Teaching and Training System of Power Grid Monitoring Technology Based on Multimodal Information Processing

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Abstract. In view of the poor teaching function and operation performance of the existing power grid monitoring technology course training system, the optimal design of the power grid monitoring technology course teaching training system is realized by using multi-modal information processing technology from three aspects of hardware, database and software functions. Firstly, adjust the operation mode of the system server, refit the curriculum teaching information collector, system communication network architecture, embedded processor, memory and other hardware equipment, and use the optimization circuit to realize the connection of hardware equipment. Then set the unified storage mode of data, and build the system database combined with the logical relationship between data. Based on this, a virtual training scene of power grid monitoring technology course teaching is constructed, in which the implementation process of power grid monitoring technology is simulated, and the course resources are retrieved by using multimodal information processing technology. Experiments show that compared with the traditional system, the functional operation success rate and throughput of the system in this paper are higher.

Keywords: Multimodal information processing · Power grid monitoring technology · Course teaching · Training system

1 Introduction

Power grid monitoring technology is the product of the era of digitalization and informatization, and has been widely used in high/low voltage distribution in many fields such as buildings, stadiums, scientific research facilities, airports, transportation, hospitals, power and petrochemical industries. in the electrical system [1]. The power grid monitoring technology monitors the working status of high-voltage switchgear, low-voltage switchgear, emergency generator sets, power transformers and EPS/UPS/ATS. Real-time monitoring is achieved by recording various parameters such as single-phase/three-phase voltage, single-phase/three-phase current, power, power factor, electrical degree, frequency, and current switch status, and generates early warning and alarm when the parameter value exceeds the allowable range, and control related equipment. It greatly

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improves the reliability, safety and automation level of the power supply and distribution system with less investment. With the deepening of the "three sets and five five" reforms of the State Grid Corporation, many positions and business processes have been adjusted. Under this "big operation" and "overhaul" pattern, the changes brought about by the positions and responsibilities of power grid technicians more prominent. In order to help employees adapt to their jobs as soon as possible, the power grid industry does not provide professional talents, and corresponding curriculum development and training are also urgently needed to be established and carried out.

Today's power grid monitoring technology training not only strengthens the theory, but also pays more attention to the training of on-site practical operation level. The power grid monitoring technology training course teaching is not only the main carrier of power skill training, but also an important way to carry out professional training teaching. The equipment and site of the training room have a large investment, but the utilization rate is not ideal. How to make better use of the existing resources, develop the teaching tasks of the training room, study the new training functions of the equipment of the training room, and meet the training needs is the top priority of the current research. It will have guiding significance for the teaching construction and application prospect of power grid monitoring technology training course. In order to break the limitation of time and space and reduce the teaching cost of power grid monitoring technology training course, a power grid monitoring technology teaching and training system is designed and developed.

Judging from the current research on the teaching and training system of power grid monitoring technology courses, simulation technology is increasingly applied in the field of training and teaching, solving the problem of practical skills training for on-site personnel. At present, the training system generally adopts a software and hardware mixed mode simulation system. The software simulation can be carried out through the computer workstation to carry out the simulation of the primary and secondary systems and monitoring systems of the whole station. Physical simulation. The relatively mature teaching and training systems currently developed mainly include: teaching and training system based on CAXA numerical control simulation, teaching and training system based on FluidSIM software and teaching and training system based on network environment. However, the application of the above-mentioned traditional teaching training system to the teaching work of power grid monitoring technology has obvious problems such as narrow application scope, single teaching mode, and imperfect training teaching resources, which ultimately affect the teaching function of the curriculum teaching training system and application performance. To this end, the multimodal information processing technology is introduced to realize the optimal design of the teaching and training system of the power grid monitoring technology course.

The concept of multimodality comes from the research of information representation in the field of computer human–computer interaction. The term "mode" is defined as the representation and exchange of information on a specific physical medium. Multimodal information processing technology processes the data and information of multiple modes. It is mainly used in the fields related to intelligent system and artificial intelligence, such as object recognition, information retrieval, man–machine dialogue and so on.

