CONTROL ENGINEERING CURRICULA - A CASE ON THAILAND

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Abstract: Engineering curricula in Thailand must be complied with the requirement for programme accreditation. One requirement for electrical power engineering programme at an undergraduate level is to have its contents on feedback and control engineering. Courses on control both theoretical and experimental are compulsory. This paper gives details of undergraduate control engineering courses at Suranaree University of Technology (SUT), Thailand, as well as experience learned from the course delivery. In addition, it gives an overview on the postgraduate programme major in control at SUT.

Keywords: control engineering curricula, undergraduate, postgraduate.

1. INTRODUCTION

School of Electrical Engineering, Suranaree University of Technology (SUT), Thailand, is responsible for the provision of undergraduate and postgraduate programmes in electrical engineering. The undergraduate programme emphasizes electrical power engineering considered as one of the most important fields for the development of the country. In this regard, the Board of Engineering Profession imposes some requirements on course contents one of which is to have control engineering in the curriculum. This article describes undergraduate courses on control engineering at SUT. It gives details of course outlines and laboratory experiments as well as experience learned from delivery of the courses. In addition, the article gives an overview of the postgraduate programme that emphasizes control engineering and applications of artificial intelligent techniques to control.

2. CONTROL COURSES FOR UNDERGRADUATE PROGRAMME IN ELECTRICAL ENGINEERING

The undergraduate programme in electrical engineering at SUT is power engineering major. The programme composes of

- general education	23 %
- basic science	21 %
- engineering	52 %
- co-operative education	4 %.

The programme is accredited by the Board of Engineering Profession of Thailand (BEPT). It fulfills all requirements one of which is to have its content on control engineering. The undergraduate students have to undertake two compulsory courses on control, one theoretical, another practical. The theoretical course is to provide basic knowledge and awareness of feedback control concepts and technology. Graduates are expected to apply their knowledge on control to a limited area of operation and maintenance of power systems. The practical laboratory course is designed to complement the theoretical one such that some important issues that have been omitted can be covered. The details of both are described below.

2.1 Theoretical Control Course

This control course is to be undertaken by all undergraduate EE students. Normally, the course offer is twice a year. The requirement of the BEPT for this course is to cover major aspects in classical control methods. So, there is not enough room left for other interesting aspects such as state-space method, algebraic design approach, etc. to be included. It is rather unfortunate that this course coverage is rigidly limited. From the viewpoint of having graduates capable of working in operation and maintenance of power systems, the classical control techniques would form an adequate background for them.

Course description : 403321 Control Systems (4 credits)
Prerequisite : Electric Circuit Theory II
Basic principles of feedback and control, modelling of dynamical systems, performance specifications, time-

domain and frequency-domain approaches for analysis and design of control systems, stability.

The course is delivered 48 hours through a 12-week trimester with 4 hours of lecture per week. With the prerequisite subject, students have a solid background on engineering mathematics as well as have exposed to applications of Laplace transform, Fourier transform, and linear algebra for solving problems of dynamics of electrical circuits. The students have passed two courses in engineering mechanics. They have gained adequate knowledge on statics and dynamics that are useful for modelling part of the course. In order for the readers to grasp the overall picture of this course, the learning objectives with course outlines are given as follows.

Learning objectives : Students should be able to

(i) model electrical, mechanical, and electro-mechanical systems,

(ii) understand and prescribe performance and stability specifications,

(iii) analyze and design control systems using time- and frequency-domain approaches.

Course outlines:

- Control system concepts, open- and closed-loop control, tracking and regulating purposes ; modelling of electrical, mechanical, and electromechanical systems (4 hours).
- Transfer functions, block diagram and signal-flow models, state-variable models, obtaining transfer functions from state-variable models (4 hours).
- Test signals, first- and second-order systems, time-domain performance specifications, poles/zeros and their effects on performance; modelling based on transient test; effects of feedback (4 hours).
- Sensitivity, disturbance, system types and steady-state errors, tutorial works (4 hours).
- Stability of SISO systems, Routh-Hurwitz criterion, relative stability ; root-locus concepts (4 hours).
- Sketching of root-locus diagrams, gain selection (4 hours).
- Phase-lead and phase-lag compensations via root-locus technique, tutorial works (4 hours).
- Frequency-domain approach, sketching of Bode diagrams and Nichols chart (4 hours).
- Nyquist criterion, relative stability, closed-loop frequency domain performance, relations between frequency- and time-domain responses, gain design via Bode diagram (4 hours).
- Phase-lead and phase-lag compensations via Bode diagram (4 hours).
- Three-term controller design via Bode diagram, controller tuning, implementation (4 hours).
- Review and tutorial works (4 hours).

