Research on the Application of Simulation Experiments in the Teaching of Railway Signal Power Supply System

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Abstract: Railway signal power supply system is a device that provides safe, stable and reliable AC and DC power for rail traffic signal equipment. Students majoring in urban rail transit communication and signal need to learn the working principles of various railway signal power supply systems. In the teaching of railway signal power supply system, the use of computer software for simulation experiments can improve the learning effect of students. This paper discusses the methods of using Proteus and CADe SIMU software to build experimental circuits and shows the results of simulation experiments, focusing on the difficulties in railway signal power supply system teaching. By comparing the test scores of the classes with and without simulation experiments, it is concluded that simulation experiments can help improve the average score, excellent rate and passing rate.

1. Introduction

Railway signal power supply system is a critical device that provides safe, stable and reliable AC and DC power to signal infrastructure such as track circuits, axle counters, switch machines and signal machines.[1] Signal maintenance workers need to perform maintenance on the railway signal power supply system according to the prescribed maintenance schedule and tasks. In the event of a failure, they should be able to complete tasks such as viewing alarm records, operation records, switching and troubleshooting. Therefore, it is essential for signal maintenance workers to master the working principle, operation and maintenance methods of the railway signal power supply system.[2]

In order to cultivate signal equipment maintenance talents that meet the needs of the rail transit industry, some vocational colleges have opened urban rail transit communication signal majors and set up professional courses on railway signal power supply system.[3][4] In the teaching process for students of this major, the future "signal maintenance workers", it was found that the students' learning effect of the railway signal power supply system related content is not good, especially in the aspect of analyzing the electrical schematic diagram of the railway signal power supply system. The main manifestations are in three aspects: first of all, facing the complex electrical schematic diagram, students feel at a loss and gradually develop a sense of fear; secondly, students cannot apply the knowledge and skills of the previous courses (such as electrical and electronic technology, electrical control and urban rail transit communication signal foundation) to the analysis of electrical schematic diagram; thirdly, students gradually lose interest and curiosity in the traditional teaching methods, and have difficulties in understanding the abstract electrical schematic diagram.

Simulation experiment is a means of using computer software to simulate complex systems and processes in the real world to obtain results close to the real ones. Simulation experiments have the advantages of high safety, low cost, easy modification and repeatability. The most important thing is that simulation experiments can make abstract problems concrete and easier to understand. Therefore, the simulation experiment method can be used in the teaching of railway signal power supply system to improve the teaching effect.[10]

2. Overview of Railway Signal Power Supply System Teaching Content

The teaching content of the railway signal power supply system is complex. According to the type

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of railway signal power supply system, it is divided into three parts: relay interlocking railway signal power supply system, computer interlocking railway signal power supply system and 25Hz railway signal power supply system. Each part contains many contents with several real railway signal power supply system schematic diagrams. As shown in Table 1, the main contents of the railway signal power supply system are deconstructed to form several knowledge blocks. There are 13 main teaching contents in 10 railway signal power supply system schematic diagrams, including power switching, voltage regulation and adjustment, and main-standby switching.

Table 1 Main Teaching Contents of Railway Signal Power Supply System

Type Function	PYT-10Y	PYJZ-10Y	PH1	PJ-15	PZ-15	PDT-20Y	PDT-30-4Y	PWJ1	PWZ1	PZT-2000/25
Power Switching	Y	N	Y	N	N	N	Y	N	N	N
Voltage Regulation	Y	N	N	N	N	Y	Y	N	N	N
Main-Standby Switching	Y	N	Y	N	N	Y	Y	N	N	Y
Working Indication	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Fault Detection and Alarm	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
AC-DC Conversion	N	Y	N	N	Y	Y	Y	Y	Y	N
AC Power Supply	N	Y	N	Y	N	Y	Y	Y	N	Y
DC Power Supply	N	Y	N	N	Y	N	N	N	Y	N
Parameter Measurement	N	Y	N	Y	Y	Y	Y	Y	Y	Y
Phase Loss Detection	N	N	Y	N	N	Y	Y	N	N	N
Voltage Comparison	Y	N	N	N	N	Y	Y	N	N	N
Frequency Conversion	N	N	N	N	N	N	N	N	N	Y
Lightning Protection and Grounding	Y	Y	N	N	N	N	Y	Y	Y	Y