In this study, multimodal information processing technology is applied to the optimization design of the teaching and training system of power grid monitoring technology, in order to improve the teaching and training function and application performance of the system.

2 System Hardware Design

The embedded hardware design needs to meet the normal teaching and training of application development power grid monitoring technology course, but as a product, its stable performance must be fully considered [2]. The architecture of the overall system hardware design is shown in Fig. 1.

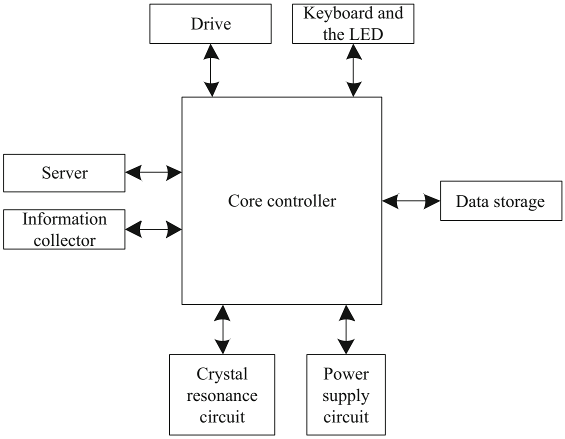

Fig. 1. The hardware structure diagram of the course teaching and training system

According to the modularization method, according to the performance parameters, price, application field and the convenience of technical support as the chip selection criteria, the support chips for the functions of each module are selected and connected according to the method shown in Fig. 1.

2.1 Configure the System Server

Server hardware configuration refers to setting and performing operations on the server hardware as required to meet users' service requirements [3]. In this system, the Boa Web server is used as the system server. Boa server is mainly used for information exchange between interconnected embedded devices. It can monitor the embedded devices through the network and automatically upload the feedback information to the main control device.

2.2 Course Teaching Information Collector

Course teaching information collector mainly includes three parts: DDS signal generating circuit, dedicated A/D and D/A conversion circuit. A DD signal generation circuit is designed in the TMS320C6722B floating-point DSP experimental teaching system. The generated signal can be output through the DDS output terminal on the front panel of the system, and can also be connected to the input of the system A/D through a jumper, so that the system itself can play the role of The function of a signal generator, without the need for an external signal generator. In addition, considering that the DDS signal circuit needs to be used, and the corresponding algorithms and programs are used to generate more complex special signals, such as TVM430 signals, the requirements for phase and accuracy are very high. Therefore, this module is not suitable for connecting to the periphery of the STM32 coprocessor. Instead, it is connected to the TMS320C6722B floating-point DSP chip with high arithmetic precision and strong real-time performance, which is easy to control and send various regular signals such as single frequency, FSK, PSK and some special special signals, and is also conducive to the application teaching of DSP.

In addition, the D/A conversion circuit of the experimental teaching system is realized by the D/A conversion chip AD5547 produced by ADI Company with a simple peripheral circuit. The AD55471 is a parallel input, dual current output, 16-bit multiplying DAC with 4-quadrant resistors and a + 3.3 V supply voltage [4]. The circuit connection diagram of its 4-quadrant multiplying DAC AD5547 with an external reference voltage is shown in Fig. 2.

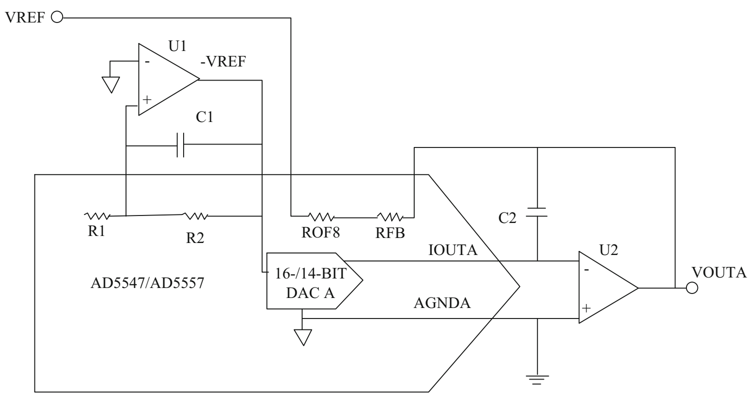

Fig. 2. D/A conversion circuit diagram

2.2.1 System Communication Network Architecture

The teaching data of power grid monitoring technology course is transmitted from the server of data acquisition module board to the student terminal through LAN. Figure 3 is the network transmission framework of teaching information of power grid monitoring technology course.

