Case Study Based Teaching – Learning

Control Systems: Design and Analysis

Dr. K.P.Lakshmi
Department of ECE
BMS College of Engg.
Bangalore, India
kpl.ece@bmsce.ac.in

***Abstract*— There has been a paradigm shift in various areas of engineering education such as teaching-learning process, teaching methodologies, evaluation methods, etc. This paper attempts to propose a new scheme of teaching, 'Case study based teaching' with a particular example of the subject titled *'Control Systems'* which is a second year course for branches that come under electrical cluster. This paper discusses about a change in the method of teaching or in the orientation of syllabus with no changes in the contents of the syllabus. The method of discussing the course 'Control Systems' in a 'top-down approach' is outlined. This approach helps in better understanding of the concepts and serves as a motivation for students to take up project work in this area. This top-down approach: application oriented learning and discussions could be followed in other subjects as well for a better motivation in learning and applying concepts.**

The need or scope of change in the syllabus is not of importance for this paper. In this paper, the term 'program' refers to the branch of engineering and 'course' refers to an individual subject of the branch.

***Index Terms*—case study based learning, Control Systems, Design and stability**

I. Introduction

The study of control system engineering is essential for students pursuing degrees in electrical, mechanical, aerospace or chemical engineering. Control systems are found in a board range of applications within these disciplines from aircraft and spacecraft to robots and process control systems. Control engineering has an essential role in a wide range of control systems ranging from household machines to complex aviation machineries like high performance fighter aircrafts. A control systems engineer is required to work in a broad arena and interact with people from numerous branches of engineering and the sciences unlike engineers who work in circuit design or software development [1,2].

Engineering curricula tend to emphasize *bottom-up* design. That is, start from the components, develop circuits, and then assemble a product. In *top-down* design, a high-level picture of the requirements is first formulated. Then the functions and hardware required to implement the system are determined. In many universities, a major reason for not teaching top-down design throughout the curriculum is the high level of mathematics initially required for the systems approach. However, while progressing through bottom-up design courses, it is difficult to see how such design fits logically into the large picture of the product development cycle.

For courses like control system, which involves design and analysis, a student will appreciate the subject if case studies are discussed first and then the underlying techniques are elaborated. Stating the relevance of the subject at the beginning makes it more interesting.

II. Current Scheme of Teaching:

In our program (ECE), four course outcomes are listed as:

- Knowledge of control systems:Modeling, Transfer function
- Understanding the time-domain response of second order systems and evaluate steady state response
- Frequency-domain analysis of systems through graphical method
- Stability analysis of linear time-invariant systems

Currently the syllabus is divided into five units as:

Unit-1 Introduction:
Mathematical Modeling of Linear Systems: Transfer functions, Mechanical Systems, Analogous Systems, Block diagram, Signal Flow graph
Unit-2 Time Response Analysis Of Control Systems:
Step response and steady state error and error constant analysis
Unit-3 Stability Analysis:
Applications of RH criterion, Nyquist plot, Polar plots
Unit-4 Root Locus Technique:
Analysis of stability by root locus plot
Unit-5 Frequency Response Analysis:
Bode plots, Relative stability

Each unit of the syllabus is about the different aspects of control systems. In the current scheme of teaching the different concepts involved in the study of control systems is taught in such a way that each concept is viewed as a separate entity and the students find it difficult to realize that all the concepts are interlinked with each other. The students should be made aware that by changing any of the parameter of the system, the entire system specifications, starting from transfer function, pole-zero plot, time response, frequency response and stability are altered. Progressive Analysis and Design is missing in the present method of teaching.

As of now, it is up to the course instructor to elaborate on the importance of the concepts. People teaching the course for the first time might fail to impart the importance of this aspect with sufficient examples.

Also, in the current method of teaching focus is on problem solving and very little or NO importance on the origin of the problem and applicability of the problem solving techniques. With this, the course is just about learning problem solving techniques in control system, with no relevance to the '*Control Systems'* as such.

III. PROPOSED NEW SCHEME: CASE STUDY BASED TEACHING – LEARNING

The students should be driven towards learning and applying the design concepts of control theory to design systems with desired behaviors. It should be oriented in a way to understand physical systems, use mathematical modeling, in terms of inputs, outputs and various components with different behaviors and analyze the stability of the system.

At the completion of the course, the Students of our program (ECE), should be able to analyze, interpret, modify, design and produce electrical and electronics systems. Therefore, the desired outcome of the course should be to design, build, test and troubleshoot electronic circuits, equipment, systems and subsystems in accordance with job requirements, functional specifications and relevant standards.

To achieve this, the same course contents can be discussed in a top-down approach. In the first few introductory classes, introduce the various terms and concepts involved in the course through a few case studies: for example, electronic pace maker, auto pilot system (any specific operation mode), any robotic system, etc.