3. Application of Simulation Experiments in the Analysis of Railway Signal Power Supply System

By using Proteus 8 Professional and CADe SIMU, it is possible to quickly build a simulation circuit of the railway signal power supply system.[7] In the process of selecting circuit elements, laying out wires and configuring parameters, students can deepen their understanding of the circuit principle of the railway signal power supply system. After the simulation circuit is built, students can directly observe the experimental phenomena. In this way, complex, abstract and difficult circuit analysis can be transformed into simple, concrete and easy simulation experiments. This paper takes the "voltage regulation" and "phase loss detection" which are considered difficult by most students, and the "fault detection and alarm" which appears the most, as examples to illustrate the method of using simulation experiment to carry out teaching.

3.1 Automatic Voltage Regulator Circuit

The automatic voltage regulation circuit in the PDT-30-4Y railway signal power supply system is shown in Figure 1. The working principle of the automatic step-down circuit is to use two voltage comparators F1 and F2 to compare the actual voltage and the reference voltage. If the actual voltage is higher than the reference voltage, the input voltage at pin 3 of voltage comparator F1 is higher than the input voltage at pin 2, and there is a voltage output at pin 6 of F1. The input voltage at pin 3 of voltage comparator F2 is lower than the input voltage at pin 2, and there is no voltage output at pin 6 of F2. The voltage output from pin 6 of voltage comparator F1 is amplified by the amplifier and then drives the coil of the voltage too high relay JG, causing the relay JG to be energized. The (8, 12) contacts of the relay JG are closed. At this time, the circuit to drive the step-down relay 5J will be connected:

IV → 4HK(7, 8) → JD(1, 9) → JG(8, 12) → 6J(41, 43) → 5J(1, 2) → 3KA(1, 2) → 4KA(1, 2) → Neutral Point

When the step-down relay 5J is energized, the (11, 12) contacts of the relay 5J are closed, and the circuit of the step-down action relay 7J is connected:

V → 3J(41, 43) → 5J(11, 12) → 8J(21, 23) → 7J(1, 4) → Neutral Point

When the step-down action relay 7J is energized, its contacts will connect the circuit of the forward rotation of the voltage regulating motor, and the voltage will be lowered.

