Study of the Exploratory Course of Electrical Engineering
Based on ECE4980 Curriculum of Cornell University

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Abstract. The purpose of this paper is to constitute a development course system with the Chinese characteristics based on ECE4980 curriculum of Cornell University. Core work is to give a multi curricula integration system associated with mechanism analysis and engineering implementation of the subject based on taking the most advancing front research results into this development course system. By analyzing logic relationship between general education, curricula and experiments of joint research laboratory of HIT and Eaton, a development course system consists of understanding, integrating and solving knowledge has been proposed. This work can give a solution for constructing development curriculum system of electrical engineering with international characteristics.

1. Introduction

According to the teaching experience for many years, students will encounter some common problems after entering the stage of professional courses in the fourth grade of university [1-3]. As not knowing how to make the best use of my knowledge, garbling statement from research, unable to connect basic courses with professional courses, etc. These problems hinder the cultivation of Applied Undergraduate Talents. Therefore, before students enter the graduation project, strengthening the link between basic course learning and professional course learning by adding extended course is conducive to improving students' basic cognitive ability in mastering the system mechanism and control law, and promoting the cultivation of Applied Talents in research universities in China [4-7].

Cornell University (CU) is the top 10 Ivy League University in the United States. Its undergraduate extended course ECE4980 (Supervised Teaching Experience) can provide us with teaching reference. By learning ECE4980 course, students can understand the logical relationship between basic courses and professional courses, clarify the systematicness and coherence of theory, understand the purpose and application prospects of each course, and promote students' learning initiative. ECE4980 course is taught by professors who have rich practical experience. The application prospects of basic courses and professional courses are illustrated through the perspective of engineering practice, which is far superior to textbooks or theory-oriented professional extension [8-10].

Based on the experience of studying ECE4980 course in Cornell University and aiming at the existing problems in classroom teaching and practical teaching, the author improves the practical teaching from the aspects of teaching concept, teaching content, teaching methods, and etc. Based on HIT-Eaton Joint Laboratory, the author sets up undergraduate professional extension course with characteristic of ECE4980 course. Based on the urgent need to solve the problem of "wind abandonment energy storage" as the engineering background [11], the courses of "higher mathematics", "university physics", "analog/digital electronics", "circuit theory", "electric machines", "computer principle and application" and "automation control theory" are organically combined to
teaching theory. The combination of learning and experimental demonstration will enable students to fully understand the necessity and application prospects of the knowledge they have learned, improve the specialty cognitive level of freshmen and sophomores, improve the Professional extension ability of junior and senior students, and provide solutions for training Chinese qualified undergraduates.

2. ECE4980 Extended Course Teaching System

The purpose of setting up the extended course is to better enhance students' discipline awareness, expand their academic horizons and improve their practical ability. Its essence is to expand the professional extension on the basis of the existing curriculum, which is an organic supplement to the national standard curriculum.

Based on ECE4980 of Cornell University, this paper is focusing on: (1) to mobilize students' disciplinary initiative and innovative consciousness by combining ECE4980 course idea with the current engineering teaching at HIT. (2) to adjust and expand curriculum content according to the needs of personnel training under the new situation, and (3) to clarify the logical relationship between general courses and professional courses by taking advanced mathematics and automation control.

2.1. Establishing the Professional Application System of General Education Courses

In the general courses of freshmen and sophomores, advanced mathematics tests the beginners' mathematical operation ability, abstract thinking ability, logical reasoning ability and spatial imagination ability. At the same time, due to the limited hours, teachers usually do not introduce much about the professional application prospects of higher mathematics related knowledge points. Students often only study this course, but do not know how to apply advanced mathematics to engineering practice. Extended courses such as ECE4980 can make up for this deficiency.

Through learning this course, students can master the practical application of knowledge points such as calculus of one variable function, calculus of multiple functions, vector algebra and spatial analytic geometry, infinite series, ordinary differential equation, and so on. So as to improve the disciplinary initiative of learning. Because Fourier series is complex and widely used, I will take it as an example to illustrate how to apply ECE4980 to extend teaching.

