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# Development of Training Software for Node Instrument External Detector String Maintenance

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## Abstract

**With the increasing use of acquisition equipment in high-density exploration projects, the number of geophone strings to be repaired has significantly increased, and the number of geophone string maintenance workers can no longer meet the current demand for geophone string maintenance. Therefore, how to quickly train qualified detector string maintenance workers has become an important issue to ensure normal field construction. The article first analyzes the current situation of detector string maintenance and proposes a solution for developing training software for detector string maintenance; Then, the design process and characteristics of the training software were introduced in detail; Finally, the conclusion that the software meets the development goals is obtained through the effectiveness of software training.**

## Keywords

**Geophone String; Tranining Software; Fault Analysis; Software Model; Database.**

## 1. Introduction

Seismic detectors are electromechanical conversion devices that convert mechanical vibration energy transmitted to the ground or water into electrical energy, and are widely used in petroleum exploration, geological monitoring, and engineering measurement fields. Dynamic coil detectors use the induced current intensity generated by the relative motion between the coil and magnet to measure mechanical vibration energy, and are mainly used in conventional exploration on land. Dynamic coil detectors currently mainly include high sensitivity single detector and conventional detector. In geological loose areas such as Loess Plateau and Gobi Desert, conventional detectors such as 20DX and 30DX are often buried by combining them into a detector string. The detector can improve the recognition ability of seismic signals, reduce the interference of random noise, effectively improve the signal-to-noise ratio, and significantly enhance the reliability of seismic data through specific combinations according to construction requirements. Therefore, the reasonable use of detector strings is an important means of improving the quality of current seismic exploration.

With the rapid development of geophysical exploration, the maintenance of detector strings currently faces the following problems: ① There is a large number of detector strings to be repaired. Due to the increase in high-density exploration projects, the usage of detector strings has grown rapidly, resulting in a significant increase in the number of detector strings to be repaired [3]; ② Lack of experienced maintenance workers. Experienced detector string maintenance personnel are aging severely and decreasing year by year; ③ The new maintenance worker lacks the ability. Due to limited maintenance experience and poor training effectiveness, new maintenance workers are unable to meet current maintenance requirements in terms of maintenance capabilities. Therefore, the current maintenance capability cannot meet the growing demand for repairing detector strings. How to improve the maintenance

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ability of new maintenance workers in high quality and efficiency has become an important issue in ensuring efficient construction of exploration projects.

## 2. Problem Analysis of Existing Methods

The existing training process for repairing detector strings is as follows: Firstly, train basic circuit knowledge. Due to the low level of education among the students, it is necessary to provide training on basic circuit knowledge such as series, parallel, short circuit, and open circuit; Secondly, train on the use of a multimeter. Training on using a multimeter to measure the basic operations of circuit resistance, voltage, current, on/off, etc; Once again, train on wiring techniques. Training on the use of electric soldering iron welding wires, wire stripping, bundling and other techniques; Finally, train the fault diagnosis of the detector string. In the series of training courses, as shown in Table 1, the training effect on fault diagnosis of detector strings is the worst.

**Table 1.** Existing training effectiveness for a certain detector string maintenance

| | Circuit knowledge training | Multimeter training | Wiring training | Fault diagnosis training |
|---|---|---|---|---|
| Average score (total score of 100) | 83 | 92 | 86 | 62 |

Through communication and analysis with the students, the main reasons for the poor training effectiveness in identifying detector string faults are as follows: ① Poor circuit foundation of the students. Circuit knowledge training uses circuit diagrams as equivalent circuit connection diagrams. Due to the significant difference between the equivalent circuit connection diagram and the actual circuit connection diagram, students are unable to effectively grasp it; ② The training content is limited. Due to the limitations of teaching detector types and string assembly methods, students can only learn a few types of fault diagnosis methods for detector strings; ③ The difficulty of troubleshooting is high. When simulating detector string faults, the instructor focuses on several basic fault simulations, which cannot achieve full category fault simulation; ④ Poor time utilization. Students are unable to effectively utilize their spare time to determine faults in different types of detector strings. Therefore, how to use actual circuit connection diagrams for all types and periods of time to train trainees on fault analysis has become an important challenge in current training on detector string maintenance.

## 3. Software Design

Developing a training software for detector string maintenance can not only effectively improve students' ability to analyze detector string faults during training time, but also fully utilize the significant regularity of detector string fault diagnosis methods, which is currently the best solution. The detector string maintenance training software can comprehensively simulate different types of faults in the field. Students can independently choose the appropriate time and method for fault diagnosis, and finally, the software will judge whether the selection is correct based on the content, and provide the optimal solution and cause analysis based on the fault content.