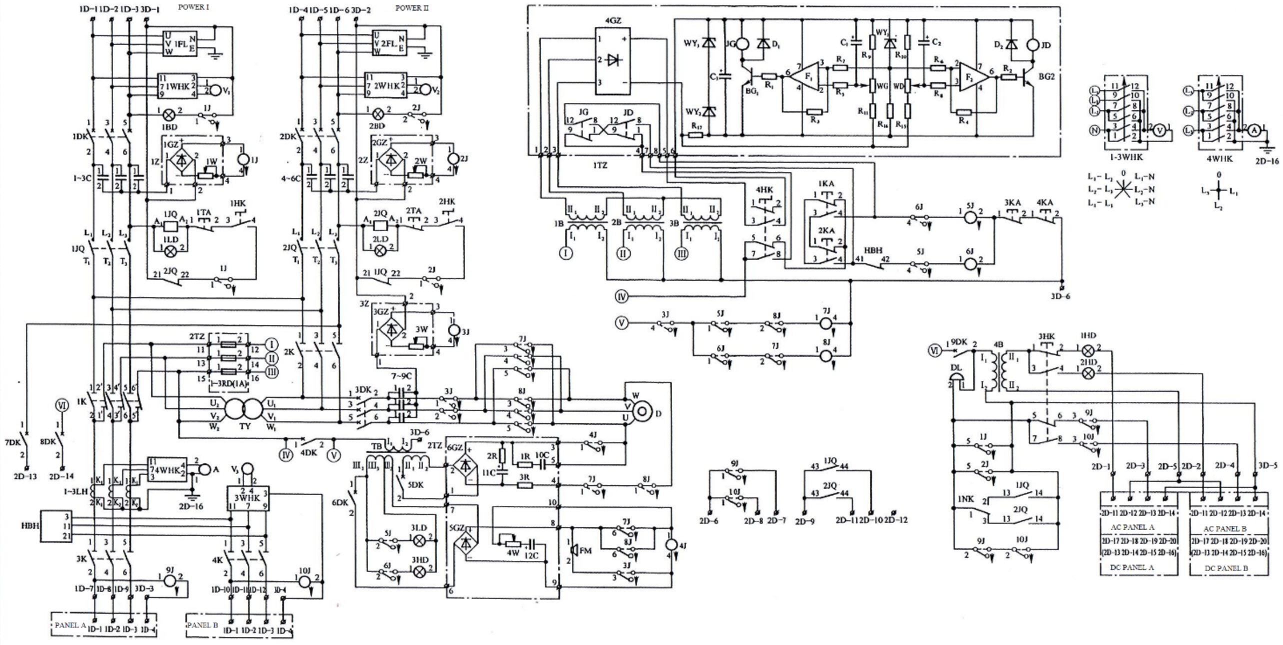

Figure 1 Schematic Diagram of PDT-30-4Y Railway Signal Power Supply System

If the actual voltage is lower than the reference voltage, the input voltage at pin 3 of voltage comparator F1 is lower than the input voltage at pin 2, there is no voltage output at pin 6 of F1, and the input voltage at pin 3 of voltage comparator F2 is higher than the input voltage at pin 2. There is a voltage output at pin 6 of F2. The voltage output from pin 6 of voltage comparator F2 is amplified by the amplifier and then drives the coil of the voltage too low relay JD, causing the relay JD to be energized and closed. The (8, 12) contacts of the relay JD are closed. At this time, the circuit to drive the step-up relay 6J will be connected:

IV → 4HK(7, 8) → JG(9, 1) → JD(12, 8) →HBH(41, 42) → 5J(41, 43) → 6J(1, 2) → 3KA(1, 2) → 4KA(1, 2) → Neutral Point

When the step-up relay *6J* is energized and attracted, the *(11, 12)* contacts of the relay *6J* are closed, and the circuit of the step-up action relay *8J* is connected:

V → 3J(41, 43) → 6J(11, 12) → 7J(21, 23) → 8J(1, 4) → Neutral Point

When the step-up action relay 8J is energized and attracted, its contacts will connect the circuit of the reverse rotation of the voltage regulating motor, and the voltage will be raised.

It is possible to build a project named AVR Circuit.pdsprj in Proteus 8 Professional and use a voltage comparator F1, a potentiometer, 2 relays, a DC motor and 4 DC power supplies to build a simulation circuit. After running, as shown in Figure 2a, when the actual voltage VA is higher than the reference voltage VR, the voltage comparator F1:A outputs a DC voltage of 4.98V, driving the step-down relay JYJ, and the motor rotates forward. When the actual voltage VA is lower than the reference voltage VR, the voltage comparator F1:B outputs a DC voltage of 5V, driving the step-up relay SYJ, and the motor reverses. When the actual voltage VA is equal to the reference voltage VR, the voltage comparators F1:A and F1:B only output a voltage of 0.03V, which is not enough to drive the step-down relay JYJ and the step-up relay SYJ, and the motor does not rotate.[8]

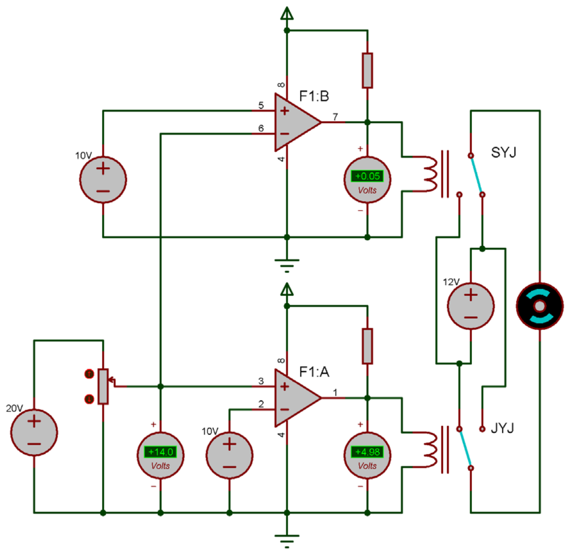

Figure 2a Automatic Voltage Regulator Circuit (Voltage Too High)

