Design and implementation of data collection scheme for photovoltaic power stations

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Abstract. With the continuous increase in society's demand for clean energy, photovoltaic power generation, as an environmentally friendly and renewable form of energy, has attracted much attention. This article mainly studies the data collection issues of photovoltaic power stations, with the photovoltaic power station in the plant of Guoneng Shouguang Power Generation Co., Ltd. as the research object. Design a collection plan by analyzing the types of data and the methods of collection that photovoltaic power station need to collect, including the architecture of the data collection system, data processing and storage, and data display and application. Finally, through the collection of data from the photovoltaic power station within the Guoneng Shouguang Power Generation Co., Ltd., the effectiveness of the data collection scheme is verified.

Keywords: Photovoltaic power station; Data collection; Operating data; Environmental monitoring data; Data analysis.

1 Introduction

With the continuous development of solar energy technology, photovoltaic power stations are playing an increasingly important role in the power system [1-2]. The power generation efficiency and output of photovoltaic stations are influenced by various factors [3]: low conversion efficiency of photovoltaic cells, temperature influence, light intensity influence, dust and pollution influence, weather change influence, module aging influence, etc. The existence of these problems affects the efficiency and stability of photovoltaic power generation. In order to ensure the safe and stable operation and efficient production of photovoltaic stations, it is necessary to collect and process a large amount of data. By analyzing the collected data, the power generation efficiency and output of the photovoltaic system can be maximized. With the rapid advancement of smart grids, the large-scale deployment of smart meters and sensing technology has brought massive and diverse data to the photovoltaic industry. These data sources are complex and have different structures. Technical personnel often face problems such as difficulty in obtaining real data, uneven data quality, and insufficient data volume. Moreover, during the process of collecting photovoltaic

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power generation data, researchers often lack a comprehensive and in-depth understanding of the involved data [4]. All these factors impact the stable operation and efficient production of photovoltaic power stations.

This article analyzes the types of data that need to be collected at the photovoltaic power station in Guoneng Shouguang Power Generation Co., Ltd., selects appropriate collection methods, and realizes the collection and processing of multi-source data through the design and implementation of collection schemes. By analyzing the collected data, a comprehensive understanding and optimization of the operation status of photovoltaic power stations can be achieved, which is of great significance for the operation, management, optimization, and decision-making of photovoltaic power stations.

2 The Data Types and Collection of Photovoltaic Power Stations

2.1 Data Type

This article collects data from the photovoltaic power station plant of Guoneng Shouguang Power Generation Co., Ltd., which mainly includes two categories: one is environmental monitoring data, which includes data such as light intensity, wind speed and direction, temperature and humidity; the second is operational data, which includes information such as the power, voltage, current, daily power generation, temperature, and light intensity of the solar panels, as well as the current, voltage, frequency, efficiency, and operational status of the photovoltaic inverter. This also includes data on the operating status of transmission and transformation equipment, reactive power compensation equipment, high-voltage circuit breakers, isolation switches, grounding switches, and other equipment. At the same time, it also involves technical indicators and operation logs related to the grid operation of photovoltaic power generation systems.

2.2 Collection Methods

Traditional photovoltaic power station data collection relies on local monitoring methods, requiring maintenance personnel to manually view and record station operation data and modify control parameters on site. This not only consumes a lot of manpower, material resources, and financial resources, but also is not suitable for the development of modern economy[5].

In modern collection methods, a remote monitoring technology combining computer networks and data collection technology is adopted. Automatic data storage is achieved through sensors and communication devices, without the need for real-time recording, and data can be automatically saved [6]. The advantage of this technology is that technicians can always grasp the operating status of the equipment, respond quickly to faults, improve efficiency, and simplify traditional data collection methods [7].

3 Desin of Data Collection Scheme for Photovoltaic Power Stations

To achieve effective data collection, remote monitoring systems and data collection equipment are used to ensure timely and accurate data collection and transmission. Design a data acquisition system suitable for the photovoltaic stations within the Guoneng Shouguang Power Generation Co., Ltd. plant, while considering the safety and effectiveness of data transmission, as well as seamless integration with the dispatch system. The architecture of the data collection system is shown in Fig. 1.

