COURSE CODE: *ELE 501*

COURSE TITLE: *Control Engineering I*

NUMBER OF UNITS: *3 Units*

COURSE DURATION: *Three hours per week*

COURSE DETAILS:

Course Coordinator: **Engr S. G. Oyagbinrin**
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Office Location: **College of Engineering building**
Other Lecturers: **None**

COURSE CONTENT:

Linear control systems stability: Nyquist stability criterion. Bode diagram approach; the root locus and toot contour method. Design of linear servo systems,. Compensation designs using the Bode and root locus methods. Multiple loop feedback systems; Minimization of unwanted disturbances. Single and multiterm electronic process controllers. Hydraulic and pneumatic controller. Introduction to analogue and hybrid computation, sensitivity of control systems.

COURSE REQUIREMENTS:

This is a compulsory course for all 500 level students in the College of Engineering. In view of this, students are expected to participate in all the course activities and have minimum of 75% attendance to be able to write the final examination.

READING LIST:

- John J. D'Azzo and Constanttine H. Houpis Linear Control system Analysis and Design with MATLAB New York Marcel Dekker, Inc 2003

- Katsuhiko Ogata Modern Control Engineering United State of America Prentice Hall. 1997
- Paraskevopoulos P. N. Modern Control Engineering New York Marcel, Dekker, Inc 2002
- Norman S. Nise Control Systems Engineering Fourth Edition John Wiley and Sons, Inc 2004

LECTURE NOTES

LECTURE1

GENERAL INTRODUCTION

1.1   Introduction

Control Engineering is primarily concerned with understanding and controlling natural resources and forces of nature purposefully and for the benefit of mankind. That is, it is concern with the design and development of machines equipment by which man can utilize power.

Example: A switch to turn on a simple filament lamp, the accelerator or throttle pedal of a motor car, the oven control knob on a gas cooker etc.

1.2   Open and close loop control system

When the control action of a system is independent of the output, the system is said to be an open loop control system. The lighting of a room is an open loop control system. However, if the control action is somehow independent of the output, the system is called a closed loop or feedback control system. A refrigerator is a close loop system.

1.3   Control system components

- Strain gauges
- Potentiometer
- Variable inductance transducers
- Tachometer and Tachogenerators
- Thermocouples
- Resistance thermometers
- Photo-electric cells: Barrier-layer cells, photo-inductive cells, photo-emissive cells, photo- transistor, etc.

LECTURE II
CONTROL SYSTEM STABILITY

2.1   Introduction

The most essential requirement of any control system is that the output should at all times be under the control of the input. If the output of a system is bounded for every bounded input, the system is said to be stable.

2.2   Characteristics equation

Characteristics equation is formed by equating the denominator of the transfer function of a system to zero.

2.3   The S-Plane

The complex quality $s = \sigma + j\omega$, where σ and ω are real variables, is of particular interest in control engineering, a plane in which the real axis is represented by σ and the imaginary axis is represented by ω , is referred to as the complex plane or the s-plane. S is the Laplace operator and it transforms a function from the time domain to the frequency domain.

2.4   Poles and Zeros

Most transfer functions are complex and may be expressed in forms of s, as the ratio of two polynomials in the product form of equation below;

$$F(s) = (s-z_1)(s-z_2)/(s-p_1)(s-p_2)$$

Any value of s making F(s) zero is called a ZERO of F(s). a value of which makes F(s) infinite is called a pole of F(s). A closed path showing the variation of s or of F(s) is known as a CONTOUR.

2.5   Routh Stability Criterion

This is a method of determining whether or not a system is stable by examine its character equation. A system having a characteristics equation of the form.

$$a_n s^n + a_{n-1} s^{n-1} + \ldots\ldots + a_1 s + a_0 = 0 \text{ , will be stable if}$$

1.   All coefficients of s from n to o are present and are positive, and

2.   All the terms in the first column of the arrays formed from the characteristics equation have the same sign.

Any change of sign indicate a pole in the right hard hall of the s-plane.

LECTURE III

DETERMINATION OF CONTROL SYSTEMS STABILITY

3.1   Nyquist Diagrams

The open-loop frequency response of a system represent as a polar plot is called a NYQUIST DIAGRAM. The merit of nyquist diagrams is that they based on open loop measurement and calculation, and , therefore, stability of a system can be determined without actually closing the feed-back loop.

This can be illustrated using a system whose open-loop transfer function is given by

$$G (j \omega) = 50/(1+j2.5\omega)(1+j0.05 \omega)$$

3.2   Nyquist Stability Criterions

The Nyquist stability criterion is based on the open-loop frequency response and is a graphical method of determine the stability of a system under close-loop condition. The simplified criterion is stated as follows;

A closed-loop system will be stable if, when moving along the open loop frequency response plotted on a nyquist diagram, in the direction of increasing frequency, the point (-1,j0) lies on the left of the locus.

The simplified criterion does not account for conditionally stable systems and is not applicable to unusual system with unstable open-loop.

3.3   Relative Stability

It is very important to know how close a stable system is to being unstable. This is called the degree of stability.

The relative stability of a system is usually defined in term of two design parameters; phase margin and gain margin.

3.4   Root Locus

The root locus techniques, based on the positions of poles and zero in the s-plane, is a graphical mean of determining the root of the characteristics equation of a close-loop control system.

3.5   Bode Plot

The bode plot logarithmic diagram in which the modulus (amplitudes) ιG (jw)ι in the decibels and the argument (phase)Q in the degree of a transfer function G(jw)are plotted separately against the logarithm of frequency.

LECTURE IV

COMPENSATION

4.1   Introduction

The term compensation is often used when an element is introduce in either the forward path (series compensation) or the feedback path (feedback compensation) in order to stabilize an unstable system or to increase are the stability margins. The two most commonly used elements are the phase-lead and phase-lag circuits.

The general effects of series compensation on the systems may be summarized as following.

4.2   Phase-Lead Network

1.   The relative stability is increased

2.   The overall gain is reduced

3.   The bandwidth of the system is increased

4.   The overshort is decreased

5.   The raised time is usually shorted

4.3   Phase-Lag Network

1.   The relative stability is improved

2.   The steady-state error may be reduced

3.   The bandwidth of the system is reduced

4.   The error constant is usually increased

5.   The response time is increased

Both the Bode diagram and Nyquist diagram are plotted for phase-lag and phase-lead network respectively. The effects of series compensation on the open loop frequency response of a stable system are also illustrated in diagrams.