

Development of Historical Database for SF6 Extra High Voltage Circuit Breaker Intelligent Monitoring System

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Abstract—Considering the importance of the SF6 extra high voltage circuit breakers in the power supply system, an intelligent monitoring system is developed. And a historical database system is designed for this monitoring system in this article. This historical database can store and manage such information as historical data, historical fault information, report and device information, etc. Furthermore, there is a simple device expert database in this historical database developed to assist fault detect. The SQLite, a lightweight relational database, is adopted as the backend database in this historical database system. According to the specific requirements of the actual application for monitoring task, the Entity-Relationship model is designed. Application experiments in the actual working environment reveal that this historical database system can well accomplish the information storage and management work and completely meet the requirements of the intelligent monitoring system.

Keywords—extra high voltage circuit breaker; monitoring system; historical database; SQLite; Entity-Relationship model

I. INTRODUCTION

In recent years, there have been several power supply system blackout accidents happened around the world which resulted in huge economic losses. Therefore to improve the reliability of power supply system is of great significance.

SF6 EHV (Extra High Voltage) circuit breaker[1, 2] is one equipment which plays a key role in control and protect the electric power supply system. It can switch off or break a failure circuit to keep the stable operation of the rest of power supply system when in emergency. So its security and stability are directly relevant to the stable operation of the power system. And it is one important resource for ensuring the stability and security of power supply system through maintaining the stable operation of SF6 EHV circuit breakers.

With the continuous development of smart grid[3], it becomes more and more urgent to develop the intelligence technology of SF6 EHV circuit breakers. Therefore it requires an intelligent monitoring system[4, 5] for SF6 EHV circuit breakers in order to ensure the stable operation of them. Historical data recording system is a key sub-system in the monitoring system. That is because historical data contains all of historical

status information of SF6 EHV circuit breakers, and through analyzing these information it can validate the correctness of the control strategy for oil pressure and SF6 gas pressure. Moreover when fault occurs, it can be detected and repaired through analyzing these historical status information. So a stable and safe historical database is needed to record the historical data in the monitoring system.

This article concerns the SF6 EVH circuit breakers with the model of LM12-550 which are running in Hunyuan 500kV Opening and Closing Station of Datong Ultra-High Voltage Power Supply Company in Shanxi province China. According to the requirements of future smart grid and intelligent monitoring system for SF6 EHV circuit breakers, a historical database system based on SQLite[6, 7] is developed. Firstly, the system architecture is described. Secondly, in view of the practical application of monitoring system, the E-R (Entity-Relationship)[8] model of the database system is designed. Finally, running experiments on this system are conducted and the experimental results are analyzed.

II. SYSTEM ARCHITECTURE

In order to enhance the expandability and maintainability, the modularization conception is adopted in the design of intelligent monitoring system for SF6 EHV circuit breakers. As shown in Fig. 1, the monitoring system is mainly composed of seven modules including ARM master controller, relay board, optical fiber communication interface card, alarm controller, monitoring computer, SF6 pressure transducer and oil pressure transducer. As the central controller of lower computer, ARM master controller is mainly used to control and coordinate the running of other modules. Besides that, it contains some necessary control strategies to keep the normal operation of SF6 EVH circuit breakers. Optical fiber communication interface is the bridge between lower computer and monitoring computer which contains CPLD (Complex Programmable Logic Device), CAN bus controller and two optical fiber modules. Optical fiber is adopted in the communication between lower computer and monitoring computer to reduce the EMI (Electro-Magnetic Interference) and improve the transmission speed. SF6 gas pressure transducer and oil pressure transducer are used to gather the SF6 gas pressure and oil pressure respectively, and