The relevance of the first unit of syllabus can be discussed with respect to any example system for example, say pace maker system as identifying the different parts of the pace maker and circuitry involved in interfacing it with human body. The classification of control systems and different terminologies involved with control systems like open loop system, closed loop system, forward path, feedback path, linear and non-linear systems, etc can be highlighted with this example. This can be followed by more examples/illustrations of control systems.

The second unit discusses block diagram and signal flow graph representation of control systems. The various aspects of these representation models like summing point, take off point, forward path gain, feedback path gain, loop, etc., can be introduced to the students with the example system first and then extended to any other system as a general approach.

The same methodology of introducing concepts (each unit) through a specific example first and then the elaborating on the different techniques involved in analyzing systems can be adopted. If the same case study is considered for discussing all design concepts, it is even better.

IV. A CASE STUDY OF 'CONTROL SYSTEMS' DEPICTING ALL THE CONCEPTS OF CONTROL SYSTEM DESIGN AND ANALYSIS TECHNIQUES

I would like to cite the example of antenna azimuth-position control system [1]. A position control system converts a position input command to a position output response. Position control systems find widespread applications in antennas, robot arms, and computer disk drives. The radio telescope antenna is as shown in Figure 1. The purpose of this system is to have the azimuth angle output of the antenna, ¸ *$_0(t)$,* follow the input angle of the potentiometer, ¸ *$_i(t)$*. Figure 2 is the schematic representation of the same and figure 3, 4 is the block diagram representation and signal flow graph representation of antenna azimuth-position control system. The input command is an angular displacement. The potentiometer converts the angular displacement into a voltage.

Step 1: Identify the different parts of the system, write the functional diagram and find the transfer function of each subsystem. Together this constitutes the first unit of the syllabus.

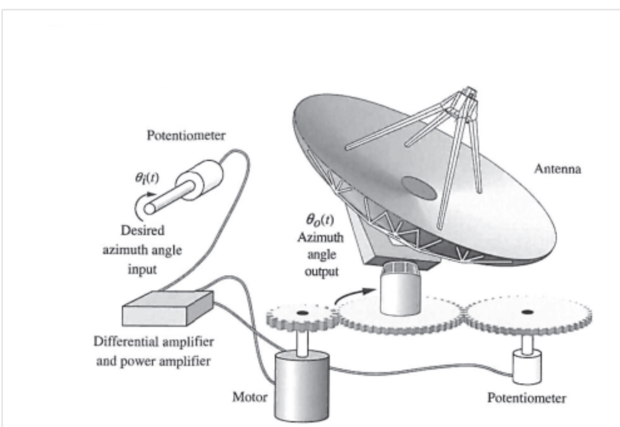

Figure 1: Layout of antenna azimuth- position control system

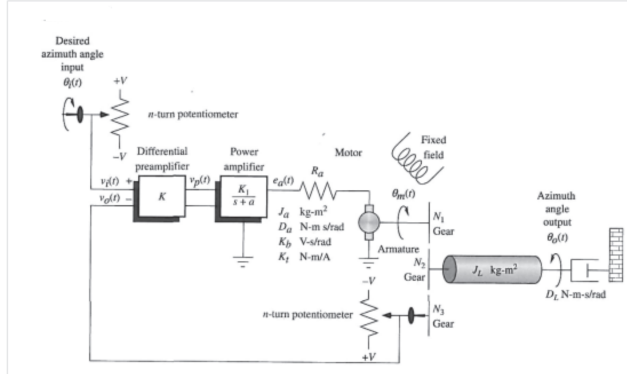

Figure 2: Schematic of antenna azimuth- position control system

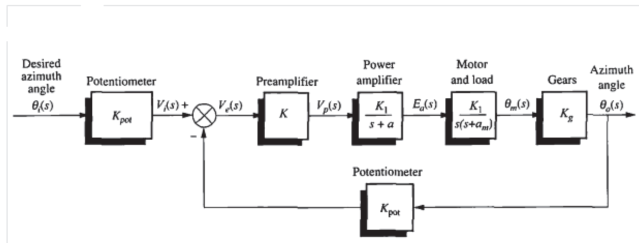

Figure 3: Block Diagram of antenna azimuth-position control system

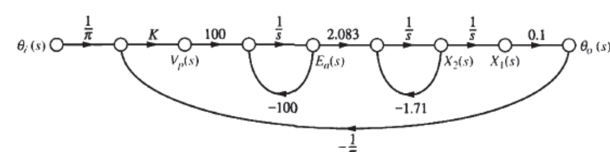

Figure 4: Signal Flow Graph of antenna azimuth-position control system

The transfer function of the system is evaluated using Mason's gain formula as

$$T(s) = \frac{C(s)}{R(s)} = \frac{T_1\Delta_1}{\Delta} = \frac{6.63K}{s^3 + 101.71s^2 + 171s + 6.63K}$$

Step 2: As a part of unit 2 of the syllabus, time response analysis is to be discussed. Time response of antenna azimuth- position control system is as shown in figure 5.

