Design of Substation Battery Condition Monitoring System Based on SDH Network

Feng Xu(✉), Quan Zi, Chen Zhao, Nannan Wang, and Yan Wang

Suzhou Power Supply Company, Suzhou 23400, China
19166586244@163.com

Abstract. In the process of substation battery condition monitoring, because the status parameters are real-time fluctuations, resulting in relatively large errors in the monitoring results, this paper proposes the design and research of substation battery condition monitoring system based on SDH network. TW-SDH6000 is used as the hardware device of the substation battery condition monitoring system. In the software design phase, the SDH network is used to simulate and process the battery resources, so that when the relevant equipment in the substation is abnormal and the battery status fluctuates, the self-healing function can be used to filter this part of data. In the condition monitoring phase, the PCA method is used to reduce the dimension of the original data, and Pearson correlation coefficient is used to analyze the relationship between the original data and the simulation processing results. Realize accurate monitoring. In the test results, the error of the design method for the monitoring results of battery voltage amplitude, input frequency and coil proportion is significantly lower than that of the control group.

Keywords: SDH Network · Substation Battery · Condition Monitoring · TW-SDH6000 · Simulation Processing · Self-Healing Function · Pca Method · Pearson Correlation Coefficient

1 Introduction

The maximum usable capacity that the battery can release as a backup power supply is the most important indicator. It can be seen from the definition of the state of health (SOH) of the battery that under certain discharge conditions, its value is the ratio [1] of the capacity released by the battery from the full state at a certain rate to the cut-off voltage and its corresponding nominal capacity. Therefore, the maximum usable capacity of the battery is directly related to its SOH value. However, SOH can be directly measured and displayed [2], unlike the amount of fuel in a household car, because there is no exact parameter that is proportional to the health status of the battery, and the health status depends on the comprehensive evaluation and estimation of multiple time-varying parameters of the battery [3]. Research on battery SOH estimation methods can be roughly divided into three categories: traditional offline method, data driven method and fusion model method. The traditional off-line method is to measure the terminal

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voltage, discharge current, temperature and other basic physical electrical quantities [4] of the battery for off-line large current discharge, and establish a mathematical model based on various physical parameters using statistical model identification method [5, 6]. The offline method mainly includes internal resistance folding algorithm, capacity attenuation method, partial discharge method, impedance analysis method [7], etc. Therefore, the off-line method is not widely used at this stage and is only applicable to theoretical research in the laboratory. The data driven method can be adaptive to meet the changing system parameters, with excellent real-time performance, good robustness and high precision. Data driven methods mainly include Kalman filter, support vector machine (SVM), correlation vector (RVM) and artificial neural network (ANN) [8]. The estimation principle of the data-driven method is relatively simple, and it does not need to pay attention to the complex degradation mechanism inside the battery. The estimation principle of the fusion model method is relatively complex. The circuit model and digital drive fusion method not only focus on the complex degradation mechanism inside the battery [9], but also need to learn the historical data from the perspective of the historical degradation data of the battery in the subway power supply system with the help of machine learning algorithm to estimate the parameters of the circuit degradation model. Combined with the high accuracy of the circuit model, the battery SOH is evaluated [10]. At present, the fusion model method, which is a new SOH estimation method integrating several battery models or estimation methods, is more and more important in practical situations. Its purpose is to maximize the use of the advantages of two different models to overcome their shortcomings, so as to improve the estimation accuracy [11].

At this stage, there have been some achievements in the estimation of battery SOH, but there are still many problems, because most of the time when the battery pack is in standby, it is connected in parallel with the charging device for trickle charging. The battery with a service life of less than five years has only been discharged for two years. If the power supply system is not powered off, the battery will never be discharged. However, most of the existing online monitoring systems rely on floating charge information for health assessment, which has a large error or even no reference. Or the battery needs to be discharged in depth offline, but the reliability and safety of power supply cannot be guaranteed when the battery capacity is less than 80%.So how to use shallow discharge or even floating charge to evaluate the battery performance is the difficulty of the current online detection technology.

On this basis, this paper proposes the design and research of the substation battery condition monitoring system based on SDH network, and carries out targeted design from both hardware and software perspectives, and analyzes the application performance of the design system. To solve the problem of low reliability of monitoring data, TW-SDH6000 is used as the main hardware equipment for data transmission, SDH network is used to filter battery resources, PCA method is used to reduce the dimension of original data, and the problem of large errors in monitoring results caused by high data complexity is solved. Accurate monitoring of battery status parameters is completed through Pearson correlation coefficient.