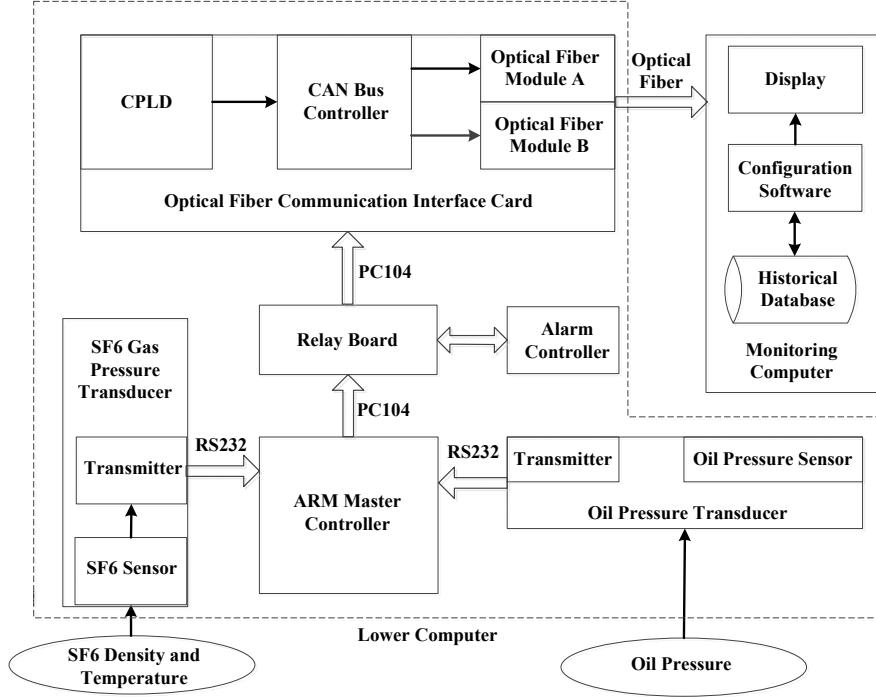


Fig. 1. Monitoring system function block diagram

they are connected to ARM master controller through RS232. Alarm controller is used to send or receive alarm signal to alarm device. Monitoring computer is the human-computer interaction interface mainly including configuration software, historical database and display module. In the listing above, the configuration allows the user to configure the monitoring system arbitrarily, while the historical database is used to store the historical status of SF6 EHV circuit breakers and the basic information of the motoring system.

Considering the requirements of monitoring system for SF6 EHV circuit breakers, the historical database should be able to store such status information and control signal as oil pressure data, SF6 gas pressure data, switch off latching, switch on latching, reclosing latching and oil pump bulging. Meanwhile, the alarm signal and historical fault information should also be recorded in the database. In addition, there should be report and expert database function used to analyze data, detect and repair faults. Fig. 2 shows the database structure which mainly consists of eight modules including historical fault information module, basic information module, oil pressure data module, SF6 gas pressure data module, control signal module, alarm signal module, report module and expert database module. Basic information module is used to store the basic information of monitoring system like event log, user permissions, etc. And some basic information of device monitored is also stored in this module, such as manufacturer, production date, using date and some performance parameters information, etc. Oil pressure data module and SF6 gas pressure data module are used to store oil pressure and SF6 gas pressure historical data respectively. Similarly, alarm signal module and control signal module are used to store alarm signal and control signal historical status information separately. Historical faults information is stored in the historical fault information module. Furthermore,

there are some failure diagnosis information stored in the expert database in order to assist in detecting and repairing the faults when failure happened. And report module can generate historical data information report, and through analyzing this report the maintenance personnel can validate the control strategy, find and eliminate the trouble.

