Research and Design of a Novel Photovoltaic Plant Monitoring System based on Component Technology

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Abstract. The development of photovoltaic plants has put forward a lot of challenges to the traditional power monitoring system. In view of the new demands, on the basis of the reusable software components of the traditional photovoltaic plant monitoring system, a novel photovoltaic plant monitoring system is established, which has practical application requirements and significance. This paper discusses in detail the concept of component design, then gives the development model of a novel photovoltaic plant monitoring system based on the component technology and the specific steps of the development, and finally implements the photovoltaic plant monitoring system based on the proposed development model. The operation results show that the designed monitoring system is stable and reliable, and can fully meet the monitoring requirements of the large-scale photovoltaic power plants.

1. Introduction

Photovoltaic plants are power generation systems which directly convert the solar radiation energy into electrical energy using the photovoltaic effect of solar cells. The large-scale photovoltaic plants are photovoltaic plants which access to the power grid through 66 kV and above voltage level [1]. The large-scale photovoltaic plant monitoring system realizes the safe, economical and reliable operation of the photovoltaic power generation grid-connected system by means of the monitoring, controlling and adjusting of power equipment, control and adjustment equipment and systems [2].

The large-scale photovoltaic plant monitoring system involves the contents such as the communication network, equipment monitoring and control, communication protocol, data model, power control and voltage regulation, relay protection, scheduling communication and other aspects. At present, some literatures have studied on the contents which are related to the large-scale photovoltaic plant monitoring system. The literature [2] designs the communication network and system structure of the large-scale photovoltaic plant monitoring system, discusses the photovoltaic power station equipment model according with CIM standard, the data mapping between IEC104 and Modbus, the communication with the dispatch center, AGC/AVC control flow and other key technologies, and finally implements the monitoring system software based on the above contents. On the basis of the analysis of the structure and functions of the photovoltaic plant monitoring system, the literature [3] proposes a solution of the large-scale photovoltaic plant monitoring system based on industrial Ethernet technology to meet the monitoring requirements of the large-scale photovoltaic plants. A local area network is formed through industrial Ethernet switches to achieve the data sharing. In literature [4], the computer monitoring system of a large-scale grid-connected photovoltaic plant is discussed. Although the above three literatures can meet some requirements of the large-scale photovoltaic plants, they are not universal. If new requirements are proposed, it is likely to repeat the development, and waste the development, testing personnel quantity and quality, time cost and other inputs.
Although the types of photovoltaic plants and the requirements of the monitoring systems are different, on the basis of actual requirements, all types of photovoltaic plant monitoring systems should have the following functions [5]:

1) Data acquisition: the real-time acquisition of solar cell array output voltage, current, ambient temperature, and etc. If the battery pack is configured, the battery pack voltage, charge and discharge current, single battery voltage, single battery temperature and etc. should also be collected.

2) Fault monitoring: the real-time monitoring of the running states of photovoltaic plant equipment. When the equipment malfunctions, the sound, light and remote alarm signal should be sent immediately to notify the maintenance personnel in a timely manner.

3) Data storage: the operation data of the photovoltaic plant is stored in the memory, so that the fault analysis and location can be carried out when the system malfunctions.

4) Remote monitoring: the remote communication interface is existed so that the remote monitoring center has the ability to understand and remote control on the working status of photovoltaic plant. That is, the system has the functions of telemetering, telecontrol, telesignalling, and teleadjusting.

To a certain extent, the basic functions of the photovoltaic plant monitoring system are independent. Therefore, the photovoltaic plant monitoring system can be decomposed into several independent components, and the development process of the monitoring system is transformed into a process which is similar to the process of building blocks. The integration of the system is realized through the composition of different monitoring system components. According to the viewpoint of component technology, the development of monitoring system software becomes the integration process of various components. With the continuous development of new requirements of the photovoltaic power generation control system such as the processing of millions of measurement points, and new technologies such as distributed storage, computing and large data applications, it is more and more significant and urgent to construct a large-scale photovoltaic plant monitoring system, following the objective law of software engineering and based on software component technology.

2. Component technology analysis

Component is a software component that can be used to construct a software system or a binary software unit which can be independently manufactured, distributed, sold and assembled [6]. It can be regarded as independent modules, providing a certain function and a common interface for users to access to it, but hiding the internal working mechanism. Component technology is a software development technology based on component, and its basic idea is to construct an application software system by means of component composition. Component technology is embodied in two aspects: component development and component-based development. The purpose of component development is to produce reusable software components. The purpose of component-based development is to develop the software system utilizing the existed components [7]. The development method of component-based software system is oriented to reuse, interface and connection [8], as shown in Figure 1.
Reuse is one of the most important concepts in software. Its basic idea is to make full use of previously developed software components, such as a data structure or a logical function, rather than redevelop new components every time the software application system is constructed. Software reuse is a strong and powerful software practice. It can significantly improve the efficiency and quality of software production, and significantly reduce the cost of software development and maintenance [7]. Software reuse embodied by component technology can be considered from two aspects [9-11], as shown in Figure 2.