For Fourier series, the most difficult to understand is the harmonic order \( n \). In order to enhance the understanding of the physical meaning of multiple \( n \), the topology of the corresponding relationship between Fourier series and other courses be added to the extended course is shown in Fig.1.

![Figure 1. Expansion of the relationship between Higher Mathematics (Fourier series) and other courses.](image-url)
In Fig. 1, the application relationship of Fourier series is illustrated as follows:

1. Corresponding to university physics, Fourier series can be used to analyze the spectrum of force, heat and electromagnetic signals. The significance of fundamental frequency \( (n = 1) \) and high frequency \( (n \geq 2) \) signals can be explained by the spectrum analysis of oscilloscope.

2. Corresponding to the basic circuit theory, Fourier series can be used to analyze the distortion rate of the output voltage and current signals of the circuit, and the physical meaning of Fourier series can be demonstrated based on the waveform of Eaton tester.

3. Corresponding to analog/digital electronics, Fourier series can be used to analyze zero drift of operational amplifier and distortion waveform of output signal. So as to solve the abstract analysis problem of operational amplifier in this professional course.

4. Corresponding to electric machine, Fourier series can be used to decompose the output torque oscillation and find out the current-frequency multiples that lead to the torque oscillation. See Figure 2, which enhances the understanding of Fourier series.

5. Corresponding to the theory of automatic control, Laplace transform, especially the analysis of non-linear negative reciprocal characteristic function, needs Fourier series, which is an example of the development from general theory to professional application.

6. Corresponding to the principle and application of computer, the extraction of voltage and current characteristic frequency signal is directly related to the frequency multiple of Fourier series, which is a necessary measure to highlight the application of Fourier series.

2.2. Designing the Supporting System of Professional Education Course

In many professional courses, the non-linear theory in the course of automation control theory is difficult to understand because of its complicated calculation process, obscure theory and abstract application effect. In the process of learning, students often record four typical non-linear negative complementary characteristic functions: dead zone, saturation, gap and relay mechanically. The phenomenon of self-sustaining oscillation, waveform distortion and jump caused by these functions is often poorly understood. In view of this learning situation, drawing lessons from the ECE4980 course idea, we collate the logical relationship between non-linear theory and other course content, and get the graph shown in Fig. 2, which is used to enhance understanding of non-linear theory.

![Figure 2](image_url)

Figure 2. Expansion of the relationship between Automation control theory and other courses.

In Fig.2, a typical application case of nonlinear theory is illustrated as follows:
1. Corresponding to advanced mathematics, the solution of non-linear differential equation in advanced mathematics can be used to explain the non-linear theory, which highlights the non-superposition of saturation, dead-zone, relay and gap non-linear solutions.

2. Corresponding to university physics, we can use the non-linear oscillation and non-linear electromagnetic oscillation in university physics to explain the non-linear theory, and emphasize that the time-varying coefficients of the dynamic equation are the non-linear root.

3. Corresponding to the basic circuit theory, the application prospects of the theory of non-linear self-excited oscillation can be illustrated by applying the non-linear circuit, resonance circuit and LC series-parallel resonant circuit in the circuit foundation.

4. Corresponding to analog/digital electronics, the output oscillation of operational amplifier can be used to explain the application of non-linear theory, and the essence of non-linear oscillation of operational amplifier can be explained by time-varying temperature coefficient.

5. Corresponding to electric machine, its speed jitter and torque oscillation can be explained by non-linear theory. The root of this phenomenon is to suppress the non-linear perturbation of the stator and rotor coefficients of the motor itself.

6. Corresponding to the principle and application of computer, the differential control of sampling process, especially the development process of non-linear discrete algorithm for continuous signals, is emphasized, which is the path of realization of non-linear theoretical engineering.

