Case Teaching Design and Practice Research for the Course "Modern Power System Analysis"

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Abstract: The traditional course "Modern Power System Analysis" faces issues such as a single teaching model and insufficient case library development, which has led to ineffective improvement in students' mastery of theoretical knowledge and practical application abilities. To address these problems, this paper proposes principles for case library development and practices the "Engineering-Theory-Engineering" teaching method, establishing an efficient cyclical teaching system from case library development to teaching feedback. Practice has shown that this teaching method effectively enhances students' enthusiasm for learning and their ability to apply knowledge, cultivates engineering thinking and innovation awareness, and also promotes teachers' mastery of cutting-edge knowledge. This has improved the overall quality of the course and provided strong support for the teaching reform of the Modern Power System Analysis course.

Keywords: Modern Power System; Case Library Development; Case Teaching

1. Background of Case Teaching Design

With the continuous promotion of the "Carbon Peak and Carbon Neutrality" goals, the power system is gradually transitioning from the traditional unidirectional transmission model and centralized power generation to a complex network with bidirectional power flow and distributed generation. The proposal to "build a new power system with new energy as the main body" provides policy guidance for achieving the dual-carbon goals, while also posing new challenges for the training of master's degree students in electrical engineering. The modern power system not only includes a large number of new energy generation devices but also needs to address numerous uncertainties in grid operation [1]. To accurately analyze the operational state of the power system and ensure its stable and efficient operation, numerical simulation methods are used for safety analysis of the power system's operational behavior under given conditions, to develop corresponding control strategies for potential risks, and play an important role in dealing with the uncertainties of modern power systems and ensuring their safe and stable operation. This requires students to master the use of numerical simulation tools, aligning with the contemporary graduate training objectives [2,3].

Currently, there are widespread issues in course teaching, such as an overemphasis on theoretical knowledge, course content lagging behind the development of new technologies, and insufficient emphasis on cultivating students' practical and innovative abilities [4]. To change the traditional teaching model and integrate theory with practice, transforming students from passive recipients of knowledge to active explorers of practice, we have designed case-based teaching in the "Modern Power System Analysis" course. This approach follows the "Engineering-Theory-Engineering" teaching method, guiding students to identify problems from engineering cases, actively think and refine issues from a professional perspective, conduct simulation analysis based on these refined problems, develop experimental plans, and ultimately implement these plans to solve engineering issues. Through comprehensive training, we aim to cultivate students' engineering thinking and literacy. Simultaneously, the ideological and political education elements are seamlessly integrated into professional teaching, fostering students' professional identity and sense of responsibility. Modern information and teaching technologies are fully utilized, and online and offline teaching content is reasonably designed to guide students in enhancing their awareness and ability for autonomous learning.

2. Case Library Development

Case teaching is an effective teaching method, which can connect abstract theory with practical application and help students better apply what they have learned. Its implementation depends on a rich case base and needs to consider the adaptability of theoretical knowledge and technical implementation. The cases can come from the course content, related research or the scientific research project of the tutor team. Integrating the topic into the classroom can stimulate students' learning interest and innovation enthusiasm, and promote the mutual promotion of teaching and scientific research [5].

Taking the modern Power system analysis course as an example, it focuses on the power flow calculation, complex faults, small disturbance stability and transient stability of AC and DC systems, and adopts the theories of electrical network, linear algebra and numerical analysis for modeling, simulation and analysis. Through case analysis and programming simulation, theory and practical problems are closely combined. This teaching method can not only inspire students to apply new technologies to solve technical problems in modern power system analysis, but also provide them with a learning demonstration of theory and practice, thus improving the engineering practice ability of graduate students.

2.1 Principles of Case Library Development

The selection of teaching cases should be based on real-world engineering practices, while also aligning with the theoretical knowledge of the course to facilitate student understanding and promote the development of engineering thinking. Therefore, case selection should adhere to the following principles:

(1) Integration of Theory and Practice: The selected cases should cover core theories of modern power system analysis while also considering practical engineering applications. This ensures that students can understand theoretical knowledge through cases and apply it to solving real-world problems.

