Design of Remote Monitoring System for Substation DC Power Supply under the Background of Big Data

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Abstract. The DC power supply (DPS) system is an important part of the substation. In order to adapt to the current unmanned operation and maintenance mode of the substation and the new requirements of state maintenance and management, it must develop in the general direction of digitalization, programming and intelligence. To ensure the safety and stability of the new operation and maintenance mode of the power system. Through the design and application research of the DPS remote monitoring system of the substation, the real-time data collection of the domestic DPS device is realized, the collected data information is summarized, and the cooperation of the remote control center and related operation and maintenance management teams is requested. The management software effectively analyzes the collected equipment operating parameters and real-time data, extracts fault information and hidden dangerous data required for operation and maintenance, which is helpful for the scientific management and risk prediction of DC power equipment in substations. The operation and maintenance personnel and the DPS system of the substation ensure the operation in a high-quality and healthy state and the safe and stable operation of the entire power network. This paper studies the design principle, structure and function of the DPS remote monitoring system used in the substation. On this basis, in-depth study of battery voltage equalization technology, internal resistance measurement technology and other core technologies related to DPS remote monitoring system design. In order to realize the online monitoring, analysis and diagnosis of the operation information data of DPS devices such as remote charging and discharging operation safety management strategy, DC power information collection and communication network design, the theoretical and technical foundations have been formulated.

Keywords: Big Data, Substation DC Power Supply, Remote Monitoring, System Design

1. Introduction
As the power supply equipment of the secondary equipment in the substation, the DPS equipment is the source of the working power source such as the relay protection, automatic device, circuit breaker
tripping and closing control circuit and emergency lighting in the station. Its health can be said to directly affect whether the entire substation and even the power grid can operate safely and stably [1]. The consequences of a DC power failure in the station are unimaginable, and the resulting protection failures and switch refusal to operate are likely to lead to large-scale blackouts. The need for comprehensive, real-time remote monitoring and intelligent management of DC power equipment in substations has become very urgent [2-3]. The DPS remote monitoring system of the substation performs comprehensive real-time remote monitoring and intelligent management of the DC system in the 220kV and 110kV substations. It can monitor the operating data of all DC power equipment in the substation online in real time, automatically judge its operating status and determine which affects the safety of the power grid. The factors of stable operation can predict the possible failures of DPS equipment in advance, which can not only minimize the failure rate of DPS equipment in substations, but also reduce manpower input and increase labor productivity [4]. This is of great practical significance for improving the intelligence and automation level of substations, and improving the operation, maintenance and inspection modes of DC equipment in substations [5]. Recently, unmanned substations have become the general trend and general direction of the operation and maintenance mode of power grids. The remote monitoring system of the DPS devices of substations will become a solid technical foundation for unmanned substations.

DPS plays a very important role in the power system. In hydroelectric power plants, nuclear power plants and other power plants, metallurgical industries and coal chemical companies in substations, DPS devices are used as starting power supply devices for switches and circuit breakers, protection, control and signal equipment and power supply equipment [6]. In the power system, the DPS device generally refers to the power supply system composed of batteries, frequency converters and other auxiliary circuits [7].

In the field provided by DPS devices, in order to operate stably, DPS devices are required, and higher requirements can be easily adjusted during operation and can be remotely monitored [8]. Current status of the DC power system in substations: On the one hand, the diversity of DC power charging module manufacturers leads to inconsistent communication protocols. If there is a problem with the equipment, the DC power system defect cannot be eliminated in time. The removal of the manufacturer's location, manpower, cost, etc. of the manufacturing company will lead to hidden dangers in the safe operation of the substation [9]. On the contrary, due to the low importance of the DPS system of the substation, a lot of DC information leads to the background of incomplete monitoring of the DPS system of the substation [10]. These factors increasingly limit the intelligence, safety and reliability of substation operations.

