Design and Implementation of the “Internet plus” Intelligent power simulation and learning system

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Abstract. Aiming at the shortcomings of the existing power simulation training system, this paper proposes a design of the Internet plus intelligence power simulation and learning system based on cloud computing, artificial intelligence and adaptive learning technology. The system solves the problems of dispatching, monitoring, operation and maintenance personnel unable to use fragmented time to carry out simulation learning at any time and anywhere, can not carry out adaptive learning according to learners' knowledge and skills, lack of guidance and evaluation system in the process of distance autonomous learning, lack of interest in the system, and can not effectively stimulate the learning interest of learners. The research results of this paper have been successfully applied in Gansu Electric Power Company, with the characteristics of convenient use, high cost performance, more intelligent and so on, and obtained good training effect.

1. Introduction

With the rapid development of power grid, cross regional transmission capacity is increasing. The scale and complexity of the power grid are increasing day by day, and the disposal measures are complex; the large-scale integration of new energy brings uncertainty, and the power grid regulation ability is declining, which makes the problems of power grid frequency stability and power balance increasingly prominent; the traditional AC system characterized by synchronous generator multi mass block and inertia motion has attached a large number of power electronic equipment, two different types and different times At the same time, the influence of external environment on power grid operation is becoming more and more obvious, the stability form after system failure is more complex, the influence range is greatly expanded, and the operation risk is increasing. Therefore, it is urgent to improve the skill level of power grid operators.

If the power system fault is not handled properly, it is likely to cause a catastrophic accident with a huge impact. Considering the high security requirements and complex structure of the power system, in view of the fact that it is not allowed to artificially create actual grid faults, the best way to improve the skills of power grid operators in dealing with accidents is to simulate the actual operation of power system by computer. The establishment of power simulation training system is the most effective means to carry out training for dispatching, monitoring, operation and maintenance personnel.

At present, provincial electric power companies have developed an integrated simulation and training system for provincial, prefecture and county-level control, covering multiple operation specialties such as dispatching, monitoring and substation at all levels, providing rich and practical training functions, and effectively supporting the improvement of employees' post skills and performance. With the
increase of the deployment of simulation training system, the problems such as poor maintainability, unable to carry out remote self-study and lack of analysis of training behavior have gradually become prominent, which are mainly manifested in the following aspects: lack of unified centralized management and maintenance, high labor cost of software upgrade and update; too much reliance on teachers for simulation system training, cumbersome use and training process, and lack of interest, Unable to effectively carry out remote self-learning, resulting in a waste of training resources; lack of tracking, recording and analysis of staff training behavior; unable to automatically analyze the weak points of trainees' skills; unable to timely insight into the abnormal operating habits of trainees and carry out relevant counseling and correction; unable to inherit and share work experience.

In recent years, the rapid development and application of information technology such as cloud and cloud moving and artificial intelligence have provided new ideas for solving these problems. In order to solve the above problems, this system puts forward the solution of network intelligent power comprehensive training simulation platform. Based on the research and development of public platform architecture and core technology based on Internet technology support simulation training, the system software of the platform is developed, and the typical simulation training system is transformed and upgraded and deployed on the platform. This paper is based on the power simulation training system, combined with cloud computing, artificial intelligence, adaptive learning technology, to build a network, intelligent, personalized simulation operation environment for grid operators. The relevant research results have been put into operation in Gansu Electric Power Company. This article will focus on the architecture design, implementation of key technologies and application of the Internet plus power simulation intelligence learning system.

2. Network topology analysis method

2.1 System structure

This paper proposes the architecture and solution of Internet plus power simulation intelligent learning system based on network, intelligence and game. Students can make full use of fragmentation time to carry out power simulation learning, training, examination and assessment, so as to rapidly improve the skills of the power grid operators, especially the ability to respond quickly to accidents.

![System Structure](attachment:figure1.png)

This system adopts hierarchical, component-based and service-oriented architecture (SOA) to study the multi-functional architecture of the platform. Through in-depth study of the architecture of each functional sublayer, an open technical architecture of the simulation platform is proposed. The Internet plus power simulation intelligence learning system is divided into device layer, basic function layer, intelligent function layer and user application layer. The function and overall structure of the "Internet plus" intelligent power simulation training system are shown in Figure 1, which is divided into
equipment layer, platform level, function layer and application layer. The device layer refers to the infrastructure of cloud platform. The platform layer includes learning behavior record database, learning feature model database, basic services, online evaluation and joint anti accident exercise, system management. The intelligent function layer includes learning behavior acquisition and adaptive learning, automatic simulation evaluation and game simulation. User application layer refers to the personal computer containing web browser software.

