ECET 221 Control Systems for Renewable Energies

Hours: 3/2.5/0

Prerequisites: ECET 242 Analog Electronics, ECET 281 System Dynamics

Short description:
Students will study open and closed loop systems, a second order model for system responses, transfer function analysis, stability of control systems, PID controller design, gain and phase margins, and fuzzy control. In addition, they will learn specialized control schemes for wind energy, solar thermal, solar photovoltaic and battery systems. Students will focus on applications of control in the renewable energy domain throughout this course.

Learning outcomes:
Upon successful completion of this course a student will be able to:

- explain fundamental concepts of control systems, including closed loop feedback, damping, and steady state errors;
- assess the stability of a system, in particular for wind energy systems;
- evaluate controlled systems in the presence of disturbances;
- apply PID tuning control techniques to solar and wind systems;
- analyze controlled systems through simulation;
- design a controller in the frequency domain;
- design a fuzzy logic controller for a renewable energy system;
- explain the differences between analog control and digital control;
- analyze specialized control techniques used in renewable energy systems, including maximum power point tracking (MPPT) control.

Course outline:

1. Introduction **2 hours**
- 1.1 Basic concepts
- 1.2 Definitions of control systems
- 1.3 General block diagram
- 1.4 Closed loop and open loop systems and the concept of feedback[1]

2. System response **3 hours**
- 2.1 Second order system analysis
- 2.2 Overdamped, critically damped and underdamped conditions
- 2.3 Sallen-Key filter example
- 2.4 Wind energy system response

3. Transfer function concept in closed loop systems **4 hours**
- 3.1 The feedback loop and transfer function calculation
- 3.2 Review of poles and zeros and stability[2]

3.3 Effects of feedback on first order system response
3.4 DC motor example
3.5 Induction generator example
3.6 Analysis of second order systems in a closed loop
3.7 Second order model of point absorber wave energy converter
3.8 Steady state output and steady state error
3.9 Steady state errors in solar tracking systems

4. Stability of general systems **3 hours**
4.1 Pole positions
4.2 The Routh-Hurwitz test

5. Control of continuous processes **5 hours**
5.1 Proportional/Integral/Derivative controller
5.2 Criteria of good control
5.2.1 The Ziegler-Nichols rules
5.2.3 Quarter amplitude damping (quad) criteria
5.3 PID control for solar tracker
5.4 PID control for wind turbines
5.4 Gas flow, temperature and humidity control for fuel cell stacks

6. Study of servomechanisms **3 hours**
6.1 The DC motor in a closed loop system
6.2 Disturbances
6.3 Shading, gusts and storms: disturbances affecting renewable energy converters

7. Specialized control techniques for renewable energy systems
7.1 Wind energy systems **4 hours**
7.1.2 Model of wind turbine
7.1.1 Maximum power point tracking (MPPT)
7.1.1.1 Tip-speed ratio control
7.1.1.2 Power signal feedback control
7.1.1.3 Optimal torque control
7.1.1.4 Load angle control
7.1.1.5 Hill-climb searching
7.2 Residential pumped solar thermal hot water systems **1 hour**
7.2.1 Typical set-up
7.2.2 Controller
7.3 Batteries **2 hours**
7.3.1 Modelling
7.3.2 Charge controllers
7.3.3 Thermal control of battery packs in electric cars

8. Controls in the frequency domain **4 hours**
8.1 Compensation methods
8.2 Gain and phase margins
8.3 Controller design
8.4 The Nyquist criteria

9. Fuzzy Control **4 hours**

- 9.1 Concept of Fuzzy logic
- 9.2 Fuzzification and de-fuzzification examples
- 9.3 Fuzzy control of solar tracking
- 9.4 Fuzzy control for wind energy MPPT

10. Digital Control **2 hours**

Tests and review 5 hours
Total **42 hours**

Notes for instructors:

[1] Basic concepts of feedback were introduced in ECET 141 Analog Devices.

[2] Laplace transforms, poles, zeros and stability were studied in ECET 281 System Dynamics.

Labs:

1. Exploration of the second order Sallen-Key response to different gain settings
2. Servomotor position control using feedback systems
3. Proportional-Integral-Derivative control techniques
4. Velocity and position control strategies (P, PI, PD, PID) and LabVIEW simulation
5. PV panel controllers: Tracking and MPPT (PWM)
6. Wind turbine control: LabVIEW and experimental
7. Fuzzy logic control systems – mini project.