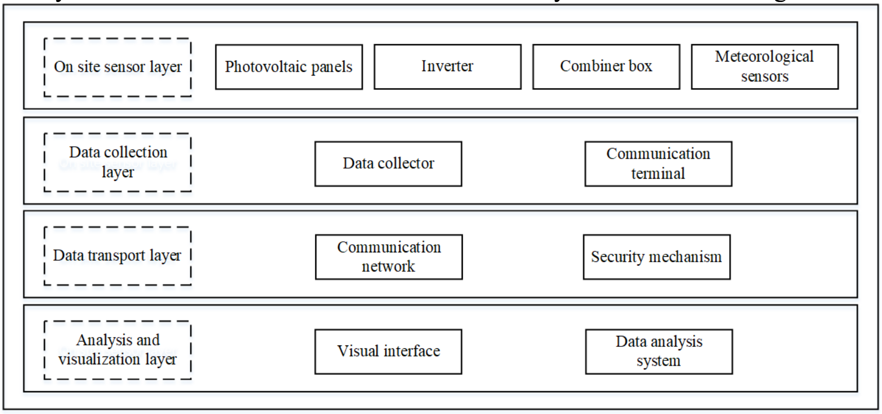

Fig. 1. Architecture of data collection system.

3.1 Architecture of Data Collection System

Based on the analysis of the above data types and collection methods, design the architecture of the photovoltaic power station data collection system, including data collection, transmission, storage, and analysis.

3.2 Data Acquisition and Processing

The data collector adopts a modular design to adapt to different data collection needs. Detect the equipment status, respond to equipment failures in a timely manner, and prevent data distortion; implement a redundant network architecture to reduce the impact of network interruptions on data collection, while using local caching to prevent data loss and ensure data accuracy and integrity. Data processing can perform preliminary quality checks and calibration on data. Data cleaning and preprocessing are required for the collection of switch and measurement quantities; for environmental monitoring data, raw data processing and data fusion are required. At the same time, parallel computing data processing technology is adopted to improve data processing speed and cope with the constantly growing amount of data.

3.3 Data Transmission

Using standardized communication protocols to communicate with the station monitoring center system and scheduling system, achieving real-time data transmission and sharing. The data transmission adopts the Internet of things communication devices to ensure real-time data transmission, and uses secure and reliable data transmission protocols to achieve secure data transmission. Simultaneously compress and encrypt data to ensure its integrity and security during transmission.

3.4 Data Storage

Use high-performance database storage systems to handle large-scale data, implement data compression and indexing strategies, and improve storage efficiency. Data storage is divided into real-time storage and historical storage: real-time database is used to store real-time data to support real-time monitoring and feedback of the operation status of photovoltaic stations; Store the cleaned data in a historical database to support subsequent data analysis, reporting, and querying. At the same time, it is necessary to consider the backup and recovery mechanisms of data to ensure its reliability and integrity.

3.5 Data Display and Analysis

By establishing a three-dimensional realistic model and integrating multi-source data with the three-dimensional realistic model, it provides technicians with intuitive visual data display and real-time monitoring to support decision-making. At the same time, a data analysis system is used to conduct in-depth analysis of historical data, achieving functions such as performance evaluation, fault diagnosis[8], and report generation.

4 Data Collection of Photovoltaic Power Stations within Guoneng Shouguang Power Generation Co., Ltd

By designing a data collection plan and developing a data collection system, information and data on various aspects of the photovoltaic modules, inverters, meteorological conditions, and other aspects of the photovoltaic power stations in the Guoneng Shouguang Power Generation Co., Ltd. plant can be collected.

The station is equipped with a monitoring system to collect switch and measurement quantities. The monitoring of photovoltaic equipment is achieved by the data collector in the intelligent sub array control cabinet of each sub array, mainly monitoring the operational data of the string, inverter, and box transformer, and achieving remote control of the inverter and box transformer. The synchronous phasor measurement device collects voltage, current, and switch signals of the busbar, main transformer, and line, and the installed sky imager and micro meteorological instrument collect environmental data.