2 Hardware Design

The substation battery condition monitoring system designed in this paper is based on SDH network. Therefore, it is necessary to set up a reliable SDH optical transceiver device according to the actual needs. Therefore, TW-SDH6000 is used as the SDH optical transceiver of the system in this paper.TW-SDH6000 is a new generation open MSAP integrated service access platform. SDH group channel optical port rate supports STM-1, STM-4 levels, and can be smoothly upgraded to STM-16 level. It has the bidirectional bearing capacity of SDH/MSTP transmission network and IP MAN, supports SDH and Ethernet independent bus architecture, and can truly achieve high reliability integrated service access and transmission.

The TW-SDH6000 has powerful slot crossing and IP data exchange capabilities, which can realize flexible scheduling of various services, and perfectly realize the access and convergence of traditional E1 services, optical branch services, EOS/EOP services and other services; Provide complete service protection capability and provide customers with stable transmission lines; It supports multiple network topologies and can meet the application requirements of complex networks; It has a comprehensive and intelligent management platform, which can realize end-to-end monitoring and management of business [12]. It is widely used in the field of large customer dedicated line access, base station interconnection and video monitoring. After analyzing the characteristics of TW-SDH6000, its structure configuration is shown in Table 1.

Table 1. TW-SDH6000 Equipment Structure Configuration

Category	Board name	Model	Brief description	Insertable slot
SDH uplink	STM-4 Optical cluster road panel	CU622	Two × STM-4, built-in cross connection and SET functions	5, 8
	STM-1 Optical cluster road panel	CU155	Two × STM-1, built-in cross connection and SET functions	5, 8
Ethernet Core convergence	Ethernet Core aggregation disk	CUGE4A	Two × GX + 2 × GE supports port VLAN and 802.1QVLAN and link aggregation Trunk function. The 1000M Ethernet data of up to 9 service slots can be aggregated	6, 7

The overall structure of TW-SDH6000 is displayed as a 19 inch 7U plug-in box with 16 card slots; LVDS has no clock wiring backplane, SDH and GE independent bus structure. It can be seen from the information shown in Table 12 that the TW-SDH6000 has a dual SDH cluster board, dual Ethernet core convergence board, dual network management board, and dual power supply board structure, so it is safer and more reliable in the operation phase.

The configuration of SDH group service of TW-SDH6000 is analyzed, as shown in Table 2.

Table 2. SDH Group Service Configuration of TW-SDH6000 Equipment

Board name	Model	Brief description	Insertable slot
E1 mapping disk	E1-16	16 channel E1, optional 75 Ω or 120 Ω	1–4, 6–7, 9–11
STM-1 Optical branching board	TU155-8	Eight × STM-1, built-in cross connection function.VC12 full crossing is supported in the board	1–4, 6–7, 9–11
EoS Optical access panel	EoS-8FX8	Eight × FX, 8VCG physical isolation, EoS, GFP/LCAS/VCAT, flow control, TS1000 protocol	1–4, 6–7, 9–11
EoS Electric access panel	EoS-8FE8	Eight × FE, 8VCG physical isolation, EOS, GFP/LCAS/VCAT, flow control	1–4, 6–7, 9–11
EoP Optical access panel	EoP-8FX8	Eight × FX, 8VCG physical isolation, EoP, GFP/LCAS/VCAT, multiple E1 converter mode; HDLC package, single E1 converter mode;TS1000 protocol	1–4, 6–7, 9–11
EoP Electric access panel	EoP-8FE8	Eight × FE, 8VCG physical isolation, EoP, GFP/LCAS/VCAT, multiple E1 converter mode; HDLC package, single E1 converter mode;	1–4, 6–7, 9–11

According to Table 2, the TW-SDH6000 equipment can provide up to four STM-4 or STM-1 group optical interfaces; LC type SFP optical transceiver module is used for group optical ports, which can support hot plug; Maximum cross capacity is 32VC4 × 32VC4、96TU-3 × 96TU-3、2016VC12 × 2016VC12. In addition, the TW-SDH6000 device also supports 1 + 1 cluster board card protection to achieve hot backup of cluster, crossover, and clock modules, as well as single/double end 1 + 1 linear multiplex section protection and SNCP protection, which can maximize the connection requirements of point-to-point, chain, ring and other topologies.