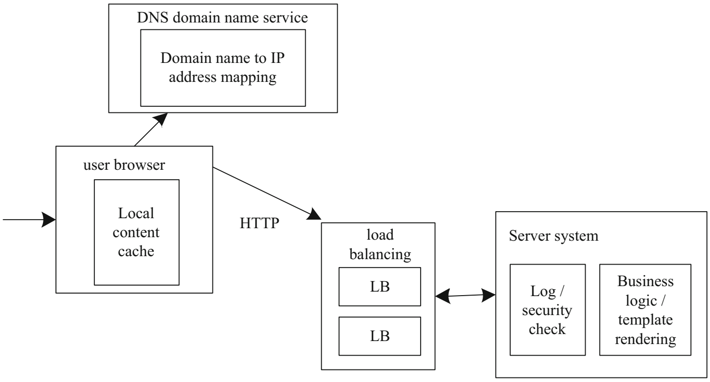

Fig. 3. Communication network architecture diagram

Common local area network file transfer protocols include Transmission Control Protocol and User Datagram Protocol [5]. Transmission control protocol requires three-way handshake, has functions such as timeout retransmission, data verification and control flow, etc., and the reliability of data transmission is good. However, when using transmission control protocol, a TCP connection must be established between the student terminal and the server. The student terminal and the server to exchange data with each other. The user datagram protocol is a simple datagram-oriented transport layer protocol, which is only responsible for transmitting the data packets sent by the server application to the IP layer, without establishing any connection between the student terminal and the server. Therefore, the user datagram is used. The protocol transfer speed is relatively fast [6].

After comparing the two file transfer modes, it can be seen that in order to ensure the correct delivery, TCP will perform additional calculations to verify the correctness of the delivery, which increases the complexity of file transfer and significantly increases the transfer time, which will affect the real-time nature of the learning resource transfer., and the UDP protocol does not need to establish a virtual connection, which saves time. The transmission of Tibetan language resources has good real-time performance, and can provide point-to-point transmission, multicast and broadcast, which is suitable for the teaching and training of power grid monitoring technology courses.

2.3 Embedded Processors

According to the selection requirements for the core data processor of the course teaching and training system, we mainly consider the C672x series floating-point DSP chips, a sub-series of the C67x family, which mainly includes C6722, C6726, C6727 and C6720. In the hardware design of the experimental system, based on the principle of the most cost-effective chip, the industrial standard requirements of the chip and the simple TQFP packaging form are integrated, TMS320C6722B is selected as the core data processor of the system, and its internal structure is shown in Fig. 4.

The TMS320C6722B processor shown in Fig. 4 adopts the enhanced CPUC67x + , which has been significantly improved in terms of speed, code density and floating-point

