ESE 586 Microgrids (Fall 2022)

Syllabus

Advanced modeling, control, resilience and security technologies useful for the grid modernization from a unique angle of microgrid design, analysis and operation. Smart inverters, microgrid architectures, distributed energy resources modeling, microgrid hierarchical control, microgrid stability, fault management, resilient microgrids through programmable networks, reliable networked microgrids, and cyber security.

Instructor

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Office: Light Engineering 215
Office hours: Thursday 1:00 pm-4:00 pm (online or in-person)

Prerequisite

Undergraduate courses in circuits and power systems, or consent of instructor.

Location and Time

Humanities 3008
Tuesday 6:30 pm - 9:20 pm

Outline

Topic 1: Introduction (Week 1)

- Concept of microgrids
- Operation mode and architecture of microgrids

Topic 2: Microgrid Modelling (Week 2-3)

- Distributed energy resources (DERs) modelling I: PV system, MPPT, and energy storage
- Distributed energy resources modelling II: Wind Turbine, Microturbine, and other DERs
- Microgrid inverter structures

Topic 3: Microgrid Control (Week 4)

- Centralized control
- Hierarchical principle: Primary, secondary and tertiary control
- Distributed control

Topic 4: Enhanced Microgrid Power Flow (Week 5-6)

- Distribution power flow
- Microgrid power flow
- Networked microgrid power flow

Topic 5: Microgrid Stability (Week 7)

- Small signal analysis and modal analysis
- Stability enhancement of inverter-based microgrids

Topic 6: DC Microgrids (Week 8)

- Overview of DC microgrids
- Stability of DC microgrids

Topic 7: Formal Analysis of Networked Microgrids (Week 9)

- Introduction to reachability theory
- Reachable analysis of microgrids

Topic 8: Cyber Security in Microgrids (Week 10)

- Introduction to cyber attacks
- Active detection of cyber attacks

Topic 9: Active Fault Management for Networked Microgrids (Week 11)

- Fault ride through
- Multi-functional Active Fault Management (AFM)

Topic 10: Resilient Microgrids through Software Defined Networking (Week 12)

- SDN-enabled control and communication architecture
- Distributed regulation of networked microgrids
- Hardware-in-the-loop testbed

Topic 11: Advanced Computing Techniques of Microgrids (Week 13-14)

- Learning-based analytics of microgrids
- Quantum computing in microgrid analysis

Learning Outcomes

By the time the course is completed, students will have acquired knowledge and skills with microgrids which include the ability to:

* Understand the concepts of microgrids, and networked microgrids;

* Model PV power systems and standard grid-tied inverter;

* Analyze distribution grid power flow;

* Understand centralized control and distributed control in microgrids, especially primary, secondary and tertiary control;

* Conduct power flow analysis for droop-control-based microgrids and networked microgrids;

* Understand fault ride-through and active fault management for microgrids;

* Understand basics of cybersecurity in microgrids and active defense strategy.

Course Notes

All course materials will be available online.

Reference

[1] P. Zhang, *Networked Microgrids*. Cambridge University Press, 2021.

Experimental and Computing Tools

Matlab/Simulink

Evaluation Scheme

Homework Assignments: 50%
Term Project: 50%

Grading Scale

Score	Grade	Score	Grade
≥90	A	70-74	B−
85-89	A−	65-69	C
80-84	B+	60-64	D
75-79	B	<60	F

Policy

1. No cheating. Even though discussion and study groups are encouraged, students who copy answers or procedures in homework assignments or who allow their answers or procedures to be copied will be considered to be cheating and corresponding penalties will be applied.

2. Late homework is not accepted unless extenuating circumstances are present.

3. Projects can be done individually or by teams of two or three. If the homework is done by a team, both students need to submit the report and source files individually but the teamwork should be declared in the report. Projects done individually will receive a 5% bonus.