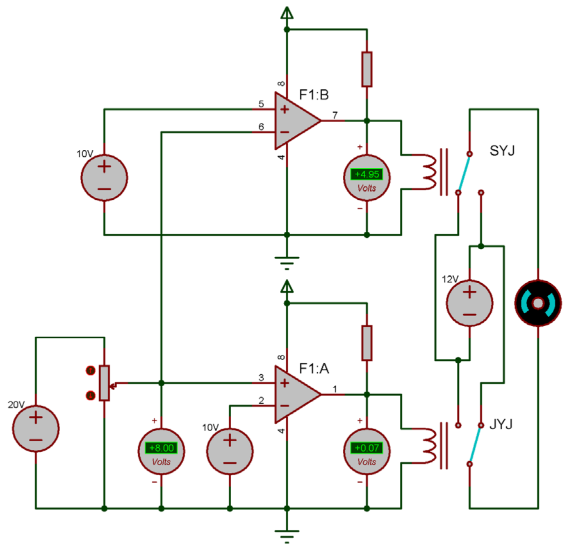

Figure 2b Automatic Voltage Regulator Circuit (Voltage Too Low)

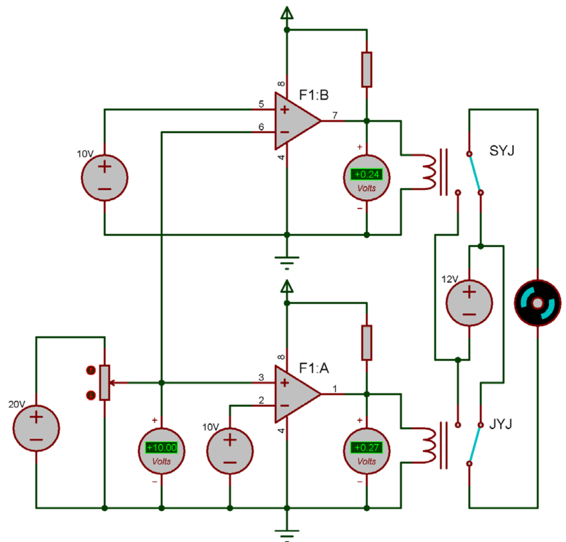

Figure 2c Automatic Voltage Regulator Circuit (Voltage Normal)

3.2 Phase Loss Detection Circuit

As shown in Figure 3, the phase loss detection circuit is used in the PDT-20Y type large station voltage regulator screen. The phase loss detection circuit is a circuit used to detect whether there is a phase loss fault in the three-phase AC power supply. The phase loss detection circuit connects the three live wires together through three capacitors to form a common point, and then connects them to the input of the rectifier 3GZ composed of four 1N4007 rectifier diodes, and finally connects the variable resistor W and the phase loss relay DXJ in series at the output of the rectifier 3GZ to form a loop.

