Exploration and Evaluation of Virtual Simulation Experimental Teaching for New-Type Power Systems Based on OBE Theory

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Abstract. To address the urgent demand for interdisciplinary talents in electrical engineering amid the transformation of the new power system, and to overcome the limitations of traditional experimental teaching in terms of safety, cost, and cutting-edge relevance, this paper explores the construction of a virtual simulation experimental teaching model integrating OBE (Outcome-Based Education) philosophy and inquiry-based learning. Taking "Virtual Simulation of Design and Fault Handling for New-Type Energy Storage Intelligent Microgrids" as the carrier, it designs four modules of inquiry-based teaching content covering planning and design, equipment cognition, energy storage optimization, operation control, and fault handling, guiding students to shift from passive verification to active exploration. Meanwhile, a multi-dimensional evaluation mechanism featuring "student-centeredness, output orientation, and continuous improvement" is established. Through three assessment dimensions—basic operation standards, complex task execution, and original problem-solving—combined with dynamic learning portfolios to record students' growth trajectories, the model strengthens innovation incentives and continuous improvement. Practice has shown that this model effectively promotes the in-depth integration of theoretical knowledge and engineering practice, significantly enhances students' abilities in system design, fault analysis, and innovative decision-making, and provides valuable theoretical reference and practical examples for the reform of experimental teaching in electrical engineering. In the future, further exploration will be conducted on the integrated application of intelligent technologies to advance the interdisciplinary expansion and optimization upgrading of the teaching model.

Keywords: Virtual Simulation Experimental Teaching, OBE, New-Type Power System, Electrical Engineering Talent Cultivation

1 Introduction

With the in-depth advancement of the "dual carbon" strategy, the continuous growth of energy demand, and the rapid development of new energy technologies, a new-type power system characterized by high proportions of new energy and power electronic

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devices is accelerating its construction and undergoing profound transformations. This transformation places higher requirements on the training of electrical engineering talents, necessitating the cultivation of compound talents with solid theoretical foundations, cutting-edge engineering practice capabilities, innovative spirits, and international perspectives. Emerging engineering education conforms to this trend, promoting the shift of engineering education from discipline-oriented to industry demand-oriented, with the core goal of continuously improving students' innovative capabilities and interdisciplinary comprehensive practical abilities.

Faced with the complexity of the source-grid-load-storage in the new-type power system, the traditional experimental teaching system of power systems is facing severe challenges. Due to the complex structure, high cost, variable operation modes of distributed generation and energy storage equipment in the new-type power system, as well as the difficulty in modifying the control parameters of energy conversion devices, conducting experiments such as fault simulation and operation mode switching in actual systems carries high risks, which greatly limits the practical teaching links. Currently, the experimental teaching of this major mainly focuses on the verification of classic theories such as power flow calculation and short-circuit analysis. It can only realize power system power flow calculation, three-phase short-circuit calculation, and limited hardware-in-the-loop transient stability experiments, and it is even difficult to ensure that each student has practical operation opportunities. This not only restricts the systematic training of students' practical abilities but also makes it difficult for students' logical thinking and systems engineering capabilities to be effectively improved in traditional practical links such as pure simulation or hardware-in-the-loop simulation, leading to a significant gap between talent training and the cutting edge of industry technology.