(2) Diversity and Representativeness [6]: The case library should include a variety of case types, including both classic, representative cases and innovative, cutting-edge cases to broaden students' horizons and cultivate innovative thinking.

(3) Appropriate Difficulty and Clear Levels: Cases should be categorized according to difficulty and complexity, progressing from basic to advanced. This ensures that cases cater to students with weaker foundations while also offering challenges for stronger students, maintaining gradual and systematic teaching.

(4) Technical Feasibility and Operability: The content of the cases should consider the feasibility of technical implementation, ensuring that students can practice through simulation software or experimental platforms, deepening their understanding of theoretical knowledge through hands-on practice [7].

2.2 Case Library Content

Based on the principles and process of case library development, existing cases have been supplemented and improved, and new cases have been added to address the characteristics of modern power systems. Table 1 lists the typical cases designed and developed in this study.

Table 1. Typical Cases in Modern Power System Analysis

Research Question	Case Name	Content of Development
Complex Power System Power Flow Calculation and Operational Mode Adjustment	Case of Power Flow Calculation and Control for a Complex Power System in a Region of Jilin	Use the power flow calculation software in the PSAT simulation tool to compute system power flow using the NR method and PQ decomposition method. Observe changes in the Jacobian matrix and compare the advantages and disadvantages of both methods. Identify the weak points in grid operation and take corresponding measures for adjustment, comparing the effects of different measures.

The transient stability of multi-machine system is calculated by numerical simulation method	Case of Transient Stability Analysis for a Multi-machine System in a Region Based on Time-domain Simulation	Use the transient stability analysis module in the PSAT simulation tool to compute the system's dynamic process and evaluate its transient stability. Apply sensitivity theory to analyze parameters that significantly affect transient stability, adjusting them and assessing the effects of the adjustments.
Provincial Grid Reactive Power Fluctuation Optimization Plan Design and Implementation	Optimal Power Flow of AC-DC Hybrid System — Reactive Power Optimization of the Grid	Construct the objective function for reactive power optimization and set corresponding equality and inequality constraints. Solve using optimization methods like the interior-point method, while utilizing simulation tools such as PSASP and PSAT to implement the reactive power optimization function. Finally, analyze and compare the effects of different optimization strategies to determine the optimal strategy.
For the provincial-level grid operation mode, conduct continuous power flow calculations under different load growth patterns to obtain the static voltage stability margin	Multi-machine System Continuous Power Flow — Static Voltage Stability Analysis	To analyze the stability of the provincial power grid, first obtain its typical operation mode, then set the load growth mode of different regions, and use the simulation tool to perform continuous power flow calculation, and finally evaluate and give the static voltage stability margin of the power grid under different regions and different load growth modes.
The problems of high current and low voltage caused by the fault are analyzed by the phase and sequence boundary conditions of the port.	Power System Complex Fault Teaching Case	This case involves analyzing the impact of specific faults on low voltage and high current by programming to form port calculation conditions, under the given system structure parameters and initial operating conditions. The severity of the fault is then assessed based on these factors.
For low-frequency oscillation phenomena in provincial and higher-level grids, extract important information such as the dominant oscillation mode and participation factors in complex systems	Complex Power System Small Disturbance Stability Analysis — Dominant Oscillation Mode Recognition	The oscillation mode and feature vector information of power grid are obtained by small disturbance stability analysis. Further extract the dominant oscillation mode and its participating factors, determine the weak link of power grid operation, and analyze the influence of adjusting the output of specific generator groups on the dominant oscillation mode.
Based on the Phillips-Heffron model, study the impact of excitation system amplification factor, grid operation mode, and other factors on damping characteristics, and configure the power system stabilizer (PSS).	Small Disturbance Stability Analysis of Simple System using the Complex Torque Coefficient Method — Phillips-Heffron Model and Its Application	This case implements the Phillips-Heffron model under given initial power flow and structural parameters, used to analyze the effects of various parameters and initial operating conditions on damping torque. A PSS (Power System Stabilizer) model is designed and implemented to analyze the specific effects of PSS parameters on damping torque.
Analysis of Transient Stability in Provincial and Higher-level Grids Under Specific Operating Conditions and Faults Using Energy Function Method	Energy Function Method Case for Power System Transient Stability	In this case, based on the steady state operation of the power grid, a variety of faults and disturbances are set up to analyze the impact of faults on the operating state of the system, and the corresponding energy function is established to judge the transient stability qualitatively and quantitatively. The characteristics of transient energy function method and numerical simulation method in analyzing transient stability of systems are discussed.

