Low Voltage Distributed Photovoltaic Power Station
Connected Estimation Model Based on Dispatch Automation System

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Abstract. A large number of distributed photovoltaic access grids pose great challenges to the safe and stable operation of the grid. In view of the fact that the dispatching automation system does not realize the real-time acquisition and monitoring of low-voltage distributed photovoltaic data, this paper proposes the station estimation method as an auxiliary means for real-time acquisition of low-voltage distributed photovoltaic power plants, and estimates the comprehensive low-voltage distributed photovoltaic power plants through appropriate algorithms. Access. Through case analysis, the deviation between the estimated value and the measured value is basically controlled within 8%, which proves the accuracy of the estimated model. This method is of great significance for the power dispatching department to strengthen the operation monitoring and statistical management of distributed photovoltaics, and to reasonably arrange the dispatching plan and coordinate the power supply.

1. Introduction
In recent years, distributed photovoltaic (DPV) is showing explosive growth. By the end of March 2019, the installed capacity of DPV in China has exceeded 53GW [1]. The rapid growth of grid-connected scale of distributed photovoltaic generation has brought many challenges to distribution network planning and safe operation of power grid. After a large number of scattered photovoltaic power stations with different individual capacities are connected to the grid, the grid has gradually changed from the traditional radiation network to an active network with power supply, which increases the complexity of the power grid and brings a series of power quality problems such as harmonic pollution, voltage, frequency jitter and so on [2-3]. At the same time, the characteristics of small and scattered volume of distributed photovoltaic, intermittent and unstable output of photovoltaic power also increase the difficulty of coordinated power supply control and grid operation control.

Faced with many challenges brought by a large number of distributed photovoltaic access to the grid, it is necessary to improve the photovoltaic absorptive capacity of power grids at all levels, rationally arrange dispatching plans and manage photovoltaic power plants, power grid dispatching departments need to make dispatching and maintenance plans according to the power generation curve of photovoltaic power plants, reasonable dispatch of power supply switching, load dissipation and grid maintenance, and further coordinate with grid operators in formulating generation and maintenance
plans, predict potential photovoltaic power plant failures, etc. [4-5]. To this end, distributed photovoltaic data collection and statistical management has been highly valued by the power industry.

At present, the dispatching terminal does not achieve full coverage of distributed photovoltaic data access, and data acquisition is incomplete, low frequency [6-7]. In order to strengthen the data collection and statistical management of distributed photovoltaic, the National Survey Center requires that the distributed photovoltaic data be integrated into the dispatching automation system based on data acquisition methods such as marketing and mining system, national photovoltaic cloud network, wireless public network/private network, etc. If the data access has not been realized, the data access of in-service distributed photovoltaic system can be realized by appropriate algorithm estimation.

As the largest distributed photovoltaic monitoring and operation platform in China, photovoltaic cloud network extracts photovoltaic related data, including basic information of power station, hourly power, power generation and settlement data, by using ETL from marketing basic data platforms of each province. At present, more than 1.2 million distributed photovoltaic power plants have been connected to the national grid for grid-connected settlement and subsidy distribution. At the same time, the photovoltaic cloud network has also built a photovoltaic poverty alleviation information monitoring center to realize the inverter-level access of the national poverty alleviation power station, which is used for real-time data collection of the photovoltaic branch, inverters and other equipment of the poverty alleviation power station, and monitoring and analysis of the operation status of photovoltaic power generation.

2. Estimation model of low voltage distributed photovoltaic power station access

2.1. Estimation principle of area estimation method
Based on the real-time power generation output of photovoltaic power stations connected to high-voltage stations of 10kV and above in dispatching automation system, the power generation curve is fitted to obtain the distributed photovoltaic power generation curve of kW, the unit of installed capacity in this area. According to the installed capacity of low-voltage 380V/220V distributed photovoltaic power station in a 9kM×9kM grid in the same area, the power generation curve of low-voltage distributed photovoltaic power station is estimated. Finally, the measured and estimated values are analyzed to verify the accuracy of the model.

The power station data of photovoltaic cloud network access can be roughly divided into two categories. One is the national photovoltaic poverty alleviation power stations which collect and monitor from the equipment level by optimizing sensor placement. The access data of such power stations are comprehensive, including not only the basic information of photovoltaic power stations, but also the electrical parameters such as current, voltage, active and reactive power collected by shunt boxes and inverters, as well as the Geo-Meteorological information of power stations. Secondly, photovoltaic cloud network reuses the original power communication link, and extracts photovoltaic related data from the marketing basic data platform of each province through ETL, including basic information of power station, hourly power, power generation and settlement related data. The power station data acquired by photovoltaic cloud network through the above two ways belong to the measured value of power station. One is to upload and obtain the relevant data collected by shunt boxes, inverter, environment monitor and other equipment through intelligent collection gateway, data collector and other means such as power wireless private network/wireless public network GPRS, 4G/ NB-IOT etc. Another is the hourly power and power generation extracted from the basic marketing data platform of each network by the ETL program of photovoltaic cloud network for the relevant data of electricity bill settlement.

2.2. Algorithm implementation steps
(1) Power curve of distributed photovoltaic power station in 400V low voltage station area
It is assumed that there is a photovoltaic power station in the 400V low-voltage platform area with an installed capacity of \( N \) kW. The power generation of this photovoltaic power station is collected in real time by the inverter, equal interval collection \( n (n \geq 24) \) times per day, obtain the power sequence
z of this photovoltaic power plant in one day, \( Z = (z_1, z_2, \ldots, z_n) \), using least square method, \( m \)-order fitting the power curve \( z_x \) of this photovoltaic power station:

\[
z_x = \sum_{j=0}^{m} p_j x^j
\]

\[
x_i = \frac{24}{n} \times i, \quad 1 \leq i \leq n
\]

In the middle, \( x \) is the measurement time, and \( x_i \) is the time of the \( i \)th measurement, \( x^j \) is the \( j \)th power of \( x \), \( p_j \) is the \( j \)th order fitting coefficient.

