Research on the Reform of Assessment Methods for High Voltage Technology Course Oriented to Engineering Accreditation

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Abstract: *In line with the engineering accreditation requirements, an evaluation mode should be established to determine and track the achievement of the goals of the High Voltage Technology course by students. The structure of the current method is not suitable for engineering problems, and it does not consider the different working conditions in the scoring. According to the map analysis of graduation requirements and course objectives, taking into account the measurability decomposition of ability indicators, a supporting relationship model for assessment methods and levels of achievement has been constructed. To solve the problems of coverage blindness and lack of contextual authenticity in the old evaluation system, a new assessment system has been introduced that can change the weights of formative and summative evaluations dynamically, use a multi-dimensional quantitative scale for all abilities, and add a closed-loop correction mechanism for achievement levels. Based on the data of quantitative ability, the system will meet the requirements of the engineering accreditation index.*

Keywords: *Engineering Accreditation, High-voltage Technology, Assessment Methods, Evidence of Ability Achievement, Degree of Course Objective Achievement*

Introduction

High-Voltage Technology is an essential subject in electrical engineering that covers all kinds of knowledge related to gas discharge, dielectric insulation, overvoltage protection and high-voltage testing, etc., and helps students develop the ability to solve difficult problems in high-voltage engineering. The engineering accreditation assessment should be able to judge not only the students' learning of theory but also all other kinds of abilities they have gained, such as analysis, design, judgment and creativity. At present, most of the evaluation methods are closed-book final examinations, laboratory reports and regular homework; thus, skills such as engineering problem definition, comparison of multiple schemes, fault diagnosis and analysis in non-standard operating conditions are not being assessed. The grades are in a straight line, so we do not know whether the knowledge has been learned or applied; thus, the different levels of ability in the dimension of technological innovation cannot be effectively shown. Generally speaking, the content of the assessment is in an ideal state or in the form of a standard waveform; however, it does not match the actual working environment of typical equipment, and there are often environmental changes, waveform distortions and random discharges. To address the problems of structure mentioned above, this paper puts forward a reform plan for assessment based on evidence of achievement of ability. Revise the assessment criteria, introduce a variable-weighting method, build a multi-dimensional quantitative evaluation scale, add a closed-loop correction mechanism, and improve the validity of the assessment results that will be used to support the indicators for engineering accreditation in this paper.

1. Logical Restructuring of the Assessment Criteria for the High Voltage Technology Course in Light of Engineering Accreditation

1.1 Mapping Analysis of Engineering Accreditation Graduation Requirements and Course Objectives for the High-Voltage Technology Course

One of the requirements for graduation in the Engineering Accreditation is the "ability to solve complex engineering problems", and the corresponding index can be found in the High Voltage Technology course; it integrates many applications of knowledge units, such as gas breakdown, insulation characteristics of liquid and solid dielectrics, overvoltage protection, and high-voltage testing methods. By comparing the indicator points of the graduation requirements and the teaching content of the courses step by step, one can find two types of mapping relationships: direct support and indirect support. For example, if the graduation requirement is that students should be able to carry out research on complex engineering problems based on scientific principles and apply scientific methods, this is in line with one of the goals of the course, which is to design test plans for high-voltage insulation withstand voltage tests and analyze impulse voltage waveforms; thus, a one-to-one mapping chain has been formed.

The goals of the High-Voltage Technology course are to learn some basic theoretical knowledge, conduct engineering calculations and analyses, and carry out experiments and data analysis. To build an ordered map analysis, each graduation requirement should be broken down into a few observable ability behaviours, and then these will be linked with the specific learning objectives in the course objectives. Mapping analysis should consider not only the correspondence of content but also specify the degree of support, such as strong support, medium support or weak support. Based on the correlation matrix of the objective indicators, a foundation has been laid for distributing the assessment weights so that no part of the course objectives and graduation requirements is left out or redundant[1].

1.2 Decomposition Principles for the Measurability of Ability Indicator Points in High Voltage Technology

Measurability is the property of being able to obtain a numerical index of an attribute through observation and measurement. For the ability in "Analysis of the breakdown process of an air gap in a non-uniform electric field" for the High Voltage Technology course, the following three measurable sub-indicators can be set: identification of the characteristics of the electric field distribution, calculation of the inception field strength and breakdown voltage, and judgment of the polarity effect. Decomposition is hierarchical; that is to say, there are several stages, starting with knowledge reproduction (e.g., explaining the streamer theory), followed by engineering judgment (e.g., determining the insulation withstand level of the actual electrode structure), and at each level, there are specific response formats and scoring criteria for the sub-indicators.