The network behavior collection and adaptive learning engine, training intelligent guidance and automatic quantitative evaluation system, and game based power simulation training system are combined together by simulation learning support platform, forming the whole Internet plus power simulation intelligence learning system.

2.2 Design of intelligent simulation and learning support platform

Simulation intelligent learning support platform is the basis of remote simulation intelligent learning system. It has the following two functions: 1) as the operation support system of network simulation training, it realizes the interactive operation between various simulation training applications, and is the link connecting all parts of the simulation learning system, and provides a transparent and efficient virtual operating environment for each simulation training application software. 2) The platform includes data resources, basic services, online evaluation and system management functions, providing technical support for remote simulation intelligent learning system[1].

2.2.1 Data Source. The main function of data resources is to provide heterogeneous massive training knowledge, resources and data storage, access functions and operational capabilities. Data resources include learning behavior record database, learning feature model library, simulation resource database, test question database, system database and other modules.

(1) Learning behavior record library

Users access to the new generation substation simulation intelligent learning system through the network to carry out and learn all kinds of learning behavior data, including learning platform login, game simulation training operation, online evaluation, personal data modification and other behavior data will be collected and transmitted to the learning behavior record library through unified specification xapi. The learning behavior record library is responsible for the unified storage and management of all kinds of learning behavior data, and provides database access interface. It supports the functions of adding, deleting, modifying and querying learning behavior data by other modules, and exporting learning behavior data.

(2) Learning feature model base

Learning feature model data includes user model, domain model and teaching model data, which is the basis of providing personalized and intelligent training services for users. The learning feature model library is responsible for the unified storage and management of the above learning feature model data, and provides the database access interface to support other modules to add, delete, modify, query the learning feature model data, and import the learning feature model data.

(3) Simulation resource library

The simulation resource database includes the models and data needed for the operation of the simulation system, including game based 3D scene model, power grid model, equipment mechanism model, equipment 3D model, equipment parameters, simulation function parameters, etc. The simulation resource library is responsible for the unified storage and management of the above data, and provides the database access interface. It supports the functions of adding, deleting, modifying and querying the above data by other modules, as well as the data import function.

(4) Simulation question bank

The test paper resources stored in the simulation intelligent learning system are the test questions for the substation training simulation system. The test database is responsible for the unified storage and management of the above practical test questions, and provides the test question access interface. It supports the functions of adding, deleting, modifying and querying the test data of other modules, as well as the import and export function of the test data.
(5) System database
In addition to the above data, the data related to the normal operation of the simulation intelligent learning system also includes the platform basic data such as organization structure, user information, authority information, integral information, training files, etc. The system database is responsible for the unified storage and management of the above data, and provides the database access interface to support other modules to add, delete, modify, query the above data, as well as the data import and export functions.

2.2.2 Basic services. Basic services provide common resource access and scheduling services for upper application functions. Basic services include registration services, storage access services, resource scheduling services, computing services, message services, help services and other modules:
(1) Registration services
Registration service provides unified registration and authorization services for learning platform, unified authentication service for distributed clients, and centralized management function for users and application access rights.
(2) Resource scheduling service
Resource scheduling service can manage all the scheduling tasks, and complete the unified scheduling cluster optimization, expansion, task management and other work.
(3) Computing services
The calculation service provides the power flow calculation and short circuit calculation services of simulation power grid.
(4) Message service
Message service provides point-to-point and point-to-face message transmission capabilities among distributed applications within the platform, as well as the function of individual message publishing and group message sending between the system and users.
(5) Help service
Help service provides users with online help and prompt information service related to system use.