2. Particle Swarm Optimization Algorithm
The particle swarm optimization algorithm can be regarded as a kind of bionics algorithm. The origin of this algorithm is the predation behavior in the bird population. In the process of foraging for food, the initial state of each bird is in a random position, and the direction of flight is also random. Every bird does not know where the food is, but over time, these birds initially in random positions learn from each other in the group, share information, and individuals continue to accumulate the experience of finding food, and spontaneously organize and accumulate into a community. And gradually move towards the only goal-food. Each bird can use certain experience and information to estimate how valuable its current position is for finding food, that is, how much fitness; each bird can remember the best position it has found, which is called the local maximum Excellent (p best). In addition, it can also remember the best position that all individuals in the flock of birds can find, which is called the global optimum (g best). The foraging center of the entire flock of birds moves toward the global optimum, which is called in biology For the "synchronization effect". Through the continuous movement of the bird flock's foraging position, that is, continuous iteration, the bird flock can be stepped towards the food. The particle swarm algorithm designs particles without mass to simulate individuals in a new group. Through the big data analysis of the characteristics of the DPS device of the substation, finding the best substation DC power monitoring system is inseparable from the
support of this algorithm.

Update rules:

Initialized as a bunch of random solutions. Then through continuous replacement to the best solution. In each change, the particles are updated by tracking two "extreme" (pbest, best). The particle uses the following formula to update its velocity and position.

\[ v_i = v_i + c_1 \times \text{rand()} \times (pbest_i - x_i) + c_2 \times \text{rand()} \times (gbest_i - x_i) \]  

\[ x_i = x_i + v_i \]  

In formulas (1) and (2), \( i = 1, 2, \ldots, N, N \) is the total number of particles in this group. 

\( v_i \) is the velocity of the particle 

\( x_i \) is the current position of the particle 

\( c_1 \) and \( c_2 \) are learning factors, usually \( c_1 = c_2 = 2 \)

The maximum value of \( v_i \) is \( V_{\text{max}} \) (greater than 0), if \( v_i \) is greater than \( V_{\text{max}} \), then \( v_i = V_{\text{max}} \)

Formulas (1) and (2) are the standard form of PSO

\[ v_i = \omega \times v_i + c_1 \times \text{rand()} \times (pbest_i - x_i) + c_2 \times \text{rand()} \times (gbest_i - x_i) \] (3)

\( \omega \) is called the inertia factor and its value is negative.

At present, the strategy of linearly decreasing weight is more adopted.

\[ \omega(t) = (\omega_{\text{ini}} - \omega_{\text{gnd}})(G_k + g) / G_k + \omega_{\text{gnd}} \] (4)

There is also a common \( \omega \) which is a linearly decreasing weight. The formula for the change of \( \omega \) with \( k \) is:

\[ \omega = \omega_{\text{max}} - k \times \frac{\omega_{\text{max}} - \omega_{\text{min}}}{N_{\text{iter}}} \] (5)

Among them, \( \omega_{\text{max}}, \omega_{\text{min}} \) represent the maximum and minimum values of \( \omega \), respectively.

When generating new particle motion speeds, in order to avoid particles easily exceeding the search range \([x_{\text{imin}}, x_{\text{imax}}]\), during iteration, the particle speed must satisfy \( v_{\text{id}} \in [v_{\text{imin}}, v_{\text{imax}}] \) and have the following relationship:

\[ \begin{align*}
    v_{\text{imin}} &= \chi(x_{\text{imax}} - x_{\text{imin}}) \\
    v_{\text{imax}} &= -v_{\text{imin}}
\end{align*} \] (6)

In the formula, \( \chi \) is the speed limit coefficient and satisfies \( \chi \in [0, 1] \).

Individual optimal position \( p_{\text{best}} \) and population optimal position \( g_{\text{best}} \).

\[ p_{i_{\text{id}}}^{k+1} = \begin{cases} 
    x_{i_{\text{id}}}^{k+1} & \text{fit}(x_{i_{\text{id}}}^{k+1}) < \text{fit}(p_{i_{\text{id}}}^{k}) \\
    p_{i_{\text{id}}}^{k} & \text{other}
\end{cases} \] (7)

\[ G_d = \min\{p_{1_{\text{id}}}^{k}, p_{2_{\text{id}}}^{k}, \ldots, p_{M_{\text{ld}}}^{k}\} \] (8)