The second rule of measurable decomposition is operability; that is, each sub-indicator should be observable by some means of measurement. For example, the instruction "Select a suitable high-voltage test circuit" can be broken down into the following three observable behaviours: draw the schematic diagram of the circuit, calculate the parameters of each component, and list the safe operation steps. The three kinds are a drawing question, a calculation question, and a short-answer question. For indicator points that are abstract physical concepts in High Voltage Technology, such as the effect of space charge accumulation, one can increase the objectivity and differentiability of measurements by changing them into problems of interpreting simulation waveforms or identifying abnormal data in the laboratory.

1.3 Support Relationship Model of Assessment Methods for Degree Achievement of Course Objectives

The support relationship of the assessment methods and the course goals should be built in a quantitative model. Based on the goals of the course, different weights are given to all kinds of assessments, such as class quizzes, lab reports, thematic homework, closed-book tests, etc., to determine how much each will contribute to achieving these goals. The supporting relationship model is in the form of a matrix; the rows are the course objectives, the columns are the specific assessment items, and the elements of the matrix are preset weight coefficients that show how much each assessment item contributes to achieving the objective. The weight of the weight coefficient is determined by the number and depth of the ability indicator points in each assessment item.

Based on the model above, the degree of achievement for each course objective is calculated by taking the raw scores of all assessment items, and then the weighted achievement score of an objective is obtained by weighting these scores. Based on the feedback and corrections, the support relationship model will also be modified; if the achievement level of a particular course objective is consistently far below the norm, we can reasonably change the number or weight of assessment items for that objective instead of only increasing the difficulty of the examination questions. The model can show that there are many-to-many mapping relationships among assessment methods and objectives, and thus the bias of achievement evaluation by a single type of assessment will be reduced. Based on the data from the model, some links in the alignment of course objective setting and assessment are weak; therefore, we will establish a quantitative basis for improving course teaching in the future[2].

2. Structural Deviation Analysis of the Current Assessment Methods for the High Voltage Technology Course

2.1 Coverage Blind Spots of Traditional Assessment Components in Engineering Problem-Solving Ability

The original content of the assessment for the High Voltage Technology course is a final closed-book test, a small number of regular homework assignments and lab reports. Most of the short-answer questions and calculation problems in the final examination papers are based on the memorisation and application of basic knowledge, such as the theory of gas discharge, dielectric polarisation and loss, and impulse voltage generators. The above assessment items do not cover all the sub-processes of the ability to solve engineering problems systematically, such as problem definition, constraint identification, multi-scheme comparison and verification. For example, in the typical engineering problem of "suppressing lightning intrusion overvoltage in a substation", the old way is to only consider the switching impulse withstand voltage value or the calculation of the arrester residual voltage, and does not include the selection of waveform parameters, verification of protection distance or evaluation of insulation coordination margin.

Generally speaking, the evaluation of the experimental period is a verification experiment; students need to carry out the power frequency withstand voltage or dielectric loss measurement experiment according to the given steps and fill in the data table. The only defect of this kind of test is that it cannot find faults; that is, problems such as fault diagnosis, identification of abnormal waveforms, or adjustment of the test circuit will not be uncovered. The Design of this evaluation will not be an open-ended engineering problem; for instance, it will not elaborate on why the test data are non-linear during construction. The old assessment items do not cover the combined abilities of engineering design, analysis and judgment; thus, it is not possible to determine whether students can "solve complex engineering problems" according to the engineering accreditation standards.

2.2 Lack of Differentiation in Knowledge Application and Technological Innovation Dimensions in the Grading Method

The current grade system is a linear accumulation model based on percentages; that is to say, the final exam accounts for 60-70% of the total, and the regular performance score includes attendance, homework, lab reports, etc. The sum of the grades in the above grading method is used directly, so the differences among students in the two dimensions of "knowledge reproduction" and "knowledge application" cannot be distinguished. For example, if a student answers the short-answer questions correctly but loses many points in the calculation problems about the voltage correction for air gap breakdown, only a difference in the total score will be shown, and the weakness in application ability will not be highlighted. The distribution of grades is relatively narrow, and often the only distinction between excellent and passing grades is whether one can correctly answer memorisation-based questions[3].

At present, there is no index to measure the degree of technological innovation in the assessment system. The new programmes will be to improve the present high-voltage test method, provide reasonable explanations for the insulation ability of non-standard waveforms, or carry out preliminary demonstrations of the application of new insulating materials. All of the current test questions are closed-ended questions and have only one correct answer. Even if there is a course design or a themed essay, the main scoring factors will be format specifications, the completeness of the literature review and the consistency of the conclusions with the textbook; generally, novelty, depth of analysis and engineering value are not given much weight. In this case, it will be impossible to distinguish between creative thinkers and those who can only complete the tasks given to them, and it will not provide a good basis for evaluating the non-technical index of "innovativeness" in engineering accreditation.