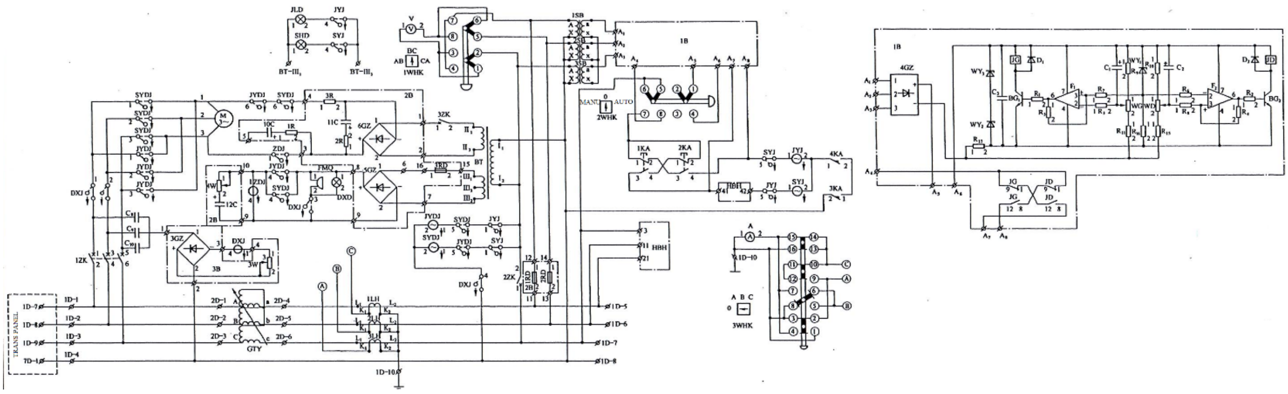

Figure 3 Schematic Diagram of PDT-20Y Railway Signal Power Supply System

The working principle of phase loss detection circuit is shown as follows:

When the three-phase sinusoidal AC power supply is normal, the voltage at the common point is balanced, the voltage between the common point and the neutral line is 0, the output voltage of the rectifier 3GZ is 0, the voltage on the coil of the phase loss relay DXJ is 0, and the phase loss relay DXJ drops.

When there is a loss fault in one or two phases of the three-phase sinusoidal AC power supply, the voltage at the common point is unbalanced, there is a voltage between the common point and the neutral line, the rectifier 3GZ has a voltage output, the coil of the phase loss relay DXJ has a voltage, and the phase loss relay DXJ is energized.

It is possible to build a project named Phase Loss Detection Circuit.pdsprj in Proteus 8 Professional, and use a three-phase sinusoidal AC power supply V3PHASE, 3 switches, 3 capacitors, 4 1N4007 rectifier diodes, a potentiometer W, a relay and a red LED to build a simulation circuit. As shown in Figures 4a, 4b and 4c, the phenomena when the three-phase sinusoidal AC power supply is normal, when one or two phases loss are shown.[9]

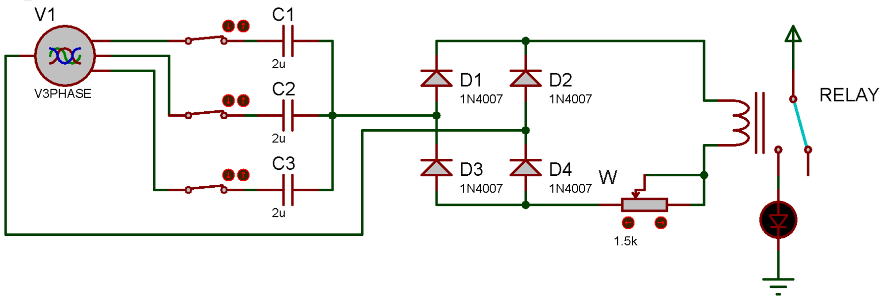

Figure 4a Phase Loss Detection Circuit (Normal)

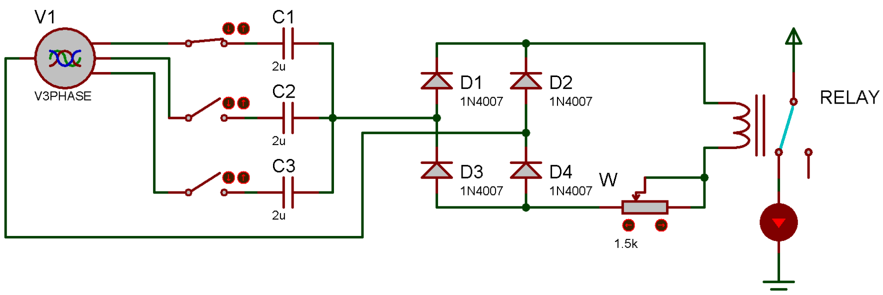

Figure 4b Phase Loss Detection Circuit (One Phase Loss)