Historical database schematic diagram is shown in the Fig. 3. Two processes are adopted to improve the data storage speed. Among them, one process named store is used to store the data in database. And the other one named report is used to generate the subtotals for historical data which will be sent to the monitoring system configuration software display and will be stored back to the database meanwhile. Monitoring configuration software is used to configure system, gather data and display

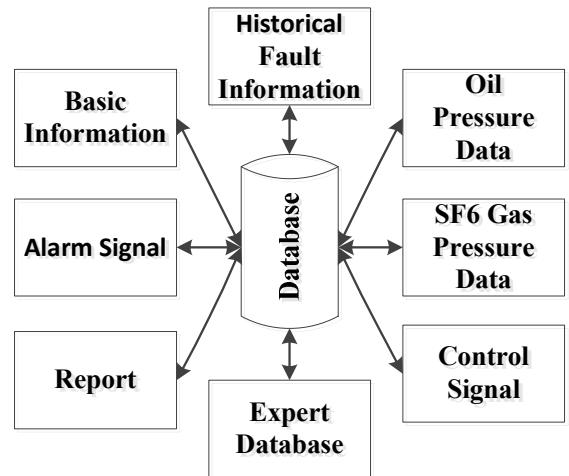


Fig. 2. Historical database structure

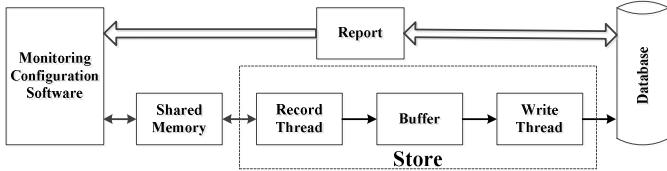


Fig. 3. Historical database schematic diagram

the data visually. Shared memory technology is adopted to share data between monitoring configuration software and store process. As is well known, memory reading/writing is much faster than file reading/writing. And the data should be ultimately written into database file, so the store process processing speed is much slower than reading/writing shared memory from monitoring configuration software. Therefore, in order to match them, there are two threads created inside the store process. The two threads, record thread and write thread, are connected through one buffer. Record thread is used to read data from shared memory, then insert them to the rear of buffer, while write thread to get and remove the data from the front of the buffer, then write them in the database file.

The SQLite, a lightweight relational database, is adopted as the backend database of the historical database for the monitoring system. Fig. 4 shows the SQLite architecture. And it is mainly composed two parts, core and backend. Backend is the interface between database and OS and used to finish the concrete data storage, management and organization work, which contains B-Tree, page and OS interface. The SQLite core is composed three parts, interface, SQL compiler and virtual machine. Through the interface, user can interact with the database. SQLite completely supports SQL standard, and user can operate or query the database by specific SQL command. SQL compiler can parse the SQL command to special code that the virtual machine can execute.

As a RDMS (Relational Database Management System) abide by the ACID (Atomicity, Consistency, Isolation, Durability), the SQLite is an open source project created by D. Richard Hipp which is contained in a relatively small C programming

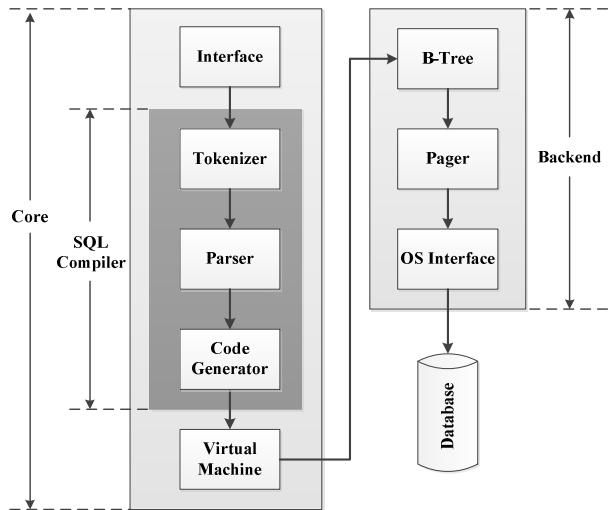


Fig. 4. SQLite architecture

library. Unlike common client/server database architecture, SQLite engine is not a separate process accessed by the client application but an integral part of the application. So all of the communication process is the direct API calls within the programming language, and it plays an important role in reducing the delay time. The entire database (definitions, tables, indexes, and data) are stored in a single file which makes it extremely simple and flexible. It occupies a very low resources and there are only hundreds kilobytes of memory needed in system. In conclusion, the advantages of SQLite lie in zero configuration, portability, compactness, simplicity, flexibility and reliability. Indeed these advantages make SQLite the first choice as the backend database of the historical database for SF6 EHV circuit breakers intelligent monitoring system.