The configuration of Ethernet core switching service of TW-SDH6000 equipment is analyzed, as shown in Table 3.

It can be seen from Table 3 that the TW-SDH6000 device supports up to 4 gigabit optical ports and 4 gigabit electrical ports in terms of Ethernet core switching service configuration; Each disk can independently aggregate data from nine gigabit Ethernet ports on the backplane.

Table 3. Ethernet core switching service configuration of TW-SDH6000 equipment

Board name	Model	Brief description	Insertable slot
EoP optical access convergence disk	EoP-8FX8A	Eight × FX, 8VCG, EoP, GFP/LCAS/VCAT, multiple E1 converter mode; HDLC package, single E1 converter mode; Support switching function	1–4, 6–7, 9–11
EoP power access convergence panel	EoP-8FE8A	Eight × FE, 8VCG, EoP, GFP/LCAS/VCAT, multiple E1 converter mode; HDLC package, single E1 converter mode; Support switching function	1–4, 6–7, 9–11
EoS service convergence disk	EoS-16GE2A	One × Combo port + 1 × GE port + 1 × FE test port.16 VCGs; Board convergence ratio: 16:1;Port VLAN and 802.1QVLAN support QinQ. Support GFP/LCAS/VCAT	1–4, 6–7, 9–11
EoP business Convergence disk	EoP-16GE2A	One × Combo port + 1 × GE port + 1 × FE test port.16 VCGs; Board convergence ratio: 16:1;Port VLAN and 802.1QVLAN support QinQ. Support multiple E1 or single E1 conversion mode. It can support GFP and HDLC packaging structures	1–4, 6–7, 9–11

In addition, in terms of multiple branch service configurations, the TW-SDH6000 device supports the access and convergence of downlink SDH optical branch, E1, EOS, EOP and other branch services. With such settings, it can be interconnected with remote Ethernet optical transceiver, protocol converter, SDH optical termination and other products. At the same time, the TW-SDH6000 equipment also supports 1 + 1 channel protection and built-in E1 bit error tester test function, which maximizes the stability and reliability in the operation phase. Combine application requirements in different environments. The TW-SDH6000 device is designed specifically for the timing function. It can track the timing source of group optical ports, external synchronous timing source and branch timing source, provide it with external synchronous timing source output, and support automatic or forced selection of timing source, as well as four timing modes of free oscillation, tracking, locking and maintaining.

Finally, the configuration of TW-SDH6000 equipment management is shown in Table 4.

Table 4. TW-SDH6000 Device Management Configuration

Category	Board name	Model	Brief description	Insertable slot
Snap in	Network management panel	NMU7000	The dual network management disks are backup to each other, providing system management functions and supporting network management cascading	12, 13
Power Supply	DC power panel	RPW300DC	Dual power redundant backup	14, 15
	AC power panel	RPW300AC		14, 15

With the help of the management configuration shown in Table 4, the TW-SDH6000 device can provide equipment rack top alarm output, and support the DCC management channel and the built-in DCN network management channel. In SNMP_V1 and SNMP_Under the V2 protocol, it can be used with the RayView network management platform of C/S architecture to realize the online software upgrade function of local device boards and remote devices.

3 Software Design

3.1 Simulation Processing of Battery Resources Based on SDH Network

In order to reasonably show the structure of the power SDH communication network to users, observe the impact of faults on the SDH network, the impact on the circuit carrying service, and the recovery process of the circuit to the service, the author determines the functional requirements, network resource simulation requirements, and network behavior requirements of the power SDH communication network self-healing simulation system through the research on the self-healing mode of the power SDH communication network. SDH network operation and maintenance personnel apply self-healing simulation in the simulation system in the following ways, as shown in Fig. 1.

(1) Configuring the SDH network includes setting and removing the connection of devices and logical ports; Configuration of cross connection in the circuit; The configuration of the power protection group and the configuration of the circuit carrying the services.
(2) Simulate and repair the accident, observe the impact of the accident on the business in the SDH network, and get the alarm reported by the corresponding equipment after the accident. Realize the repair of the accident, eliminate the impact of the accident on the SDH network, and eliminate the corresponding alarm after the accident is repaired.
(3) SDH network self-healing application: the system receives the incentive of service failure and network failure, and completes network self-healing through protection, so as to recover services.