2.2.3 Online evaluation. The online evaluation component provides the network simulation operation skill evaluation function, as well as the test questions, examination papers, examination management functions. Online assessment includes online examination competition, test paper management, examination management, joint anti accident exercise and other modules. The functions of each module are as follows:
(1) Online exam competition
The online examination competition module provides the whole process and multi-dimensional support for the user's simulation practical skill test and examination, and supports the functions of registration, answering questions, practical examination, automatic scoring, examination result analysis, examination result viewing, etc.
(2) Examination question management
The test management module manages the data of the simulation test database, and realizes the management functions of adding, deleting, modifying and querying the test questions.
(3) Examination paper management
The paper management module realizes the management function of the test paper information, provides the management functions such as the addition, deletion, modification and query of the test paper, provides the function of manually associating the test paper data to create the test paper, provides the function of automatically extracting the test questions according to the setting conditions, and provides the function of setting the test paper parameters.
(4) Examination management
The examination management module realizes the management function of examination information, with the function of examination information viewing, examination creation, examination registration approval, examination release and cancellation, examination score management and so on.
(5) Online joint anti accident exercise
Online joint anti accident exercise module realizes remote joint anti accident exercise for power grid operators. Support users to log in the exercise system through the web, manage the login users through the authority configuration, support to view the execution of teaching plan events, protection actions, actions of automatic safety devices, alarm information, etc. during the exercise; monitor the login and exit of users in real time; grant the chief director of the joint anti accident exercise with user rights to conduct the overall control of the exercise Operation authority, start, pause, resume and exit of training simulation system; state function of adding exercise system in the middle and synchronizing exercise system.

2.2.4 System management. The system management component provides the basic and public data management functions of the simulation intelligent learning system. The system management includes user management, authority management, integral management, training management and other modules.

(1) User management
The user management module can manage all users of the platform, add, delete, modify, query and view user information, and support the import of user data through excel template. Users include students or administrators.

(2) Authority management
The authority management module is used to manage and set the user's access rights to system functions and data, realize the creation, parameter setting and modification functions of various types of access rights, realize the functions of platform role creation, deletion, authority assignment and query, and realize the function of platform role assignment for users. According to the authority configuration of training computer room, the management of traditional computer room simulation training authority and remote joint anti accident exercise authority is realized.

(3) Integral management
The integral management module realizes the management function of the user's integral data, provides the function of viewing and modifying the user's integral, and provides the function of creating, modifying, deleting and viewing the integral obtaining conditions and integral parameters.

(4) Training management
The instructor controls the operation, monitoring and dynamic tracking of the simulation system through the training management system, records the operation of the trainees and evaluates the operation process of the trainees.

2.3 Learning behavior collection and adaptive learning engine design

Learning behavior acquisition and adaptive learning engine is based on the latest learning technology specification xapi, which can collect, store and retrieve all kinds of learning behaviors generated in the process of power simulation training. Through analysis and visualization, it can realize the three-dimensional and in-depth presentation of user learning process. At the same time, based on learning feature model and learning behavior data, learning recommendation algorithm is used for real-time calculation to generate and push personalized training content for users.

This system plans to use the latest learning technology specification xAPI to collect, store and access the learning behavior data. Based on the xapi specification, develop and provide a complete collection, processing, transmission and storage interface functions. Through the activity provider (activity The function of provider collects the detailed learning behavior, defines the learners' learning behavior by activity, records all the attributes of the learning behavior through the activity generation statement, and transmits the learning behavior data to the server-side learning record library LRS through the standard xAPI interface for storage. By establishing the learning characteristic model of standard electric power training, the learning behavior of the students in the electric power training activities is matched with the standard feature model, and the learning behavior of the students is identified, and the training behavior analysis based on the feature model is carried out.
The core technology of building adaptive learning module includes developing adaptive model and building domain model, user model, teaching model and other learning feature models. The domain model describes the structure of domain knowledge, including the relationship between concepts and concepts, and describes the relationship between domain knowledge and corresponding learning content. This system intends to establish a domain model of substation operation and maintenance skills. User model is the abstract description of user (i.e. student) characteristic information, including knowledge structure, learning objectives, background experience, cognitive style, learning preference, learning achievement, ability status and so on. The teaching model defines the rules for accessing each part of the domain model according to the information in the user model. The adaptive engine analyzes students’ learning request or learning behavior in real time, selects, assembles and presents personalized learning content for learners according to the information in other models, and updates and maintains user model according to user's learning behavior and learning effect. The adaptive engine can monitor and detect the learning process in real time, generate and push the learning content intelligently, and guide the students to master the required skills. Learning behavior acquisition and adaptive learning engine includes learning behavior acquisition and transmission, learning behavior analysis, learning feature model management and adaptive learning engine.