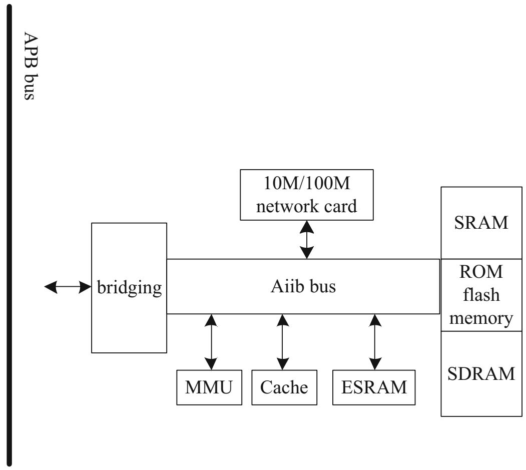

Fig. 4. Communication network architecture diagram

computing capability on the basis of being compatible with the C67xCPU. The number of internal registers of C67x + CPU is increased from 32 to 64, with 256 KB of RAM and 384 KB of ROM on-chip, which can be used as unified program/data memory; the capacity of instruction cache is increased from 4 to 32 K; The number of "instructions" has been increased from 2 to 4 [7]. The C6722B introduces the dMAX engine, which moves the processor's load to dedicated off-chip memory. The high-performance crossbar switch is used as a central hub between different bus masters to control different targets, so that multiple data transmissions can be carried out in parallel. The C6722B has peripherals dedicated to audio applications, including 2 McASP, 1 EMIF, 2 12C, 2 SPI, 1 RTI, and more.

2.4 Teaching Information Storage of Power Grid Monitoring Technology Course

Using SDRAM as the information memory of the power grid monitoring technology course teaching and training system, that is, synchronous dynamic random access memory, using 3.3v working voltage, 64-bit bandwidth, based on dual memory structure, including two interleaved memory arrays, when the CPU from one When one storage bank or array accesses data, the other is ready for reading and writing data, and the read efficiency can be multiplied by the close switching of the two storage arrays. Considering that the experimental system is a high-speed digital signal processing system, and it will be used as a hardware development platform for engineering applications in the future, the off-chip memory capacity requirements are relatively strict, therefore, the 8 M-word SDRAM memory MT48LC8M16A2 is selected. On this basis, the mode register is added to define the specific mode of SDRAM work.

2.5 System Circuit Design

According to the crystal oscillator circuit and LED display circuit of the power grid monitoring technology course teaching and training system, the optimal design of the system circuit is carried out. The working clock is provided by the crystal oscillator circuit. The LPC2294 crystal oscillator can be connected to an external crystal oscillator, and the clock signal is generated by the external crystal oscillator. The frequency range of the external crystal oscillator is generally 1-30 MHz. The crystal oscillator frequency of the system hardware selection part is 12 MHz. After frequency multiplication, the frequency of the crystal oscillator can reach 60N. The crystal oscillator circuit is very simple. Just connect the XT1 and Xtopll of the LPC2294 to the external crystal X2 and capacitor. The principle of the crystal oscillator circuit is as follows shown in Fig. 5.

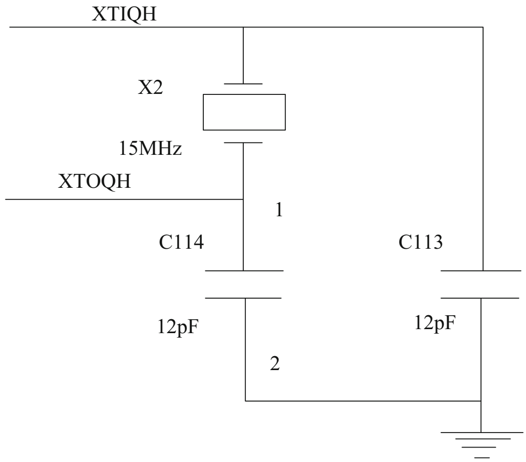

Fig. 5. Crystal oscillator circuit diagram

From the perspective of LED display circuit, 16 buttons and 8-bit digital tubes are designed, and ZLG7290 is selected as the LED driver chip. The rC interface of ZLG7290 has stable performance and the transmission rate is 32kbis. Using the C bus mode can save the I/O port resources of the processor. The working voltage of ZLG7290 is 3.3 V, and 220 ohms is used as the current limiting resistor of the LED. The 16 buttons are connected to the SEGB and SEGA pins of the driver chip respectively. The scan values of the 16 buttons S1-S16 are 1–16 respectively. The interrupt pin of LPC2294 is P0.30/EINT3, which is connected with the keyboard interrupt output signal of ZLG7290. SDA and SCL of ZLG7290 are connected to P0.3 and P0.2 of LPC2294 respectively.

