Research Article
Application of Industrial Big Data Cloud Control Platform Based on Fusion Transmission Sensor

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In order to solve the problem that the traditional operation and maintenance system of photovoltaic operation and power station is mainly based on statistical analysis and multisite and multilevel deployment mode, which wastes software and hardware resources, is not easy to expand and has extremely low efficiency, which cannot meet the urgent needs of users to reduce costs and increase efficiency. This research proposes a methodology for integrating big data, cloud computing, and photovoltaic operation and maintenance. This method constructs the business model, data model, application model, and technical model of the photovoltaic power station operation and maintenance cloud platform. The results obtained are as follows: the system provides diagnostic services for the application system of a 30 MWp photovoltaic power station in a certain place, and a total of 87 defects are found, the defect elimination rate is 88.51%, and the monthly power generation of the power station is increased by 122,529 kWh; the use effect of the system in this research after it goes online. The evaluation is 93.04 points, ranging from very satisfactory (A) to satisfactory (B) and biased towards A, indicating that the use effect is good. It is proved that the successful research and promotion of the system in this research will be of great significance to improve the intelligent operation and maintenance level of photovoltaic power plants and improve the operation and maintenance efficiency of photovoltaic power plants.

1. Introduction

In recent years, in the field of new energy photovoltaic power generation, with the strong support of national policies and a relatively open and favorable market environment, the number of enterprise groups investing in photovoltaic power generation and the number and scale of new photovoltaic power plants under the group have increased year by year [1]. However, in the context of the thriving development of the photovoltaic power generation industry, there are many problems, especially, the operation and maintenance management of photovoltaic power plants under the jurisdiction of power generation groups. The operation and maintenance management level or means of most photovoltaic power generation groups are far from matching their power plants [2]. The speed of construction, coupled with the scattered geographical location of photovoltaic power stations, large power station area, and relative scarcity of professionals and other characteristics and status quo, has led to the insufficient production and management capabilities of photovoltaic power plants in photovoltaic power generation enterprise groups and the low power generation efficiency of photovoltaic power plants; corporate profits cannot be reliably guaranteed. With the continuous improvement of China’s industrial automation level, the computer-centered ICT (Information and Communication Technology, ICT) technology has developed rapidly through the network and penetrated into all fields of social life [3]. Figure 1 is based on fusion transmission sensor data fusion technology and application research. With the development of Internet of Things technology, cloud computing technology, big data technology, and mobile communication technology, the traditional operation and maintenance software of photovoltaic power plants, which is mainly based on statistical analysis and multilevel deployment, can no longer meet the actual needs. The operation and maintenance of
The world power station operation and maintenance, Meteo Control, an experienced evaluation organization in the world. In terms of Germany, in terms of power station evaluation and monitoring system, the lead to the development of corresponding technologies [8]. The construction scale of photovoltaic power plants will inevitably increase by 480% year-on-year, becoming the new second fastest growth rate. In 2007, the newly installed solar capacity grew by 57% year-on-year in 2007, while the Japanese market began to decline after the government canceled certain policy subsidies, dropping by 22% in 2007 [7]. Spain has a rapid growth of the construction scale of photovoltaic power plants. The photovoltaic power station operation and maintenance system is also gradually developed from scratch. The early photovoltaic power station operation and maintenance system was generally deployed in the existing formation, and was generally deployed in the existing form. With the intelligentization of photovoltaic power station-related equipment and the development of ICT technology, the photovoltaic power station operation and maintenance system has gradually turned to focus on monitoring, monitoring the status of equipment, and alarming. With the development of cloud computing technology, each enterprise has built its own private cloud platform, and the photovoltaic power station operation and maintenance system has been used in more than 3,000 power stations in the world, with a total installed capacity of more than 8 GW and a power station investment of more than 10 billion euros. With the world’s largest power station operation database, the independent third-party operation and maintenance model created by it has been relatively mature in Europe [9]. Meteo Control’s photovoltaic power station operation and maintenance products have also used big data technology in meteorological data, solar energy forecast, technical operation and maintenance management, power generation report, system rating, and other functions [10]. China’s renewable energy started relatively late. From the “Golden Sun Demonstration Project,” which was implemented by the state in 2009 to support the technological progress of the photovoltaic power generation industry, to the large-scale development of photovoltaic power plants in 2012, and then, to the current full-scale outbreak of distributed photovoltaic power plants. The photovoltaic power station operation and maintenance system is also gradually developed from scratch. The early photovoltaic power station operation and maintenance system focused on management and was generally deployed in the existing formation.

