ELEG 5443 Nonlinear Systems

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Textbook (Required): Applied Nonlinear Control; J. Slotine and W. Li.: Prentice Hall, 1991.

Welcome to the study of nonlinear dynamic systems! This course extends the theory developed for linear systems (transient and steady-state response, state-space, stability, feedback, etc.) to the more realistic case where nonlinearities exist in practical applications. We will employ Matlab-Simulink throughout the course for both analysis and design. Applications will focus on power electronics and energy conversion systems. Areas of particular interest to students can be explored in the course project.

Course Topics Summary:

1. Analysis
   a. Mathematical modeling and simulation of nonlinear dynamic systems
   b. Stability Analysis and Lyapunov Theory
   c. Describing Function Analysis
2. Design
   a. Feedback Linearization
   b. Variable Structure Systems (sliding Mode Control)
   c. Introduction to Adaptive Control

Grading:

- Homework 50%
- In-Class Test 20%
- Final Project 30%

Approximately 5 homework assignments will be given. The in-class test will cover the analysis portion of the class. A design/analysis project will be assigned and its completion will count as the final exam.

Prerequisites by Topics

1. Time-domain solutions to linear differential equations.
2. Abstract linear algebra (vector spaces).
3. Introductory course in feedback control systems.

Course Objectives

After completing this course, electrical engineering graduate students should be able to determine the following:

- Develop mathematical models of nonlinear systems that include hysteresis, backlash, preload, and multilinear products of state-variables.
- Solve nonlinear differential equations in the time-domain by using computer-based numerical methods such as Matlab/Simulink.
- Apply Lyaponov's First and Second Theorems to determine the stability of nonlinear dynamic systems.
- Determine the associated describing functions for commonly encountered nonlinearities in electrical circuits.
- Apply feedback linearization techniques based on the Frobenius Theorem to apply feedback linearization techniques to n^{th}-order systems with full state-feedback.
- Design variable structure and sliding mode control systems based on defined closed-loop dynamic requirements.
- Evaluate sliding mode control system designs for switched mode power electronic circuits such as dc-dc converters and three-phase inverters using computer simulation tools.

Topics by week number:

1. Phase plane analysis, Limit cycle phenomena
2. Numerical methods and solution of nonlinear differential equations
3. Equilibrium points and definitions of stability
4. Lyapunov stability analysis – linearization and the First Theorem
5. Lyapunov stability analysis – Second (Direct Method) Theorem
6. Describing function analysis
7. Variable structure systems, Frobenius Theorem and sliding mode control
8. Computer simulation design project and class presentations

There are 4 videos per week for the 8 week course schedule.