III. DATABASE E-R MODEL

The database E-R model contains seven entities, device, sensor, data type, sensor data, report, device fault and fault type which are shown in Fig. 5. Device entity is used to store the basic information of device monitored in the system such as SF6 EHV circuit breakers and mainly contains five field properties, device id, name, manufacturer, production date and responsible person. For the convenience of system configuration, every data point, like SF6 gas pressure data, oil pressure data, all kinds of control signal and alarm signal and so on, is considered as sensor and stored in the sensor entity. Thus, sensor entity contains four basic field properties, sensor id, name, category and assembly time, which are used to store the sensor serial number, the sensor name, the sensor category and the assembly time of the sensors respectively. Besides that, sensor entity also contains two field properties, device and data type, used to store device the sensor is equipped in and the sensor data type separately. And the value of device comes from device entity, while the value of data type comes from data type entity which contains four field properties representing four data types, float, integer, bool and byte. Sensor data entity is used to store the historical data and contains two field properties, data and acquisition time. Report entity is used to store the subtotals for the historical data which contains two field properties, report data and time. In addition, these two entities, sensor data and report, both have one extra field property used to store sensor the data is from and whose value comes from the sensor entity. Historical fault information is stored in the device fault entity which contains four field properties, fault id, fault location, repair personnel and time. Among them, fault id field property is used to store the fault serial number; fault location field property, to store the device where the failure happened; repair personnel field property, to store the personnel who repaired the failure; time field property, to store the time when the failure was detected. Moreover, device fault entity also has one extra field property fault type used to store the fault type whose value comes from fault type entity. Fault type entity contains five field properties, fault code, fault name, fault grade, fault feature and fault image. This entity actually forms a simple expert database for SF6 EHV circuit breakers monitoring system and the system can diagnose the fault type by comparing the fault features. On the basis of different fault priorities, the faults are divided into different grades and will be stored in the fault grade field property. When fault detected,

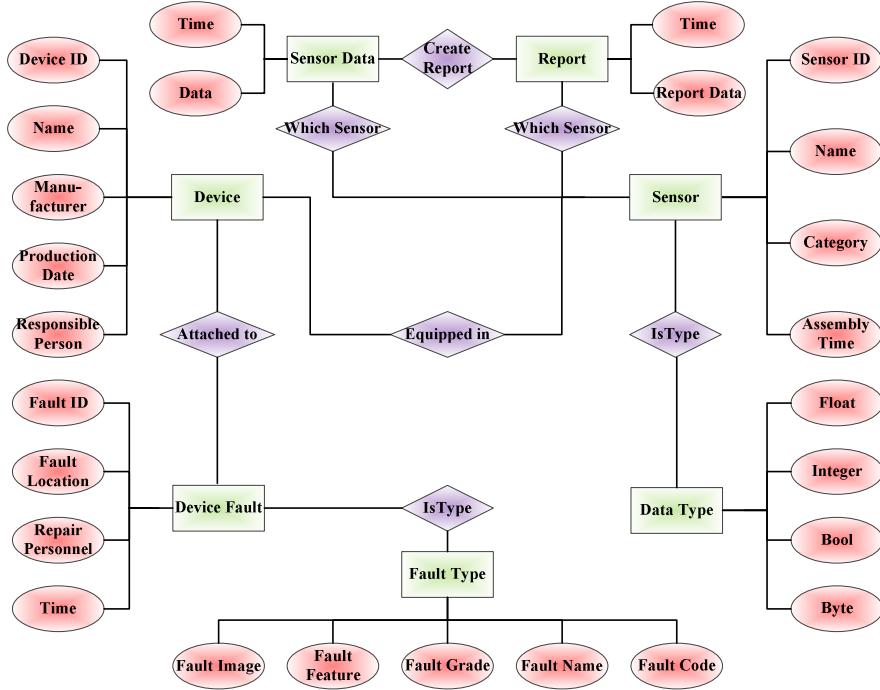


Fig. 5. Database E-R model

the monitoring system will take the corresponding treatment method according to the fault grade.