3 Course Teaching and Training System Database Design

The goal of database design is to design and optimize the logical and physical structure of the database according to specific user needs and certain computer software and hardware environment, establish an efficient and safe database, and provide a good platform for the development and operation of database application system [8].

The database of the system in this paper is composed of power grid monitoring technology courses, student training records, training topic table, student training topic and other information. Taking the training subject information as an example, the corresponding database table design results are shown in Table 1.

Table 1. Training subject database

Field	Instruction	Type	Is empty
Training_ID	Course ID	INT (4)	No
Training_Name	The name of the training subject	VARCHAR2 (500)	No
Training_type	Types of training topics	INT (4)	No
Training_order	Training order	INT (4)	Yes
Training_Preview	Preview content	TEXT (16)	Yes
Training_content	Training content	TEXT (16)	Yes
Training_video	Video resources	INT (312)	Yes
Training_address	Video resource storage location	VARCHAR2 (500)	Yes
Training_special	Training topic ID	INT (4)	Yes
Training_proportion	Operating scale	INT (4)	Yes
Training_score	The percentage of training report scores	INT (4)	Yes

Similarly, the construction results of other database tables in the system can be obtained. According to the internal logical relationship between data, the links between database tables can be formed to facilitate the real-time update of data.

4 Software Function Design of Course Teaching and Training System

4.1 Build a Training Scene for the Power Grid Monitoring Technology Course

Before the development of virtual simulation software, the model needs to be made, and the information collection of equipment is the first step of model making. In the process of collecting device information, it is necessary to focus on collecting detailed information of the device, such as the arrangement of buttons and the distribution of screens. Then the proportional modeling is carried out according to the information of the equipment, and the images collected in the field can be used as model textures to increase the sense of realism. In the process of modeling, due to the large amount of project engineering and the large number of models, in order to ensure the matching degree between the models and make it easier to manage, it is necessary to establish certain specifications, such as naming, units, axis positions, and material maps. The unified modeling specification can also reduce the calculation pressure of the calculation platform in the later stage of the project. The establishment of the three-dimensional model of microgrid equipment is the premise and basis for the realization of the microgrid virtual simulation experiment teaching system. The quality of the model directly affects the authenticity of the scene and the operating efficiency of the system. The microgrid equipment has a complex structure and many components, so the powerful and easy-to-operate 3ds Max software is used for modeling, which requires commands such as extrusion, turning, and lofting. In the process of modeling, the size of the model is determined according to the size of the actual equipment. Taking the grid structure as an example, its size structure can be calculated by formula 1.

$$\begin{cases} x = \kappa \cdot X \\ y = \kappa \cdot Y \\ z = \kappa \cdot Z \end{cases} \tag{1}$$

In the formula, κ is the size scale factor between the simulated scene and the actual power grid, and (x, y, z) and (X, Y, Z) are the device node coordinates in the simulated scene and the actual scene.

Complete the construction of important equipment models such as power grid cabinet and switch through the connection of nodes, and set its control buttons. In order to be closer to the real microgrid equipment, the three-dimensional model must have high simulation and realistic feeling. The establishment of the three-dimensional model of microgrid is only a preliminary construction, which is very different from the real equipment in both color and material [9]. In order to make the model more realistic and give people the feeling of experiencing its environment, it is necessary to optimize the model. In 3ds Max, the optimization of the model is mainly by adding materials and textures. After creating the model of each component of microgrid equipment, it is necessary to build the model according to the situation of real equipment. Create a new file in 3ds Max, then import and merge all 3D models into the file, and combine the models.

4.2 Implementation Process of Simulated Power Grid Monitoring Technology

First, collect the real-time voltage and current phase data of the power grid. When a digital signal is connected to its digital input port, the high and low level changes of the input voltage will be input to the CPU of the main control module through optical couple isolation for square wave signal comparison. The rising edge of the default voltage signal square wave signal comes first, That is, the rising edge of the square wave signal first enters the analog acquisition port of the main control module. At this time, the timing counter starts timing until the rising edge of the square wave of the current signal arrives.

