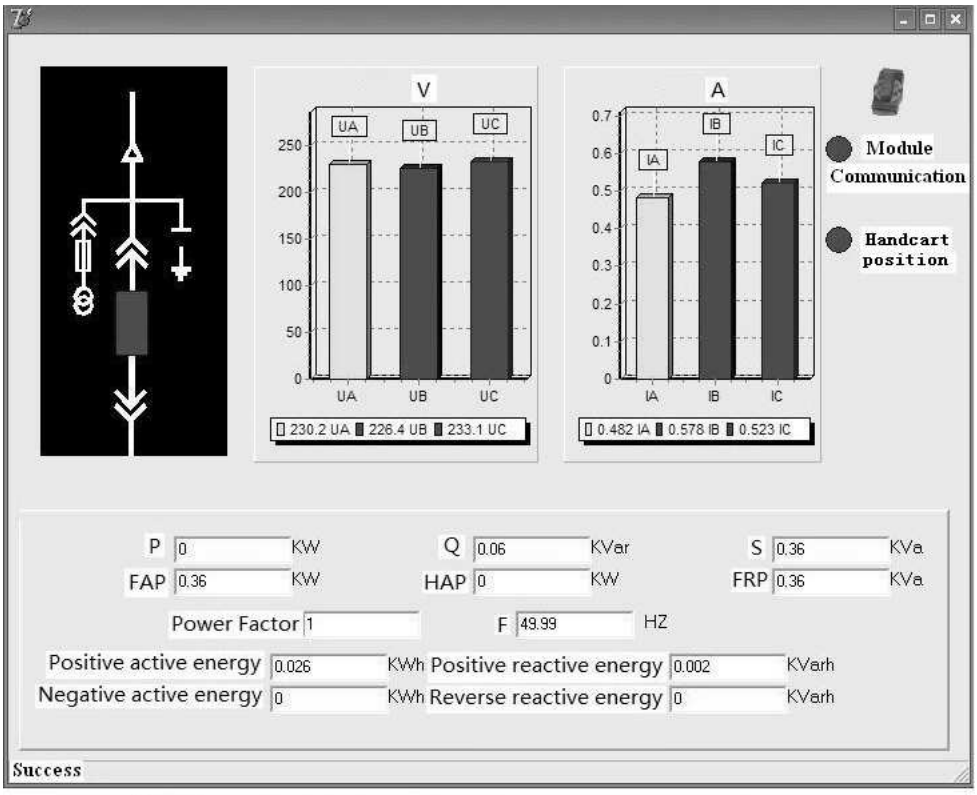

FIGURE 3. Monitoring interface of inlet and outlet circuit

Otherwise, operation record interface, history curve interface, system setting interface, alarm record interface and so on are designed. As shown in Figure 4 to 6.

The flow chart of the monitoring software is shown in Figure 7. The monitoring interface can realize the functions as follows: controlling the breaker closed when the close button is pushed and then collecting the closing signal. The detected current, power and so on