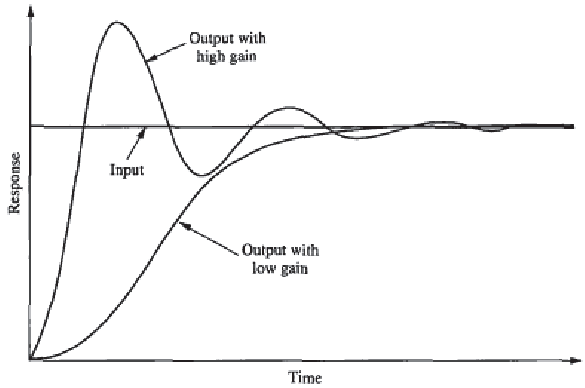

Figure 5: Time Response of antenna azimuth-position control system showing the effect of high and low controller gain on the output response

The system normally operates to drive the error to zero. When the input and output match, the error will be zero, and the motor will not turn. Thus, the motor is driven only when the output and the input do not match. The motor will still stop when the actuating signal reaches zero, that is, when the output matches the input. The difference in the response, however, will be in the transients. A possibility for a transient response to consist of *damped oscillations* about the steady-state value if the motor gain is high can be outlined. This illustrates the effect of change of subsystem parameter (here motor gain) on the time response.

Step 3: Finding the stability of the system using various methods

The Routh's table of the system is

s^3	1	171
s^2	101.71	$6.63K$
s^1	$17392.41-6.63K$	0
s^0	$6.63K$	

Table 1: Routh's array of antenna azimuth- position control

The stability analysis is then performed as the value of pre-amplifier gain, k=2623 makes the system marginally stable and the system is stable for all values of k in the range 0<k<2623.

It can be shown that the steady state errors of the system due to step input is 0,due to ramp input is 29.54/k and due to parabolic input is infinite. Further the students can be asked to design the gain such that the steady state error is within some specified limit.

Step 4: Frequency response analysis

The bode plots of the system for the pre-amplifier gain set to 1 is as shown below:

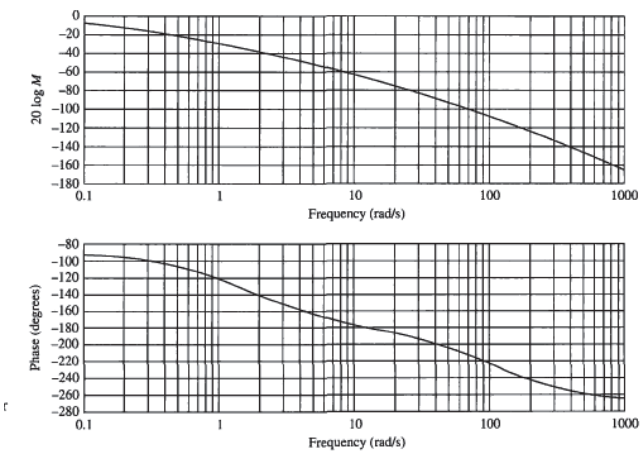

Figure 6: Bode magnitude and phase plot of antenna azimuth- position control system

Using the various plots shown above (figure 5, 6) changes in the system response for required specifications such as settling time, peak over shoot, steady state error range, etc can be demonstrated. Additionally, analysis tools like Labview and MATLAB can be used to effectively demonstrate the effects of change in system parameters on the system response and stability.

This method of discussing the course with case studies would help the students know where the concepts are applicable. Otherwise, this course will remain as a course to learn problem solving techniques with no idea of the origin of the problem and the applicability of the problem solving techniques.

V. Conclusion

I would like to conclude by saying that the effectiveness of certain courses like '*Control Systems'* can be increased by adopting *top-down* approach. Case studies in every domain are in plenty and using them to teach the analysis and design concepts is an effective way of orienting the students towards creative learning. In my knowledge, there are no students who want to take up any studies or project work related to control systems which I think can be attributed to the way in which the course is organized (*bottom-up* approach). I would also suggest usage of tools like MATLAB to demonstrate various concepts involved.

ACKNOWLEDGMENT

I would like to express my gratitude to Mr. Norman S. Nice, the author of the book on control systems. I have extensively used the examples of this book to express my ideas in this paper.

REFERENCES

[1] Norman S Nice control-system-engineering-6th-edition John Wiley & Sons, Inc

[2] Control Systems Engineering - A Practical Approach by Frank Owen, PhD, P.E., Mechanical Engineering Department California Polytechnic State University, San Luis Obispo, California