Control Design for Servomechanisms

12 – 14 July 2005, Glasgow

Detailed Training Course Agenda

DAY 1 INTRODUCTION TO SYSTEMS AND MODELLING

9.00 Introduction

The Need For Control
- What Is Control?
- Feedback Control
- Benefits Of Feedback Control
- Drawbacks Of Feedback Control

9.30 Linear Systems And Transfer Functions

The Integrator
- -Gain And Phase Characteristics
- -What Are They And Why Use Them?

The Laplace Transform
- -Introduction To Transforms
- -Use Of The Laplace Transform
- -Laplace Transform Of Integrator

The First-Order Transfer Function (Or The Simplest Servo In The World!)
- -Closed-Loop Transfer Function
- -First-Order Transient Response
- -Frequency Response

The Second-Order Transfer Function

More General Transfer Function Properties
- -Zeros
- -Poles
- -Examples
- -Definition Of Gain And Phase

11.00 Frequency Response Analysis

Advantages Of Frequency Response Analysis

The Bode Diagram
- -Bode Plots Of Integrators
- -Bode Plots Of Poles
- -Bode Plots Of Zeros
- -The Complete Transfer Function

The Nichols Chart
- -Nichols Chart Representation Of Integrators

Nyquist Plot Representation of Poles and Zeros

13.00 Linear Modelling and Simulation

What is Modelling
- -Objectives of Modelling
- -How do you get a Plant Model
- -Fundamentals of Modelling

What is Simulation
- -Simulation Tools

Modelling Examples

-Landing Gear Model
-Linear Modelling Examples
-Non-linear Modelling Examples

13.30 Hands-On Session - Introduction to MATLAB & SIMULINK

14.45 Hands-On Session - Modelling for Control Design

16.00 Physical Components of Servomechanisms

Principles Of DC Motors

Explanation Of Terms Used To Describe Components Of DC Motors
Fleming's Left-Hand Rule For Torque Generation
Torque Constant Of A DC Motor
Fleming's Right-Hand Rule And Back-Emf Constant
Relationship Between Torque And Back-Emf Constant
Stationary Torque Characteristics
Functions Of Brush And Commutator
Pole And Neutral Zone
Relationship Between Motor And Generator
Relationship Between Motor, Generator And Brake
Calculation Of Servomotor Characteristics
Static Characteristics
Practical Limitations For Static Parameters
Installation Issues
Higher Order Motor Transfer Functions

Gears

Benefits Of Use Of Gears
Gear Types
Features Associated With The Use Of Gears
System Parameter Relationships In The Presence Of Gears
Criteria For Selection Of Gear Ratio/Maximisation Of Performance

Bearings

Bearing Design
Assembly Of Ball Bearings
Angular Contact Ball Bearings
Duplex-Pair Configuration
Benefits Of Bearing-Mounted Systems
Bearings Considerations/Limitations Within Tracking/Stabilisation System
Measures To Prevent Degrading Bearing Performance

Gyroscopes

Gyroscopic Motion
Types Of Gyroscope
Comparison Of Fogs And Dtgs /Benefits Of Fogs
Latest Gyroscopic Devices

Other Servomechanism Position Sensors

Resolvers

Variations On Synchros And Resolvers

Rotary Inductosyns
Uses Of The Rotary Inductosyn
Encoders
Comparison Of Different Position Sensors
Velocity Measurement/Tachogenerators
Drive Electronics

Basic Servo-Amplifiers
Characteristics Of Linear Servo-Amplifiers
Configuration Of Current-Controlled Pwm Servomotor

DAY 2 CLASSICAL CONTROL DESIGN

09.00 Fundamentals of Control Design

Tracking Performance
Control Accuracy
- Final Value Theorem
- Step Position Input Error
- Other Cases

Stability
- System Behaviour Based On Pole Position
- Gain And Phase Margins
- Gain Margin
- Phase Margin

Disturbance Rejection
Noise Immunity

10.00 Hands-On Session - Control Fundamentals

11.00 Root Locus and Lead-lag Compensation

Root Locus Technique
- -Learning Objectives
- -History

The Root Locus
- -Root Locus for an Integrator
- -Second Order System Root Locus
- -Higher Order System Root Locus
- -Location of Roots and Dynamic Response of the System
- -Example
- -Theory

Modulus Condition
Argument Condition
Some Useful Rules
Example
- -Effect of Compensation
- -Conclusion

Controller Design Using Lead-Lag Compensation
Justification For Dynamic Controllers
Classical Controllers And Design Methods
Frequency Responses Of Lead-Lag Compensators
Lead Compensation Design
Lag Compensation Design

13.15 Hands-On Session - Root Locus and Lead-Lag

14.00 PID Controllers

Introduction To PID Control

Motivation
Limitations
Generic Equations
PID Parameterisation
Proportional Term
First-Order Plant
Second-Order Plant
Integral Term
Introduction
First-Order Plant
Derivative Term
Introduction
Implementation
First-Order Plant
Second-Order Plant
Equivalence Of PID And Lead-Lag Controller Characteristics

15.30 Hands-On Session - PID Tuning

16.15 Implementation Issues and Nonlinearities

Implementation Aspects
Bumpless Transfer
Derivative Filtering
Integral Windup
Graphical Representation
-Antiwindup Mechanisims
Practical Non-linearities
Coulomb and Static Friction
Deadband
Backlash
Saturation
Quantisation

DAY 3 PRACTICAL ISSUES IN SERVOMECHANISM CONTROL

09.00 Discrete-Time Systems Modelling and Control
Digital Control
Modern Control Systems
Sampling
Spectra Of Sampled Signals
Aliasing
Difference Equations
The Z-Transform
Mapping Between Z-Plane And S-Plane
Some Intuitive Appreciation
Impulse Response Of Integrator (Impulse Invariant Transform Example)
The DAC Reconstruction Process
Total Z-Transform Of Sampled Plant Function
Sampled-Data Control Systems Analysis
Frequency Response Analysis
Design Of Digital Compensators
Continuous Domain Approach
Direct Digital Design
Example

10.45 Hands-On Session - Discrete Time Systems

13.00 Servomechanism Testing

Servo Testing

Servomotor Tests

Back-EMF Test
Armature Resistance and Inductance Test
Torque Test

Mechanism Tests

Inertia Testing
- Torsional pendulum method
- Torque versus acceleration test
- Frequency response testing

Friction Testing
Torsional Stiffness Testing
- Static deflection measurement
- Dynamic frequency response test

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14.00 System Identification

System Identification Application
System Identification Procedure
On-line and Off-line Identification
- Off-line
- On-line

Methods of Identification
- Non-parametric methods
- Parametric methods

Non-parametric Models and Identification Methods
- Transient analysis
- Frequency analysis (swept sine test)
- Spectral analysis (FFT/PRBS)
- Correlation analysis

Parametric Models and Estimation Methods

15.15 Real-life Design Example
- Servomechanism with motor, load, gear and position sensor