Western University
Faculty of Engineering
Department of Electrical and Computer Engineering

ECE 9405B (M.E.Sc., Ph.D.), ECE 9045B (M.Eng.)

Computational Methods for the Modern Power Grid

Course Outline - Winter 2018

Description: This course aims to provide an introduction to applied mathematical constructs such as convex optimization, game theory and dynamic programming in the context of the modern power grid. With the recent proliferation of flexible power components that are able to communicate and intelligently actuate, scalable computational methods and effective modelling techniques that capture underlying interactions and dependencies are imperative for optimally coordinating today's electric grid. Students will be equipped with the ability to identify and apply various mathematical tools introduced in the course for power grid applications and also understand the associated advantages and tradeoffs.

Instructor: Dr. Pirathayini Srikantha, P.Eng.
Room: TEB 257
Phone: (519) 931 5777 X 84460
Email: psrikan@uwo.ca
Office hours: By appointment

Contact Hours: 3 lecture hours per week, 0.5 course.

Prerequisites: ECE 3333A/B or equivalent (not compulsory but recommended)
Familiarity with fundamental aspects of power grid operations is recommended.

Required Textbook:
Convex Optimization of Power Systems
Author: J.A. Taylor
Publisher: Cambridge University Press (2015)
ISBN: 9781107076877

Recommended References:
- S. P. Boyd and L. Vandenberghe, *Convex Optimization*. Cambridge University Press, 2011. (Available for download: http://web.stanford.edu/~boyd/cvxbook/)
- T. Başar and G. J. Olsder. *Dynamic Noncooperative Game Theory*. SIAM Series in Classics in Applied Mathematics, 1999.

General Learning Objectives:

The following are broad learning objectives for this course:

1. Understand the rapidly evolving nature of the modern power grid and associated research challenges.
2. Introduce and motivate the application of advanced mathematical constructs in the context of the modern power grid.
3. Demonstrate how theoretical constructs in applied mathematics constitute of a rich set of tools that can be utilized to formulate and construct practical and efficient solutions for current problems in the power grid.
4. Equip students with rigorous and innovative computational thinking that can be applied across a broad range of power engineering applications.

Course Outline and Specific Learning Objectives:

1) Review fundamental power system and optimization concepts.
- Introduce fundamental power system constructs (electrical quantities, power flow, etc.).
- Introduce the main elements of an optimization problem (objective and constraints).
- Identify common classes of optimization problems in the context of power engineering (e.g. unit commitment, demand response, storage scheduling, etc.).

2) Identify challenges associated with various optimization problems in power grid applications.
- Introduce convex functions, convex sets and convex optimization.
- Understand the challenges associated with solving a non-convex optimization problem.
- Identify whether optimization formulations are tractable or not using the notion of convexity.

3) Formulate the optimal power flow (OPF) problem and apply relaxations as necessary.
- Highlight the difficulties associated with directly solving the OPF and introduce the notion of relaxation for simplifying computations (linearization, semi-definite relaxation, etc).
- Identify circumstances in which relaxations can be exact (e.g. radial distribution networks) and the tradeoffs incurred otherwise.

4**)** Demonstrate how duality and optimality conditions relate to power grid economics.
- Introduce Lagrangian duality and the Karush Kuhn Tucker (KKT) conditions.
- Illustrate how dual optimization and complementary slackness conditions intuitively and theoretically translate to nodal pricing and financial rights in the power grid.

5**)** Introduce multi-period optimization problems in the grid.
- Present examples of power components that have dependencies across multiple time periods (storage, load shifting, etc.) which are also associated with uncertainties.
- Demonstrate how recursive techniques such as dynamic programming can be applied to solve optimization problems involving these components.

6) Modelling natural interactions between self-interested power entities using game theory.

- Introduce fundamental principles of game theory (e.g. payoffs, and Nash equilibrium) and these relate to optimization.
- Present the use of game theory to model various interactions in power applications such as the electricity market, auctions and demand response.

Evaluation:
This course consists of three evaluation components. The following are the weights associated with each component:

Component	Weight	Maximum Penalties *	
		English	Presentation
Midterm	30%	10%	10%
Project Report	15%	10%	10%
Project Presentation	5%	10%	10%
Final Exam	50%	10%	10%

Both the midterm and final exams will be closed book evaluations. The project will entail the writing of a report (using the IEEE conference template) and a brief presentation. These projects are to be completed individually. Each student can elect to work on a topic selected from the list presented at the beginning of the course. M.E.Sc. and Ph.D. students must choose a project that is application-based and will entail an implementation using MATLAB and/or MATPOWER. M.Eng. students can elect to conduct a literature survey. The course instructor must approve the selected topic for all students.

* In accordance to the policy of the University, the grade assigned to all written and oral work presented in English shall take into account syntax, diction, grammar and spelling. In addition, in the professional life of an engineer, the manner in which oral and written communications are presented is extremely important. An engineering student must develop these skills as an integral part of the graduate program. To encourage the student to do so, the grades assigned to all written and oral work will take into account all aspects of presentation including conciseness, organization, neatness, use of headings, and the preparation and use of tables and figures. All work will be marked first for content after which a penalty not to exceed the maximum shown above may be applied for lack of proficiency in English and/or presentation.

Attendance:
Any student, who in the opinion of the instructor is absent too frequently from class in this course, will be reported to the Dean (after due warning has been given). On the recommendation

of the Department concerned, and with the permission of the Dean, the student will be debarred from taking the regular examination in the course.

Absence Due to Illness or Other Circumstances:
Students should immediately consult with the instructor or department Chair if they have any problems that could affect their performance in the course. Where appropriate, the problems should be documented (see the attached "Instructions for Students Unable to Write Tests or Examinations or Submit Assignments as Scheduled"). The student should seek advice from the instructor or department Chair regarding how best to deal with the problem. Failure to notify the instructor or department Chair immediately (or as soon as possible thereafter) will have a negative effect on any appeal. For more information concerning medical accommodations, see the relevant section of the Academic Handbook:
http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_medical.pdf
For more information concerning accommodations for religious holidays, see the relevant section of the Academic Handbook:
http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_religious.pdf

Cheating and Plagiarism:
University policy states that cheating is a scholastic offence (see Scholastic Offence Policy in the Western Academic Calendar). The commission of a scholastic offence is attended by academic penalties that might include expulsion from the program. If you are caught cheating, there will be no second warning.

Plagiarism is a major academic offence. Students must complete their reports and assignments in their own words. Appropriate citations must be included when ideas are obtained from another source. All submissions maybe subject to textual similarity review via commercial plagiarism-detection software (Turnitin http://www.turnitin.com) under the licensing agreement established by Western University.

Accessibility:
Please contact the course instructor if you require material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at (519) 661-2111 X 82147 for any specific question regarding an accommodation.

Support Services:
Office of the Registrar, http://www.registrar.uwo.ca/
Student Development Centre, http://www.sdc.uwo.ca/
Engineering Undergraduate Services, http://www.eng.uwo.ca/undergraduate/
USC Student Support Services, http://westernusc.ca/services/

Students who are in emotional/mental distress should refer to Mental Health @ Western, http://www.health.uwo.ca/mental_health/, for a complete list of options on how to obtain help.