### 3.1. Program Architecture

The design strategy for training software is to choose a layered architecture. Layered architecture typically divides software modules into multiple layers in a horizontal partitioning pattern. Each layer has independent responsibilities and only handles the logic of its own layer, reducing dependencies between systems. The hierarchical structure has the characteristics of strong independence, simple functionality, strong adaptability, strong scalability, and easy standardization. The architecture of the detector string maintenance training software includes the user interface layer, business logic layer, data access layer, and database. The user interface layer is the bridge for interaction between trainers and the system. Trainers can choose the type of detector, string connection method, and fault diagnosis method through the data content presented on the interface. The interface also provides users with intuitive content display, including operation results, optimal solution description, and analysis. The business logic layer is the core of software architecture, mainly responsible for handling business-related logic and processes. The business logic layer of the training software plays a role in interacting with the user interface layer and data access layer. It matches the input information of the user interface layer, such as detector type, string grouping method, and judgment method, with relevant rules and entrusts it to the data access layer for execution. At the same time, it conveys the feedback information from the data access layer to the user interface layer for display according to specific rules. The data access layer is responsible for interacting with the database and managing data. The training software can access and query specified databases through the data access layer. The database mainly stores fault analysis schemes for different types of detectors in different string combinations. The layered architecture of the detector string maintenance training software can not only provide fault analysis training to training personnel throughout the entire period, but also effectively expand the database based on the increase in detector types and string grouping methods.

## 3.2. Mathematical Modeling

The mathematical model of training software is mainly determined by the fault characteristics of the detector string. The main cause of the malfunction of the detector string is an open circuit or short circuit in the connecting wires. The fault of the detector string circuit is mainly determined by testing the resistance value. The multimeter uses an ohmmeter to detect the resistance value R of the detector string port. The multimeter can also test the continuity of the circuit through the on/off mode. By measuring the resistance value R of the port, the resistance value R1 of a single string detector, and the on/off relationship of the circuit, the specific location of the faulty port in the detector string can be determined step by step. When the detector string is in series mode, the mathematical formula for resistance is as follows:

$$R=\sum R1$$

When the detector string is in parallel mode, the mathematical formula for resistance is as follows:

$$1/R=\sum 1/R1$$

The detector string may also experience polarity faults caused by assembly errors. Polarity faults are mainly judged by testing induced current. A multimeter can detect the direction of the induced current of the detector after vibration through a weak battery level. By sequentially shaking a single detector downwards, the first peak value i of the induced current is obtained. When $i>0$, the detector is positive polarity; When $i<0$, the detector is negative polarity. Students can determine whether the polarity of the shaken detector is correct based on the characteristics of the detector being tested. The faults of the training software are mainly judged by the resistance value of the port test and the direction of the induced current.

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## 3.3. Software Modeling

The training software selects the tested port resistance and induced current direction as variable parameters, and establishes a classification model based on different types and string combinations of detectors. Software selection focuses on data-driven information engineering modeling methods [6] for modeling.

Firstly, conduct logical modeling. Logical modeling is the process of establishing the logical structure of data, logically organizing conceptual entities and their relationships at the database level, ensuring that software can accurately and efficiently process data. The logical modeling uses entity connection diagrams to describe the fault diagnosis relationship of the detector string. The maintenance training software tests the resistance value, polarity, and on/off properties of the repaired detector string in a specified way through a multimeter. After testing, various test results will appear for each attribute. Based on the test results, students will use various testing methods for further analysis and obtain various fault diagnosis solutions. The software determines whether the solution provided by the student is the only optimal solution through a database. The logical modeling of software can establish the training logic relationship for fault diagnosis through entity relationship diagrams, optimize data structure, and improve data processing efficiency.

Then, conduct business modeling. Business modeling uses flowchart analysis to describe the business, providing strong support for software programming. Under the business process of maintenance training software: Firstly, the type of detector string selected by the trainees corresponds to fixed attribute parameters. Select the corresponding type of sub database for software calls. Then, the software randomly calls the fault detector string in the sub database to test the port resistance, polarity, on/off, and other test results. Secondly, students can make fault judgments based on the above information. If the fault location can be accurately identified, provide the result and end the training. If the fault location cannot be determined, a solution will be provided based on simulation testing information to enter the fault handling cycle. Once again, the software determines whether the student's disposal plan is correct by calling database data. If the plan is correct, the software will proceed to the next process to obtain testing information. If the plan is incorrect, go back to the previous process and the student will continue to design the disposal plan until it is correct. Finally, the trainees completed this maintenance training by completing multiple rounds of fault handling cycles to obtain the accurate fault location. Throughout the entire maintenance training business process, students optimize their disposal plans by judging the testing information of the detector string, until they choose the best disposal plan that matches the database, and ultimately determine the accurate fault location. The software business modeling adopts a cyclic judgment approach to achieve maintenance training, which has good interactivity.