To address the aforementioned dilemmas, virtual simulation technology, with its highly simulated virtual experimental environment and the advantage of breaking time, space, and cost constraints, provides an effective approach for safely and efficiently simulating various complex and even high-risk scenarios. This technology has demonstrated great potential in multiple disciplinary fields, offering valuable references for its application in emerging engineering education. However, its application still has limitations. The virtual power plant modeling in Reference [1] adopts an improved federated learning method, successfully optimizing the power generation scheduling process, improving computational efficiency and accuracy, and solving the delay problem of traditional optimization algorithms; however, this model focuses on single-mode scheduling optimization and fails to integrate interdisciplinary knowledge, restricting the development of students' innovative thinking. The internet-based electrical engineering laboratory in Reference [2] realizes remote experimental operation and real-time data interaction by integrating virtual and physical experiments, effectively overcoming geographical limitations and equipment cost issues; but the experimental content mainly revolves around traditional disciplines such as circuits and microprocessors, lacking interdisciplinary integration with cutting-edge fields such as new energy and control engineering, resulting in insufficient improvement of students' comprehensive practical abilities. The distributed wind power virtual simulation system in Reference [3] cultivates students' ability to solve complex engineering problems such as power prediction and fault diagnosis by simulating the steady-state and transient processes of real wind farms; however, the system design focuses on wind power technology itself and does not introduce multi-dimensional analysis of economic, environmental, or social factors, making it difficult to stimulate interdisciplinary innovation. The electrical training hardware based on embedded systems in Reference [4] improves students' practical abilities and learning interest through scenario-based troubleshooting training, such as marine electrical grounding fault simulation; nevertheless, the training content is limited to preset fault modes and does not encourage students to independently design solutions or explore innovative applications. These cases indicate that although virtual simulation can solve the problem of inaccessibility to operations and promote skill development through a safe and controllable environment, it has obvious deficiencies in cultivating innovative thinking and interdisciplinary capabilities.

To make up for these shortcomings, the Outcome-Based Education (OBE) concept, as a key support for the implementation of emerging engineering education, is introduced to systematically improve students' comprehensive abilities. OBE emphasizes learning outcomes orientation, ensuring that students achieve established ability goals through closed-loop evaluation and continuous improvement mechanisms. Reference [5] applies the integrated method of Design-Based Learning (DBL) and OBE in industrial engineering teaching, confirming that this model can effectively stimulate students' learning interest and improve their teamwork and innovative abilities. Reference [6] further compares OBE with traditional education systems and finds that OBE significantly improves students' academic performance, classroom participation, and comprehensive abilities in engineering education through closed-loop evaluation and continuous improvement mechanisms, verifying the superiority of OBE as an educational paradigm shift. These practices show that OBE can make up for the shortcomings of virtual simulation in innovation and interdisciplinarity, providing theoretical basis and practical references for education in the field of electrical engineering.

Based on the requirements of "two characteristics and one degree" for first-class courses and focusing on the urgent demand for talent training in the new-type power system, this paper explores a virtual simulation comprehensive experiment teaching model that deeply integrates the OBE concept and inquiry-based learning methods. Firstly, it elaborates on the necessity of carrying out virtual simulation experimental teaching for the new-type power system; then, taking "virtual simulation of new energy storage intelligent microgrid design and faults" as an example, it details the design of inquiry-based experimental content covering four modules: planning and design, equipment cognition, energy storage optimization, operation control, and fault handling; finally, it constructs a multi-dimensional teaching effect evaluation mechanism based on the principles of "student-centered, outcome-oriented, and continuous improvement". This study aims to systematically address the key issues in the current construction of virtual simulation experiments for this major, providing valuable theoretical references and practical examples for deepening the reform of experimental teaching in electrical engineering and improving the quality of talent training.

2 Design of Virtual Simulation Experimental Teaching Content for New-Type Power Systems

The OBE concept and inquiry-based learning methods are adopted to design relevant experimental content. Taking the virtual simulation experiment of new energy storage intelligent microgrid design and faults as the entry point, a curriculum system of "student-centered, outcome-oriented, and inquiry-based" is constructed.