2. Literature Review

For the utilization of solar energy, Germany is the country that mainly utilizes solar energy. In 2007, its installed solar energy capacity reached more than 1300 MW, accounting for nearly half of the global newly added capacity. It is currently the largest solar power generation market in the world. Japan and the U.S. are second only. The U.S. market grew by 57% year-on-year in 2007, while the Japanese market began to decline after the government canceled certain policy subsidies, dropping by 22% in 2007 [7]. Spain has a fast growth rate. In 2007, the newly installed solar capacity increased by 480% year-on-year, becoming the new second largest market in the world. The rapid growth of the construction scale of photovoltaic power plants will inevitably lead to the development of corresponding technologies [8]. In terms of power station evaluation and monitoring system, Germany’s TUV Süddeutsche Group is already a very experienced evaluation organization in the world. In terms of power station operation and maintenance, Meteo Control, the world’s largest solar power station operation and mainte-

![Image](image-url)

**Figure 1:** Research on sensor data fusion technology and application based on fusion transmission.
has turned to centralized management. From 2014 to 2016, with the development of big data technology and Internet of Things technology, the operation and maintenance of photovoltaic power plants took the lead in entering the era of remote monitoring. At this stage, the photovoltaic power station operation and maintenance platform realizes basic management and control such as report statistics, power generation upload, fault work order management, and real-time display of equipment data. However, in 2017, with the increase of the number of power stations, the data volume has become a reality, and the current power station operation and maintenance platform has been unable to meet the deep-level needs such as in-depth analysis and refined management and control of trend warning [11, 12]. On the basis of remote monitoring and operation, photovoltaic power plant operation and maintenance has entered the era of big data operation platform, that is, using big data technology to analyze, give early warning, and propose solutions. With the development of mobile Internet, photovoltaic power plants have entered the era of "no entry, less the centralized and intelligent era of human operation and maintenance, remote monitoring, and big data improvement."

Based on these foundations, this topic combines cloud computing, big data, and mobile communication technology with the actual business needs of photovoltaic power plant operation and maintenance and uses the massive data generated by photovoltaic power plants in the daily operation process to predict the power generation of equipment and to predict the power generation of the equipment that may be generated. Early warning of faults, accurate positioning of actual faults, health inspection, and benchmarking of photovoltaic power plants achieve standardized, intelligent, and professional operation and maintenance of photovoltaic power plants. The success and promotion of the system research will be of great significance to improve the intelligent operation and maintenance level of photovoltaic power plants and improve the operation and maintenance efficiency of photovoltaic power plants.

3. Research Methods

3.1. Effective Integration of Big Data, Cloud Computing, and Photovoltaic Power Plant Operation and Maintenance

Google published three technical researches on MapReduce (distributed computing framework), Google File System (GFS, distributed file system), and BigTable (GFS-based distributed database system), proposing a new set of distributed computing theory. Subsequently, various scientific research institutions and large IT companies began to implement their own distributed computing systems based on Google's new theory. The distributed computing framework MapReduce, distributed file system GFS, and distributed database system BigTable have therefore become the mainstays of the era of big data development technical foundation [13].