The power information acquisition system collects the information of current, voltage, power and power on the generation side and the grid side of photovoltaic power station through intelligent meters. 96 times a day at equal intervals (15 minutes). The photovoltaic cloud network obtains the power generation information of the photovoltaic power station from the basic marketing data platform of each province through ETL program, and collects \( n \) times every day at equal intervals. Obtaining the power sequence \( Q \) of the photovoltaic power station in one day, \( Q = (q_1, q_2, \ldots, q_n) \), using least square method, \( m \)-order fitting of the power function \( q_x \) of the photovoltaic power station:

\[
q_x = \sum_{j=0}^{m} h_j x^j
\]

\[
x_i = \frac{24}{n} \times i, \quad 1 \leq i \leq n
\]

In the middle, \( x \) is the measurement time, and \( x_i \) is the time of the \( i \)th measurement, \( x^j \) is the \( j \)th power of \( x \), \( h_j \) is the \( j \)th order fitting coefficient.

The generation power curve \( z_x' \) of the photovoltaic power station is obtained by differential calculation of the electric quantity, \( z_x' = \frac{\sum_{a=0}^{m} h_{ja} x^j}{a x} \), this curve can be approximately regarded as the real-time power curve of the power station.

(2) Parametric modeling of real-time data for 10kV photovoltaic power station

It is assumed that there is a photovoltaic power station with a 9kM×9kM grid in the same area of the 10kV high voltage station, and the installed power is \( M \) megawatts. The dispatching automation acquisition system collects the data of this photovoltaic power station \( n \) times a day. Obtain the real-time generation power sequence \( Y \) of the station area within one day, \( Y = (y_1, y_2, \ldots, y_n) \), using least square method, \( m \)-order fitting of power function curve \( y_x \) of photovoltaic power generation in this area:

\[
y_x = \sum_{j=0}^{m} k_j x^j
\]

\[
x_i = \frac{24}{n} \times i, \quad 1 \leq i \leq n
\]

In the middle, \( x \) is the measurement time, and \( x_i \) is the time of the \( i \)th measurement, \( x^j \) is the \( j \)th power of \( x \), \( k_j \) is the \( j \)th order fitting coefficient.

Therefore, it is estimated that the power function of the installed capacity of \( N \) kW photovoltaic power generation on the same day in the same area of the low-voltage station is \( j_x \):

\[
j_x = N \times \frac{\sum_{a=0}^{m} p_j x^j}{M \times 1000}
\]

Through the error analysis of \( j_x \) two \( z_x/z_x' \), the correctness of the low-voltage distributed photovoltaic power station access estimation model is verified by the verification of the station area estimation method.
3. Case analysis
For example, the installed capacity of a photovoltaic power station in Hengshui 10kV high voltage station area of Hebei Province is 1.582 MW. Communicate with the inverter through the Modbus protocol to collect the relevant operation information of the power station [9], collected every 15 minutes. Take August 13, 2018 as an example, its real-time power data is shown in Figure 1:

![Figure 1. Actual measured value and fitting curve of a photovoltaic power station in a 10kV high voltage station](image)

The same area 9kM × 9kM grid has a 400V low-voltage station area distributed photovoltaic power station with an installed capacity of 5kW. The electricity information of the photovoltaic power station can be obtained by the inverter, and is collected every hour. On August 13, 2018, the real-time power curve of this photovoltaic power station is shown in Figure 2:

![Figure 2. Measured power and fitting curve of a photovoltaic power station in 400V low voltage station](image)
The real-time power of the distributed photovoltaic power station in the low voltage 400V area shown in Figure 2 is differentiated and its real-time power curve is obtained in Figure 3, the curve can be approximated to the measured real-time power of the distributed photovoltaic system. For comparison, the real-time power of a 5kW distributed photovoltaic power plant with the same area of 9km × 9km grid estimated based on the 1.582MW photovoltaic power station in the 10KV high-voltage station area is also shown in Figure 3.

![Real-time power curve comparison](image)

**Figure 3.** Comparison of measured and estimated values of power generation of a photovoltaic power station in 400V low voltage station area

By comparison, it is found that the error between the estimated and measured values of 5kW distributed power plants is small, the trend of the curve is roughly identical. The maximum error is 8% at about 15 o'clock, which is within the allowable error range, thus confirming the accuracy of the estimation model.

### 4. Conclusion

A large number of distributed generators are connected to the power grid, which brings a great test to the safe and stable operation of the power system. Therefore, it is urgent to strengthen the operation monitoring of distributed generation, power statistics and power dispatching management of dispatching automation system. Different from centralized photovoltaic power stations, there is relatively little automation information for power distribution dispatching agencies on distributed photovoltaic power plants. The grid-connected devices are used to sample voltage, current, active power, reactive power and other information through grid-connected devices. The main protocols such as Modbus and IEC-103 are used to collect operation information of inverters, power quality detection devices and environmental monitoring devices, simultaneously receive and execute remote control and remote adjustment commands issued by the power dispatching agency master station system.

For 380V/220V low-voltage distributed photovoltaic power plants with small installed capacity, the station area estimation method is used as an assistant means of real-time data acquisition. In the allowable error range, the management of dispatching automation system with 380V/220V distributed photovoltaic full access can be realized. In areas with large scale of distributed photovoltaic and more than 25% of distributed photovoltaic permeability, the corresponding power dispatching departments also need to equip with optical power prediction, active and reactive power control, power monitoring and other functions.
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