2.1 Implementing the OBE Concept Throughout the Teaching Process

The OBE theory represents a fundamental transformation in the educational paradigm: it shifts the focus from "what was taught? Was the knowledge content of the syllabus delivered?" to "what have students learned? What can students do after graduation? (including knowledge, abilities, and literacy)". It starts with the expected ability outcomes that students should ultimately achieve, reversely designs courses and teaching, and ensures the achievement of these outcomes through continuous evaluation and improvement. In traditional teaching, experimental instructions are detailed, including purposes, principles, steps, and expected results. Students operate step by step, pursuing consistency with standard answers, and are passive recipients of knowledge and operators: following instructions and completing predetermined processes. The design of this virtual simulation experimental teaching content takes engineering practice as the scenario, guiding students to explore and design in the virtual simulation platform. Students are active explorers, designers, and the main body of learning. They are required to raise questions, propose design schemes, solve problems, summarize and reflect, and raise new questions. Focusing on "what students can do" after completing the experimental course of the new-type power system, it enables students to master the planning and design principles of different types of microgrids, as well as the steady-state operation, energy management, and operation mode switching methods of microgrids. Taking question-raising as the core of the entire experiment, it encourages divergent questioning and association. On the one hand, it enables students to master the planning and design principles of different types of microgrids, as well as the steady-state operation, energy management, and operation mode switching methods of microgrids. On the other hand, it cultivates students' innovative thinking through question-raising training, thereby developing their ability to apply theoretical knowledge to solve practical engineering problems, and ultimately improving their comprehensive analysis and innovative abilities in the field of electrical engineering technology.

2.2 Applying Inquiry-Based Learning Methods

Based on the OBE theory, inquiry-based, design-based, and interactive teaching methods are embedded. Inquiry-based learning is an active learning method that holds that learning is not the passive acceptance of information, but a process in which learners construct new knowledge and understanding through active exploration, questioning, investigation, and problem-solving. Starting from students' needs, it guides them to experience an interactive and immersive learning atmosphere. It transforms the experimental classroom from a place for knowledge verification to a workshop for knowledge creation and ability generation. The OBE theory clarifies what students we aim to cultivate can do after experimental teaching (i.e., learning outcomes), ensuring that teaching does not deviate from industry needs and educational goals. Inquiry-based learning serves as the "boat": providing the methods and paths to achieve these outcomes, that is, not passively accepting verification experiments, but actively exploring, trial and error, discovering, and solving real or simulated real problems. Thus, the experimental teaching content of four modules based on inquiry-based learning methods is constructed, as shown in Figure 1. The design uses virtual simulation experiments to simulate the operation of power systems in different scenarios, providing students with an intuitive and interactive learning environment. It transforms abstract theories into innovative thinking and independent work abilities to solve real problems. Before the virtual simulation experiment, students are guided to independently design various parameters of their virtual industrial parks, and some questions are raised to trigger students' thinking, inspire them to put forward core questions, and realize the implementation of inquiry-based and design-based learning methods. The teaching method is more interactive: students operate through the virtual simulation experiment system, and group and class discussions are organized for students to share their experiences and understandings. The specific experimental steps are shown in Figure 2.

