Michigan Technological University

Course Syllabus

EE5200 – Advanced Methods in Power Systems Analysis
College of Engineering
Fall 2023

Instructor Information

Instructor:	Bruce A. Mork, PhD, Professor
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Office Hours:	TR 11:00am–12:00pm or by appointment

Course Identification

Course Number:	EE5200
Course Name:	Advanced Methods in Power Systems Analysis
Course Location:	508 EERC
Class Times:	TR 9:30am – 10:45am
Prerequisites:	EE4222 – Power System Analysis (or equivalent)

Course Description/Overview

Advanced analysis and simulation methods for large networks (100s or 1000s of nodes), load flow, symmetrical components, short circuit studies, optimal system operation, stability, and transient analysis. Application of commonly used software reinforces concepts and provides practical insights.

Course Resources

- ECE Learning Center (for fundamentals and EE4221/4222 pre-req concepts).
- Grader
- Canvas Designer

Course Website(s)

- Canvas [https://mtu.instructure.com/courses/1472228]
- At-a-Glance Overview of Course [https://pages.mtu.edu/~bamork/ee5200/]
- Personal Website [https://www.mtu.edu/ece/department/faculty/mork/

Required Course Text

- Power Systems Analysis, J.J. Grainger, W.D. Stevenson, G.W. Chang, 2nd Ed, McGraw-Hill Higher Education, © 2015 . ISBN 1259008355.

Course Fees/Supplies

Online students pay $114 fee.

Course Learning Objectives

EE 5200 is the lead-off graduate course in Electrical Power Systems and provides the foundation for the remaining EE52xx courses in the "power area." The main goal of the course is to quickly review and then advance the student's existing knowledge of power systems analysis. Emphasis is on foundational theories, advanced analysis methods, developing conceptual insights, and gaining experience with applicable software simulation and analysis packages. In order to properly apply the software and interpret the results we must have both a good analytical understanding and a practical/conceptual "big picture" understanding of how the system behaves and of all of the interactions between the equipment and components that make up the system. Power systems consist of hundreds or thousands of "buses" or nodes, and the network equations dealt with may have thousands of variables. New smart grid technologies, operational complexities imposed by deregulation of the power industry, lessons learned from major blackouts, NERC system security/reliability concerns, installation of distributed generation, application of FACTS, micro-grid control strategies for islanded systems, and other state-of-the-art equipment has renewed the need for sound analysis, simulation, and design skills.

Upon successful completion of this course, students will be able to correctly

- *Apply double subscript notation, active/passive sign convention, visualization via phasor diagrams, and form and solve systems of equations for voltages and currents in large (hundreds or thousands of nodes) networks.*
- *Perform three phase and per phase circuit calculations: sources, transformers, transmission lines, and loads - wye, delta, & zig-zag.*
- *Determine parameters and equivalent circuit models for transformers, generators, and transmission lines.*
- *Simulate RLC switching and traveling waves on transmission lines and cables.*
- *Apply symmetrical component analysis for short circuit studies.*
- *Implement Newton-Raphson power flow algorithm and apply to system planning studies.*
- *Understand Park's Transformation and begin to apply d-q analysis.*
- *Apply droop frequency control or Automatic Generator Control (AGC).*
- *Determine optimal dispatch of generation resources.*
- *Apply the swing equation to power system angle stability.*
- *Program in Matlab and utilize it as an engineering tool. Run simulations in industry-standard software packages for power flow (system planning), short-circuit studies, and transient (time domain) studies.*

Grading Scheme

Grading System (Note: This is an example and not a Michigan Tech standard)

Letter Grade	***Percentage***	***Grade points/credit***	***Rating***
A	90% & above	4.00	Excellent
AB	89.9% – 85%	3.50	Very good
B	84.9% – 80%	3.00	Good
BC	79.9% – 75%	2.50	Above average
C	74.9% – 70%	2.00	Average
CD	69.9% – 65%	1.50	Below average
D	64.9% - 60%	1.00	Inferior
F	59.9% and below	0.00	Failure
I	Incomplete; given only when a student is unable to complete a segment of the course because of circumstances beyond the student's control.		
X	Conditional, with no grade points per credit; given only when the student is at fault in failing to complete a minor segment of a course, but in the judgment of the instructor does not need to repeat the course. It must be made up by the close of the next semester or the grade becomes a failure (F). A (X) grade is included in the grade point average calculation as a (F) grade.		