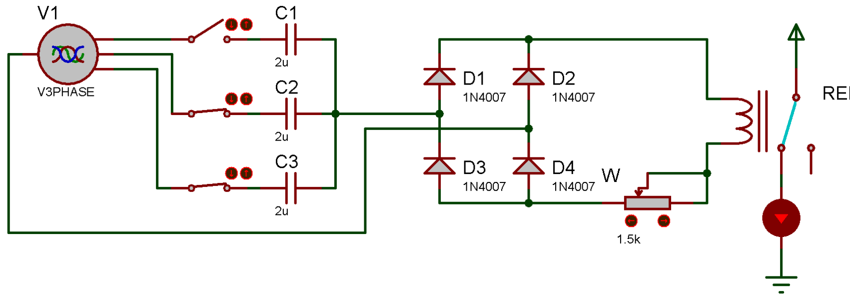

Figure 4c Phase Loss Detection Circuit (Two Phases Loss)

As can be seen from the simulation experiment, when the three-phase sinusoidal AC power supply is normal, the red LED is off; when one or two phases of the three-phase sinusoidal AC power supply are missing, the red LED is on. It should be noted that in the actual PDT-20Y railway signal power supply system circuit, when the phase loss fault occurs, the working circuit of the voltage regulator system will be cut off and an alarm will be issued; in the built simulation circuit, when a phase loss fault occurs, an alarm signal is conveyed by turning on a red LED.

3.3 Fault Detection and Alarm Circuit

Figure 5 shows the fault detection and alarm circuit of PYJZ-10Y railway signal power supply system. The fault detection and alarm circuit are able to detect and alarm faults by monitoring relays.[5][6] Its working principle is to connect the coils of several monitoring relays (JDJ, DDJ, BSJ, 1XHJ and 2XHJ, etc.) to the monitored circuit respectively, and connect the middle contacts and front contacts of the monitoring relays to the white working indicator lights (JBD, SBD, DBD and XBD, etc.) in the loop, and connect the middle contacts and rear contacts of the monitoring relays to the fault alarm red light GHD and the alarm bell FMQ in the loop.