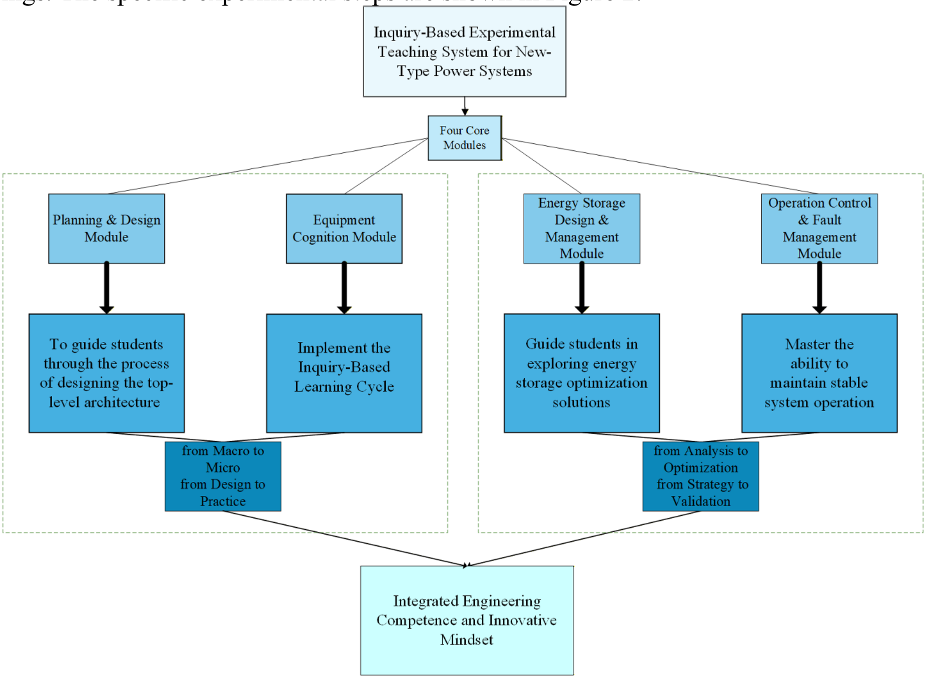

Fig. 1. Inquiry-Based Experimental Teaching System for New-Type Power Systems .

3 Teaching Effect Evaluation Mechanism

Taking encouraging breakthrough thinking oriented to engineering practice as the core goal, the implementation of evaluation and innovation bonus mechanism is the core concept. It ensures that students master necessary practical abilities through the standardized evaluation of basic operational skills. On this basis, a special "innovation bonus" item is set up to give clear rewards to students who propose original schemes beyond the standard answers in tasks such as system optimization and fault handling, with theoretical or simulation data supporting the superiority of their schemes. This mechanism directly guides students to conduct critical thinking and transcendent exploration, shifting the evaluation focus from "whether it is done correctly" to "whether it can be done better and more creatively".

3.1 Evaluation Concepts

Innovation Dimension. Taking encouraging breakthrough thinking oriented to engineering practice as the core goal, the implementation of evaluation and innovation bonus mechanism is the core concept. It ensures that students master necessary practical abilities through the standardized evaluation of basic operational skills. On this basis, a special "innovation bonus" item is set up to give clear rewards to students who propose original schemes beyond the standard answers in tasks such as system optimization and fault handling, with theoretical or simulation data supporting the superiority of their schemes. This mechanism directly guides students to conduct critical thinking and transcendent exploration, shifting the evaluation focus from "whether it is done correctly" to "whether it can be done better and more creatively".

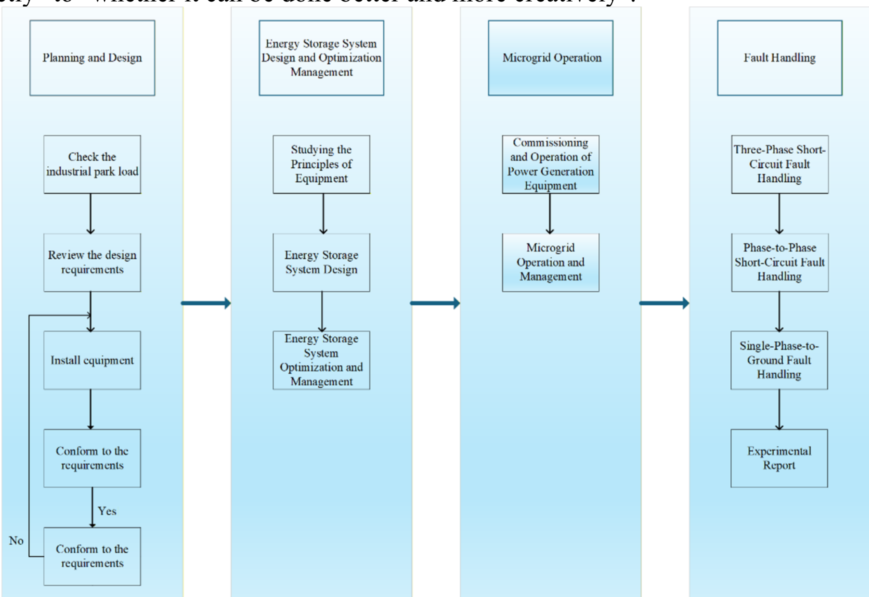

Fig. 2. Experimental Procedure.