The time difference between the rising edge of the voltage and current square wave is recorded as time t, the period of the voltage and current square wave signal is the same, both are set as T, the period of the AC power grid is 20 ms, and the period T

is 20 ms, then the phase shift difference between the voltage and current square wave signal can be calculated, which can be expressed as:

$$\mathrm{f} = \left(\frac{t}{T} \times 360^{\circ}\right) \tag{2}$$

The real-time collected data is stored in the system memory, because the power factor is the cosine value of the phase shift of the voltage and current signals, and its power factor can be expressed as:

$$\mathrm{cosf} = \cos\left(\frac{t}{T} \times 360^{\circ}\right) \tag{3}$$

From this, the real-time data acquisition results of voltage, current and power can be obtained as follows:

$$\begin{cases} U = E_{t1} + \left[a(t - t_1) + b(t - t_1)^2 + c(t - t_1)^3\right] \\ I = \dfrac{U}{R^2} \\ P = UI \times \cos f \end{cases} \tag{4}$$

In the formula, E_{t1} represents the grid electromotive force, a, b and c are constant coefficients, and the specific value of the coefficient is determined by the grid structure, t and t_1 correspond to the grid acquisition time and acquisition interval, and R is the grid in the grid. total resistance value. The result calculated by formula 4 is the real-time monitoring value of the power grid. On this basis, the grid control quantity is calculated according to the ideal target of grid operation. The specific calculation formula is as follows:

$$\begin{cases} \Delta U = U_{\text{ideal}} - U_{\text{collection}} \\ \Delta I = I_{\text{ideal}} - I_{\text{collection}} \end{cases} \tag{5}$$

In the formula, the variables U_{ideal}, $U_{\text{collection}}$, I_{ideal} and $I_{\text{collection}}$ are the ideal and collected values of the grid voltage and current, respectively. Substitute the calculation result of formula 5 into the grid controller, so as to complete the monitoring and control of the grid.

4.3 Retrieval of Course Resources Using Multimodal Information Processing Technology

For text, video, audio and other types of curriculum resources, the characteristics of each curriculum resource are extracted by using multimodal information processing technology. Finally, the retrieval of training curriculum resources is realized through the relationship between keywords and resource characteristics. Taking audio course resources as an example, the audio feature items to be extracted include short-term energy, loudness, Short-term zero crossing rate, center frequency, bandwidth, etal. The short-time energy refers to all the energy gathered by the sampling point signal in a short-time audio frame, and its calculation formula is:

$$\eta_{\text{energy}} = \sum_m [x(n)w(n-m)]^2 \tag{6}$$

In the formula, $x(n)$ and $w(n)$ are the n sampled signal value in the m short-time frame and the window function of length N, respectively. The loudness distribution of the audio signal reflects the variation of the amplitude of the audio signal with time, and the root mean square of the amplitude of the audio signal in each frame can approximately represent the audio loudness of each frame. The calculation formula is:

$$\eta_{v(n)} = \sqrt{\frac{1}{N}\sum_{n=1}^{N-1} x^2(n)} \tag{7}$$

In addition, the calculation formulas of the short-term zero-crossing rate, center frequency, and bandwidth characteristic indicators are as follows:

$$\begin{cases} \eta_{Z_n} = \sum_m |\text{sgn}[x(n)] - \text{sgn}[x(n-1]|w(n-m) \\ \eta_{FC} = \int_0^{\omega_0} |F(\omega)|^2 d\omega \\ \eta_{BW} = \frac{\int_0^{\omega_0} (\omega - \eta_{FC})|F(\omega)|^2 d\omega}{E} \end{cases} \tag{8}$$

In the formula, sgn[·] is the sign function, $F(\omega)$ is the Fourier transform coefficient of each frame, and ω_0 is half of the sampling frequency. Input the keywords of course resources to be retrieved into the system environment, and use formula 9 to perform similarity matching.

$$\text{Sim} = \sum |\eta - \eta_{in}|\, \text{Sim} = \sum |\eta - \eta_{in}| \tag{9}$$

In the formula, η and η_{in} are the set course resource feature and the input keyword extraction feature, respectively. If the calculation result of formula 9 is higher than 0.9, it is determined that the current course resource is the resource to be retrieved, and the output can be directly output to complete the retrieval of the course resource.