From the emergence of the concept of big data to the rapid development of big data today, through the analysis of actual application, Hadoop, Spark, and Storm are the three most widely used and popular platforms in the current big data field. It is only analyzed from the perspective of big data processing, and the comparison results of the three platforms are shown in Table 1.

There is a loose relationship between the three services of SaaS, PaaS, and IaaS in cloud computing, that is, the three service modes can have dependencies or no dependencies on each other. For example, SaaS can run on PaaS or not on PaaS. In the same way, PaaS can run on IaaS or not. In terms of service objects, SaaS provides application system services, and the users are mainly the actual users of the business system. PaaS is to provide platform development and other services, and the general users are mainly application system developers. IaaS provides the underlying IT infrastructure as a service and is mainly used to deploy applications, so the users are generally IT resource users and managers [14]. Although the three models are at different levels, any one of the services can be independently provided externally and provide corresponding cloud services. Its relationship is shown in Figure 2.

In the field of photovoltaic power station informatization, the construction goal of the photovoltaic power station management and control platform is to "reduce costs and increase power generation."

Therefore, the IaaS and PaaS service models are mainly used when the photovoltaic power station management and control platform realizes cloud computing integration. In the IaaS layer, the hardware resources of the centralized control center are used, and virtualization technology is used to realize the deployment and operation of multiple application platforms; in the PaaS layer, a unified operating platform is used to meet the needs of the company for running multiple applications.

Big data and cloud computing are mutually influenced and developed together. From the perspective of practical application, the purpose of cloud computing is to better call, expand, and manage computing and storage resources and capabilities through resource sharing to reduce the IT cost of enterprises; the purpose of big data is to fully exploit massive information in data to discover value in data. Cloud computing saves users’ IT resource costs, big data helps users discover the value in data, and the integration of the two from the application level can bring great benefits to users. From a technical point of view, cloud computing provides a basic support environment for the storage and processing of big data, and big data also broadens the technical application of cloud computing. Cloud computing and big data learn from each other’s technical ideas and integrate with each other. By establishing a unified and shared infrastructure resource pool, on-demand allocation, unified scheduling, and mutual coordination of resources for different business application systems can be achieved, to achieve the purpose of intensive and efficient utilization of resources. Based on a unified infrastructure, big data can be stored, processed, and analyzed more conveniently, thereby maximizing the value of data mining [15, 16].

3.2. Data Process Analysis of PV Operation and Maintenance Cloud Platform. The entire data flow of the system is shown in Figure 3.
The acquisition software collects real-time data (photovoltaic power station acquisition equipment related data) and nonreal-time data (meteorological data, electrical energy data, and optical power prediction data) and stores them in the real-time database. Whether to alert or control the real-time monitoring platform also accepts the instructions sent from the scheduling and performs corresponding control according to the instructions. The big data platform reads data from the real-time database for processing and visual analysis and writes the resulting data into the structured database.

Table 1: Comparison of distributed computing platforms.

| Platform     | Types of big data processing | Remark                                      |
|--------------|------------------------------|---------------------------------------------|
| Hadoop       | Offline, complex             | With data collection and storage capabilities|
| Spark        | Offline, fast                | With data collection and storage capabilities|
| Storm        | Online, real-time            | No data collection and storage capabilities  |

![Figure 2: Cloud service hierarchy diagram.](image)

![Figure 3: System data analysis flow chart.](image)
database for subsequent statistical analysis by the operation and maintenance cloud platform. The intelligent operation and maintenance cloud platform obtains relevant data from the structured database for statistical analysis and early warning. Management data is written into the structured database through the intelligent operation and maintenance cloud platform for subsequent query and analysis [17].

3.3. System Functional Architecture. System functions mainly include the following aspects:

1. Big data collection and transmission

Big data acquisition and transmission mainly includes software/hardware equipment and related facilities required for data acquisition, data uploading, and communication management at each power station and solves the problem of communication interface protocol between each system of the centralized control center and the equipment of various local intelligent monitoring system manufacturers. All the collected data is encrypted and uploaded to the centralized control center through the intermediate transmission link layer, which is unified into the data platform integrated with the centralized control center system, and the dispatching channel is opened to realize the remote monitoring function of all power stations.