IV. EXPERIMENTS AND ANALYSIS

The historical database system is constructed based on the architecture above and several application experiments are carried out to test it. The storing response time is an important indicator of database system performance, so the delay time is tested through contiguously storing different number of records. The statistic results are shown in Fig. 6 and Fig. 7. In the two figures, records number is the continuous storing number of records in abscissa, and ordinate represents the delay time of continuous storage without SQLite transaction in Fig. 6, while ordinate represents the delay time of continuous storage with SQLite transaction in Fig. 7. It can be seen that, with the increasing of the number of continuous storage, the delay time of continuous storage without SQLite transaction is also obviously increasing in Fig. 6, whereas with SQLite transaction the delay time is less increasing and keeps in a few milliseconds within certain limit of continuous storage number (In this experiment, the maximum number is 500) in Fig. 7. For SQLite, file IO operation is the bottleneck of reading/writing of the database, so the storing response time of database mainly depends on file I/O operation speed. But the file I/O operation speed depends on OS and hardware environment, so SQLite can't improve the storing response time through changing the file I/O operation speed. In this case, the only way to improve the storing response time is reducing the number of file I/O operation as much as possible in one storing operation. And SQLite transaction is introduced for this purpose. In SQLite transaction, all operations are suspended to the queue rather than directly synchronized to the database file, and opera-

tions in the queue will be sequentially synchronized to the database file when the user commits the transaction. Thus it can perform many database operations and only need just one file I/O operation by using SQLite transaction. Then it can greatly improve the storing response time with SQLite transaction which is proved by the statistic results in Fig. 6 and Fig. 7. Without SQLite transaction, one storing operation needs one database file I/O operation which results in that the delay time is obviously increasing with the increasing of the number of continuous storage as shown in Fig. 6. In contrast, with SQLite transaction, many operations only need just one file I/O operation which results in that the delay time is less increasing with the increasing of the number of continuous storage as shown in Fig. 7. Hence, the storing response time can fully meet the requirements of monitoring system historical database by using SQLite transaction mechanism.