4.4 Interactive Design of Course Teaching and Training

Interactivity is one of the most important characteristics that distinguish the teaching and training of power grid monitoring technology course from other teaching forms. The traditional courseware form only electronizes the experimental textbooks or allows students to watch videos, lacks communication with students, and students can not simulate the training operation [10].

In the teaching system of power grid monitoring technology course, we should not only present the teaching information, but also allow users to easily control the training process and obtain the training feedback information, so as to achieve the effect of real-time communication with users. Set menu, window, button, icon, man–machine dialog box and other elements. The menu is the navigator of the whole simulation experiment system. Through the pop-up menu, users can complete the whole experimental project, select learning content and control the experimental process.

The teaching and training system of power grid monitoring technology course is composed of a large number of forms, and each form can be divided into several different areas: title area, scene demonstration area, operation prompt area, information input area, information feedback area, etc. Different interaction modes are designed in different regions, and they form an interactive set to complete the whole training project together. The training instrument is composed of a large number of operation buttons. Each button realizes different functions. When users click them, corresponding experimental scenes will appear, such as switch closing, power flashing, instrument horizontal adjustment, pointer change, object movement, button rotation and so on.

In the simulation experiment system, when the user moves the mouse close to the experimental instrument and button, if the hand icon appears, it means that the experimental instrument can be operated and the button can be clicked. The dynamic icon reminds the user to pay attention to the experimental instrument and carry out the experimental operation through graphic flashing. If the air cushion guide rail is leveled, a dynamic icon will appear at the bottom corner screw, prompting the user to click the bottom corner screw for horizontal adjustment. The function of man–machine dialog box is to allow users to change experimental parameters, input experimental data and control experimental process. You can control and adjust the components in the virtual environment during the teaching and training of power grid monitoring technology course in three ways: pull list, text box input and pop-up dialog box, and finally complete the teaching and training task.

To sum up, with the support of hardware equipment and database, business processes can be reorganized on the basis of analyzing existing business processes to generate new and more reasonable business processes. The business process of the teaching and training system of power grid monitoring technology course based on multi-modal information processing is shown in Fig. 6.

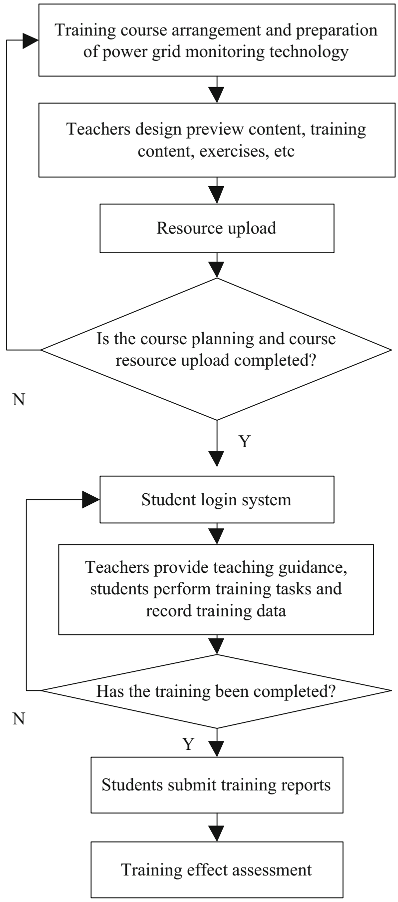

Fig. 6. Flow chart of course teaching and training

5 System Test

The purpose of testing is not only to detect the errors of the software, but also to In order to verify the power grid monitoring technology course teaching and training system based on multi-modal information processing, the following experiments are designed.