The station side of the power station mainly collects real-time operating data such as photovoltaic equipment (including photovoltaic arrays, combiner boxes, inverters, booster stations, energy metering devices, and box-type transformers) and nonreal-time data such as power prediction. Upload it to the centralized control center of the headquarters, and send it to the big data processing platform through the program [18, 19].

2. Real-time monitoring platform

Set up a centralized control center at the company’s headquarters, which is the company’s operation and maintenance management center, display center, and evaluation and decision-making center. The real-time monitoring platform and operation and maintenance cloud platform are deployed in the centralized control center. The real-time monitoring platform receives the real-time data and nonreal-time data uploaded by the subordinate power plants and remotely and centrally monitors the operation of the main equipment of the subordinate photovoltaic power plants. Realize the integration of on-site operation monitoring, and realize remote control and monitoring of station equipment.

3. Intelligent operation and maintenance cloud platform

The operation and maintenance cloud platform is the core platform for the operation and maintenance management of photovoltaic power plants, which realizes the remote management and control of the subordinate photovoltaic power plants, including the regional/group management and the local operation and maintenance management of each power station.

(4) Mobile platform

The mobile platform adopts a lightweight design, which can be accessed directly by scanning the QR code or integrated into the group’s official account. Users do not need to download additional APP programs and do not occupy mobile phone memory [20].

The system functional architecture is shown in Figure 4.

4. Analysis of Results

4.1. Evaluation of Economic Effects of System Application. After the system was launched, during the one-month experiment period, a diagnostic service was performed on the application system of a 30 MWp photovoltaic power station in a certain place. A total of 87 defects were found, and the defect elimination rate was 88.51%. The monthly power generation of the power station was increased by 122,529 kWh. The specific defect statistics are shown in Table 2.

4.2. Evaluation of System Application Use Effect. The basic idea of analytic hierarchy process (AHP) is to first determine the main factors affecting the evaluation object, form a hierarchical structure, and establish an index system according to the affiliation of each factor, and then, judge the relative importance of each factor by experts. And assign values to get the judgment matrix and check its consistency; finally, calculate the combined weight of each layer factor to the system. The following uses the analytic hierarchy process to evaluate the actual use effect of the system [21–23].

1. Construction of evaluation index system

After analysis, the evaluation index system of this system is divided into two levels: the first level analyzes the evaluation indexes from the user’s point of view (B1 is the management personnel, B2 is the on-site operation and maintenance personnel, and B3 is the system’s own status); the second level is based on different users build different indicators, B1 includes C11, C12, and C13, B2 includes C21, C22, and C23, and B3 includes C31, C32, and C33.

2. Construct judgment matrix

When determining the weights between the factors at each level, the consistent matrix method is used, that is, all factors are not compared together, but compared with each other. To improve accuracy, relative scales are used when comparing with each other. The scaling method of the judgment matrix element \( a_{ij} \) is shown in Table 3.

The judgment matrix element \( a_{ij} \) can be obtained by:

\[
    a_{ji} = \frac{1}{a_{ij}}. \tag{1}
\]

3. Calculate the weight vector and do the consistency check
Cloud platform for photovoltaic power station operation and maintenance based on big data

**Real-time monitoring platform**
- Run security monitoring
- Remote control
- Remote lock
- Event alert

**Intelligent operation and maintenance cloud platform**
- Real-time detection
- Visual analysis
- Benchmarking management
- Smart alert
- Intelligent operation and maintenance
- Basic configuration
- Operational statistics

