Remote Sensor Network based on Data Mining in Photovoltaic Power Generation

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Abstract—The specific implementation mode of remote equipment monitoring for remote sensor networks in photovoltaic power systems using web-based gateways is described in detail. Message conversion and transmission in the process of data transmission using Ethernet and a communication mode are explained. The sensor signal is converted to light or electrical signals by the remote monitoring system. Many problems can be resolved effectively using a remote sensor network. A mining database system model Web facing has been proposed using database mining, log files, and user profiles.

Keywords—Sensor network, gateway, data mining, data warehousing, transmission protocol

1 Introduction

Currently, most traditional photovoltaic power generation systems tend to install the sensor at the place that needs to be monitored, and the monitoring personnel receive relevant data at the site after a period of time. However, many problems exist in manual measurement, so real time monitoring of data changes cannot be realized; additionally, places that are uneasy to get to or are unsafe cannot be monitored. After the sensor signal is converted to light or electrical signals by the remote monitoring system, these problems can be resolved effectively using a remote sensor network. Because of the rapid development of photovoltaic power generation technology, cost reduction of solar power generation and the increasing shortage of traditional energy, the capacity of photovoltaic power generation is increasing and more photovoltaic plants are being developed, especially in Tibet and Qianghai in China where there are abundant solar energy resources, rendering a brighter future to the power industry. More and more enterprises are beginning to use an RFID (Radio Frequency Identification) technique [2]. Energy from photovoltaic is random, so if operated within a network, the randomness of its power generation will impact the general power system [3]. Collection and monitoring of real time operation information are the basis for guaranteeing normal operation of photovoltaic power generation systems.

Like wind power generation, photovoltaic power generation is volatile and intermittent. But through supervision of the real operation conditions of photovoltaic cell panels, the negative effects on the power system by randomized problems of photovoltaic power generation will be reduced if the generating capacity curve can be obtained via a prediction model in accordance with practical situations and the power generating schedule can be made in coordination with the curve.

To achieve this goal, the photovoltaic power station's operating condition shall be accurate and timely, which is needed to build a complete set of monitoring systems to perform power plant performance evaluation and daily work monitoring, the main basis of the transportation and allocation schemes. The remote monitoring system uses three tandem structures: the control center, monitoring unit and monitoring sensor [1].

Using information mining technology through the Web will guarantee safety and efficiency, which has changed the relationship between remote terminal of photovoltaic power generation systems and control centers. The mining database system model Web facing has been proposed using database mining, log files and user profiles.

2 Composition of the Sensor network

Photovoltaic monitoring systems can be divided into remote monitoring and local monitoring according to transmission distance and can be divided into wireless monitoring and wired monitoring based on whether or not a bus is employed. A remote automation monitoring network will also need to be established for monitoring, as shown in Fig. 1.

Sensor network mainly consists of sensor and data collection. A single sensor or multiple sensors can be selected in the sensor network for a real time measurement value. Through centrally controlling the parameters of the inverter of the photovoltaic battery and power network parameter, collecting, computing and

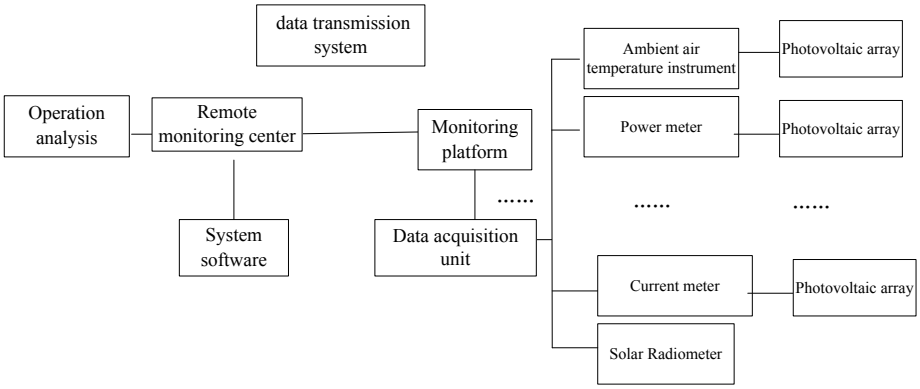

Fig. 1. Block Diagram of Remote Sensor network

converting through DSP, solar energy radiative intensity will be measured by a solar energy radiometer sensor; environmental temperature will be measured by an environmental thermometer sensor, and power generation capacity will be measured by a digital electric energy meter to realize comprehensive and real time monitoring of the system's operating parameters.