2.3.1 Collection and transmission of network operation behavior. The learning behavior acquisition and transmission component running in the user terminal realizes the real-time acquisition of various learning behaviors generated in the process of power simulation training, and encodes the learning behavior based on xapi specification, and then transmits it to the learning behavior record library for unified storage. The collected learning behaviors include not only knowledge learning test related behaviors, but also related behaviors generated in the process of skill training.

2.3.2 Analysis of learning behavior. Through the statistical analysis of the collected learning behavior data, the learning behavior analysis component analyzes the laws, trends and problems of individual and group learning behavior from multiple directions and dimensions.

2.3.3 Learning feature model management. The management of learning feature model realizes the modeling of user model, domain model and teaching model, as well as the creation, deletion, modification and query of model data. At the same time, it also provides the function of real-time updating related models according to individual and group learning behavior record data and learning effect data analysis.

2.3.4 Adaptive learning engine. The adaptive learning engine makes real-time analysis and calculation on training demand, knowledge level and learning style according to the parameters of user's learning feature model and personalized learning behavior data, and selects the most matching application function, assembles the most appropriate personalized training test content and pushes it to users according to the platform function and resource situation.

2.4 Design of training intelligent guidance and automatic quantitative evaluation system

The existing simulation training system is lack of intelligent guidance and automatic evaluation tools, which can not objectively and quantitatively evaluate and guide students intelligently in the process of network training, and can not effectively stimulate students' desire for learning. This system designs and develops an intelligent guidance and evaluation system for power grid operators [2], which realizes the function of intelligent guidance and training evaluation. In the process of network training, it guides and evaluates the trainees and helps them quickly master the necessary operation skills.

The system adopts intelligent guidance and evaluation system based on artificial intelligence technology, which has perfect tracking, guidance and evaluation functions of trainees' training process,
and can provide guidance and help for power grid operators. The simulation system is used to standardize the operation task. The rule editing function module reads the teacher's operation records and automatically generates the evaluation rules of the operation task, which are used as the specification of the task guidance, comparison and evaluation. In the daily training, if the operation of the trainees is different from the set standard operation specifications, the system will pop up the error operation prompt menu to guide the students' operation. The training guidance and automatic quantitative evaluation system developed by this system mainly consists of task rule base, task rule editing management, evaluation behavior collection, online guidance and evaluation module.

2.4.1 Task rule base. The task rule base includes the standard answers made by the instructor in advance and the evaluation basis for the students' operation process. The operation of each task has standard operation rules. Each operation rule contains the key fields (operation object, target state and score value) that can evaluate students' operation, as well as the reasonable expression of logical relationship between rules, namely operation conditions, and provides convenience. The editing tool is used to edit rules, and then save them according to the reasonable tree structure to optimize the search. The default score is defined for each operation rule statement according to the importance of the operation object of the simulation system. The task rule is composed of one or more equipment rules, which is the basis for the administrator to set the task according to the training content. After the trainees complete the operation assessment, they can make online evaluation.

2.4.2 Task rule editing management. Task rule editing and management tool provides teachers with friendly interface, flexible and convenient knowledge base, human-computer tools for editing and managing rule base, including editing, inputting, deleting of rule base, editing, inputting and deleting of equipment and task rules.

2.4.3 Operation behavior collection. The operation behavior acquisition module collects the power grid operation status, simulation operation and disposal records of the trainees. The collected grid operation status includes bus voltage, line and main transformer power flow, Section power flow, load, etc., and students' monitoring operation and disposal records.

2.4.4 Online training evaluation guide. The online training evaluation and guidance module compares the monitoring, operation and disposal records, equipment rules and task rules one by one. When the comparison results meet the requirements, the trainees get corresponding scores. In the process of practical training, a friendly, flexible and convenient man-machine interface is provided for practical operation guidance. After the training, the intelligent evaluation results of the whole training process are displayed.

2.5 Design of game power simulation training system

The system applies serious game mode to power simulation training[3-4]. By creating game mode such as breakthrough and confrontation, and adopting game oriented means such as grade, props, points and ranking, the system closely combines the entertainment of the game with the seriousness of simulation training, so as to realize the education in fun. The game based power simulation training system includes breakthrough system, confrontation system, integral system, props system, points ranking list, etc., which can stimulate users' interest in learning and improve the training effect.