Sustained Thinking Development. The dynamic learning portfolio evaluation method is introduced. An electronic portfolio is established for each student, continuously collecting all experimental data, reflection reports, innovative schemes, peer evaluation records, etc., from the beginning to the end of the course. Through vertical comparison of the content in the portfolio, students can intuitively see their growth trajectory in terms of fault handling efficiency, scheme complexity, etc. Teachers take the degree of students' learning progress as an important evaluation dimension, which makes "continuous improvement" itself visible and measurable, greatly enhancing students' willingness and ability for lifelong learning.

3.2 Evaluation System

The practical operation evaluation system of this course takes the OBE concept of "student-centered, outcome-oriented, and continuous improvement" as the core. It aims to go beyond the single evaluation of traditional operation correctness and construct a multi-dimensional evaluation system focusing on the advancement of practical abilities and the development of innovative thinking. The system combines automatic data collection by the virtual simulation platform with process evaluation to ensure the objectivity and professionalism of the evaluation. Its overall framework and core assessment dimensions are described as follows.

Overview of the Evaluation System. Practical operation evaluation runs through the entire learning process from basic standardization to complex innovation, and records students' growth trajectory through dynamic learning portfolios. The evaluation not only focuses on the final results but also attaches great importance to the strategic planning, innovative attempts, and reflective optimization abilities demonstrated in the process of task execution, thereby achieving the goal of "promoting learning and innovation through evaluation". The core of the evaluation system consists of three progressive ability levels, and their relationships and evaluation focuses are shown in Figure 3.

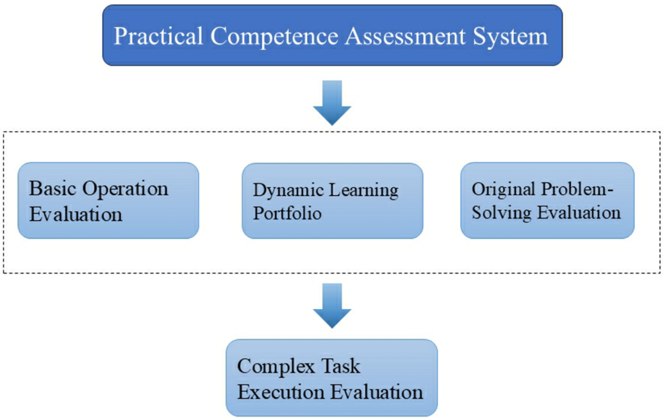

Fig. 3. Evaluation Process.

Multi-dimensional Assessment Criteria Matrix. This evaluation system is grounded in Outcome-Based Education (OBE) and moves beyond traditional lab assessment that prioritizes knowledge verification over capability development. It establishes a holistic, process-oriented mechanism centered on engineering practice competencies. Emphasizing "student-centeredness, outcome orientation, and continuous improvement," the system utilizes dynamic e-portfolios to document learning trajectories, transforming assessment from a summative judgment into a formative tool that drives competency advancement. Crucially, it fosters innovative thinking through flexible incentive mechanisms, encouraging students to autonomously explore and iteratively refine solutions within authentic engineering contexts—thereby enabling a progressive leap from standardized operations to system-level design and original problem-solving, fully aligning with the goals of New Engineering Education Reform. Refer to Table 1 below for details of the specific evaluation system.

Table 1. Multi-dimensional assessment criteria matrix.