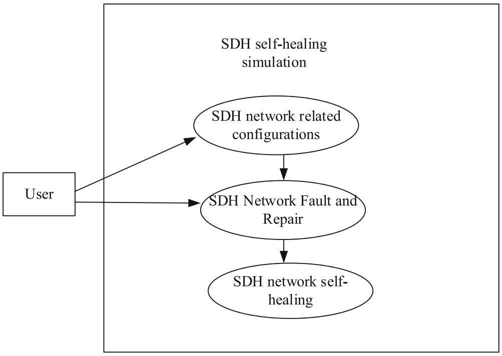

Fig. 1. SDH network self-healing simulation function implementation mode

Figure 2 is the structure diagram of battery resource model based on SDH network.

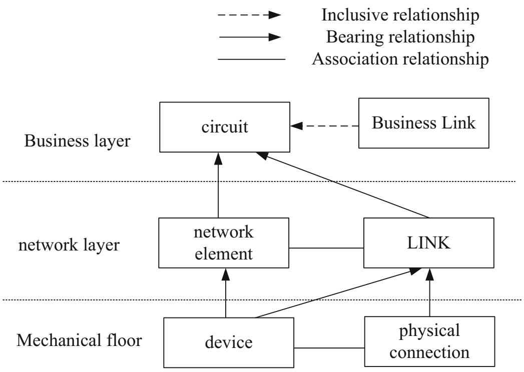

Fig. 2. Structure of battery resource model based on SDH network

As shown in Fig. 2, the network resource model required for self-healing simulation of power SDH communication network can be divided into three levels of equipment, network and service for modeling. The device layer mainly models the information of the physical network composed of physical devices and physical connections; The network layer mainly models the information of the topological network composed of logical network elements and logical links; The service layer is mainly used to model the information of the service network composed of the service link and the circuit carrying the service link.

Based on the condition monitoring of the battery in the substation, the self-healing simulation function of the power SDH communication network is mainly divided into the following three parts:

(1) Simulation of equipment layer resources and their status changes caused by faults, including resource simulation of infrastructure sites in SDH network and resource simulation of physical connecting optical cables in SDH network.

(2) The simulation of network layer resources and the simulation of their state changes caused by faults, including the resource simulation of transmission system, SDH equipment, logical port, multiplex section, time slot, cross connection and protection group in SDH network.
(3) Simulation of business layer resources and corresponding alarm generated due to accident; Resource simulation of circuit, circuit protection relationship, service and service group.

On this basis, in the resource management phase, the self-healing simulation function of the power SDH communication network needs to meet the demand for SDH network simulation. The resource management mainly completes the creation and deletion of the topological network composed of logical network elements and logical links. The basic behavior settings of SDH transmission can be expressed as.

$$s(x) = \sum [d_i(s), c_i(s)] \tag{1}$$

Among them, $s(x)$ Indicates the basic behavior of SDH transmission, $d_i(s), c_i(s)$ Indicates deletion and modification actions with transmission SDH as the core, including adding transmission system and setting transmission system related information; Modify the information related to the transmission system and delete the transmission system, and delete the station, device, port, cross connection, time slot and other information in the transmission system in cascade. The basic behaviors of the site include adding sites and setting site related information; Modify the relevant information of the site and delete the site, and cascade delete the device port, cross connection, time slot, connection with other sites and other information in the site.

For the basic behavior of optical cables, the specific settings can be expressed as.

$$l(x) = \sum [d_i(l), c_i(l)] \tag{2}$$

Among them, $l(x)$ Represents the basic behavior of the optical cable, $d_i(l), c_i(l)$ Indicates the deletion and modification actions with optical cable as the core, including adding optical cable, and setting the information such as the initial site and type of optical cable; Modify the optical cable, set the initial site and type information of the optical cable, and delete the optical cable.

For the basic behavior of the SDH equipment TW-SDH6000, the specific settings can be expressed as.

$$S(x) = \sum [d_i(S), c_i(S)] \tag{3}$$

Among them, $S(x)$ Represents the basic behavior of TW-SDH6000, $d_i(S), c_i(S)$ Indicates the deletion and modification actions with TW-SDH6000 as the core, including adding SDH equipment and setting the corresponding information of SDH equipment; Modify the corresponding information of the SDH device, delete the SDH device, delete the connection information between the SDH device and the power supply device, and cascade delete the port, cross connection, time slot and other information on the SDH device.

According to the way shown above, the design of battery resource simulation processing operation is realized based on SDH network.

