The research of diagnosing Photovoltaic building fault based on State Grid Distributed Photovoltaic Cloud Platform

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Abstract. SGCC invented State Grid Distributed Photovoltaic Cloud Platform (SG-DPCP) in 2018, which is the largest distributed photovoltaic public service cloud platform in China. Based on the power generation data of SG-DPCP, in use of Big Data analysis technology, this paper proposes a method to accurately diagnose the fault types of photovoltaic buildings. The effectiveness of this method is verified by a specific application study.

Keywords: Photovoltaic Cloud Platform, inverter, fault diagnosis, gross error.

1. Introduction

In April 2019, the International Energy Agency released authoritative data on global Carbon dioxide (CO₂) emissions: in 2017 and 2018, CO₂ emissions from energy use increased by 1.6% and 1.7% year-on-year respectively, among which, CO₂ emissions from buildings accounted for about 28% of the total. Under the background of energy conservation, environmental protection, green development and low-carbon industry, future development trend of photovoltaic and building is the same: Building-integrated Photovoltaic (BIPV). Photovoltaic building is the future of photovoltaic system, zero energy consumption building is the future of construction industry. To achieve zero energy consumption of buildings, the key is to increase the photovoltaic area of buildings.

“The opinions on promoting the healthy development of photovoltaic industry”, which issued by the State Council of China points out that clearly: in the process of urbanization, we should make full use of solar energy and develop BIPV.

Professor Liu Jiaping, academician of Chinese Academy of engineering, said on November 20, 2018: future industrial and civil buildings should be green buildings, which can save land, materials, water and energy, protect the environment, reduce pollution, provide people with healthy and efficient living space, maximize the realization of its ‘green’ function.

Musk, hailed as a modern Edison by President Trump of the United States, announced in February 2020 that he would expand the "solar roof" business in China and Europe. This concept of advanced "solar roof" is the inevitable trend of the future development of the construction industry, promoting the development of buildings to low-carbon, friendly, energy-saving direction.

For the first time, the concept of BIPV was proposed by the World Energy Organization, that is, in order to achieve the dual goals of building technologies and building aesthetics, to meet the requirements
of building safety performance, lighting, assembling convenience, lifetime, land resource saving, etc., a complex system is composed of many photovoltaic modules and main part of building.

State Grid Corporation of China (SGCC) earnestly implements new energy development policies of the State Council of China, and fully promotes the healthy development of China's distributed photovoltaic industry. With the help of technologies such as Internet of Things, Cloud computing, Mobile Internet, Block chain and Big data, SGCC invented State Grid Distributed Photovoltaic Cloud Platform (SG-DPCP) in 2018, which is the largest distributed photovoltaic public service cloud platform in China. SG-DPCP solves the key pain points in the photovoltaic power industry, and constructs a new Internet + Distributed photovoltaic mode.

By December 2019, SG-DPCP has connected 1.58 million distributed photovoltaic power stations, its cumulative PV power scale reached 60.53 million kilowatts, and its accumulated contract amount reached 75.4 billion Yuan (¥), moreover, SG-DPCP is serving 852 photovoltaic Manufacturers.

2. Fault analysis of BIPV

BIPV power generation system of is consists of several parts: photovoltaic module, combiner boxe, inverter, transformers and other equipment. The faults of BIPV power generation system mainly come from following aspects: Photovoltaic module fault, Inverter fault, Combiner box fault, Switch fault, as shown in Figure 1.

![Figure 1. Fault types of BIPV power generation system](image1)

3. Fault diagnosis for BIPV power generation system

In use of real time data collected by Edge Computing Terminal, data of Power Consumption Information Collection System of State Grid, SG-DPCP can realize fault diagnosis of BIPV power generation system in following two methods:

According to method 1, we can judge fault state of BIPV power generation system. Method 1 has relative low accuracy, but it has more applications. According to method 2, we can diagnose which specific photovoltaic string has failed.

3.1. Method 1: Fault diagnosis in use of the historical simultaneous data

Comparing historical simultaneous engraving data, we can track and judge fault status of BIPV power generation system in real time. SG-DPCP obtains the power data (once an hour) and generation energy data (once a day) in use of Power Consumption Information Collection System of State Grid.