2.3 The contents of the test do not meet the general operating conditions of high-voltage equipment

Typical operating conditions refer to the types of voltage, environment, fault development process, etc., that high-voltage equipment will be exposed to in actual operation. The content of the current tests is mainly theoretical calculations under ideal conditions or in standard test conditions, such as calculating the breakdown voltage of a plate electrode gap in a uniform electric field and the equivalent capacitance of parallel capacitors. In fact, the switching overvoltage waveform that a power transformer experiences often has high-frequency oscillations, multiple polarity reversals and chopping phenomena; however, the switching wave in the assessment questions is always taken as a standard 250/2500 μs waveform, and the randomness and dynamic process of partial discharge caused by particles in gas-insulated switchgear do not occur in the assessment.

The other is that the assessment contents do not meet the operating conditions, and the environmental factors have not been considered. Due to the high altitude, there are fluctuations in humidity, accumulation of pollution, etc., and the insulation performance of the high-voltage equipment will be lower than the test values in a normal environment. Currently, the examination questions do not include the correction calculation, and even if they did, only one formula is required; we do not need to consider the boundary conditions for selecting correction coefficients. Special operating conditions that are electromagnetic compatibility, superimposed harmonics with impulses, and very fast transient overvoltages rarely appear in the assessment content of the High Voltage Technology course; therefore, it is difficult for students to connect the assessed knowledge with the actual insulation coordination design of equipment. Therefore, the accuracy of the prediction for engineering application ability is relatively low, and the problem of not considering environmental and operating conditions in the engineering accreditation index has not been solved.

3. Redesign of the Assessment Method System Based on Evidence of Ability Achievement

3.1 Dynamic Weighting Scheme for Formative and Summative Assessments

Collection of evidence for the achievement of ability needs to cover the entire teaching cycle of the High Voltage Technology course, and the weight given to formative assessment and summative assessment should not be fixed in advance. However, it should be changed dynamically according to the achievement cycle of the ability dimensions in line with the course goals and the measurement reliability of these dimensions. The horizontal axis is the sequence of teaching weeks, and the basis for classification is the type of evidence obtained in each assessment and its corresponding ability level; thus, a sliding weight window is employed. At the start of the course, the first few sections will introduce the necessary foundation knowledge, such as the basic theory of gas discharge and safety regulations for high-voltage testing. At this time, formative assessments, such as timed quizzes in class and unit homework, will be given more weight to determine how well students have grasped the basic concepts and principles covered so far. In the middle and later parts of the course, as the teaching content moves towards engineering calculation analysis (such as insulation coordination and estimation of switching overvoltage amplitudes) and comprehensive evaluation of test schemes, the weight of the summative assessment gradually increases, and it is used to evaluate students' engineering design judgment ability in integrating all the knowledge points[4].

To change the distribution of weights dynamically, we can either increase or decrease them based on how well things are going at that time. Set the lower bound for the formative achievement score of each course objective in advance. When the ability indicator point of a student reaches the upper limit according to all the formative assessment materials, the weight of the corresponding objective in the summative assessment is automatically reduced; conversely, it is increased. Therefore, a single error in the final weighted score will not result in an incorrect judgment of the overall process ability, and at the same time, we can avoid overlooking all aspects of the application ability by giving too much weight to formative assessments. For the practical part of the High Voltage Technology course, such as electrical test operation and discharge data analysis, weights will be given based on how thoroughly a student has investigated the causes of errors and whether the waveform interpretation in each laboratory report is reasonable; thus, the distribution of weights can show changes in students' abilities over time and differences among them accurately.

3.2 Construction of a Quantitative Evaluation Scale and Scoring Criteria for Multidimensional Ability Dimensions

Given that we need to assess the current situation of all relevant activities in the engineering accreditation of technical knowledge, engineering analysis, experimental operation and written expression, the quantitative evaluation scale should systematically cover the following four independent dimensions: reproduction of theoretical knowledge, modelling of engineering calculations, design of high-voltage test circuits with fault identification, and technical documentation writing. Each dimension should have three or four descriptive scoring anchors, and therefore we will no longer use a single total score based on a general impression. The most typical case is the "Design and Safety Analysis of a High-Voltage Test Circuit". Level One is a serious topological error or the omission of a safety device in the circuit diagram; Level Two is a basically correct circuit structure but lacks component parameters; Level Three is a complete circuit with reasonable parameters but no grounding and overcurrent protection; Level Four is a reasonably designed circuit that clearly shows safety measures; and Level Five is a circuit with a redundant protection scheme and an explanation for handling abnormal operation. The grades of the graded anchors are the same and easy to inspect.