3.2 Substation Battery Condition Monitoring

PCA (Principal Component Analysis) is the most commonly used linear dimension reduction method [13, 14]. The main measure of PCA dimension reduction is the maximum value of data variance after coordinate transformation. When the square difference is the largest, the dimension of the transformed coordinate axis is lower, but the original data information is relatively perfect. Principal component analysis (PCA) is a dimensionality reduction method that retains the most original data information. In the stage of substation battery condition monitoring using battery resource simulation processing data in SDH network, the data dimension is reduced first. Let the n-dimensional vector be a coordinate axis direction of the target subspace (called the mapping vector), maximize the variance after data mapping, and have

$$\max_{W}\frac{1}{m-1}(\sum W^{T}(X_{i}-\overline{X}))^{2} \tag{4}$$

Among them, m Is the number of data instances of battery resource simulation processing in SDH network, X_i Is the vector representation of data instance i, $\overline{X}$ Is the average vector of all data instances. It is defined as a matrix containing all mapping vectors as column vectors. After linear algebraic transformation, the following optimization objective function can be obtained

$$\min_{W} tr(W^{T}AW), s.t.W^{T}W = I \tag{5}$$

Among them, tr Represents the trace of the matrix, A Is the data covariance matrix, which can be expressed as

$$A = \frac{1}{m-1}\sum (X_{i}-\overline{X})(X_{i}-\overline{X})^{T} \tag{6}$$

Easy to get the best W Is determined by the data covariance matrix k It is composed of the eigenvectors corresponding to the largest eigenvalues. These eigenvectors form a set of orthogonal bases and best retain the information in the data. PCA output Y Can be expressed as

$$Y = W'X \tag{7}$$

from X The original dimension of is reduced to k Dimension. PCA seeks to maximize the internal information of the data after dimensionality reduction, and measure the importance of the projection direction by the size of the data variance in the projection direction. Principal component analysis is to condense data and condense multiple indicators into several unrelated general indicators (principal components), so as to achieve the purpose of dimension reduction.

The relationship between the characteristic parameters obtained after dimensionality reduction by PCA and the status data after simulation processing of battery resources in SDH network is unknown, so the dimensionality reduction is directly used.

It is unreasonable to use the parameters of as the input of the health evaluation model to evaluate the state data, so the dimension reduced feature.

The correlation coefficient between the characteristic data and the state data is determined, and the characteristic parameters that meet the linear relationship are extracted as the health factor input of the model to obtain the state data value. In this paper, Pearson correlation coefficient is used as an evaluation index to measure the degree of correlation between each group of data, which is calculated by the product difference method. Based on the deviation between the two groups of data and their respective average values, the correlation between the two variables is reflected by multiplying the two deviations. Pearson correlation coefficient is defined as the quotient of covariance and standard deviation between two variables, which can be expressed as

$$\begin{aligned}\rho_{X,Y} &= \frac{\operatorname{cov}(X, Y)}{\sigma_X \sigma_Y} \\ &= \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y}\end{aligned} \tag{8}$$

Among them, $\rho_{X,Y}$ The Pearson correlation coefficient between the status data after simulation processing of battery resources and the ideal value, σ_X and σ_Y Represent the covariance of characteristic parameters that meet the linear relationship, μ_X and μ_Y Represent the covariance of the characteristic parameter covariance satisfying the linear relationship respectively. The Pearson correlation coefficient is [–1,1], and the degree of correlation between data is determined by ρ the absolute value of reflects that the larger the absolute value is, the higher the correlation between data X and Y. It should be noted that the correlation coefficient can be defined only when the standard deviation of two variables is not zero.

In this way, according to the correlation between X and Y, combined with the simulation results of battery resources in SDH network, the monitoring of battery status parameters is realized.

4 Test Analysis

4.1 Experimental Platform Setting

In the experimental demonstration phase, simulation experiments are mainly used to determine the feasibility of the scheme. The simulation experiments are mainly based on MATLAB tools. MATLAB is mainly used for data analysis, calculation and model simulation. Its main feature is that it has strong data operation and processing capabilities, and can realize matrix operation, fourier transform and optimization algorithms. Simulink is a visual simulation tool in MATLAB, which supports system design simulation and automatic code generation, while providing graphics editor, result export and other functions, its main function modules are as follows:

(1) Continuous module: mainly including calculus kernel function model;
(2) Discrete module: mainly including integrator filter;
(3) Function & Tables: mainly including function calls and user-defined functions;
(4) Math module: mainly including common mathematical operation module;
(5) Receiver module (Sinks): mainly including oscilloscope and other graphic display modules;

(6) Input source module (Sources): mainly includes some signal generation modules, such as sine signal generator.