Traditional information technology of remote sensing can no longer satisfy enterprises' demands under the current environment of electronic websites. Along with the increase of Web users and amount of information as well as the expansion of application scope, page speed begin to slow down sharply. Normal access time becomes very long or simply provides an error page. This will cause database connections to exceed the maximum limitations, databases to become locked, servers to exceed maximum connections and so on. To guarantee stability of the power supply, data at the monitoring site need to be collected continuously, which requires a stable and reliable monitoring system to work for a long time. To save manpower and material resources and to improve monitoring efficiency, the remote automation monitoring system consists of five parts: sensor network, monitoring platform, remote data transmission system, and operation analysis.

Functions of the remote monitoring center include data collection analysis, data processing, multisource processing, communication link management, and adopting multi-computer redundancy and load balancing techniques to meet the requirements for handling capacity and high reliability and to realize the operating data exchange with a superior control center. The system collects various operating data about the photovoltaic power generation to meet the requirements of real time monitoring.

The remote monitoring center conducts monitoring analysis and finds the association analysis of multi-type data such as the power data, meteorological data, and equipment condition data using multi-theme window and visualization technology. The monitoring platform adopts the layered monitoring mode (such as the measuring point, equipment, area and system) to master the actual operation conditions of the power generation system. The measuring point is conducive to grasping each measuring value in detail; equipment monitoring helps to monitor the operation of the photovoltaic power station, the energy storage station, and the transformer substation. System monitoring helps to monitor the power output, energy storage backup, and reactive power reserves of a combined power generation system.

The remote data transmitting system is used for connecting sensor networks, transmission of data and setting the order among main engines.

Luminous energy analysis contributes to the distribution of light irradiation at different periods of time. Electric quantity analysis can achieve statistical analysis of the generating capacity of photovoltaic power stations at different periods of time. Network adaptability analysis helps the photovoltaic power generation system achieve statistical analysis of the power network volatility under various operation modes. In solar power plants, electricity comes from solar energy, and therefore changes in sunlight intensity control grid electricity, so network adaptability analysis is needed to study the changes of maximum solar irradiance.

The sensor and collector are connected using the wireless media or cable within the sensor networks. Data transmission between the collecting module and monitoring

master station can be selected in accordance with the project's specific condition. The system can adopt reliable and effective communication media according to actual conditions to realize remote collection and transmission of huge amounts of data and to realize remote communication between the photovoltaic power generation site and the control center.

A photovoltaic power generation remote automatic monitoring system can complete functions of the whole process, such as reception of the original observation data, data conversion, and data resolution as well as data input and results submission.

Historical data are stored in the computer, and data from a measuring point at a certain period of time can be queried according to the input query condition. At the same time, the changing curve of the measuring point at this period of time can be displayed and the changing trend of measuring point can be displayed.

The web obtains remote sensing information from the sensor networks through browsing websites from a web browser. With the rapid development of network technology and Web technology, the research focus of information transmission technology of more and more industrial and enterprises has been shifted from traditional information transmission of remote sensing to web information analysis and management on the internet. The new emerging internet service will substitute the old monitoring network for an information transmission function.

In traditional combined photovoltaic monitoring systems, there is only one inverter. To meet the requirements when the loading equipment requires high power capacity, the sensor networks system of information networks is formed through a gateway. A network monitoring system can conduct monitoring of multiple inverters.

3 Data mining for operation analysis

A traditional Web database system of remote sensing can adopt two ways to realize connection and application. One is to provide middleware to connect to the database server at the Web server terminal, and the other is to access the database directly through the application program that has been downloaded at the client-side. Middleware can directly call the external program or script code for utilization that is responsible for the management of the communication between the Web and database server.