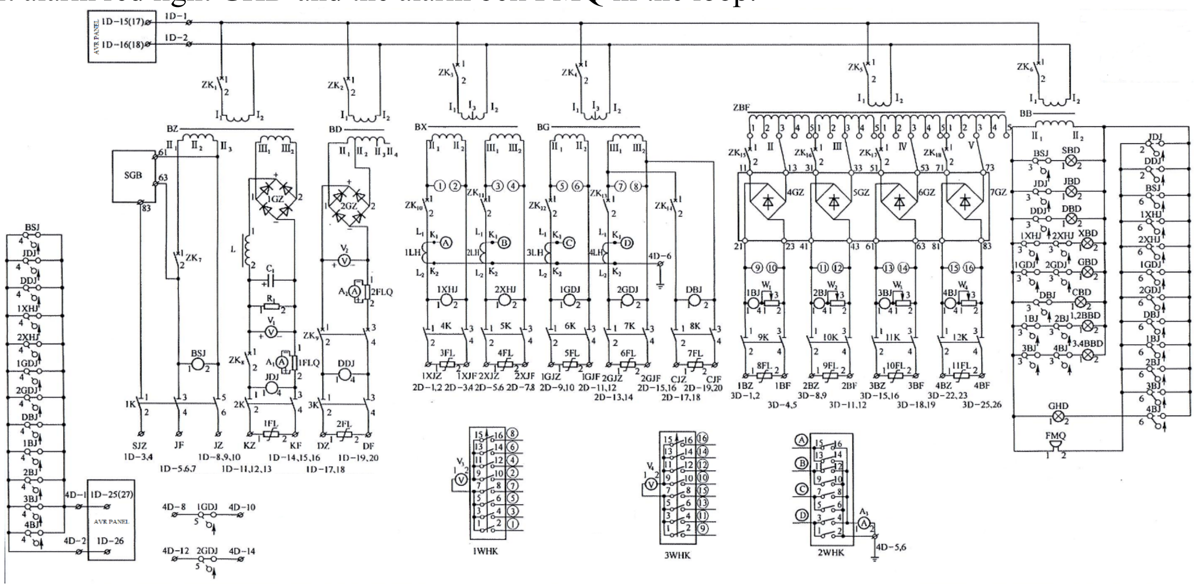

Figure 5 Schematic Diagram of PYJZ-10Y Railway Signal Power Supply System

When all circuits are normal, all monitoring relays are energized because the voltage on the coils is not lower than the set voltage. At this time, all the middle contacts and front contacts of the monitoring relays are closed, all the white working indicator lights are on; the middle contacts and rear contacts are open, cutting off the fault alarm red light GHD and the alarm bell FMQ circuit, and no sound and light alarm is issued.

When a power failure occurs in a circuit, the monitoring relay of this circuit is de-energized because the voltage on the coil is lower than the set voltage. At this time, the middle contact and front contact of the monitoring relay are open, and the white working indicator light of this circuit is off; the middle contact and rear contact are closed, and the fault alarm red light GHD and the alarm bell FMQ circuit are closed, and a sound and light alarm is issued.

In CADe SIMU software, an engineering named Fault Detection and Alarm Circuit.cad can be established, and a simulation circuit is built using several components such as 1 three-phase four-wire power supply, 6 transformers, 3 monitoring relays, 3 green lights, a red light and a bell. Figures 6a and 6b show the phenomena when the circuit is normal and when the circuit is faulty, respectively.

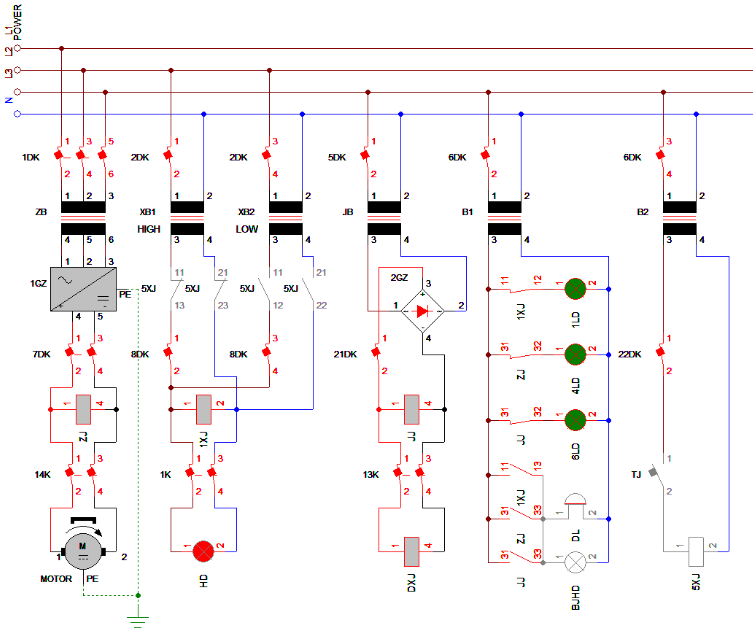

Figure 6a Fault Detection and Alarm Circuit (Normal)