It can be noticed from the course outlines that only modelling of mechanical and electromechanical systems are covered in the first week of this course. Then, follow in the third week some introductory materials on modelling based on step-transient test. These should be appropriate to form principal idea on analytical and empirical modelling. The students also have some opportunity to perform tests for empirical modelling both in time- and frequency-domain during their laboratory sessions.

The well-known textbooks such as (Dorf and Bishop, 1998; Phillips and Harbor, 2000) have been adopted as prescribed texts. Additional materials on tuning methods for three-term controllers, and electronic implementation of controllers are provided for the students. A term-time design problem is assigned to all students such that they must be able to integrate their knowledge throughout the course and to perform system simulation. A problem on control of power generator extracted from (Saadat, 1999) has been used as the term-time assignment. The students are recommended to use MATLAB ™ for simulation. This is due to the availability of the software, its easy-to-use environment, several toolboxes available, educational price offered by the MathWorks Inc., and good academic supports found in various kinds of media. In this regard, the students have to explore MATLAB ™ and Control Toolbox by themselves. Since they have prior experience on C programming, self-study of MATLAB ™ should not be a hurdle for them. This assignment requires about 8-10 weeks for completion.

Teaching and evaluation. The most favorite teaching method in Thailand is still "chalk and talk" technique. This is supplemented by various kinds of media including free accessed Internet available throughout the campus. From the author's observation, it is hard to persuade the students to explore materials outside the prescribed textbook. One possible reason could be the students' belief of control not being a major responsibility of power engineers at works.

Evaluation has been conducted in two folds. One is the evaluation of students through assignments, quizzes, and examination questions. Quizzes and examinations are of problem-solving and design types of questions. A quiz normally lasts an hour, and 3 hours for an examination. The other is the evaluation of lecturers through questionnaire issued to all students by the end of each trimester. The evaluation results are summarized by the university and reported to the lecturer. SUT began its operation in 1993. This control course was firstly offered to the third year undergraduates in 1995. In the first few years of the university's operation, the results of lecturer evaluation by the students were not quantified. Unfortunately, the students' opinions reported to the lecturer were not in the form for clues to be drawn so easily. Hence, the data shown in table 1 starts in the year 1997 till the most recent year of 1999. It is the author's belief that students' attitude, lecturer's and students' performance, and class size or number of students in a class-room all contribute to the class GPA (maximum of 4.00).

Referring to table 1, the class GPA of one particular term is very low. This class was a regrade-class offered to some students who had obtained the D+, D, and F grades from their previous enrollment of the course. This group of students was not so academically strong. The results of lecturer evaluation (maximum of 4.00) conducted by students show noticeable figures in the trimesters 2/1997 and 3/1998. They are relatively lower than the others while the corresponding class sizes are

Table 1 Trimesters offered for control course and evaluation results

Trimester/ Year	Class GPA	Lecturer Evaluation	Class Size
2/1997	2.00	3.44	166
3/1997	1.89	3.66	54
3/1998	2.12	3.33	190
2/1999	2.32	3.78	33
3/1999	3.14	3.75	78

relatively larger. The simple reason to explain this is that the lecturer is unable to pay adequate attention to all students. Although the lecturer evaluation results show some improvement in the other trimesters having smaller class-sizes, a class-size of 15 to 20 students would be ideal for a lecturer to pay good attention to all students.

2.2 Control Laboratory Course

Since the students have not had much experience in computing and simulation, this laboratory course thus aims to enhance their skills in modelling, simulation, and design. This course also offers students opportunities to explore some new materials in control by themselves. Examples of these new materials that cannot be covered in the theoretical course are measurement with sensors, systems with nonlinear element, and empirical modelling. Students' prior experience with the term-time assignment while undertaking the theoretical course is particularly useful for some laboratory sessions on simulation and design. Mainly, the course is offered twice a year. Two students work as a group during their laboratory sessions. Two to three instructors look after about ten to eighteen students in each section during 3 hours of classes. The details of course description, experiments and objectives are as follows.

Course description : 403421 Measurement and Control Laboratory (1 credit)

Prerequisite : Control Systems , Electrical Measurement and Instrumentation

Laboratory experiments on measurement with sensors, feedback and control techniques, modelling, simulation, and design.