3. Remote Monitoring System Model

Due to the imperfections in the design of the traditional DPS remote monitoring system of the substation, it cannot meet the current detection of the DPS system information of the substation in many aspects, and cannot effectively use all the original equipment information related to the DPS. The accuracy of substation system identification is not accurate enough. Therefore, the establishment of a new model for remote monitoring of DPS systems in substations based on big data is of great help to the industry upgrade of my country’s power industry. Thanks to the optimization brought by computer algorithms, the network analysis method can combine big data technology and traditional
remote monitoring technology of substation DC power. The establishment and application of this model will promote the technical improvement of the remote monitoring system for DPS in substations. This paper proposes a technology based on the combination of big data technology and traditional substation DPS remote monitoring technology. The combination of the two forms a better remote monitoring effect, making the detection effect more accurate and efficient. The combination of big data technology and objective function is transformed into a least squares estimation problem:

\[ \{z(t)\} = [U]\{Y(t)\} \] (9)

The response is

\[ \{Y(t)\} = \int_0^t [h(t - \tau)]\{F(\tau)\}d\tau \] (10)

Given that \( Y(t) \) is the feature vector detected by artificial intelligence, the algorithm formula can be listed as follows:

\[ Y_j(t) = -m_j^{-1}\int_0^t e^{\lambda(t - \tau)}\{V_j\}^T\{f(\tau)\}d\tau \] (11)

In order to ensure the rationality of the weights, the consistency check of the comparison and judgment algorithm is compared, and the utilization rate of the remote monitoring system distribution of the DPS of the substation can be expressed as

\[ x_{ob} = \sum_{j=1}^{5} u_{bj} Y_j(t) \] (12)

\[ x_1 = \sum_{j=1}^{5} F_{uj} Y_j(t) \] (13)

Through the clustering and integration of index parameters, the corresponding resource allocation plan is compiled, thereby realizing the optimization of the remote monitoring system of the substation DPS.

4. Evaluation Results and Research

4.1. Balance Effect

Figure 1 shows the cell voltage data without the equalization function:

DPS remote monitoring system single battery report.

![Figure 1. Voltage data without equalizing effect](image)

Minimum voltage: 2.254V, maximum voltage 2.277V, average voltage: 2.264V.

At this time, the highest voltage of the battery pack is 16#2.277V, the lowest voltage is 14#2.254V,
the difference is 23mV, and the normal float voltage should be between (2.23, 2.28)V, so the battery higher than 2.28V will be in the long-term. The overcharge state will cause the performance of individual batteries to decline over time, thereby affecting the discharge capacity of the positive battery.

Figure 2 shows the cell voltage data with the equalization function turned on:

![Figure 2. Effect picture after turning on equalization](image)

The lowest voltage: 2.262V, the highest voltage: 2.268V, and the average voltage: 2.264V.

Table 1 shows the test results of the A power company's pilot statistics. The test time is October 2012. The test process only needs to switch the status at the monitoring station and observe the operating data while performing 3 pilot operations. The overall operation is simple and time-consuming.

| Project's Venue     | DPS Information                          | Test Count | Whether There is a Failure |
|---------------------|------------------------------------------|------------|----------------------------|
| A power station     | Two storage and two charging             | 4          | no                         |
| B power station     | Two storage and two charging             | 4          | no                         |
| C power station     | Single charge, single charge             | 4          | no                         |

It can be seen from the table that the battery capacity remote monitoring test is safe and reliable and requires a staff member to operate it. Compared with the calculation of 16 discharges, a staff member has to go to the site 16 times manually, which saves a lot of time and labor cost 30 times during the entire operation.

5. Conclusion
The remote monitoring system of the DPS of the substation can monitor the operating status of the DC charger, battery pack voltage, internal resistance and capacity, control bus voltage, close bus voltage, blood switch status and other important power characteristic parameters in real time. Battery discharge and online balance, DC equipment operation experience query, equipment abnormality report and other functions, reasonable design, complete functions, familiar interface, simple operation, etc.; this application can save and improve many manpower and material resources, and improve work efficiency, extension of normal battery life, safety of the DPS system, improvement of stability and
automation, and standardization and remoteization of the operation and maintenance of DPS devices play an important role in ensuring safety and stability.

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