System Modelling & Classical Control

Introduction

All physical systems exhibit dynamic characteristics, which have impact on their overall behaviour in the presence of time dependent inputs. Therefore, during the design process, efforts are made to achieve a desirable dynamic response under varied conditions. However, as it is not possible to achieve desirable behaviour for all conditions through design, we need to ensure this during actual operation.

Need for Modelling & Control

Control discipline is the enabler which provides tools to achieve the desired behaviour during 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. Present course aims to address modelling, & control of systems.

Evolution of Control Discipline

Control is an integral part of most engineering systems and has matured over the last 100 years. In 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 servomechanism. However, control concepts have existed long before these.

History of Control Concepts

Hero's device[#] for opening door of temples in Greece, 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, used control concept to provide steam at constant pressure[#] through control of water level in supply tank. Subsequently, James Watt & Willard Gibbs evolved the speed governor[#] for controlling steam engine RPM. ([#]Examples Courtesy "D'azzo & Houpis, Linear Control System Analysis & Design".)

Objectives of the Course

To provide exposure to process for creating good models of engineering systems.
To familiarize with methods to arrive at the dynamical behaviour using such models.
To provide a good understanding of basic concepts, along with various structures & elements.
To describe the various control design procedures.

Course Contents

Objective, 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, basic response analyses, frequency response & its representation using bode', Nyquist plots. Stability & response connection, asymptotic/ BIBO stability, Routh's & Nyquist stability analyses. Control objectives, open/ closed loop control structures, unity negative feedback systems, basic control actions, transient & steady-state responses, tracking/transient specifications. 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. 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 technique, rate and acceleration feedback based minor loop structures. Parameter based optimal design, error based optimal controllers, closed loop robustness/sensitivity analysis, uncertainty models. Types of non-linear behaviour, gain scheduled controllers, describing function approach.

Course Pre – requisites

The course has no formal prerequisites. However, familiarity with Ordinary Differential Equations & solution, MATLAB & SIMULINK, and other numerical techniques, complex analysis is desirable.

Texts / References

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