The Internet-based Web browser not only provides information and services through the Internet, but also contains information transmission inside the enterprise or among enterprises. It is not only the integration of hardware or software, but also the activity conducted by the remote terminal, transmission system, control station and relevant partner on the Internet, Intranet and Extranet using Internet technology and the existing information system [4].

Along with the amount of information and connections increasing, the page views may exceed the services that cannot be normally provided by machine and software. The amount of information transmission must be increased, and the page speed may slow down sharply, with the Web server exceeding the maximum connections, normal visiting time becoming very long, or an error page appearing. It is becoming increas-

ingly important to find the network information quickly and accurately from a large number of useful information and knowledge sources. Web mining technology can obtain valuable information or knowledge from Web site access, and data sources play a key role in the correctness and credibility of mining results. Mining technology is used in this system and takes advantage of the massive Web data stored in the database management system to analyze the records by virtue of machine learning and making use of the knowledge hidden in records. The Web allows obtaining the access modes and nodes of groups or individual users. Mining technology can be combined with_database technology, artificial intelligence and pattern recognition technology. Thus the page structure of the Web can be adjusted according to the users' access frequency and access to temporal dynamics to provide individualized information processing speed to assist users' information transmission, to improve information utilization, and to better meet the users' demands.

Valuable information or modes can be obtained from the information received by the parameters of photovoltaic monitoring systems. Databases about the photovoltaic monitoring systems can be regarded as an effective tool for synthesizing and consolidating multidimensional space data and for providing functions such as data conversion, data searches, data integration as well as analysis and processing. Techniques of data mining can use methods such as association rule discovery, path analysis, and cluster analysis to strengthen the development and application of integrative knowledge at multiple levels of abstraction and to establish and develop databases. Platforms for Web data analysis are provided by using mining instrument [5].

Remote monitoring systems break the limits of the geographical and environmental restrictions and achieve a wide-area distribution of controlled object centralized monitoring and complete optimization of production resources and social resources [6].

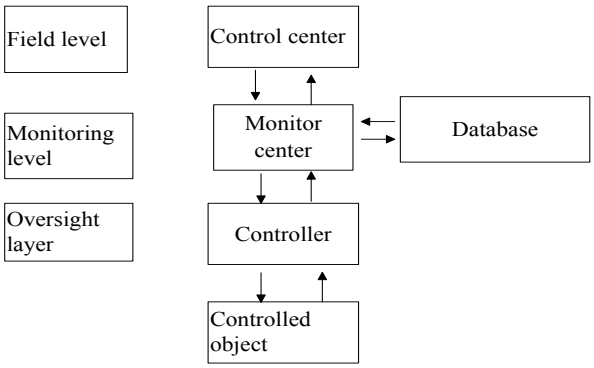

Fig. 2. Remote monitoring Architecture of remote sensing

The remote monitoring system of the working interface is shown in Fig. 2, mainly including the field, monitoring and supervision levels. The monitoring platform is taken as the controlled objects, so the collected and sorted relevant information can be uploaded to the Ethernet communication module using the data collecting module via the controller module. Meanwhile the upper layer control information can be con-

veyed to control objects using the monitoring module with B / S architecture via the controller.

The information gateway system of the working interface integrates the information gateway system and controller as a web-based interface gateway, forming a network connection using the Internet. The information gateway has realized the function of accessing the Internet router / gateway. The information controller is made up of the embedded network communication interface of the traditional controller with the information gateway and remote terminal linking together. Through the information gateway, users can control monitoring and operation of the remote terminal that has network access at any of the PCs or handheld computers connected to the Internet. The remote terminal can also release messages automatically to the website or email specified on the Internet based on the users' requirements, if necessary. Free software provides users with source codes for free.

Because Linux can provide complete network integration and has the stability and reliability of a Unix system, a Linux system was selected for the system operating platform of the gateway. The Linux operating system supports Unix development tools, has abundant system management tools, development tools and development environment, and is able to develop drivers and application software and modify program's source code in accordance with the specific needs, thereby guaranteeing the reliability, stability and flexibility of the entire system.

