

AI-Powered Fault-Setting Training Bench for New Energy Vehicle Education: Design and Research

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Abstract: To address the lack of hands-on practice in fault diagnosis teaching for new energy vehicles, this paper designs a fault-setting training bench for new energy vehicles based on voice interaction. Through a programmable relay matrix and an impedance simulation module, combined with offline speech recognition technology, the bench achieves dynamic simulation and recovery of open-circuit and short-circuit faults in the wiring harnesses between the electronic control unit (ECU), the sensors and the actuators of a new energy vehicle. The system supports voice command control in both Chinese and English, is compatible with the wiring harness interfaces of mainstream vehicle models, and incorporates multiple safety protection mechanisms, which can significantly improve the efficiency and accuracy of trainees in diagnosing faults of new energy vehicles.

Keywords: new energy vehicle; artificial intelligence; fault setting; training bench; voice command

1 Introduction

With the rapid development of the new energy vehicle industry, the demand for relevant maintenance technical personnel is increasing day by day. However, traditional training equipment can hardly meet the training needs of complex fault diagnosis for new energy vehicles. This study aims to design a fault-setting training bench for new energy vehicles based on artificial intelligence technology, so as to improve the efficiency and quality of cultivating maintenance technical personnel.

2 Research Status of the Artificial Intelligence Fault-Setting Training Bench for New Energy Vehicles

2.1 Current Status of the Technology

Most existing fault-setting training benches for new energy vehicles are controlled by buttons or touch screens, lacking natural interaction modes and the capability of progressive fault simulation. As a result, teachers and students are confronted with considerable confusion in the learning process, which affects both the teaching effect and the learning effect. The maturity of voice control technology has made innovation in teaching interaction possible. The research team has used voice control technology to replace the fault-setting method of traditional training benches, providing teachers and students with a better learning experience and effectively improving teaching quality.

2.2 Research Objectives

The research team has designed an intelligent training bench that supports voice commands, which mainly realizes the following functions. First, voice-triggered on/off switching of wiring harnesses simulates fault types such as open circuits and short circuits to ground or to the power supply; that is, open-circuit control is carried out on different wiring harnesses such as those of different sensors, controllers and ECUs, so as to reproduce the phenomena of open-circuit faults. Second, dynamic impedance adjustment triggers poor-contact faults of wiring harnesses, simulating poor contact caused by harness aging and reproducing the phenomena of various poor-contact faults. Third, a safety isolation design ensures that the fault injection process does not affect the electrical system of the original vehicle; after a fault is successfully set, no damage is caused to the components or wiring harnesses of the original vehicle, and

once the vehicle is disconnected from the training bench it can still be restored to its initial state without affecting the normal use of the vehicle.

3 Overall System Design of the Artificial Intelligence Fault-Setting Training Bench for New Energy Vehicles

3.1 Hardware Architecture Design

The hardware system adopts a layered modular design, which is mainly organized into a control layer, an execution layer and a protection layer.

The main control unit of the control layer adopts an STM32H743 + ESP32 dual-core architecture to realize voice processing and logic control; the voice module adopts a circular six-microphone array that supports 360° directional sound pickup, making it convenient for operators in different areas to perform voice control. The execution layer adopts a relay matrix, namely 32 channels of low-on-resistance optocoupler relays with an on-resistance of less than 0.1 Ω , which can control the setting of up to 32 fault points; the impedance simulation module adopts the digital potentiometer AD5280 with a resolution of 8 bit and an adjustable resistance range of 0~10 k Ω , which facilitates the setting of poor-contact faults caused by line aging.

The protection layer adopts a hardware isolation design, namely a dual design of optocoupler isolation plus magnetic coupling isolation, which effectively prevents interference with and damage to the circuit caused by high voltage, ensures relatively stable signal transmission and a relatively high transmission speed, and meets the requirements of high-speed signal transmission; the software monitoring adopts real-time current detection with an accuracy of ± 5 mA, ensuring that current stability is guaranteed in real time and that the safety of the equipment is ensured.