Finally, conduct physical modeling. The key to physical modeling is to logically classify and manage all data. It is directly related to the reliability of software storage and the efficiency of data retrieval. Choose a client server architecture for the training software, and establish the database on the terminal server for easy database expansion and front-end response. In server data modeling, training software needs to establish different types of sub databases through detector types and string grouping methods. The sub database simulates the open circuit and short circuit relationships of each line, as well as the superposition relationship of faults in different locations, to establish a complete set of fault subsystems. The sub database designs a complete set of fault location determination methods based on specific fault types, and selects the optimal fault disposal plan through process optimization. The software accesses the database through embedded methods to achieve fast data retrieval.

# 4. Software Features

## 4.1. Good User Experience

The training software has a good user experience. Firstly, the software has strong compatibility. The software selects a web browser as the client and can be used directly without installation. Therefore, it has broken through the limitations of operating systems and can run on mainstream computers and mobile operating systems such as Windows, Android, and Apple. Then, the software can be accessed at all times. The software adopts a client server architecture, which not only supports concurrent access from multiple clients, but also allows students to access it anytime during their spare time, breaking the time limit of only being able to participate in training during class hours. Finally, the software has good interactivity. The server-side database has powerful computing and storage capabilities, which can quickly respond to concurrent access from multiple clients. By using the shared network of the training center, even if the electronic products used by the students lack computing power, it does not affect the server's ability to quickly respond to instructions sent by the students through the browser client.

## 4.2. Friendly Display Interface

Select the actual circuit diagram as the circuit analysis diagram for the training software. When training on detector string maintenance, instructors usually choose simplified equivalent circuit diagrams for classroom training. However, during actual on-site maintenance, students found that the connection lines of the faulty detector string were far more than those on the equivalent circuit diagram, which could not be effectively associated with the knowledge learned in class, and the training effect was lower than expected. The schematic diagram of the six series two parallel equivalent circuit is shown in Figure 1, showing a total of 15 lines, including 2 main lines and 13 series lines. The actual circuit diagram is shown in Figure 2, showing a total of 36 lines, including 26 main lines and 10 serial lines. Students are unable to equate the actual circuit diagram to an equivalent circuit diagram through the connection method, which not only leads to slow fault diagnosis but also makes it easy to make incorrect judgments during actual maintenance. The software uses actual circuit analysis diagrams to directly display all connecting lines on the maintenance interface. Not only can the string function of the connecting lines be intuitively understood through the connection relationship between the connecting lines and the core, but it can also visually display the position relationship between the connecting lines and the core, as well as the differences in wiring between different detectors. The software circuit display interface is easy to understand and can effectively simulate real scenarios of detector string faults, which is more beneficial for training.