Currently, the most popular tool to access the Internet is the Web browser. In the remote control center, the control interface exists in a gateway in the form of Web pages. The operating system of the control center only has to support the Web browser. The control of equipment by relevant staff can be completed through the Web browser to browse or set up pages. Linux, Unix, HTML language, etc. can be used to design pages, and CGI (Common Gateway Interface) programming process data can be used to make Web pages and data format conversion.

4 Gateway of remote sensing

In the remote terminal, the data collected by the front-end data collecting module is transmitted through the serial port to the Ethernet communication module and then to the Ethernet server through the Ethernet. At the application layer, the exchange of sensor information and Ethernet information is realized. Information is transmitted via Ethernet to a monitoring center based on B / S architecture to make real-time monitoring through the client terminal. Due to the popularity of the Internet and HTTP protocol, the most important way for wide-area surveillance system is B / S and RIA / S [7]. Fig.3 is a structure diagram of a remote control gateway. Information that comes from sensors is sent to the embedded main board and then to different interfaces after being processed under the control of a microprocessor. The information that needs to be connected to the LAN may be linked to the Internet through the Ethernet interface gateway. Any of the access ways can be selected, such as telephone dial-up access, power lines, fiber optic, LAN access, etc. It can be connected to the equipment being monitored either through a wireless communication link or cable connections such as

power lines and cable. That is to say, there is an information collecting and releasing module between the gateway and the equipment being monitored. It also can be released and received via a wireless communication interface.

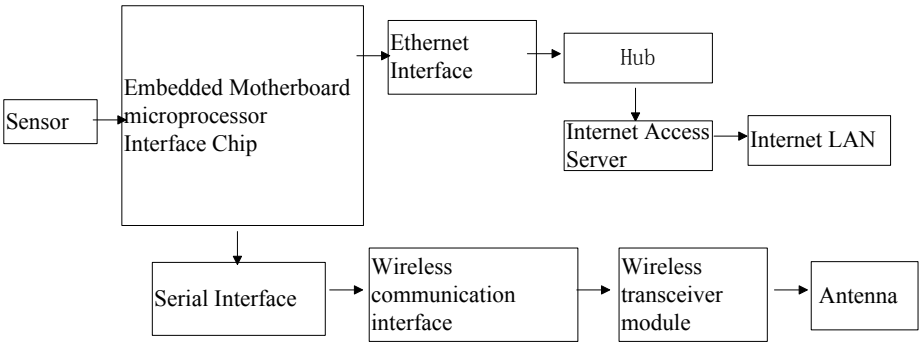

Fig. 3. Sensor Networks Information Gateway

Users can have access to the homepage of the control equipment by inputting the address of the gateway into the web browser's address bar while they are visiting the equipment being monitored through Internet. First, go into the list of information monitoring device after authentication, enter a user name and password, and then select the device number, and finally control the selected device / status page. The controller of the equipment being monitored will generate the corresponding command control according to the users' specific control options to control the operation of the equipment.

The procedures and statuses are described in the real-time information collected by the monitoring system of the working interface and are reflected on the monitoring interface via the monitoring server. The remote monitoring system based on B / S is shown in Fig. 3. As can be seen from the figure, the delay of status information of the equipment or process in the B / S mode monitoring system involves the following aspects:

- Delay caused by collecting and processing equipment or status;
- Delay caused by transmitting information from the remote terminal to monitoring server;
- Delay resulted by information process by monitoring server;
- Delay resulted by transmitting status information from the server to the browser.

Remote monitoring constitutes a closed-loop control system. Generally, the control algorithms, according to t field equipment / process characteristics, are integrated into the controller. Therefore, the delay magnitude of collecting and processing status information by the site controller is typically calculated in milliseconds or microseconds [8]. Compared with the delay of other system segments, the controller information collecting and processing delay is negligible.

With the continuous development of computer technology, computer networks and the Internet have been widely used in various industries [9]. Application of remote transmission technology saves exploration costs, improves management, and reduces the significant effect of risk [10]. Compared with the delay of other system segments, the controller information collecting and processing delay is negligible.