The power data slice $P_j$ of consecutive $h$ days are shown in Figure 3.
According to the knowledge of probability and statistics, $P_j \sim N(\mu_j, \sigma_j^2)$, the expected mean value $\mu_j = \bar{P}_{ij}$, $P_{ij}$ is a sample of $P_j$. Carrying out a statistical analysis, we get standard deviation $\sigma_j$.

[criterion 1] If $P_j - \bar{P}_{ij} > 2\sigma_j$, we take it for granted that BIPV power generation system broke down in the $i$ day.

[criterion 2] If $P_j > P_{\text{top}}$ or $P_j < P_{\text{down}}$, and $P_{j+1} > P_{j+1\text{top}}$ or $P_{j+1} < P_{j+1\text{down}}$, we take it for granted that BIPV power generation system broke down at the time $j$ in the $i$ day.

3.2. Method 2: Fault diagnosis in use of data analysis of electrical parameters

Edge Computing Acquisition Terminal collects voltage and current data in DC side, voltage, current and power data in AC side of BIPV power generation system, transmits these data to SG-DPCP in real time. SG-DPCP establishes Object Models for the BIPV power generation system to find out fault photovoltaic strings.

Fault diagnosis steps can be described as follows:
1) We compare the power values in the AC side of all inverter branches, find out the abnormal inverter branches, and get the start time and end time of the fault.
2) Analyze the voltage of each phase (A/B/C) in the abnormal inverter’s AC side, and find out the fault phase.
3) Analyze all voltage values and current values in the abnormal inverter’s DC side.
4) Find out the fault string and get the start time and end time of the fault.

4. Test verification
A BIPV power generation system have four inverters SG60KTL, power generated by many photovoltaic strings are inverted and connected to the distribution grid.

(1) Data description of BIPV power generation system
Real time data collected by Power Consumption Information Collection System of State Grid, include the following categories:
- BIPV No.: 1000000107;
- Power generation system No.: 7437844002;
- AC power code: Power;
- line voltage code: UAB, UBC, UCA;
- Phase voltage code: UA, UB, UC;
- Phase current code: IA, IB, IC;
- DC branch current code: PV_I_*;
- DC current code: PV_I;
- DC voltage code: PV_U;
- Measurement point No.: POINT_ID;
- Data collection time: 14:30, June 22, 2018 - 19:15, March 28, 2019.

For the first inverter of BIPV power generation system:
- There are ten photovoltaic strings in the DC side, their measurement point No. are 3173, 3175, 3177, 3181, 3183, 3185, 3189, 3191, 3193 and 3195.
- DC voltage measurement point No.: 3142;
- DC current measurement point No.: 3143;
- DC power measurement point No.: 3057;
- AC A-phase voltage measurement point No.: 3133 and 3139, these two voltage measurement points reflect the same bus voltage;
- AC A-phase current measurement point No.: 3134.
- AC B-phase voltage measurement point No.: 3135 and 3140, these two voltage measurement points reflect the same bus voltage;
- AC B-phase current measurement point No.: 3136.
- AC C-phase voltage measurement point No.: 3137 and 3141, these two voltage measurement points reflect the same bus voltage;
- AC C-phase current measurement point No.: 3138.
- A-phase bus/B-phase bus/C-phase bus of the first inverter, the second inverter, the third inverter and the fourth inverter are parallel connected, after the power is boosted, it will be incorporated into the distribution grid.

Logical relationship between all measurement points of BIPV power generation system is shown in Figure 4 below.
Figure 4. Logical relationship between all measurement points

(2) Data analysis of BIPV power generation system
DC voltages are described in Figure 5.

Figure 5. DC voltage analysis
AC voltage analysis are described in Figure 6, Figure 7, Figure 8. We analyze AC voltage and DC voltage during the period of 5:00:00-20:00:00 on January 1, 2019.

AC voltage arrays of the four inverters are shown in Figure 9 below:

**Figure 6.** A-phase voltage analysis

**Figure 7.** B-phase voltage analysis
Power analysis on the AC side is shown in Figure 9.

According to analyze the power data above, it can be seen that the fourth inverter corresponding to the measurement point No. 3540 went out of action from January 16 to January 22, 2019.

5. Conclusion
SG-DPCP can monitor the all BIPV power generation systems in real time, and have massive historical photovoltaic power data. In use of Big Data analysis technology, SG-DPCP established a mathematical model to diagnose the fault types of BIPV power generation systems accurately. SG-DPCP make contributions to the safety and healthy development of BIPV.
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