



## IGEE 402 – Power Systems Analysis (Réseaux électriques)

### Course Outline Fall 2021

<b><u>Instructors:</u></b>	Professor François Bouffard, P.Eng. Office: McGill University, McConnell Engineering Building, Room 642 Telephone: (514) 398-2761 Office Hours: Wednesday, 14:00 – 15:00, Polytechnique Montréal, Room A.330.5 E-mail: <a href="mailto:francois.bouffard@mcgill.ca">francois.bouffard@mcgill.ca</a>
<b><u>Equivalencies:</u></b>	ELEC 431 Electrical Power Systems (Concordia University) ELE653 Transport de l'énergie (ÉTS) ECSE 464 Power Systems Analysis (McGill University) ELE8452 Réseaux électriques (Polytechnique Montréal) GEL-4150 Réseaux électriques (Université Laval) GEI 145 Génération et transport (Université de Sherbrooke) 6GEI700 Transport et exploitation de l'énergie (UQAC) GEN43216 Réseaux électriques (UQAR) GEN4335 Conception, analyse et exploitation d'un réseau électrique (UQAT) GEN1673 Réseaux électriques (UQO) GEI1047 Réseaux de transport d'énergie (UQTR)
<b><u>Textbook:</u></b>	J.D. Glover, M.S. Sarma & T.J. Overbye. (2016). <i>Power System Analysis &amp; Design</i> , 6 <sup>th</sup> ed., Stamford, CT: Cengage Learning.
<b><u>Alternate Texts:</u></b>	J.J. Grainger & W.D. Stevenson Jr. (1994). <i>Power System Analysis</i> . New York, NY: McGraw-Hill. A. Gómez-Expósito, A.J. Conejo & C. Cañizares, eds. (2009). <i>Electric Energy Systems: Analysis and Operation</i> . Boca Raton, FL: CRC Press. These books are alternate reference books for the course, covering in more depth the topics addressed in the main text.
<b><u>Lectures:</u></b>	Polytechnique Montréal, Pavillon Lassonde – local M-2002 Wednesday: 9:30 – 12:20, Montreal time
<b><u>Laboratory:</u></b>	Polytechnique Montréal, Pavillon principal – Room A-328 Groups 1 & 2 – Every other Wednesday: 13:45 – 16:40 Assistant: Mohamed Awadalla E-mail: <a href="mailto:mohamed.awadalla@mail.mcgill.ca">mohamed.awadalla@mail.mcgill.ca</a>
<b><u>Course Website:</u></b>	<a href="http://www.moodle.polymtl.ca">www.moodle.polymtl.ca</a> ; browse for IGEE 402 / ELE 8452 Réseaux électriques.
<b><u>Course Outline:</u></b>	<u>Objectives of the Course</u> The course presents the principles of operation and methods of analysis and design in sufficient depth to give the students the basic tools for investigating basic power system issues. Students will develop a sound understanding of a broad range of topics related to modeling of power system apparatus and analyzing their responses to system disturbances, as well as their deployments in coordinated power network operations.

Topics covered

- Power system fundamentals: Principal objectives; structure and building blocks; transmission versus distribution; operating criteria; economical aspects.
- AC three-phase network analysis: Balanced three-phase networks; three-phase power.
- Transformers: Equivalent circuit models; per-unit calculations; operation.
- Transmission lines: Parameters; models for balanced operation; compensation.
- Power flow analysis: Admittance matrix; problem formulation; solution by the Newton-Raphson method; power flow control.
- Synchronous machines: Basic models for power system studies.
- Symmetrical components: Fortescue transformation and sequence networks.
- Introduction to power system protection: Symmetrical and asymmetrical fault calculations.
- Introduction to power system stability and control: Transient stability; voltage and frequency control.
- Economic operation: Economic dispatch; optimal power flow.

**Grading Scheme:**

Assignments (4)	20 %
Laboratory reports (4)	15 %
Mid-term examination	20 %
Final examination	45 %
<b>Total</b>	<b>100 %</b>

**Laboratory:**

Work using computer simulations covers the following topics and applications:

- Operation of radial lines – transmission line models
- Power flow in meshed systems – control and compensation
- Fault analysis – symmetrical and unsymmetrical short circuit studies
- Power system transient stability – transient operation under faults

Laboratory instructions will be available for download from the course website.

Laboratory experiments will be conducted using *Powerworld Simulator*.

Students are to work in pairs, and each student is required to hand in the same report.

Students in the team will receive the same grade.

Laboratory reports are normally due one week after the scheduled laboratory period.

**Assignments**

Assignments will be made available for download about every fortnight.

**Assignments have to be submitted individually.** Collaboration is expected, but individual submissions have to be produced.

Assignments will be due typically within 10 business days (actual deadlines will be indicated on Moodle).