The data communication between the monitoring server and the controller are connected by a coal mine LAN; furthermore, there are various forms of network structures between the controllers and monitoring systems with traditional Internet and wireless Internet. It is precisely the diversity of network structures that leads to the delay of data transmission from the controller to the monitoring server. The complete process of an HTTP "request / response" is shown as the Fig.4[11]. The remote monitoring system takes the structure of B / S. The control center server not only completes monitoring task, but also completes the HTTP protocol interaction between various client-sides. .

5 Monitoring platform

In the remote terminal gateway, monitoring equipment (including remote control) are controlled by one gateway, and the control data required by different equipment and the length of status data returned is different. Each remote terminal is assigned an equipment number in data transmission: for example, the equipment number is 01, 02, 03. The different number is respective of the different length of the control data and status data being indicated. In addition, there should be an error detection / correction mechanism in the data transmission to add checks on the data and the rules for circulating transmission. The data transmitted in each group consist of different information, forming one message. The message is data with one fixed format comprising several words that may contain different information. Communication between the application gateway and controllers of various equipment may be realized through interruption. That is to say, when the controller of the equipment receives a corresponding number, it will process the control / query command from the application gateway by way of interrupting the service routine. .

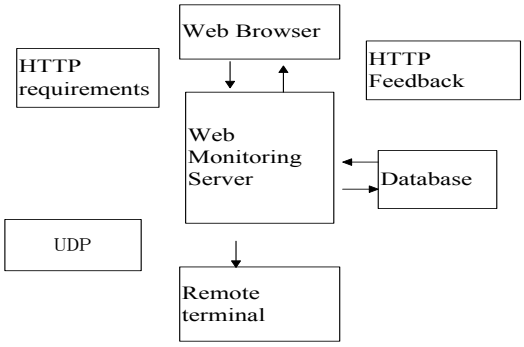

Fig. 4. Web Monitoring Server flowcharts

The specific generation, conversion and transmission processes are described, taking the movement process as an example. Table 1 is the organization form of messages in the setting, among which each data code length is one byte. Equipment number 01H and command number 81H are the setting of equipment; equipment number 01H is determined by the users' selection in the list of equipment; command number 8lH is determined by the panel setup menu. Data length 06H refers to such six bytes as the "command number, movement process, control mode, execution time, driven mode, pump pressure." Checksum refers to the additive result of the "command number, movement process, control mode, execution time, driven mode, pump pressure." Table 1 shows the corresponding operation of the five different code values of "movement process, control mode, execution time, driven mode, pump pressure."

When the user has selected the "movement process, control mode, execution time, driven mode, pump pressure" on the Web page, the user clicks on the "Menu Submitting" button to convert the options on the web page into corresponding code through CGI program processing and forms the message according to the agreed format, which may be sent to the serial interface of application gateway and be released via message collecting and releasing module, wherein the equipment number triggers the hydraulic support and the controller is put into interruption to receive data and then convert the code into a command.

Table 1. Information Organization message

Device No.	Data length	Command number	Mobile process	Control method	Execution time	Passage way	Pump pressure	Checksum
01H	06H	81H						

6 Experiments and Conclusion

In this paper, network technology was designed and studied to process collection and transmission of information come from photovoltaic power plants. A microcomputer was used in a remote monitoring network of the system. The system can monitor the PV power plant component performance data as well as the sunshine amount, temperature, and other environmental parameters and provide a reliable basis for comprehensive evaluation of the performance of the PV power plant. The system uses a Browser / Server model and realizes remote monitoring via the Internet with real-time convenient features, saves manpower and resources, and reduces the cost of photovoltaic power plant monitoring operation.

To solve the large amount of data and information transfer rate drop problem, the control center uses data mining techniques to classify data from a mining data warehouse and user access patterns to analyze photovoltaic trend forecasting, bringing better efficiency. This method will help data extraction and processing. The gateway was designed preliminarily to access the Internet through dial-up or broadband cable. For ensuring safety conditions, the users can relay to photovoltaic power stations through the Internet to remotely control, view, and monitor. According to the charac-

teristics of photovoltaic power generation transmission of information, transfer protocols of principles were proposed and laid the foundation for further research into transfer photovoltaic power stations.

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