The following laboratory orientation and experiments are offered:

- Orientation , tour of laboratory facilities (1 hours).
- Orientation for MATLAB ™, Control Toolbox and Simulink ; students will be exposed to some elementary to intermediate levels of problems to enhance their skills of using the packages (2 hours).

Practical Unit 1: Displacement transducers (3 hours).

Learning objectives: students will be able to understand the principle of a resistive displacement sensor, identify its linear model, and assess its static specifications.

This first unit contains only one simple experiment on using a resistive displacement sensor. It gives the students an opportunity to get familiar with the experimental module. The instrumentation module TK2941 of Feedback™ has been used. Students can learn about signal conditioning circuits and the sensor module. The main experiment is static calibration of the sensor. In this, the students obtain hands-on experience in calibration procedures. They have to identify the sensor's model using linear regression analysis, analyze and discuss about the important issues of the sensor characteristics, e.g. repeatability, sensitivity, accuracy, etc.

Practical Unit 2: Temperature transducers (3 hours).

Learning objectives: Students should be able to understand the principle of a resistive temperature sensor, and learn how to do signal-conditioning for the sensor.

This unit contains three experiments on measuring temperature using a platinum temperature sensor. The first experiment is concerned with estimation of a dissipation constant, and self-heating error in the sensor. The results would lead to an appropriate excitation for a Wheatstone bridge used in the second experiment. Then, using an inverting amplifier to condition the measuring signal follows in the third experiment. From the second and the third experiments, the students can compare the performance obtained from two different signal conditioners. This unit uses the TK2941 with a heat bar of Feedback™.

Practical Unit 3: Open-loop and closed-loop control (3 hours).

Learning objectives: Students should be able to perform the step transient test to model a dc servo motor, and perform open-loop and closed-loop control of the servo motor.

Empirical modelling is an important issue in control. With this practical unit, the students perform a step-transient test to fit a first-order model for a dc servo motor. At the same time, they can learn about the limitation of using an open-loop control. With another experiment, the students can learn about tracking control via closed-loop control of a dc servo motor. The hps™ servo board has been used.

Practical Unit 4: Time- and frequency-domain responses, effects of disturbance (5 hours).

Learning objectives: Students should be able to understand the principle of thermal process and transport lag characteristic through experiments on a heat exchanger experimental equipment, perform the frequency response test, and characterize the effects of disturbance on process responses.

With the theoretical course, there is very limited time to consider modelling issues. Some important characteristics of "slow" process, such as transport lag, are introduced in this practical unit. With the first experiment, the students should be able to fit a first-order with delay model via a step-transient test for a heat exchanger. The effects of disturbance are practically studied in the second experiment. The students perform a frequency-response test to obtain Bode and Nyquist plots in the third experiment. Comparison between the obtained models from different techniques is encouraged. These three experiments are conducted on the Process Trainer PT326 Mk2 of Feedback™.

- Practical Unit 5: Dynamical systems simulation (5 hours).

Learning objectives: Students should be able to model a thermal process, and a system with nonlinear characteristic, and to use MATLAB ™ to simulate the systems successfully.

Since the theoretical control course covers only electrical, mechanical, and electromechanical systems in modelling part, this fifth unit offers the students an opportunity to model a thermal process analytically, and to analyze some systems with nonlinearity present. A classic problem of a stirred tank containing fluid and a heating coil has been used for modelling a thermal process. Another classic problem of a mechanical scale with nonlinear retarding force has also been used. After modelling successfully, simulation must be performed using MATLAB™ and Simulink to analyze the system responses. In addition, the students have to simulate a system described by block diagram containing a saturation characteristic. This is to investigate the effects of loop gain and nonlinear characteristic on the system response.

- Practical Unit 6: Computer aided control system design (5 hours).

Learning objectives: Students should be able to design compensators and PID controllers using root-locus technique, Bode diagram approach, and tuning rules, and to use MATLAB ™ and Control toolbox to facilitate their design and simulation.

During the theoretical sessions, design works are conducted by hand calculations except the term-time assignment. The design techniques discussed in the class are trial-and-error. With this experimental unit, the design approach is opened for the students to choose either empirical tuning rules, trial-and-error design procedures, or analytical design formulae. Presentation on design details and simulation results for the given systems are required.

The last two units are very similar in nature. Demonstration on the operational principles of pneumatic and hydraulic elements are presented. With the available training sets, the students are able to work in a group of two. By the end of the demonstration session, roughly taking 2 hours, the students are expected to design some simple pneumatic and hydraulic circuits, and demonstrate their works.