The specific experimental process is as follows:

Step 1: Use TW-SDH6000 as the hardware equipment of the substation battery condition monitoring system;

Step 2: Use SDH network to simulate and process battery resources, and use self-healing function to filter some data;

Step 3: Reduce the dimension of the original data by PCA method;

Step 4: Use Pearson correlation coefficient analysis and process the relationship between the results to achieve accurate monitoring.

The experimental platform is mainly based on the signal generator, sensor, lock-in amplifier and battery. The core material of the sensor is nanocrystalline. As a new soft magnetic material, nanocrystalline material has high permeability and wide frequency characteristics, and has high inductance, small size, good filtering effect, and good thermal stability. It is widely used in high-performance magnetic cores, inductive components transformer, etc., nanocrystals have become high-quality materials for common mode inductance cores, and their characteristics are shown in Table 5.

Table 5. Common Mode Inductor Core Parameters

S/N	Characteristic	Index content
1	Texture of material	Fe based nanocrystals
2	Saturated magnetic induction	1.25T
3	Permeability (10 kHz)	80000
4	Permeability (100 kHz)	20000
5	Resistivity	115
6	Lamination coefficient	0.78
7	Core shape	Toroidal core

In order to ensure that the equipment has strong anti-interference capability and is easy to install, the nanocrystalline coil is often equipped with a steel shell. During the test, the data-driven monitoring method and the fusion model monitoring method are set as the control group for the test, and the performance of the designed system is objectively evaluated by analyzing the specific test results.

4.2 Induction Measurement Experiment

The experiment mainly adopts the control variable method, and the sensor material is nanocrystalline. Finally, the relationship between the output voltage and the resistance to be measured is calculated. The output voltage is mainly related to the amplitude and frequency of the excitation and the turns ratio of the original and auxiliary coils. The control variable experiment is designed at the loading end to explore the impact of each influencing element on the monitoring results of the data system and analyze the relevant errors.

(1) Amplitude experiment.

During the experiment, first determine the frequency range. Under the 0 Ω resistance test environment, the frequency changes from 10 Hz to 1 MHz. It is found that at a low frequency, the environmental interference is obvious, and at high frequency, the interference can be significantly reduced.

The data is stable, and the frequency of 500 kHz is the best. Therefore, 500 kHz frequency is selected to measure the change of output voltage caused by the change of voltage amplitude, and the average error of output voltage under different voltage amplitude is obtained by transforming different resistance values. See Table 6.

Table 6. Average error of test results under different voltage conditions/%

Amplitude/V	Data driven monitoring method	Fusion model monitoring method	This paper designs the monitoring system
1.0	16.56	17.26	16.41
2.0	16.33	16.30	15.14
3.0	15.85	15.99	15.41
4.0	13.02	14.30	11.76
5.0	2.45	3.35	1.72
6.0	2.28	3.24	1.01
7.0	2.20	3.20	1.00
8.0	1.96	2.15	1.21

According to the test results shown in Table 6, in the three groups of test results, when the voltage amplitude is within the range of 6.0–7.0V, the average error of the corresponding monitoring results is the smallest. Among them, the error corresponding to the data driven monitoring method is within the range of 2.20–2.30%, the error corresponding to the fusion model monitoring method is within the range of 3.20–3.25%, and the error corresponding to the monitoring system designed in this paper is within the range of 1.00–1.05%. In contrast, the monitoring results of the monitoring system designed in this paper are more reliable. Not only that, the data information of the overall test results is analyzed. Among them, the maximum error of the data driven monitoring method is 16.56%, the maximum error of the fusion model monitoring method is 17.26%, and the maximum error of the monitoring system designed in this paper is 16.41%. In contrast, the monitoring system designed in this paper also shows obvious advantages.

(2) Frequency experiment.

According to the amplitude experiment results, when the voltage amplitude is between 6.0 and 7.0 V, the corresponding monitoring error is small. For this reason, the voltage amplitude is selected as 6.6 V, and the average error of different monitoring methods and system outputs under different frequency inputs is tested. The data results are shown in Table 7.