**Mobile platform**
- Front page
- Detect
- Upcoming
- Work
- Statistics

**Big data collection and transmission system**
- Data collection
- Data processing
- Data transmission

**Figure 4:** System functional architecture diagram.

**Table 2: Defect statistics.**

| Serial number | Defect classification                                | Total number of defects (bars) | Missing (articles) | Elimination rate (%) |
|---------------|-----------------------------------------------------|-------------------------------|--------------------|----------------------|
| 1             | Branch circuit fuse burnt                           | 62                            | 62                 | 100                  |
| 2             | Component power is abnormally attenuated            | 3                             | 3                  | 100                  |
| 3             | Cable failure                                       | 9                             | 1                  | 11.11                |
| 4             | Inverter conversion efficiency is low               | 1                             | 0                  | 0                    |
| 5             | Abnormal data acquisition module                    | 2                             | 2                  | 100                  |
| 6             | The communication of the combiner box is abnormal   | 5                             | 5                  | 100                  |
| 8             | Environmental monitor                               | 2                             | 2                  | 100                  |
| 9             | Other                                               | 3                             | 2                  | 66.67                |
| **Total**     |                                                     | **87**                        | **77**             | **88.51**            |
The calculation steps are as follows:

(1) Calculate the maximum eigenvalue \( \lambda_{\text{max}} \) and eigenvector of the judgment matrix

(2) Judging the consistency of the matrix

The so-called consistency refers to the logical consistency of judgment thinking. The consistency index CI is obtained by:

\[
CI = \frac{\lambda_{\text{max}} - n}{n - 1}
\]

where \( \lambda_{\text{max}} \) is the maximum eigenvalue of the matrix; \( n \) is the order of the matrix.

When CI = 0, the judgment matrix is consistent; the larger the CI, the more serious the inconsistency of the judgment matrix.

Taking a group in Gansu Province that has used the photovoltaic power station operation and maintenance cloud platform as the object, the weight value calculation is carried out. The steps are: construct the index questionnaire→questionnaire survey→weighted evaluation to obtain the application effect value.

The questionnaire is designed according to the constructed first- and second-level index system, and four options of "very satisfied (A), satisfied (B), relatively satisfied (C), and dissatisfied (D)" are set for each indicator to facilitate users' selection. The "A" level corresponds to 100 points, the "B" level corresponds to 85 points, the "C" level corresponds to 75 points, and the "D" level corresponds to 60 points [24, 25].

The index system questionnaire was collected, analyzed, and weighted for evaluation. The final calculation result is shown in Figure 5.

According to the analysis in Figure 5, the evaluation of the use effect after the system goes online is 93.04 points, ranging from very satisfied (A) to satisfied (B) and biased towards A, indicating that the use effect is good.

5. Conclusion

Aiming at the problems existing in the current photovoltaic power plant operation and maintenance management process, this research analyzes the new requirements, new business processes, management modes, and management goals of photovoltaic power plant operation and maintenance. The business model, data model, application model, and technical model of the photovoltaic power station operation and maintenance cloud platform are constructed; the construction method of the overall model of the photovoltaic power station operation and maintenance cloud platform is deeply studied; in the process of platform construction, the process of reducing enterprise costs, the thinking method of improving system efficiency and intelligent operation and maintenance, adhering to the construction concept of compatible, easy-to-use, robust, and safe information system, and demonstrating its practical application effect based on individual cases.

The main work and research results of the research are summarized as follows:

(1) Combined with big data technology, cloud computing service model, and deployment model, the cloud platform architecture, business architecture, application architecture, network architecture, data architecture, functional architecture, and information security architecture of photovoltaic power plant operation and maintenance based on big data are designed. The functional modules of photovoltaic big data are designed and described in detail.

(2) Discussed the Hadoop big data processing framework and MongoDB storage technology used in the realization of the photovoltaic power station operation and maintenance cloud platform, briefly described the hardware environment, software environment requirements and system development and configuration environment of the platform operation; demonstrated the core functions of the system interface; and the application effect of the system is evaluated from the economic and usage perspectives with actual cases.
Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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