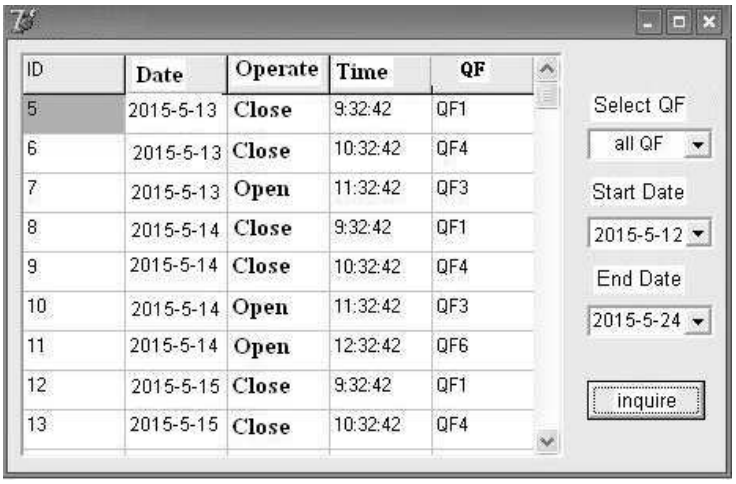

FIGURE 4. Operation record interface

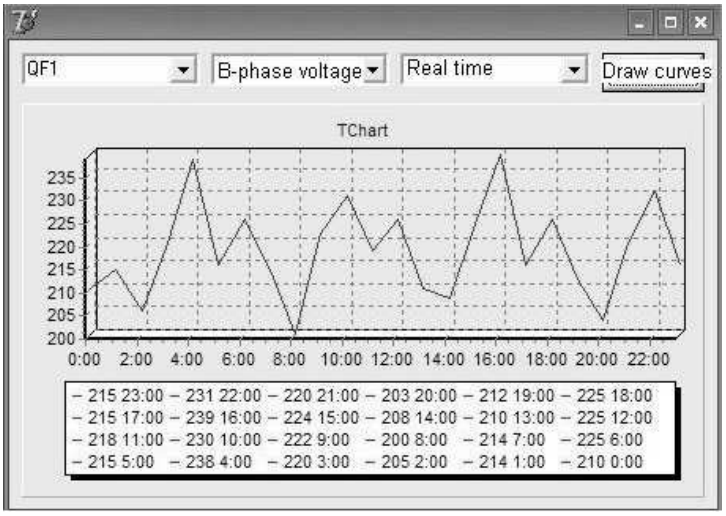

FIGURE 5. History curve interface

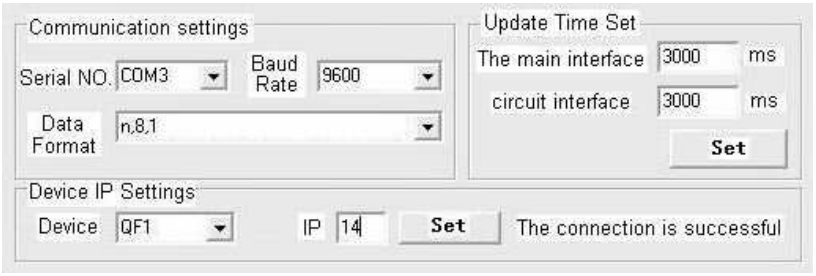

FIGURE 6. System setting interface

can be displayed on the analog instruments. The alarm lamp will flash and the alarm bell will make a sound if the current is over the limit. After 5 seconds, the breaker will break automatically. If there is a malfunction to the breaker when in the closed state, it will alarm.

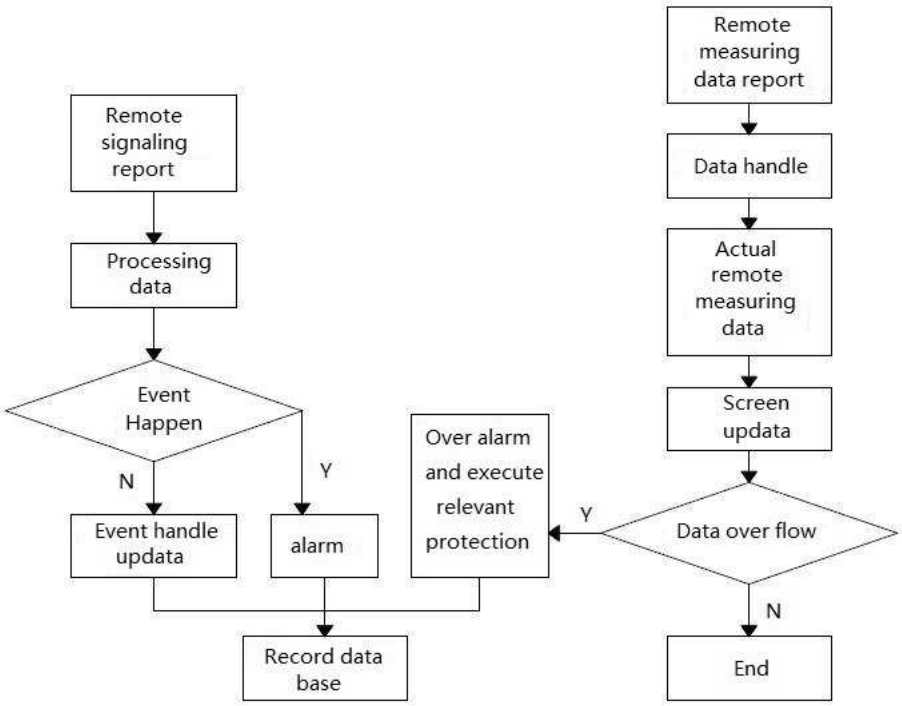

FIGURE 7. Flow chart of the monitoring

4. **Conclusion.** The system proposed has been tested in practice project, and proved to have good extensibility, good flexibility, strong real-time performance and a high cost-effectiveness. The user interface developed is friendly and flexible. It is easy to be used and managed. The monitoring system and its communication method are especially suitable for the automatic reform and update of traditional substations. For the substation with intelligent primary equipment, acquisition module is not needed by using the technology solution proposed.

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