3. Case Teaching Practice

3.1 Case Teaching Practice Design

To change the traditional "teacher lectures, students listen" teaching model [8], the "Modern Power System Analysis" course integrates real engineering cases, closely linking theoretical knowledge with practical application. The course incorporates modern teaching methods such as simulation tools and data analysis platforms to create an interactive and open learning environment, motivating students' initiative and participation. The course also emphasizes group discussions, case analysis, and practical operations, with collaboration among students and guidance from teachers, enabling a deep understanding and expansion of knowledge. This fosters positive interaction and a continuous improvement teaching ecosystem [9]. Based on the inspiration from teaching practice and literature research, this paper designs a case teaching plan for the "Modern Power System Analysis" course, which comprehensively considers the scientific nature of the teaching content, the effectiveness of classroom interaction, and the broad applicability of practical applications. The specific plan is as follows:

(1) Teaching Objectives

The teaching objectives of each case are clearly defined to ensure that students master specific analytical methods, understand key technical concepts, and are able to apply theory to solve practical problems. The goal is for students to learn to analyze power system problems and become proficient in using simulation tools to model, simulate, and optimize solutions [10,11].

(2) Case Selection and Preparation

Select the appropriate cases according to the teaching objectives, which may include classical literature, engineering practice or research projects. Provide students with the necessary background information, data sets, simulation models and guidance documents to clarify the task requirements and procedures.

(3). Case Teaching Implementation

1) Introducing the Case:

Introduce the background of the case through explanation or multimedia presentation to stimulate student interest. Divide students into groups to discuss, design solutions, and collaborate to solve the case problem.

2) Case Analysis and Experimental Operations:

Students apply the theories learned to analyze case problems in depth, identify key factors and propose solutions. After the scheme is determined, simulation experiments are carried out in the laboratory or on the computer to verify the analysis results, and the response of the system under different conditions is tested through the simulation platform to adjust the parameter optimization scheme. Teachers tour students as they discuss and experiment, answering questions, providing ideas, correcting mistakes, demonstrating or explaining when necessary, and ensuring that students understand key concepts and steps.

(4). Results Presentation and Summary

Each group reports on its case analysis process and results, presents simulation or experimental results, and explains design decisions and conclusions. Teachers comment on advantages and disadvantages, and supplement relevant theoretical knowledge and technical details to help students deepen their understanding. Finally, class discussions are organized, questions and suggestions are raised, and knowledge sharing and ideas are promoted among students [12].

3.2 Case Teaching Example

Case analysis teaching should clarify the focus of teaching, emphasize analysis regulations, and guide students to combine the theoretical knowledge they have learned with engineering practice. The "Engineering—Theory—Engineering" teaching model is used to cultivate students' engineering thinking and innovation awareness, help them master the use of relevant numerical simulation tools, and develop the basic ability to apply theoretical knowledge and technological methods to analyze and solve engineering problems. This chapter uses the "Power Flow Calculation and Operational Mode Adjustment for Complex Power Systems" teaching case of "Power Flow Calculation and Control for a Complex Power System in a Region of Jilin" as an example for analysis. As shown in Fig. 1, the electrical wiring diagram of a regional power grid in Jilin is given, which provides a detailed presentation of the topology of the grid and the distribution of generators and loads. The subsequent analyses are conducted based on this grid electrical wiring diagram.

Case Teaching Objectives:

1) To improve electrical engineering students' understanding of power system power flow and related simulation software. By combining power flow adjustment and control knowledge, reveal the impact patterns of voltage, power, and losses in the grid.

2) To make students aware of the

development status of research in power system power flow calculation and the associated policies and regulations.

3) To provide basic training in engineering design methods, computer applications, literature search, data querying, and thesis writing, cultivating students' comprehensive ability to analyze and solve engineering problems using the knowledge and techniques they have learned.