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### Detailed Schedule – Fall 2021

<b>Wk</b>	<b>Date</b>	<b>Topic</b>	<b>Chapter/ Sections</b>	<b>Assignments</b>	<b>Laboratory A-328</b>
1	1 Sept.	Power system fundamentals, ac power, three-phase circuits	1.1–1.4, 2.4–2.6, 14.1–14.3		
2	8 Sept.	Transformer equivalent circuit, operation, per-unit system	3.1–3.5, 3.7, 3.8	<b>Assignment 1</b>	Industrial power system – Intro lab – Group 1
3	15 Sept.	Transmission line characteristics & parameters	4.1–4.10		Industrial power system – Intro lab – Group 2
4	22 Sept.	Transmission line models	5.1–5.3		<b>Industrial Seminar – André Dagenais HQ - GTE</b>
5	29 Sept.	Transmission line models	5.4–5.7	<b>Assignment 2</b>	Operation of radial transmission lines – Group 1
6	6 Oct.	Power flow modelling, calculations & control	6.4, 6.6		Operation of radial transmission lines – Group 2
	13 Oct.	<b>Fall reading week</b>			
7	20 Oct.	Power flow modelling, calculations & control	6.7, 6.9, 6.10		
8	27 Oct.	<b>Midterm (all topics from weeks 1–6)</b> Symmetrical faults	7.2–7.4	<b>Assignment 3</b>	Power flow in meshed systems – Group 1
9	3 Nov.	Symmetrical components	8.1–8.6, 8.8		Power flow in meshed systems – Group 2
10	10 Nov.	Asymmetrical faults	9.1–9.4		Fault analysis – Group 1
11	17 Nov.	Transient stability	11.1–11.4	<b>Assignment 4</b>	Fault analysis – Group 2
12	24 Nov.	Power system control	12.1–12.3		Transient stability – Group 1
13	1 Dec.	Power system economic operation	12.4, 12.5		Transient stability – Group 2
	<b>TBC</b>	<b>Final Exam</b>	Exam on all topics		

*Note: The period for final exams will take place from December 10<sup>th</sup> to 23<sup>rd</sup>, 2021 inclusive.*

**Canadian Engineering Accreditation Board (CEAB) Curriculum Content**

This course contributes the following curriculum category content:

<b>CEAB curriculum category content (AUs)</b>	<b>Math</b>	<b>Natural science</b>	<b>Complementary studies</b>	<b>Engineering science</b>	<b>Engineering design</b>
	0	0	0	26	26

**Accreditation units (AU)** are defined on an hourly basis for an activity which is granted academic credit and for which the associated number of hours corresponds to the actual contact time: one hour of lecture (corresponding to 50 minutes of activity) = 1 AU; one hour of laboratory or scheduled tutorial = 0.5 AU. Classes of other than the nominal 50-minute duration are treated proportionally. In assessing the time assigned to determine the AU of various components of the curriculum, the actual instruction time exclusive of final examinations is used.

**Mathematics** include appropriate elements of linear algebra, differential and integral calculus, differential equations, probability, statistics, numerical analysis, and discrete mathematics.

**Complementary studies** include humanities, social sciences, arts, management, engineering economics and communications to complement the technical content of the curriculum

**Natural science** includes elements of physics and chemistry, as well as life sciences and earth sciences. The subjects are intended to impart an understanding of natural phenomena and relationships through the use of analytical and/or experimental techniques.

**Engineering science** involves the application of mathematics and natural science to practical problems. They may involve the development of mathematical or numerical techniques, modeling, simulation, and experimental procedures. Such subjects include, among others, applied aspects of strength of materials, fluid mechanics, thermodynamics, electrical and electronic circuits, soil mechanics, automatic control, aerodynamics, transport phenomena, elements of materials science, geoscience, computer science, and environmental science

**Engineering design** integrates mathematics, natural sciences, engineering sciences, and complementary studies in order to develop elements, systems, and processes to meet specific needs. It is a creative, iterative, and open-ended process, subject to constraints which may be governed by standards or legislation to varying degrees depending upon the discipline. These constraints may also relate to economic, health, safety, environmental, societal or other interdisciplinary factors.

This course contributes to the attainment of the following graduate attributes:

<b>Graduate attribute</b>	<b>PA</b>	<b>DE</b>	<b>IN</b>	<b>ET</b>	<b>EP</b>
<b>Level descriptor</b>	A	A	D	D	D

I = Introduced; D = Developed; A = Applied

**Problem analysis (PA):** An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.

**Design (DE):** An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, economic, environmental, cultural and societal considerations.

**Investigation (IN):** An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data and synthesis of information in order to reach valid conclusions.

**Use of Engineering Tools (ET):** An ability to create, select, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.

**Economics and Project Management (EP):** An ability to appropriately incorporate economics and business practices including project, risk and change management into the practice of engineering, and to understand their limitations.

### **Administrative Aspects**

#### **Language of submission for coursework**

In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French any written work that is to be graded.

#### **Use of calculators**

The instructor recognizes that different calculator models are used across member institutions of the IGEE. To that effect, there are no restrictions on calculator models used by students during examinations. Note, however, that calculators should not be able to connect to the internet. Therefore, mobile phones cannot be used as calculators during examinations.

#### **Academic integrity**

McGill University values academic integrity. Therefore, all students must understand the meaning and consequences of cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures.

#### **Copyright statement**

© Instructor-generated course materials (e.g., handouts, notes, summaries, exam questions) are protected by law and may not be copied or distributed in any form or in any medium without explicit permission of the instructor. Note that infringements of copyright can be subject to follow up by the University under the Code of Student Conduct and Disciplinary Procedures.

#### **Possible disruptions due to the Covid-19 pandemic**

In the event of extraordinary circumstances beyond the University's control, the content and/or evaluation scheme in this course is subject to change.