Based on the ECE4980 curriculum idea, we can establish the logical extension and engineering application system of each general course and each professional course, which will not be repeated here one by one.

3. Engineering Analysis of ECE4980 Extended Course

It is one of the goals of ECE4980 course to integrate the most advanced scientific and technological achievements into teaching cases, to establish a multi-curriculum integration system based on the analysis of the mechanism of research objects and the realization of engineering, and to cultivate students’ ability to apply their knowledge to solve the technological frontier problems. This paper combines the ECE4980 extension course idea with the advanced experimental facilities of HIT-Eaton Joint Laboratory, and establishes an engineering extension teaching system which includes mechanism analysis, system design and algorithm development.

3.1 Mechanism Analysis and Project Design

Mechanism analysis is the theoretical basis of system design and algorithm development. System design is the hardware carrier of mechanism analysis and algorithm development. Algorithms development is the software essence of mechanism analysis and system design. There are three interdisciplinary applications involved. Based on the abandoned wind energy (Fig.3), which is urgently needed to be solved by China, the teaching system of project extension is shown in Fig.4.

![Figure 3. Both actual wind power control system and simulation experiment.](image)

The engineering extension teaching system based on wind power Grid-connected Control is shown in Fig.4.
As shown in Fig.4 the detail expressions are described as follows:

1. Mechanism analysis: This is the only way from general education to specialized design. In this paper, the control mechanism analysis of wind power generation can be based on the third-year course "Electrical Engineering". The generation mechanism and analysis of voltage and current can be solved by the first-year course "College Physics" and "Advanced Mathematics" respectively, so as to clarify the course's action mechanism.

2. System design: This is the system carrier from theoretical analysis to engineering practice. In this paper, the grid-connected control system of wind power generation can be solved according to the sophomore course "Circuit Basis" and "Analog/Digital Electronics". The system architecture of control, power supply, signal conditioning and A/D conversion can be realized through the second-year course "Computer Principles and Applications".

3. Algorithmic development: This is the operation soul of the hardware system designed according to the designer's ideas. In this paper, the closed-loop PI parameter control of grid connection can be solved according to the "automation control theory" of the third-year course. Among them, the engineering ability of the main function, sub-function framework and its programming language is realized by the third course "DSP Technology" and "C Language".

3.2 Experiments Verification and Application Extension

In order to verify the actual effect of extending the teaching system of wind power Grid-connected Control system, improve mechanism analysis, system design and algorithmic development, and meet the urgent needs of freshmen and sophomores' specialized knowledge and specialized extension, we tested the system of wind power Grid-connected Control system developed with an Eaton electric energy tester “Power Xpert”. The classroom experimental demonstration is shown in Fig.5.
Fig.6 is the field measured output voltage and current waveform of the generator. Fig.6 show that, it can be seen that there is a higher distortion rate of the output current.

Fig.7 shows that the distortion rate of fan output current reaches 23% (8% of the national standard). Fig.8 is the measured curve of generator stator current and its spectrum. Among them, $n=3$, $n=5$ and $n=7$ are the current amplitude obtained by applying Fourier series decomposition to the current. The experimental results deepen students' understanding of voltage, current and Fourier series.
4. Summary

Based on the ECE4980 course idea of Cornell University, this paper establishes a logic teaching system between general education and specialized courses, highlights the improvement of teaching ideas, teaching contents, teaching methods and other aspects. Based on HIT-Eaton Joint Laboratory, this paper puts forward the extension of teaching characteristics of HIT electrical engineering specialty. The curriculum system provides a solution for training talents with engineering characteristics.

Since July 2016, we have trained 20 students in different academic years in ECE4980 Extension Course by summer course. In the training process, we use the systematic teaching shown in Fig.1, Fig.2 and Fig. 4 to achieve ideal teaching results. Now 18 of these 20 students have been submitted to the Master's study stage (the project is progressing smoothly), which to some extent verifies the effectiveness of the proposed idea of extending the curriculum.

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