Control Theory

AE 308 & AE 775 (Slot No. 2)

Monday – 0930, Tuesday – 1035, Thursday – 1135

Venue: LC 102

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Motivation for the Course

Control systems are integral parts of many **engineering applications,** including multi-disciplinary areas.

Even **consumer products** & home appliances are being made '**smart**', by incorporating some '**control**'.

Designers of such systems need to understand the **implications of the presence of a control system** on the overall system behaviour.

These aspects assume **even greater importance** if the **control** systems are used for **enhancing the system performance** e.g. stability, response etc.

In aerospace, **control** systems are important and **critical** elements of all **flight vehicles**.

Objectives of the Course

To provide a good understanding of basic concepts in **control theory**, along with the various control **structures** & control **elements**.

To expose various **tools** & **methodologies** that are available for analyzing the **impact of control systems** on the system **response**.

To familiarize with a few **basic techniques** for **designing** control systems.

Course Contents – Basics

Introduction: Control situations & objectives, broad control tasks, open-loop & closed-loop control concept, various types of control structures, unity negative feedback control systems, basic control actions.

Two-position Control Systems: On-off control concept and action of an ideal relay, 1st and 2nd order system on-off control, effect of hysteresis on the closed-loop control performance, relay modelling.

System response: Response of higher order systems to standard and generic inputs in Laplace and time domains, concept of partial fractions.

Course Contents – Analysis Tools

System Stability: Concept of stability and connection with its response, asymptotic / bounded-input bounded-output stability, role of characteristic roots in stability, Routh's criterion for absolute and relative stability analysis, including unknown parameter based stability.

Proportional Control Systems: Proportional control action modelling, stability and response of proportional control systems, concept of root locus and its application to proportional control system analysis.

Frequency Response: Concept of frequency domain & response, representation using bode, Nyquist, Nichol's plots, closed-loop system analysis using frequency response attributes, Nyquist stability analysis.

Course Contents – Design Strategies

Closed-loop Response Attributes: Transient/steady-state response, tracking control task and closed-loop error constants, integral control option for tracking, transient response and role of derivative action.

Closed-loop Control Elements: PI controllers and lag compensators for tracking tasks, PD controllers / lead compensators for transient response control tasks, PID controllers / lag-lead compensators for complex tasks.

Design of Closed-loop Control Systems: Closed-loop specifications, gain / phase margins concept, use of root locus, bode plots, Nyquist plots and Nichol's plots in closed-loop control design, design rules, methodologies and guidelines for different types of control tasks.

Pre – requisites

AE 230: Modelling & Simulation Laboratory

<u>In particular</u>, exposure to these aspects is assumed.

Knowledge of 1st and 2nd order system response in time domain, concept of Laplace transform and transfer function.

Conversant with concepts of time constant, DC gain, peak overshoot & settling time as response features.

Familiarity with MATLAB & SIMULINK as tools for solving dynamic system models.

Texts / References

1. **D`Azzo** , J. J. and Houpis , C. H., 'Linear Control Systems Analysis and Design - Conventional and Modern', 4th Ed., McGraw-Hill, 1995.
2. **Nise,** N.S., 'Control Systems Engineering', 3rd Ed., John Wiley & Sons, 2001.
3. **Kuo,** B. C. and Golnaraghi, F., 'Automatic Control Systems', 8th Ed., John Wiley & Sons, 2003.
4. **Franklin**, G.F., David Powell, J. & Emami-Naeini, A., 'Feedback Control of Dynamic Systems', 5th Ed., Pearson Prentice Hall, LPE, 2006.
5. **Gopal,** M., 'Control Systems – Principles and Design', 3rd Ed., Tata McGraw-Hill, 2008.
6. **Ogata,** K., 'Modern Control Engineering', 5th Ed., Prentice Hall India, Eastern Economy Edition, 2010.

Overall Delivery Framework

Lectures to establish concepts & methodologies for imparting basic understanding of the subject

Interactive problem solving session for better conceptual understanding.

On-line Tutorial Sheets for practice, containing solutions, to foster enhanced learning.

Discussion Forums to explore both breadth and depth of various topics.

Note: Students are encouraged to **bring their laptops with MATLAB ,** to class for better participation.

Evaluation Scheme

2 Quizzes - 20% weight. (Announced)

2 Assignments - 20% weight. (Submission & presentation)

Mid-sem - 25% weight. (Both concepts & problems)

Class Participation - 10% (Attendance + Moodle activity)

End-sem - 25% weight. (Both concepts & problems)

Note: Attendance to be marked during first 10 minutes of the class. Late arrival may not be compensated. Students must maintain 60% attendance at all times to avoid DX.