2.5.1 Breakthrough system. According to the ability items that need to be mastered in substation operation, various tasks from simple to difficult are made, such as inspection, normal operation, fault handling, exception handling, etc. within the specified time and error times, the task is completed. In order to break through the barrier successfully, the corresponding integral can be obtained and the next
task can be unlocked. The system provides a platform for the production and release of typical breakthrough tasks. You can complete the task of making a breakthrough by yourself.

2.5.2 Confrontation system. Confrontation mode refers to that multiple users enter the gaming substation simulation system at the same time to complete the same simulation task. The winner with the highest comprehensive score wins, the winner gets points, and the failure deducts certain points. Through confrontation with others, they can obtain the fun and motivation of learning.

2.5.3 Integral system. During the execution of tasks, the system will evaluate the completion standard and completion time of the task. After completing the task, it will give grading evaluation. One star is qualified, two stars are good, and three stars are excellent. In addition, the points will be added according to the multiple of stars. If the continuous operation is correct, there will be integral bonus. The character level is set according to the junior worker, intermediate worker, senior worker, technician and senior technician. The grade is improved by integral, and all the capacity values of substation operation reach the preset integral value.

2.5.4 Props system. In the completion of the task, through the points can buy a variety of attributes of game props, such as operating tips, life value increased, time increased, points doubled, etc. When encountering unfamiliar tasks, it will greatly improve the speed of completing tasks, so as to improve the cumulative speed of points, and exchange more useful skills and props.

2.5.5 Points ranking. Display customized points ranking on the platform. The establishment of the ranking list includes two categories: the "total score list" and "comparison list of the same level", which can be viewed on the platform page. You can also view the details of each participant.

3. Usage of the system
The research results have been successfully applied to Gansu Electric Power Company. After being put into application, the following aspects have been improved:
1) The system realizes the network independent simulation learning function, changes the existing methods and means of knowledge learning and simulation training for power grid operators, greatly improves the quality of learning and training by using Internet and artificial intelligence technology, shortens the learning time and saves the time cost of learning and training.
2) Through self-adaptive learning, game learning and intelligent guided learning functions, employees’ self-learning motivation is constantly stimulated, learning motivation is maintained continuously, and excellent corporate culture of continuous active learning is formed, which lays the foundation for the efficient and sustainable development of the company.
3) It can greatly reduce the cost of theoretical knowledge test and practical skills test.
4) It can effectively improve the quality and efficiency of on-site work, improve the standardization level of operation and maintenance operation, and improve the timeliness and accuracy of abnormal accident detection and handling, so as to improve the safe operation level of power grid.
5) This paper provides a unified operation support platform for other professional simulation learning systems. The proposed learning behavior acquisition, network simulation, game simulation and other technical solutions can be directly applied to the research and development of other professional simulation intelligent learning systems, so as to greatly shorten the research and development time of each professional simulation intelligent learning system and reduce the system operation cost.
6) Using cloud based deployment and operation mode to replace the traditional single machine deployment and operation mode can greatly save hardware investment.
To sum up, the "Internet plus" power simulation intelligence learning system based on networking, intelligence, game and adaptive learning technology can effectively enhance the knowledge, skill level and field work ability of the control, monitoring and operation personnel, and speed up the personnel training while providing personnel protection for the safe and stable operation of the large power grid. Since the system is put into use, it has achieved good training effect.
4. Summary
The Internet plus power simulation intelligence learning system is a new type of learning technology developed by the latest learning technologies, such as cloud computing, Internet, AI, big data, virtual reality, information technology, learning behavior collection, deep learning analysis, adaptive learning, and game based learning, which are guided by fine knowledge system and guided by refined professional knowledge system. Real learning platform. After it is put into operation, it can greatly improve the efficiency and effect of knowledge and skills acquisition, learning, drilling and evaluation of dispatching, monitoring and substation operation and maintenance personnel, and further improve the post work quality and standardization level of the above professionals. It will realize the leap from "localized simulation training system" to "Internet simulation training system". The rapid development of "thousands of people, thousands of aspects" self-adaptive learning mode has greatly improved the convenience and economy of knowledge and skills learning practice. So that the way of learning and training will be revolutionary and updated.

5. References
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