- Practical Unit 7: Demonstration on pneumatic elements and circuits (3 hours).

Learning objectives: Students should be able to understand the principle of pneumatic devices and circuits, and to design and test some simple pneumatic circuits.

- Practical Unit 8: Demonstration on hydraulic elements and circuits (3 hours).

Learning objectives: Students should be able to understand the principle of hydraulic devices and circuits, and to design and test some simple hydraulic circuits.

Evaluation. Evaluation of students are mainly based on participation, technical reports, and partly on an examination by the end of the term with the weighting 40:40:20 of 100. Evaluation of laboratory instructors is conducted using questionnaire designed differently from that for the theoretical course. Table 2 shows some historical records resemblance to table 1 but for practical course. This course was offered once to some postgraduate students in the trimester 1/1999. The data reflects that they seem to enjoy the course more than the undergraduate students do. From the open-end part of questionnaire, some opinions expressed by the students are listed below:

Table 2 Trimesters offered for laboratory course and evaluation results

Trimester/ Year	Class GPA	Lecturer Evaluation	Class Size
1/1997	2.79	3.25	30
2/1998	2.32	3.37	30
1/1999	3.42	3.71	6*
2/1999	3.17	3.44	16
3/1999	2.39	3.24	16

*remarks : this class was offered to postgraduate students

- this is the most informative and complicated laboratory course,
- they appreciate the opportunities for acquiring new materials, and building-up their simulation and design skills,
- some lab-instructors cannot provide clear information about the experiments, and cannot assist them adequately to interpret the experimental results.

For practical course having complex experiments such as these, it is necessary to have lab-instructors and technicians well-trained about all materials and technical issues concerning with the experiments.

Apart from these compulsory courses, the EE programme also offers courses relevant to control as electives. These are Industrial Control Instrumentation, Digital Control Systems, and Electric Drive. Details of these courses are omitted herein since they do not form the core of the undergraduate programme in electrical engineering at SUT.

3. POSTGRADUATE PROGRAMME IN CONTROL

This graduate programme aims to produce graduates with breath and depth of knowledge in systems and control, and are capable of conducting research and development for national needs as well as technological advancement. The programme offered emphasizes research and theses in both master and doctoral levels. There are research option and instructional courses coupled with thesis alternative for students to pursue. The research option requires applicants with strong scientific and engineering background to ensure that the students are capable of conducting research independently. Generally, candidates with honoured first degrees in electrical engineering are admitted to the research option. This scheme requires no formal course undertaken but the students may have to attend some course lectures upon the recommendation of their supervisors. For the instructional course with thesis option, master degree programme requires students to undertake the following core courses:

- Advanced Linear Algebra
- Numerical Computation
- Linear System Theory, and
- System Modelling.

To complete the requirement of the master degree programme, the students have to undertake 4 electives and thesis. Doctoral degree programme requires 2 core courses that are:

- Optimization Techniques, and
- Nonlinear System Theory.

The students have to undertake 3 electives and thesis in order to complete the requirement for doctoral degree programme. To support the control science and engineering research the following courses are available as electives:

- System Identification
- Dynamic System Simulation
- Discrete Control Systems
- Digital Signal Processing
- Applied Mathematics
- Mechatronics
- Optimal Control Systems
- Adaptive Control Systems
- Robust Control Systems
- Stability Theory
- Stochastic Processes
- Recent Topics in System Science.

The following electives support the use of AI techniques for control applications:

- Artificial Intelligence for Engineers
- Neural Computing
- Machine Learning
- Fuzzy Logic and Applications.

An applicant to postgraduate programme must hold a first degree in electrical engineering or relevant fields with minimum accumulated GPA of 2.5. Those who apply for research degrees must hold second-class honours at least. To complete a master programme requires a candidate to pass thesis examination, achieve minimum accumulated GPA of 3.0, and publish the work nationally. To complete a PhD programme requires a candidate to pass TOEFL or IELTS with scores of 550 or 6.0, respectively, additionally to passing thesis examination, achieving minimum accumulated GPA of 3.0, and having the doctoral thesis work published internationally.

4. CONCLUSION

This paper presents details of control systems course at Suranaree University of Technology (SUT), Thailand. Theoretical and practical courses are compulsory for undergraduate students in electrical engineering. Outlines of the courses are detailed. Experience learned from the course delivery is discussed. The paper also gives an overview on the postgraduate programme in electrical engineering major in control at SUT. The programme emphasizes research and thesis with either research option or instructional courses with thesis option.

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