Approved in 39th BoA Meeting (25-03-2021)

Course Number : ME 310
Course Name : System Dynamics and Controls
Credits : 3-0-0-3
Prerequisites : Engineering Mathematics (IC110) and Linear Algebra (IC111)
Intended for : UG
Distribution : Discipline Core for ME
Elective or Core : Core

Preamble: The objective of this course is to introduce students with fundamental concepts of modeling, analysis, and design of linear control systems for physical systems. Students will be taught applying modelling techniques to real physical systems and analyzing its performance and stability before building real systems. Performance and stability analysis will be done in time and frequency domain which will allow student to build linear controllers by applying classical and modern control techniques. Matlab/Simulink will be used to create models and design of controllers.

Course Outline: Modeling of mechanical, electrical, and electromechanical systems. Laplace Transform techniques. Time response analysis. Block diagram representation. Feedback systems. Root locus method. Frequency response techniques. State-space representation. Controller design.

Course Modules: In this course the student will develop and/or refine the following areas of knowledge:

- **Introduction [2 hrs]**: Control system examples, historical developments leading to modern day control theory, the basic features and configurations of control systems, control systems analysis and design objectives, control system's design process
- **Modeling in Frequency Domain [3 hrs]**: Mathematical descriptions of systems by differential equations, Laplace transform linear, time-invariant systems (mechanical, electrical, and electromechanical), linearization of a nonlinear system to find the transfer function.
- **Modeling in Time Domain [3 hrs]**: State-space representation a LTI system, conversion of a transfer function to state space and vice-versa, linearization a state-space representation.
- **Time Response [3 hrs]**: Effect of poles and zeros on the time response of a control system, quantitative description of the transient response of first-order systems, general response, damping ratio, settling time, peak time, percent overshoot, and rise time and natural frequency of second-order systems, time response from the state-space representation.
- **Reduction of Multiple Subsystems [2 hrs]**: Reduction of a block diagram of multiple subsystems to a single block, analysis and design of transient response for a system consisting of multiple subsystems, conversion of block diagrams to signal-flow diagrams, Mason's rule.
- **Stability [3 hrs]**: Making and interpreting Routh table to determine the stability of a system, Application of Routh table to determine the stability of a system represented in state space.
- **Steady-State Errors [2 hrs]**: Steady-state error for a unity feedback system, steady-state error performance, design the gain of a closed-loop system to meet a steady-state error

specification, finding the steady-state error for disturbance inputs, steady-state error for systems represented in state space.

- **Root Locus Techniques [4 hrs]**: Properties of a root locus, sketching techniques of a root locus, root locus for systems of order 2 and higher, root locus for positive-feedback systems.
- **Design via Root Locus [4 hrs]**: Use the root locus to design cascade compensators to improve the steady-state error and the transient response, feedback compensators to improve the transient response, realize the designed compensators physically.
- **Frequency Response Techniques [4 hrs]:** Plot of frequency response of a system, Nyquist stability criteria, gain and phase margins, closed-loop frequency response.
- **Design via Frequency Response [5 hrs]:** Use frequency response techniques to adjust the gain to meet a transient response specification, frequency response techniques to design cascade compensators to improve both the steady-state error and the transient response.
- **Design via State Space [5 hrs]:** State-feedback controller using pole placement, controllability, transient response specifications, observability.

Text Books:

- System Dynamics, 4th Edition by Katsuhiko Ogata, Pearson Education, 2013
- *Control Systems Engineering*, 7th Ed. by N. S. Nise, Wiley, 2015
- Control Systems: Principle & Design, 4^{th} Ed. by M. Gopal, McGraw Hill, 2012

Suggested Books:

- Feedback Control Systems, Franklin, Powell
- The Mechatronics Handbook, Robert H. Bishop
- Modeling, Simulation, and Control of Mechatronic Systems, Dean C. Karnopp, Donald L. Margolis and Ronald C. Rosenberg, John Wiley & Sons, Inc.
- Control and Mechatronics, Bogdan M. Wilamowski and J. David Irwin, CRC Press
- Mechatronics Electronic control systems in mechanical and Electrical Engineering, William Bolton, sixth edition, Pearson
- Modern Control Systems, Richard C. Dorf and Robert H. Bishop, Pearson

Note: EE301 cannot be credited if ME310 has already been credited, due to the significant overlap.

Similarity content with existing courses:

S. No.	Course code	Similarity content	Approx. % of content
1	EE 301	Time-domain analysis, Frequency-domain analysis, Stability analysis, Root-locus technique, State-space Analysis	30%-40%

Justification for new course proposal if cumulative similarity content is > 30%:

In most of the universities around the world including IITs "System Dynamics and Control", with alternative names such as "Mechatronics and Control" or "Introduction to Control Systems", is a core course for the students of mechanical engineering. Mechanical engineering students must be familiar with techniques of control systems especially applied in the control of mechanical systems, electromechanical systems, and basic electrical systems for acquiring real proficiency in managing these systems used in industries. Aerospace engineering and chemical engineering also teach similar control courses specific to their field to their students. Therefore, my proposal is that students of mechanical engineering should also learn this important course oriented to their engineering stream. Many students from mechanical engineering stream, who have not taken any course in control systems hesitate to take-up interest in robotics and related fields. Therefore, this course will not only introduce mechanical engineering students with basic control engineering but also prepare them to take-up further interest and required skill development in automation, mechatronics, robotics, and intelligent systems. Skill of the student with professional outcomes because of this course are listed as follows:

Student Outcomes:

An ability to apply knowledge of mathematics, science, and engineering.

An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.

An ability to identify, formulate, and solve engineering problems

An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Professional Outcomes: The most measurable long-term outcome from this course is the student's resulting ability to identify, formulate and organize engineering problems in a conceptual form as well as in terms of mathematical and physical models. Understanding control systems enables students from all branches of engineering to speak a common language and develop an appreciation and working knowledge of the other branches.