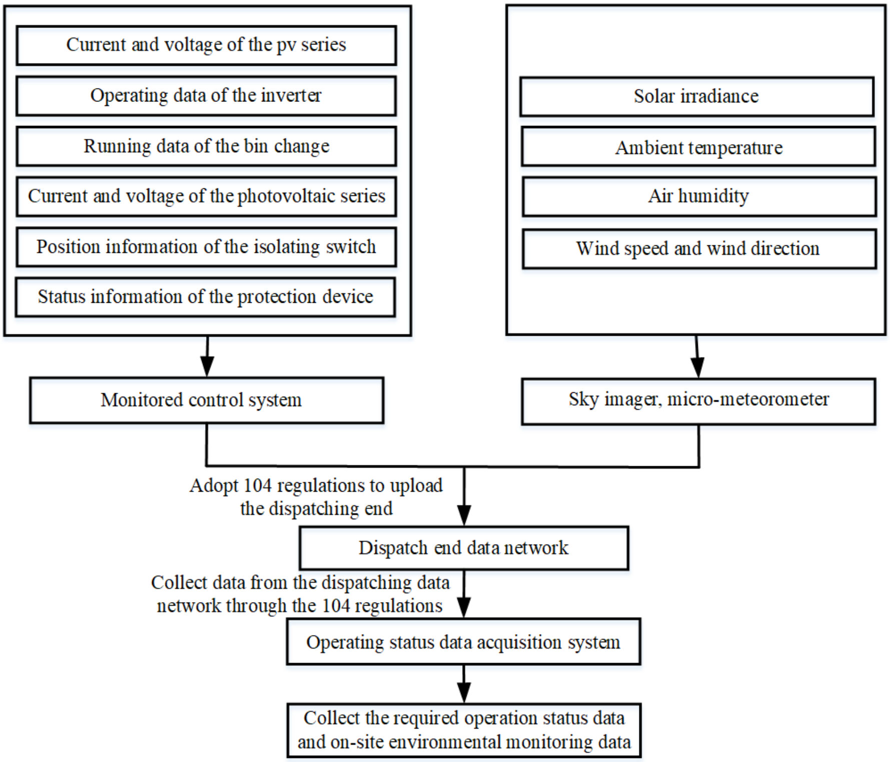

Fig. 2. The data collection process for the photovoltaic power station.

The remote control information of the photovoltaic station adopts the 104 protocol direct transmission scheduling automation main station system, and the uploaded scheduling information includes the operation data of the station and the environmental meteorological data collected by the sky imaging instrument and micro meteorological instrument. Obtain the required data from the existing system through the operational state data collection system, i.e., collecting operational status data of the photovoltaic power station and on-site environmental monitoring data from the dispatch data network through protocols such as 104 at the dispatch end. As shown in Fig. 2, it is the data collection process for the photovoltaic power station.

As shown in Table 1, the collected data of four inverters for a certain box transformer in a photovoltaic power station. From the table, it can be seen that the parameters of the inverter include voltage, current, power, daily power generation, carbon dioxide emissions reduction, and other data, which are used to monitor the operation status of the photovoltaic system in real time. Analyzing output power, efficiency and other data helps to monitor the power generation efficiency of photovoltaic modules; Based on voltage, current, and daily power generation, the performance differences of photovoltaic modules can be evaluated; By remotely adjusting the parameters of the inverter, such as voltage and frequency, it can adapt to different needs; Operating status, temperature, and other information are helpful for preventive maintenance, identifying potential problems in advance, and reducing system failure rates; Carbon dioxide emissions reduction is an important indicator for measuring the economic and environmental benefits of photovoltaic stations. By analyzing these data, remote monitoring, performance evaluation, fault detection, operation and maintenance optimization, and preventive maintenance of photovoltaic systems can be achieved. Meanwhile, through long-term data collection and analysis, system operation can be optimized.

Table 1. Data table of box transformer inverters for photovoltaic power station.

Data name	Inverter 1	Inverter 2	Inverter 3	Inverter 4	Unit
Line voltage of grid AB phase	820.8	818.4	824.5	822.8	V
Line voltage of grid BC phase	823.9	822.2	827.1	823.6	V
Line voltage of grid CA phase	826.8	828	829	828.5	V
Phase A voltage of the grid	473.3	473	475.2	474.8	V
Phase B voltage of the grid	475.2	474.4	477.5	476	V
Phase C voltage of the grid	477.3	477.5	478.1	477.7	V
Phase A current of the grid	135.763	141.449	132.982	142.582	A
Phase B current of the grid	136.32	141.685	133.584	142.674	A
Phase C current of the grid	136.125	142.275	133.352	143.281	A
The frequency of the grid	49.97	49.97	49.96	49.96	Hz
Active power	175.806	184.471	172.482	186.711	kW
Reactive power	81.238	80.377	81.27	81.143	KVar
Power factor	0.905	0.915	0.904	0.915	
Total DC input power	178.992	187.948	175.643	190.269	kW
Daily power generation	370.7	376.6	357.8	383.5	kW·h
Machine temperature	48.5	52.4	47.1	49	°C
The efficiency of inverter	98.29	98.15	98.28	98.13	%
Carbon dioxide emission reduction	491501	494791	481812	509355	kg

As shown in Fig. 3, this is the active power graph of each inverter in the photovoltaic power generation area. The active power of the inverter reflects the current electrical energy output of the photovoltaic system. By monitoring the active power in real-time, the stability and operation of the system can be evaluated, the power generation and power of the photovoltaic power station can be understood, and energy management and dispatch of the station can be achieved; It can also promptly detect and diagnose faults and abnormal situations of inverters, so as to take timely measures for repair and treatment, and improve the operational efficiency and stability of photovoltaic power stations.

