System Modelling and Classical Control

Introduction

All physical systems exhibit dynamic characteristics, which have impact on their overall behaviour in the presence of varied time dependent inputs. Therefore, during the design process, efforts are made to ensure that a desirable dynamic response is exhibited by the system for different inputs. However, as the design is generally done for a specific set of conditions, we need to ensure desirable response during actual operation through control.

Motivation for the Present Course

Control discipline is the enabler which provides tools to achieve the desired behaviour from a system during its operation. However, for this purpose, firstly, it is necessary to capture relevant features of the system and study these in a simulated environment. Secondly, we need a methodology to ensure that the deficiency, if any, is compensated. Among the different control philosophies that exist, classical control discipline is the oldest and the most intuitive of the control techniques and is also applied extensively in many engineering applications even today. Therefore, the present course aims to provide an overall understanding of the modelling methodologies and classical control practices that are commonly employed in control domain and is beneficial to all those desirous of applying these to practical engineering systems.

Evolution of Control Discipline

Control is an integral part of most engineering systems and has matured over the last 100 years. In its early days, control was used in various industrial processes e.g. petroleum, steam power etc., and, thus, was called process control. During this period, most control solutions were based on intuitive understanding / experimental verification. Control in mechanical systems began in 1950s which saw development of theory of servo-mechanism. However, control concepts have existed long before these.

History of Control Concepts

Hero's device for opening door of temples in Greece (1st Century AD), by lighting of fire on altar, was perhaps the first use of control concept for automatic operation. Ivan Polzonov, an engineer in coal mines in Siberia, ~1770, used control concept to provide steam at constant pressure through control of water level in supply tank. Also, in 18th century, James Watt & Willard Gibbs evolved the speed governor for controlling steam engine RPM. It is to be noted that classical control concepts are a natural consequence of these and many similar developments in the field of control.

Objectives of the Course

To provide exposure to the process for creating good models of engineering systems.
To familiarize with methods to arrive at the dynamical behaviour using such models.
To describe control concepts, along with various structures & elements.
To describe various basic linear control design procedures.
To provide an exposure to optimal, robust and non-linear control techniques.

Course Contents (A Total of Seven Modules)

Module-1: System Modelling - Modelling concepts & model types, mathematical models, their linearization and role of LTI forms. I/O form, block diagram representation / manipulation, test signals, Laplace transform and transfer function concepts. (**6 Hours**).

Module-2: System Response & Stability - Basic response analyses, frequency response & its representation using bode', Nyquist and Nichols plots. Stability & response connection, asymptotic/ BIBO stability, Routh's & Nyquist stability analyses. (**6 Hours**).

Module-3: Basic Control Concepts - Control objectives, open/ closed loop control structures, unity negative feedback systems, basic control actions, transient & steady-state responses, tracking/transient specifications. (**6 Hours**).

Module-4: Standard Control Elements - P control action and root locus, PD, PI, and PID control actions. Specifications in Time / frequency domains, design rules & methodologies for P, PI, PD and PID control systems. Concepts of lead, lag and lag-lead compensators and their design strategies. (**8 Hours**).

Module-5: Advanced Control Elements - Feedback path control, pole-zero cancellation strategy, sensors and filters in feedback path. PI-D and I-PD forms, two-loop and 2-DOF PID controllers, feed-forward control, multi-loop structures, zero placement design technique, rate and acceleration feedback based minor loop structures. (**8 Hours**).

Module-6: Optimal and Robust Controllers - Parameter based optimal control design, error based optimal controllers, closed loop robustness/sensitivity analysis, uncertainty models. (**6 Hours**).

Module-7: Control of Non-linear Systems - Types of non-linear behaviour, gain scheduled controllers, describing function approach. (**4 Hours**).

Course Pre – requisites

While, there are no formal prerequisites, familiarity with Ordinary Differential Equations and solution procedures, including numerical techniques, and relevant software tools for solving dynamical systems would be useful.

Texts / References

Nise, 'Control Systems Engineering', 3rd Ed., John Wiley & Sons, 2001.
Gopal, 'Control Systems – Principles and Design', 3rd Ed., Tata McGraw-Hill, 2008.
Ogata, 'Modern Control Engineering', 5th Ed., PHI, EEE, 2010.
Dorf & Bishop, 'Modern Control Systems', 12th Ed., Prentice Hall, 2011.
Houpis & Sheldon 'Linear Control System Analysis and Design', 6th Ed, CRC Press, 2014.

Mode of Conduct and Delivery

The course is planned to be conducted fully in the on-line format, with two hours per week engagement. Further, it will be run in a module-wise sequence.