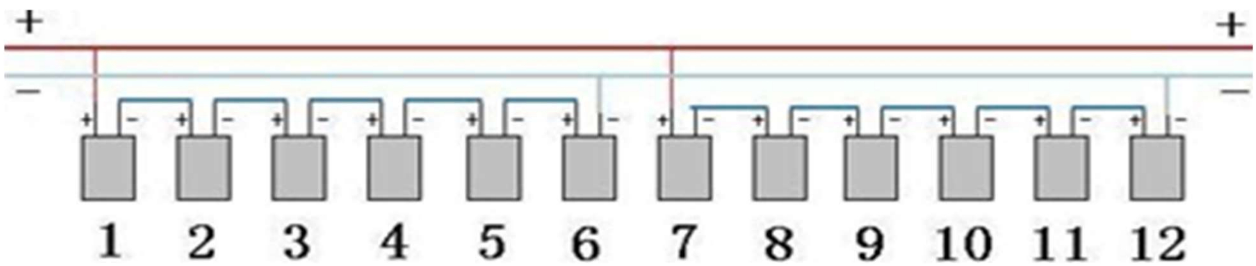


**Figure 1.** Schematic diagram of the equivalent circuit of the detector string

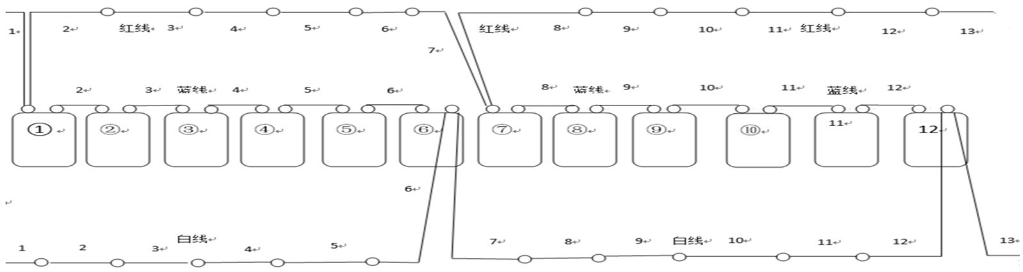


**Figure 2.** Schematic diagram of the actual circuit of the detector string

### 4.3. Rich Content

The training software allows the training content to no longer be limited to the actual situation of the training institution's detectors, and can simulate all types of conventional detector string faults. All detector string faults in the training software are stored in a database using table storage mode. Table format storage is suitable for storing and managing data with fixed patterns or structural logic, similar to detector troubleshooting. It has the characteristics of high reliability, strong scalability, and fast response speed. After inputting the detector type and corresponding indicators in the software backend, the database can automatically perform mechanical learning through serial parallel relationships. The server stores the calculation data in a new sub database and automatically links the sub database path to the main database for easy access. The software database can not only store rich cases of detector string fault diagnosis, but also effectively expand the mode of describing the parameters of new string detectors, solving the problem of limited training content.

## 5. Application Effects

### 5.1. Software Usage Effects

The training effect of the detector string maintenance training software is as follows: Firstly, students can choose a maintenance plan based on the actual circuit diagram, as well as information such as port voltage and induced current. Then, as shown in Figure 3, the software selects and judges the best solution through database matching, and provides fault resolution suggestions. Finally, the software conducts a fault analysis summary as shown in Figure 4, and provides a complete fault analysis approach and judgment process.

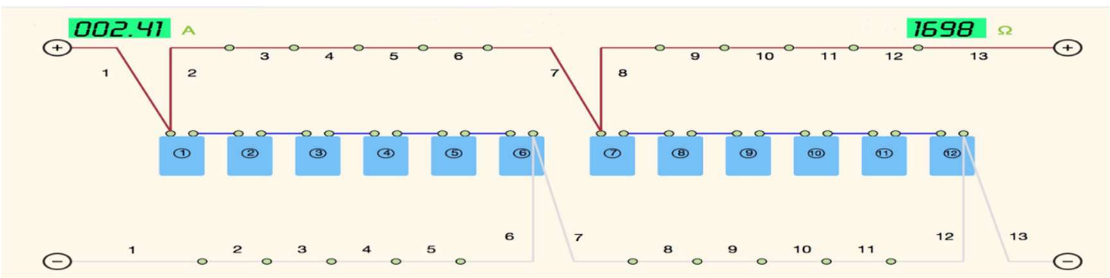


**Figure 3.** Application judgment diagram of detector string maintenance training software

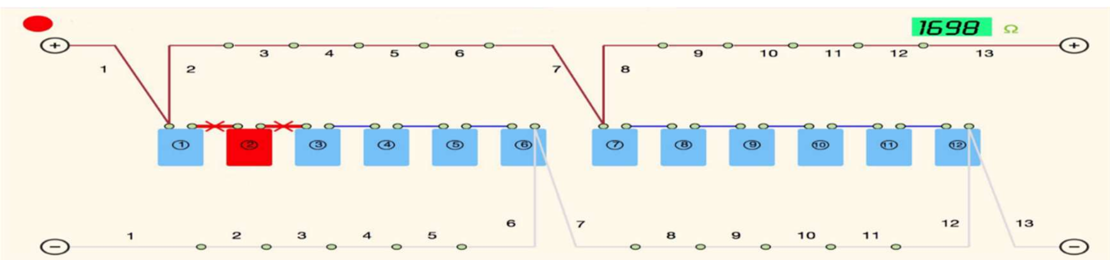


**Figure 4.** Final review of the application of the detector string maintenance training software

### 5.2. Training Effectiveness

The comparison of the effects of training institutions before and after using training software is shown in Table 2. After using the detector string maintenance training software, the average score of fault diagnosis assessment increased from 62 points to 89 points, and the pass rate of assessment increased from 57% to 85%. After using the software, the training effect has been significantly improved.

**Table 2.** Comparison of Fault Diagnosis Assessment

| | Average score of assessment | Assessment pass rate |
|---|---|---|
| Pre use training | 62 | 57% |
| Post use training | 89 | 85% |

## 6. Conclusion

The detector string maintenance training software developed based on database can not only simulate all types of detector string faults, expand the scope of fault diagnosis and learning, but also access the software through the client throughout the entire time period, effectively improving time utilization. It can also improve the software's comfort of use through fast response and intuitive display of actual circuit diagrams, achieving the expected goal of significantly improving the student's ability to analyze detector string faults. However, the software needs to be accessed through the client and cannot break free from network constraints. Moreover, the software lacks the ability to analyze complex faults, making it prone to software deadlocks. Therefore, training software still needs to be upgraded and optimized, which has further development value.

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