Competency Level	Assessment Dimension	Specific Indicator	Scoring Criteria	Data Source	Max Points
Basic Operational Proficiency (30 pts)	Compliance	Parameter Setting Accuracy	≥95%: 15 pts; 90–94%: 12 pts; 85–89%: 9 pts; <85%: 0–6 pts	Simulation system logs	15
		Adherence to Safety Protocols	No violations: 9 pts; 1 warning: 6 pts; ≥2 warnings or safety alert: 0 pts	Risk detection module	9
	Efficiency & Optimization	Timeliness of Standard Procedure Completion	Within ±10% of benchmark: 4 pts; ≤20% overtime: 2 pts; >20%: 0 pts	Operation timestamps	4
		Process Optimization Proposal	Valid suggestion with rationale & simulation: +1–2 pts (bonus)	Optimization report review	+2
Complex Task Execution (40 pts)	Strategic Planning	Design Completeness	Full 5 elements (objectives, constraints, equipment, control logic, metrics): 20 pts; −4 pts per missing element	Design report	20
		Multi-variable Coordination	Coordinates ≥3 variables (e.g., wind/solar/storage, load, price): 12 pts; 1–2 variables: 4–8 pts	Design content analysis	12
	Innovative Solution	Number of Alternative Strategies Attempted	≥2 strategies: 4 pts; 1 strategy: 2 pts; none: 0 pts	Simulation run records	4

Competency Level	Assessment Dimension	Specific Indicator	Scoring Criteria	Data Source	Max Points
Problem-solving Implementation (30 pts)	Responsiveness & Originality	Validation of Solution Superiority	Simulation shows performance gain (e.g., ≥5% loss reduction): +2–6 pts (bonus)	Innovation report + results	+6
		Fault Localization Accuracy	Correct on first attempt: 12 pts; correct after revision: 6 pts; incorrect: 0 pts	Fault handling logs	12
		Originality of Solution	Non-template, self-developed control/protection logic: +1–5 pts (bonus)	Solution report	+5
	Scientific Evaluation	Number of Evaluation Metrics	≥3 quantitative metrics (voltage deviation, restoration time, cost, etc.): 9 pts; 1–2 metrics: 3–6 pts	Evaluation report	9
		Depth of Reflection	≥2 actionable improvements with theory: 6 pts; descriptive only: 0–3 pts	Reflection report	6

Integration of Evaluation Results and Continuous Improvement. The feedback mechanism is centered on "real-time response, hierarchical transmission, and closed-loop implementation," establishing a comprehensive three-dimensional integrated system to ensure that evaluation results are accurately transmitted and efficiently transformed into a driving force for the improvement of teaching and learning. At the individual student level, the virtual simulation platform generates real-time operational data reports, marking shortcomings such as parameter errors, operation time, and risk omissions through visual charts to facilitate students' immediate self-inspection; the electronic learning portfolio automatically pushes weekly growth analysis reports, which clearly present progress items and areas for improvement by comparing quantitative indicators from previous experiments, along with targeted improvement suggestions to help students focus their efforts effectively. At the teacher-student interaction level, group interviews and one-on-one guidance are conducted every two weeks—based on quantitative assessment data, teachers focus on explaining common issues, address individual problems in a targeted manner, and clarify improvement goals and timelines; monthly class case seminars are also organized, where typical experimental reports (including excellent and problematic cases) are selected for mutual evaluation and discussion, with teachers providing comments to refine replicable improvement methods and strengthen experience sharing among teachers and students. At the university-enterprise collaboration level, 2-3 power industry engineers are invited each semester to conduct quantitative scoring of students' abilities with reference to enterprise KPIs and put forward industry-adaptive suggestions; meanwhile, real enterprise project cases are connected and transformed into simulation test questions, and teaching content and assessment standards are reversely optimized based on students' test results to ensure that teaching keeps pace with industrial needs. The entire feedback process is interlocking, achieving hierarchical feedback at the individual, teacher-student, and university-enterprise levels, while forming a closed loop through data circulation, thus providing an accurate basis for the continuous improvement of teaching.