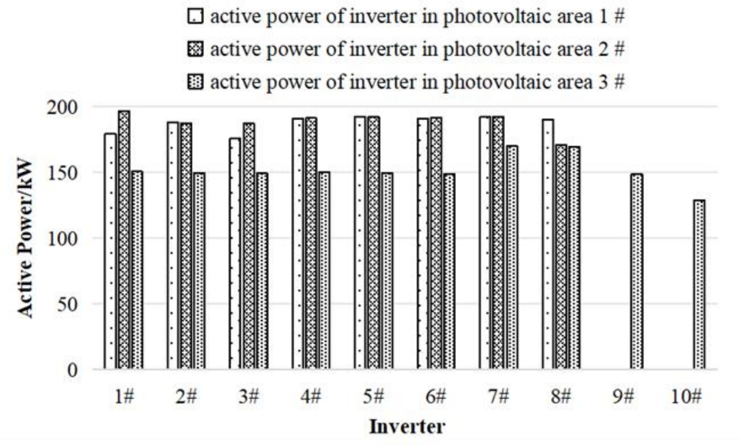

Fig. 3. Active power of inverter.

The weather distribution graph of the photovoltaic power station collected from January 1, 2022 to December 21, 2023 shown in Fig. 4. From the graph, it can be seen that sunny days account for 36.03%, cloudy days account for 35.61%, overcast days account for 13.13%, and rainy days account for 12.99%. Data of weather changes help to understand the changes in the environment where photovoltaic power station is located, so that timely measures can be taken to protect the equipment and components of the photovoltaic power station during extreme weather conditions, preventing damage to the equipment. Based on long-term meteorological data, system planning and design can be carried out to optimize the layout of photovoltaic power stations and the installation of components. At the same time, linking meteorological data with power generation efficiency can help evaluate the overall efficiency of the system under different meteorological conditions. Good weather can bring higher power generation and revenue to the station.

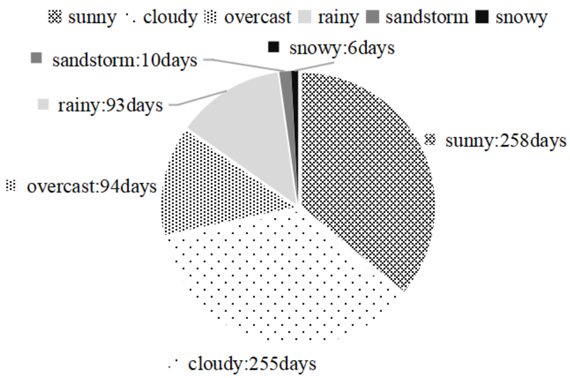

Fig. 4. Distribution of sunny and rainy weather conditions.

As shown in Table 2, the power generation of each photovoltaic zone is shown. Record the cumulative power generation for monitoring the overall performance of photovoltaic power plants; Record power generation in different time periods to analyze the performance of the system at different time periods. Based on historical energy output data trends and patterns, power generation can be predicted, which helps plan power supply, adjust grid operation strategies, and prepare energy reserves and scheduling in advance.

Table 2. Photovoltaic power generation in each area.

Data type	Photovoltaic area of 1 #	Photovoltaic area of 2 #	Photovoltaic area of 3 #	Unit
Daily power generation	3303.02	3326.76	3324.83	kW·h
Monthly power generation	217556	218618	218229	kW·h
Annual power generation	2612754	2618589	2661611	kW·h
Accumulated power generation	4039214	4050893	4069950	kW·h

5 Conclusion

This article explores the design and implementation process of data collection schemes for photovoltaic power stations, including aspects such as data types, collection methods, and collection processes. The implementation and analysis of the data collection scheme for the photovoltaic power station within Guoneng Shouguang Power Generation Co., Ltd. is of great significance for improving the power generation efficiency of the photovoltaic power station system, reducing maintenance costs, enhancing the reliability and sustainability of the system, and the long-term operation and management of the photovoltaic power station. Meanwhile, with the continuous development of photovoltaic technology and the expansion of application scenarios, as well as the continuous development of new technologies such as the Internet of Things and cloud computing, future photovoltaic power station data collection systems will become more intelligent and efficient.

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