Table 7. Average Error of Test Results at Different Frequencies/%

Frequency (Hz)	Data driven monitoring method	Fusion model monitoring method	This paper designs the monitoring system
5000	33.01	33.71	20.86
10000	22.77	22.74	11.58
15000	16.15	16.29	9.71
20000	9.46	9.74	7.2
50000	1.78	2.68	1.15
100000	1.56	2.52	1.09
500000	1.51	2.51	1.03
1000000	2.02	2.21	1.27

According to the test results shown in Table 7, among the three groups of test results, when the input voltage frequency is 500 kHz, the average error of the corresponding monitoring results is the smallest. Among them, the error corresponding to the data-driven monitoring method is 1.51%, the error corresponding to the fusion model monitoring method is 2.51%, and the error corresponding to the monitoring system designed in this paper is 1.03%. In contrast, the monitoring system designed in this paper is more reliable for the monitoring results of testing battery frequency status parameters. Similarly, the data information of the overall test results is analyzed. Among them, the maximum error of the data-driven monitoring method is 33.01%, the maximum error of the fusion model monitoring method is 33.71%, and the maximum error of the monitoring system designed in this paper is 20.86%. The battery condition monitoring system designed in this paper also shows obvious advantages.

(3) Original and auxiliary coil experiment.

Based on the above experimental results, when testing the coil, set the amplitude and frequency of the excitation signal as 6.6 V and 500 kHz respectively. On this basis, under the condition of different primary and secondary coil ratios, the output average error under different coil ratios is obtained by transforming different resistances. The specific test results are shown in Table 8.

According to the test results shown in Table 8, when the coil ratio is 1:2, the average error of the corresponding monitoring results is the smallest among the three groups of test results. Among them, the error corresponding to the data-driven monitoring method is 0.42%, the error corresponding to the fusion model monitoring method is 0.70%, and the error corresponding to the monitoring system designed in this paper is 0.01%. In contrast, the monitoring results of the monitoring system designed in this paper for testing the proportional state parameters of the battery coil are more reliable. Similarly, the data information of the overall test results is analyzed. Among them, the maximum error of the data-driven monitoring method is 1.65%, the maximum error of the fusion model monitoring method is 2.00%, and the maximum error of the monitoring system designed in this paper is 1.01%. The battery condition monitoring system designed in this paper also shows obvious advantages.

Table 8. Average error of test results under different coil ratios/%

Coil ratio	Data driven monitoring method	Fusion model monitoring method	This paper designs the monitoring system
4:1	1.65	1.76	0.91
3:1	1.49	1.54	0.02
2:1	1.48	1.49	0.01
1:1	1.18	2.00	1.01
1:2	0.42	0.70	0.01
1:3	1.25	0.99	0.19
1:4	1.17	0.98	0.85

Based on the above test results, it can be concluded that the substation battery condition monitoring system designed in this paper can achieve accurate monitoring of different state parameters of the battery. This is because the design system uses TW-SDH6000 as the hardware device of the battery, uses SDH network to filter some battery resources, combines PCA method to reduce the dimension of the original data, and uses Pearson correlation coefficient to achieve accurate monitoring of the status of the substation battery. The minimum monitoring error of the designed system under different voltage conditions, frequency conditions, and coil ratios can reach 1.00%, 1.03%, and 0.01%, resulting in the best monitoring effect.

5 Conclusion

As an electrochemical product, the health status of battery is affected by the actual charging and discharging characteristics, ambient temperature, discharge depth state of charge and other factors, especially in the application of series batteries gradually expanding, the performance of the entire battery pack will deteriorate rapidly, so it is of great significance to realize online SOH monitoring of batteries. In addition, SOC provides the basis for battery energy management and charging and discharging control strategies. Accurate estimation of battery SOC can improve the utilization rate of energy storage batteries and facilitate system energy management and scheduling. Therefore, it is of great significance for the management, maintenance and fault prevention of the energy storage system to realize the real-time data acquisition of the battery and the estimation of the SOC and the SOH of the battery state of charge. The TW-SDH6000 is used as the main hardware equipment to improve the reliability of battery condition monitoring. The SDH network is used to filter battery resources. Aiming at the problem of high dimensions of the original data, PCA method is used to reduce the dimensions of the data, and Pearson correlation coefficient is used to achieve accurate monitoring of different state parameters of the battery. The system has good practical application value. With the help of the monitoring system designed in this paper, it is also hoped that it can provide valuable help for the management of the substation battery and help the battery to maximize its role in the operation of the power system.

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