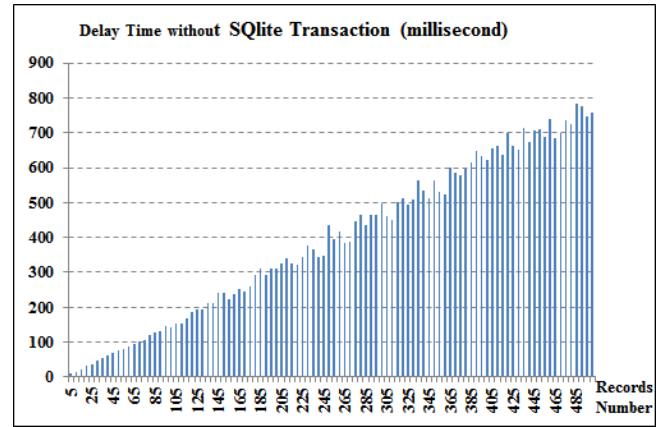


Fig. 6. Delay time without SQLite transaction

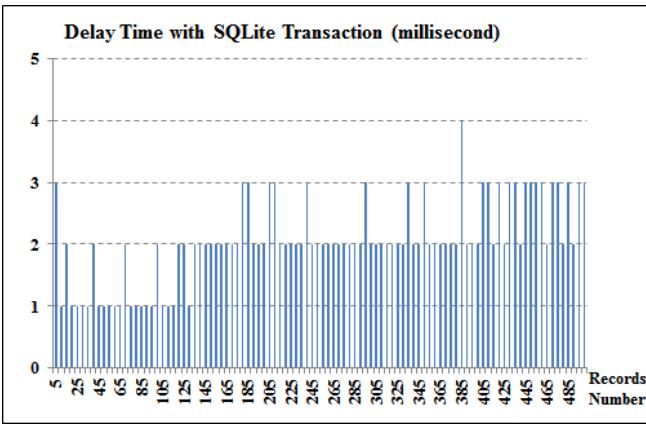


Fig. 7. Delay time with SQLite Transaction

Fig. 8 shows the historical data report generated by the historical database system above and the historical data is obtained under normal operation of circuit breaker in actual working environment. From the historical data, it can be seen that with collaboration of smart monitoring system, there are one to three times of normal oil pumping action on the SF6 EHV circuit breaker with model of LW12-500. This result actually reflects the working status of circuit breakers in Huyuan 500kV Opening and Closing Station. And the control to oil pressure can be accurate to 0.1MPa. The pumping time can be limited to 30 seconds.

As shown in Fig. 9 is home screen of the monitoring system under actual working environment. It can be seen that the monitoring system with the historical database introduced above can fully achieve the monitoring task for SF6 EHV circuit breakers.

V. CONCLUSION

According to the practical application of intelligent monitoring system for SF6 EHV circuit breakers, a complete design scheme of historical database system is proposed, which is used to store the historical data, basic device information,

序号	油压	SF6气压	分闸时间			合闸时间			重合闸时间			油压电机开启			超高压报警			SF6压力降低报警			SF6压力降低闭锁			
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
2011-9-1 10:47:04	34.1	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-3 21:20:37	32.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-3 21:21:00	34.1	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-2 7:42:49	31.9	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-2 7:43:04	34.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-2 20:55:15	32.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-2 20:55:38	34.1	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-3 4:42:29	32.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-3 4:42:29	34.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-3 9:52:43	31.9	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-3 9:53:00	34.1	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-3 19:21:10	32.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-3 19:21:33	34.1	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-4 5:30:25	32.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-4 5:30:49	34.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-4 18:12:43	31.9	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-4 18:13:07	34.1	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-5 6:07:39	32.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-5 6:07:45	34.1	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-5 20:41:30	32.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-5 20:41:53	34.1	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-6 5:42:26	32.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-6 5:42:43	34.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-6 20:16:18	31.9	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-6 20:16:41	34.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2011-9-7 6:21:08	32.0	0.51	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35

Fig. 8. Historical data report

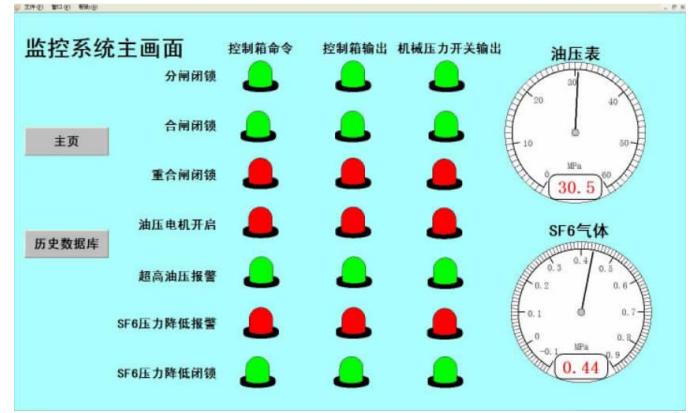


Fig. 9. Monitoring system home screen

report and historical fault information, etc. This system adopts the SQLite as the backend database. And the E-R model is designed on the basis of the specific requirements of the intelligent monitoring system. Shared memory technology is adopted to implement data interaction between the configuration software and historical database. In order to match the memory reading/writing and file reading/writing speed, dual threads technology is proposed. SQLite transaction technology is used to improve the response time of storing data in historical database. After several actual operating experiments, it proves that this historical database system can fully satisfy the requirements of the intelligent monitoring system for SF6 EHV circuit breakers.

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