4 Teaching and Learning of Virtual Simulation

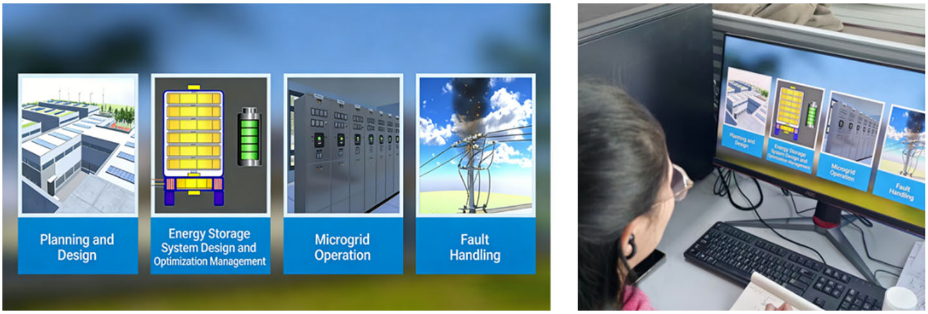

Fig. 4. Student Experiment and Virtual Simulation Platform.

As shown in Figure 4, the teaching logic of this virtual simulation experiment is a closed-loop iterative process oriented to problems and taking electronic learning portfolios as the penetrating carrier. Its core lies in cultivating students' systematic thinking and practical abilities to solve complex engineering problems. The entire process can be clearly summarized into three interlocking stages:

1. Presetting and Design: Before the start of the experiment, under the guidance of inspiring questions raised by teachers (such as "how to achieve carbon emission reduction goals through the coordinated operation of wind, solar, and energy storage"), students comprehensively apply theoretical knowledge to independently complete the personalized design of key parameters of the virtual industrial park and input the scheme into the electronic learning portfolio to establish a benchmark for subsequent verification.
2. Exploration and Verification: After entering the simulation environment, the focus of teaching shifts to active exploration. Students are first guided to discover potential problems in operation (such as power supply reliability), and the core challenges are focused through teachers' questions. Guiding questions such as "how to ensure uninterrupted power supply for critical loads during islanding switching" then transform the problems into testable hypotheses, which are verified through multiple rounds of simulation tests. All operations and data are systematically recorded.
3. Reflection and Iteration: After the simulation, through group and class discussions, students demonstrate and reflect based on data, summarize advantages and disadvantages, and update the learning portfolio. The most critical step is that based on

the reflection conclusions, students revise the original scheme or conduct re-verification for new scenarios, thereby forming a spiral ascending learning cycle of "design → verification → reflection → optimization". The personal electronic learning portfolio records this dynamic optimization process throughout.

5 Conclusion

Focusing on the demand for talent training in the new-type power system under the background of emerging engineering education, this paper systematically constructs a virtual simulation experimental teaching model integrating the OBE concept and inquiry-based learning. By analyzing the limitations of traditional experimental teaching in terms of safety, cost, and cutting-edge nature, it demonstrates the unique advantages of virtual simulation technology in breaking through the dilemmas of high-risk and high-cost experiments.

In the design of teaching content, taking "virtual simulation of new energy storage intelligent microgrid design and faults" as the carrier, an inquiry-based teaching system covering four modules: planning and design, equipment cognition, energy storage optimization, and operation control is constructed. This system creates real engineering scenarios through the virtual simulation platform, guiding students to shift from passive acceptance to active exploration, and effectively promoting the deep integration of theoretical knowledge and engineering practice.

In terms of teaching evaluation, an innovative multi-dimensional evaluation mechanism based on the principles of "student-centered, outcome-oriented, and continuous improvement" is established. Through three progressive levels of basic standardization, complex task execution, and innovative problem-solving, combined with dynamic learning portfolios to record growth trajectories, it realizes the whole-process and quantifiable evaluation of students' practical abilities and innovative literacy.

Practice shows that this model has significantly improved students' comprehensive abilities in system design, fault analysis, and innovative decision-making, providing valuable practical references for the reform of experimental teaching in electrical engineering. In the future, we will further explore the integrated application of intelligent technologies in virtual simulation teaching, and continuously promote the optimization and upgrading of the teaching model and interdisciplinary expansion.

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Disclosure of Interests

The authors have no competing interests to declare that are relevant to the content of this article.

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