![Software system development method based on component](image)

**Figure 1.** Software system development method based on component.

(1) Producer Reuse: activities of acquisition and development of reusable components. Producer reuse concerns the development of reusable software components, and it mainly includes the following steps: ① Identify candidate components that need to be constructed or are ready for reuse. ② Carry out the general and difference analysis to determine the conditions under which the component can satisfy the reuse requirements. ③ Design the reusable components. ④ Encapsulate the reusable components. ⑤ Add the reusable components to a service directory or reuse library.

(2) Consumer Reuse: activities of composition of application systems using the reusable components. Consumer reuse cares about how to construct a system with reusable components, and it mainly includes the following steps: ① Look for candidate reusable components. ② Evaluate the candidate components and select the components that are suitable for the system reuse. ③ Adjustively modify the reusable components, so that it can meet the requirements of the application system. ④ Improve the reusable components, and enhance the reusability in the future.

The biggest advantage of software development based on component technology is that it supports software reuse, which can bring about effective improvements of software productivity, quality and cost.
3. Design of photovoltaic plant monitoring system model based on component technology

Develop the photovoltaic plant monitoring system based on component technology to construct a photovoltaic plant monitoring system development model through the domain analysis, and realize the logic design and physical design of photovoltaic plant monitoring system based on the model.

First of all, organize the domain experts and developers to conduct a domain analysis on the photovoltaic plant monitoring system. Then, collect the domain topic documents carefully and deeply, and seek the consistency descriptions of common demands, characteristics, and structure in the domain, as well as the business process and object abstraction that is covered by a variable feature or similar function, so as to obtain a conceptual domain model. That is to say, separate the domain common available parts and variable parts, pre develop common parts and construct a domain general component library and corresponding system architecture. The common parts can be used in the future; the variable parts are processed as the domain knowledge information, they are easy to modify and expand, and only variable parts are required to modify in the system integration when a specific application system is developed. Finally, the system is submitted to the user. Supplemented by feedback mechanism, the development is further optimized. The development model is as shown in Figure 3.

Unlike the structured development methods or the object-oriented development methods that have to undergo three rigorous separate stages: system analysis, system design and system implementation, the development of photovoltaic plant monitoring system based on component technology undergoes system design and system implementation after the domain analysis. So it can quickly and effectively implement the system, especially system development in the similar domain. The specific steps are as follows:

(1) The requirement analysis of the objective system is carried on to determine the system functional requirements, performance requirements, operational requirements, and etc.

(2) Determine the types, functions and interfaces of components based on the requirement analysis results. It requires the developers and domain experts to cooperate closely and accurately distinguish between general components and specific components. According to the characteristics of the components, different ways of generating and acquiring are adopted.

(3) System architecture design. Integrate user needs, determine the system specifications, select the appropriate architecture and determine the implementation details of the system, such as the implementation platform and program language. According to the research and the practice of the enterprise, the architecture of component-based software system should be layered structure.

(4) System integration. That is, application system composition using the components.

(5) System test. Design the test cases according to the functional requirements and performance requirements in the requirement analysis, and conduct a comprehensive test of the system. Punctually feed back the problem found, and return to the previous steps in accordance with the nature of the problem.

(6) System maintenance. That is, the daily maintenance, care and improvement of the system after submitted to the user.
4. Implementation of the proposed photovoltaic plant monitoring system model

Photovoltaic plant monitoring system is the core system of photovoltaic plant power generation and operation management. It is used to deploy SCADA monitoring system, photovoltaic energy management system service, real-time database, historical database, monitoring interface, and etc. and realize the internal monitor and energy management of photovoltaic plant. In view of the business demands of photovoltaic plants, the photovoltaic plant monitoring system should have general functions such as system platform management, data acquisition and access, data storage and management, data and information exchange, information presentation and interaction, SCADA public application, and etc. It also should include several business functions such as power generation statistics, energy management, and etc. The functions are divided into several subsystems.

Based on the domain analysis results, the development model is established. Afterwards, the components are clearly divided into three kinds of component library, that is, the domain-common component library, the domain-specific component library and the systematic component library. General function components such as real-time database, message center, and data access component should be included in domain-common component library. Business function components such as exchange power curve control, active power dispatch, and emergency shutdown dispatch component should be included in domain-specific component library. The systematic component library is always composed of components that are frequently used in the whole photovoltaic plant monitoring system, such as log management, process management, configuration management, and etc. Finally, after system integration and system test, the proposed photovoltaic plant monitoring system based on component technology is implemented, as shown in Figure 4.
Figure 4. Photovoltaic plant monitoring system based on Component technology.

The main advantage of developing photovoltaic plant monitoring system based on component technology is not only in the development of a single system, but also in the quick and effective development of monitoring systems in a certain area, especially in wind farms, electric vehicle charging stations, and etc.

Figure 5. Monitoring interface of photovoltaic plant monitoring system.

5. Summary

This paper discusses in detail the concept of component design, and gives the development model of a novel photovoltaic plant monitoring system based on component technology and the specific steps
of the development, and then implements the photovoltaic plant monitoring system based on the proposed development model. The operation results show that the designed monitoring system is stable and reliable, and can fully meet the monitoring requirements of large-scale photovoltaic power plants. The designed photovoltaic plant monitoring system interface is as shown in Figure 5. The operation results show that the designed monitoring system is stable and reliable, and can fully meet the monitoring requirements of large-scale photovoltaic power plants.

References