3.2 Software System Design and Implementation

3.2.1 Voice Interaction Layer Design

The speech recognition module is designed on the basis of an offline recognition engine based on the hidden Markov model. The command library predefines 50 standard commands, can be expanded according to the number of fault commands, and supports the dynamic loading of new commands. For noise resistance, beamforming plus echo cancellation is adopted, achieving a recognition rate of more than 90% under 75 dB of noise. The speech synthesis module is designed on the basis of a customized TTS engine based on the MBROLA speech library, ensuring accurate recognition of the languages and dialects of different countries. The feedback logic is mainly designed as voice broadcasting, which makes it convenient for operators to obtain the current working status of the equipment; after a fault is triggered, it is broadcast in real time, for example, “the open circuit of phase U of the motor has taken effect”.

3.2.2 Fault Control Layer Design

The command parsing module converts natural language into machine-executable fault codes, for example, “motor phase line short circuit” $\rightarrow$ FAULT_MOTOR_SHORT. The open-circuit control module is designed with a relay switching time of no more than 5 ms and an on-resistance of less than 0.1 Ω . The short-circuit control module adjusts the impedance to realize the setting of short-circuit faults.

3.2.3 Data Management Layer Design

The operation log module displays the specific operation time, the original voice command, the fault code and the execution result, such as success or failure. The fault code synchronization module can read out and clear fault codes, providing operators with a better interactive experience.

4 Design and Implementation of Key Technologies

4.1 Design and Implementation of Voice-to-Fault Commands

Voice control of complex fault scenarios is realized through a multi-level command tree.

First-level commands: fault type. According to the needs of teaching organization, “open-circuit command”, “short-circuit command” and “restore command” are designed. Second-level commands are mainly used to specify the location of fault setting, that is, on which wiring harness of the new energy vehicle the fault is to be set, such as “sensor harness” and “motor harness”. Third-level commands are mainly used to select fault parameters. In the process of simulating a poor-contact fault, the expected fault setting can be achieved by setting the target impedance, such as an impedance of “5 Ω ” and a “duration of 5 s”; after the target impedance is set, a short-circuit fault is set on the target wiring harness.

4.2 Design and Implementation of the Safety Protection Mechanism

In order to ensure the safe operation of the equipment, a three-level fault fusing strategy is designed. The first is hardware fusing, namely a self-resetting fuse (trigger current 10 A); the second is software fusing, namely real-time monitoring of current fluctuations (threshold $\pm 20\%$); the third is emergency fusing, namely a physical emergency stop button (response time less than 50 ms). Through the above design of the safety protection mechanism, safety accidents during the use of the control equipment are effectively prevented.

5 Conclusion

The artificial intelligence fault-setting training bench for new energy vehicles designed in this study effectively solves the difficulties in cultivating maintenance technical personnel for new energy vehicles by integrating an advanced hardware system, software system and artificial intelligence. The application of the training bench not only improves the quality and efficiency of teaching, but also provides strong support for the development of new energy vehicle maintenance technology. In the future, the system performance will be further optimized and the application scenarios will be expanded, so as to cultivate more high-quality technical personnel for the sustainable development of the new energy vehicle industry.

References

- [1] M. Zhang and H. Li, “Research progress of fault diagnosis technology for new energy vehicles,” *Automotive Engineering*, vol. 44, no. 3, pp. 245-256, 2022.
- [2] L. Wang and S. Chen, “Design and implementation of an artificial intelligence-based automobile fault diagnosis system,” *Application Research of Computers*, vol. 38, no. 5, pp. 1456-1462, 2021.
- [3] W. Liu and M. Sun, “Innovative research on the talent training model for new energy vehicle maintenance technology,” *Vocational and Technical Education*, vol. 44, no. 2, pp. 78-85, 2023.