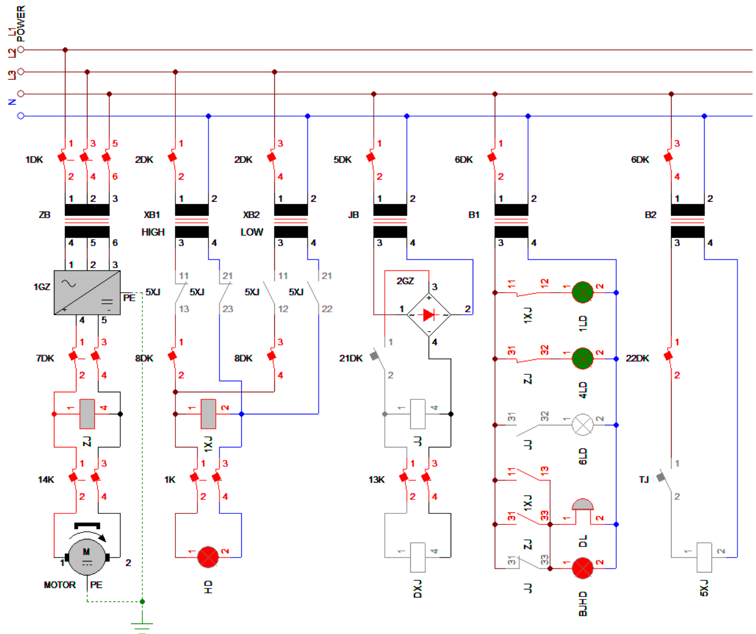

Figure 6b Fault Detection and Alarm Circuit (Fault)

4. Teaching Effect Evaluation

The author, as the course instructor, taught and assessed 177 students in four classes, two grades each, in the Department of Rail Transit Engineering, Guizhou Communications Polytechnic. Table 2 shows the teaching situation and assessment results.

As can be seen from Table 2, in the teaching of Class A, simulation experiments were not used as auxiliary teaching methods. The main teaching methods were analyzing electrical circuit diagrams in the classroom, supplemented by multimedia equipment demonstrations, and learning in the training classroom with equipment. In the teaching of Classes B1, B2 and B3, simulation experiments and multimedia equipment were used as auxiliary teaching methods, and practical teaching was also carried out in the training classroom. From the assessment results, among the three classes that conducted simulation experiments, the average scores of Classes B2 and B3 were higher than that of Class A which did not conduct simulation experiments. The average score of Class B1 was lower than that of Class A. The excellent and good rate of Class B1 was lower than that of Class A, and the excellent and good rates of Classes B2 and B3 were significantly higher than that of Class A, of which the excellent and good rate of Class B2 reached 74.29%. The passing rates of Classes B1, B2 and B3 were 100.00%, and the passing rate of Class A was 98.48%. By calculating the Spearman correlation coefficient, it was found that the correlation coefficient between whether or not to conduct simulation experiments and the average score and the excellent and good rate was 0.258, and the correlation coefficient between whether or not to conduct simulation experiments and the passing rate was 1.000. It can be seen that conducting simulation experiments has a positive effect on improving students' average scores, excellent and good rates, and passing rates.[10]

Table 2 Teaching and Assessment Situation of Railway Signal Power Supply System

Class		A	B1	B2	B3
Class Size		66	41	35	35
Simulation Experiment		N	Y	Y	Y
Practical Teaching		Y	Y	Y	Y
Multimedia Teaching		Y	Y	Y	Y
Score	Excellent	2	1	5	1
	Good	17	11	21	19
	Average	36	19	7	14
	Pass	10	10	2	1
	Fail	1	0	0	0
Average Score		77.9	75.6	82.3	79.3
Excellent and Good Rate		28.79%	27.27%	74.29%	57.14%
Passing Rate		98.48%	100.00%	100.00%	100.00%

5. Conclusion

Simulation experiments are a simple, efficient, fast, low-cost, safe, and intuitive way to verify and explore existing knowledge and theories. In the teaching of professional courses for students in higher vocational colleges, simulation experiments can help to improve students' learning interest, cultivate their ability to learn independently, help them understand abstract concepts and theories, and improve the learning effect.

This paper describes a method for using simulation experiments in the analysis of signal power supply system circuit diagrams. The method was developed by the author based on their experience teaching and assessing the course "Railway Signal Power Supply System." The paper first outlines the application of simulation experiments in teaching the signal power supply system, and examples include automatic voltage stabilization circuits, phase break detection circuits, and fault detection and alarm circuits. The paper then analyzes the achievements made in improving the teaching effect through the use of simulation experiments. This includes evidence that simulation experiments have a positive impact on student performance, as measured by average scores, the percentage of students achieving excellent or good grades, and the overall course pass rate.

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