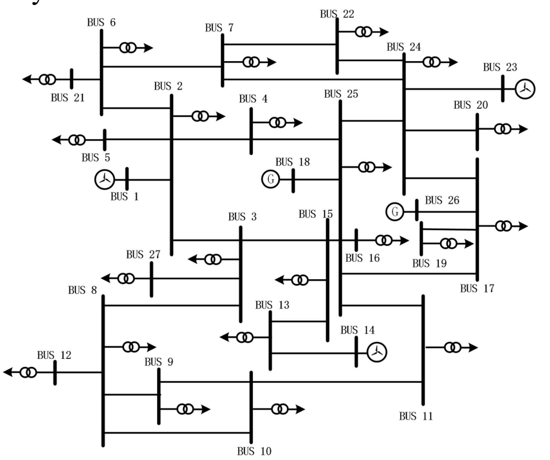

Figure 1. Electrical Wiring Diagram of a Power Grid in the Western Region of Jilin

Basic Teaching Requirements:

1) Use the power flow calculation software in the PSAT simulation tool to calculate system power flow.

2) Use the NR method and PQ decomposition method to calculate power flow, observe the changes in the Jacobian matrix in the NR method, and analyze the advantages and disadvantages of both methods.

3) Analyze system power flow conditions, including voltage magnitudes, phase angles, line overloads, and total active power loss across the grid.

4) Identify the line with the maximum active power loss in the system, propose measures to reduce the loss on that line, compare the characteristics of various measures, and validate through simulation.

In addition to the basic teaching requirements, supplementary tasks for students with a stronger background are as follows:

1) Identify the line with the maximum active power loss in the system, change the generator's active power output, and analyze the generator's active power sensitivity to this line's active power loss. Adjust effectively to reduce the loss on this line.

2) Identify the line with the maximum active power loss in the system, perform reactive power compensation, analyze the load's reactive power sensitivity to this line's active power loss, and adjust effectively to reduce the loss on this line.

3) Identify the node with the lowest voltage in the system, analyze the generator terminal voltage's sensitivity to the node's voltage magnitude, and adjust the generator terminal voltage effectively to improve the node's voltage level.

Teaching Schedule and Format:

For time allocation, power flow calculation and simulation will take 2 hours (including 1 hour for using simulation tools and setting up the simulation environment, and 1 hour for preparing input data). Power flow results will be organized and analyzed in 2 hours. Writing the case report will be done outside class in team collaboration. For the discussion format, students will be grouped in teams of three. Each team will work on the same topic but is encouraged to apply different methods. The teaching format will use multimedia presentations to explain the power system power flow simulation tools, with key theoretical steps outlined on the blackboard. For results presentation, students will be required to draw the system power flow diagram, write research reports, analyze power flow results, evaluate the safety and economy of the power flow operating mode at each power flow interface, identify weak links in the system, and propose adjustment measures, comparing the differences between the proposed measures.

4. Conclusion

By introducing the case teaching model into the "Modern Power System Analysis" course, we have not only successfully increased students' interest and participation but also effectively enhanced their ability to apply theoretical knowledge to real-world problems. Case teaching has demonstrated significant advantages in bridging theory and practice and in cultivating students' comprehensive skills. It has also provided new ideas and directions for the reform of traditional teaching methods.

This paper proposes the principles for selecting cases and the construction process, ensuring that the chosen teaching cases are timely, diverse, typical, and actionable, while also maintaining the rigor of the case library construction. In addition, this paper implements the "Engineering—Theory—Engineering" teaching method and designs a complete case teaching process aimed at creating an interactive, open learning environment that stimulates students' initiative and participation, fostering their engineering thinking and innovation awareness. Finally, a case teaching example is provided for reference by other disciplines. In the future, we will continue to improve the case library, enrich teaching resources, and optimize classroom interaction to further enhance teaching effectiveness. Additionally, as power system technologies continue to advance and grow in complexity, we will keep exploring and introducing cutting-edge technological and engineering cases that combine theory with practice, ensuring that the course content remains aligned with the development of the times and helps students better prepare for future career challenges.

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