Connect the hardware system and the main test computer together, and convert the system software function into the program code that the computer can deal with directly, and complete the development of the system and the construction of the test environment.

This experiment was tested from the teaching function and operation performance of the power grid monitoring technology course teaching training system. The set test indicators were the functional success rate, throughput rate and changes in student training scores. Among them, the calculation composition of function success rate is as follows:

$$\mu_{suc} = \frac{N_{suc}}{N_{all}} \times 100\% \tag{10}$$

In the formula, N_{suc} and N_{all} are the total number of successfully running system function tasks and setting tasks, respectively. And the numerical result of throughput rate can be expressed as:

$$\delta = \frac{num}{t} \tag{11}$$

Among them, *num* and *t* are the number of system concurrency and the average response time, respectively.

In order to reflect the advantages of the design system in functions and performance, the traditional teaching and training system based on CAXA numerical control simulation is used as a comparison system to complete performance verification with the system in this paper. Experimental group, ensure that the operating environment and processing examples of the comparison system are the same.

The test cases set in the process of system function test specifically include: collecting power grid voltage data, collecting power grid current data, collecting power grid power data, building power grid virtual environment, starting power grid controller, power grid voltage regulation, etc. a total of 500 function test cases are set in the experiment, which are divided into 5 groups on average. Mark the expected results of each function test case respectively, compare the system output results with the expected results, and judge whether the current system output results are successful. After the system operation and statistics of relevant data, the test results of system function are obtained, as shown in Table 2.

Table 2. Number of use cases required for different systems to run successfully

Experimental group	Total use cases / piece	Traditional system	System of this paper
1	100	100	100
2	100	97	100
3	100	95	99
4	100	96	98
5	100	99	100

By substituting the data in Table 2 into formula 10, it can be concluded that the average operation success rates of traditional system and design system are 97.4% and 99.4% respectively. It can be seen that the design system has obvious advantages in operation function. Extract the system background operation data and substitute it into formula 11 to obtain the test results of system operation performance, as shown in Fig. 7.

It can be seen intuitively from Fig. 7 that the throughput rate of the system in this paper is higher, indicating that the operating performance of the system in this paper is better.

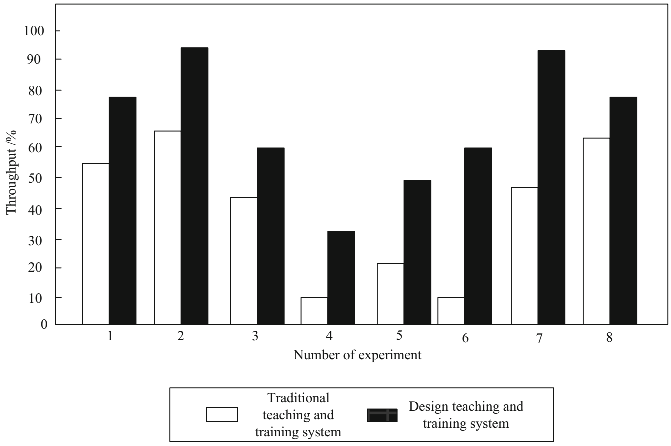

Fig. 7. System performance test results

6 Conclusion

Power grid training teaching is very important for improving the quality of power system staff and practical operation skills. Therefore, this study uses multi-modal information processing technology to optimize the teaching and training system of power grid monitoring technology from the perspective of practical training center.

The system is designed from three aspects of hardware, database and software functions. Firstly, the operating mode of the system server is adjusted, and hardware equipment such as course teaching information collector, system communication network architecture, embedded processor and memory is optimized. Then set the unified data storage mode, combined with the logical relationship between data to build the system database. Finally, a virtual training scenario for the course teaching of power grid monitoring technology is constructed, and the course resources are retrieved by using multi-modal information processing technology.

The experimental results show that compared with the traditional system, the system in this paper has higher success rate of function operation and throughput, and better application effect.

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