The Operation Definition of the scoring index should specify the observable behaviour at each level in all dimensions, and different scorers need to be able to judge consistently according to this norm. For the dimension of electrical safety operation, which is specific to the High Voltage Technology course, the scoring criteria should list particular behaviours that need to be checked item by item: confirm the connection status and connection sequence of the grounding wire before the test, observe the leakage current and partial discharge signals in real time during the voltage boosting process, and perform the discharging and re-grounding procedures after reducing the voltage and cutting off the power. The weights of the multidimensional ability scale are set according to the contribution coefficient of each dimension to the achievement degree of the course objectives, and among them, the dimension of engineering calculation and modelling has been given a relatively high weight because it directly supports core engineering abilities such as optimisation of insulation coordination and lightning overvoltage simulation analysis. Although the weight of the dimension for the expression of technical documentation is relatively small, its scoring criteria still need to be specified; this includes whether term definitions are mentioned in the test report, whether specifications for the coordinates of voltage waveforms and breakdown probability curves are provided, what is done to determine whether abnormal data should be excluded, and how far the discussion on error sources goes.

3.3 A Closed-loop Correction Mechanism to Achieve the Course Objectives Based on Assessment Results

According to the quantitative solution value of the degree of achievement in course objectives, the instructions for the constituent elements of the assessment methods are changed as the output variable, and thus a data-driven continuous improvement loop is formed by the closed-loop correction mechanism. The three modules will be the achievement degree calculation module, the deviation diagnosis module and the assessment plan update module. Based on the above support relationship model and multi-dimensional scale scoring, the achievement degree calculation module will compute the average achievement degree of each course objective and the coefficient of inter-individual distribution dispersion item by item. Set the lower bound (0.65 is recommended) and the upper bound (0.85 is recommended) for the achievement degree in the deviation diagnosis module. If the achievement level of an objective in a particular course is lower than the lower limit, the diagnosis module will identify which assessment items are related to this objective and report that there is a problem of poor discrimination or low test-retest reliability; at the same time, it will analyze the distribution of achievement to determine whether the problem is due to a structural flaw in the assessment plan or to individual differences in learning[5].

Based on the results of the diagnosis, the revised structure of the assessment plan will add the following three kinds of organised adjustment operations: item substitution, weight reallocation and form addition. Item replacement is to change the original memorisation-based short-answer questions into engineering context analysis questions that have good differentiation, such as inferring the insulation coordination margin from a given field overvoltage waveform. Increase the weight of the formative assessment of learning objectives for students who have consistently performed poorly, or increase the proportion of examination questions on these objectives in the final test. A form can be added to add an assessment form for a task that is not in the assessment plan, such as a partial discharge tracing task based on fault tree analysis or a technical scheme comparison seminar report based on an actual substation insulation coordination case. Then the revised assessment plan will be used in the next teaching period to determine how well the learning objectives have been achieved and monitor any changes in this over time to see if there has been any improvement. The closed-loop mechanism is based only on the quantitative data of ability achievement for decision-making, does not involve empirical subjective adjustment, can explicitly record the connection between each assessment reform module and the change in the degree of achievement of course objectives, and thus provide a traceable technical archive for the continuous improvement of the High Voltage Technology course in line with engineering accreditation.

Conclusion

This paper studies the ability achievement requirements for the engineering accreditation of the assessment of the High Voltage Technology course, has completed the logical restructuring of the assessment criteria, analyzed the structural deviations in the current methods, and redesigned the assessment system based on evidence of ability achievement. Based on the map analysis of graduation requirements and course objectives, and in accordance with the principle of measurable decomposition, this paper has clarified the supporting relationship model between ability indicator points and assessment items. To solve the problems in the old system of coverage for the ability to solve engineering problems, differentiate scores and align them with actual operating conditions; thus, this paper proposes a dynamic weight allocation strategy for formative and summative assessments and develops a quantitative evaluation scale and scoring criteria that cover the problems mentioned above, such as the reproduction of theoretical knowledge, engineering calculation modelling, test circuit design and fault identification, technical documentation writing, etc., and builds a closed-loop correction mechanism for the degree of achievement based on assessment results. Given the evidence of quantitative ability in decision-making, the form of assessment has changed from fixed ratios to adaptive adjustment; that is to say, it has been modified from a single total score to multi-dimensional anchor evaluation and from static schemes to data-driven closed-loop iteration. In the future, I will continue to develop the path-tracking method based on learning analytics technology in an individualized manner, build an effective correlation model for assessment data and teaching intervention, construct quantitative measurement tools for indicators of non-technical abilities in the High Voltage Technology course, establish a system that integrates all the above, and finally, develop a digital platform to support dynamic weight adjustment, automatic multi-dimensional scale scoring and online operation of the closed-loop correction mechanism.

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