Grading Policy

Grades will be based on the following:

Course Component	**Weight**
Homework & Software Applications	37.5%
Midterm Exam	25%
Class attendance/participation	7.5%
Term Project, milestones & deliverables	30%
Total	**100%**

Late Assignments

Late penalties may be assigned - typically 10% off for each day it delays your forward progress in the course (think critical path schedule) or delays return of graded homework. Please pre-arrange any known absence and we can try to accommodate. Please note that job interviews are not excused absences. Plan ahead for least impact to project and project partners.

Course Policies

Assignments will be given out regularly - typically one larger one each week. You will typically have 5-7 days to complete an assignment, depending on how long it is. Solutions will be uploaded to Canvas in pdf format. You may use a scanner or an app such as Adobe Scan. A homework cover sheet shall be attached to all submissions, see https://pages.mtu.edu/~bamork/ee5200/HMWKSUBM.pdf

For your original hardcopy solution: If there is not already enough room on the assignment sheet, attach additional sheets of 8½ x 11 engineering grid paper or plain white paper (not torn-out notebook paper), stapled in upper left corner. Show all work, illustrate by schematic or a diagram, provide assumptions, give equations before substitution, show all units and underline or circle all answers. If attaching computer simulation results, highlight important results and provide complete annotations so that the significance of the results is clear - let's develop the archival documentation habits of a design engineer - could someone else reconstruct your work? Neatness and clarity are important. You are strongly encouraged to discuss concepts and theory related to homework via the course e-mail forum, and to initiate discussion about current events and technical issues related to course material. Send e-mail to ee5200-L@mtu.edu to reach all of us and start a discussion.

Academic Integrity Rules

The university's policy on Academic Integrity (informally known as the "cheating policy")shall be strictly enforced http://www.admin.mtu.edu/usenate/policies/p109-1.htm (Note: giving away or uploading course materials (intellectual property) is a violation.)

Students may discuss homework assignments on a concept level (if authorized), but are expected to individually work/write/solve any and all submitted work. Any work not your own must be cited. Please restrict all use of cell phones and/or other electronic devices during class to course-related activities. The focus of class time should be interaction between students, and with the instructor. Any other unauthorized activities are likely to be distracting to other students and the instructor. Please make sure to bring a calculator with you to class, so you can be appropriately prepared for assignments and/or exams. Because it's important to everyone at Michigan Tech that academic standards be maintained, academic misconduct may result in an appropriate conduct sanction/educational condition(s) imposed by the Office of Academic and Community Conduct and/or in an academic penalty (lower grade/failing grade) imposed by the faculty.

University Policies

Student work products (exams, essays, projects, etc.) may be used for purposes of university, program, or course assessment. All work used for assessment purposes will not include any individual student identification.

Michigan Tech has standard policies on academic misconduct and complies with all federal and state laws and regulations regarding discrimination, including the Americans with Disabilities Act of 1990. For more information about reasonable accommodations or equal access to education or services at Michigan Tech, please call the Dean of Students Office at 906-487-2212. More information is also available from the Syllabi Policies webpage [http://www.mtu.edu/ctl/instructionalresources/syllabus/syllabus_policies.html].

Well-being of Students

Michigan Tech is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. For help or to find additional resources, contact Counseling Services at 906-487-2538 or visit the Counseling Services website [http://www.mtu.edu/counseling].

Course Schedule

Schedule and Coverage (Subject to Change Depending on Learning Needs of Students):

Weekly Module (Read Material Before Class)	Lecture Date	Material Coverage (see Canvas Module for homework postings and to confirm deadlines):
0 - Ch. 1	L0 - Aug 28th	Course prepration - Study course pre-req materials. Rate your skills, fill in any pre-req gaps you may have!
1 - Ch. 1,2 Smart Grid Overview	Tues Aug 29th L2 L3 Aug 31st	Homework 1 - Due Tues Sep 12th, 9am Proper Use of "Closed" Voltage Phasor Diagrams for Graphical Analysis Basic Phasor Analsis Concepts, Practice Problems, Intro to Matlab Solutions: Ch.1 Review Probs (Complete by Sep 8th)
2 - Ch. 2,3	L4 - Sep 5th L5 - Sep 5/7th L6 - Sep 7th	CKTS homework | Answrs - Due Tues Sep 19th, 9am Mag Circuits Review Suggested Study Probs: 2.2, 2.4, 2.6, 2.8, 2.9, 2.14, 2.16, 2.17, 2.18, 2.21 (Ch.2 Soln) Transformer connections (Delta, Y, auto, zig-zag), core structure (G&S Overview) IEEE/IEC Phase Shifts (std 30° , non-std), 3-Winding Transformers, Nameplate, Schematic XFMR Homework (Due 9am Tues Sep 26th)
3 - Ch. 3	L7 - Sep 12th L8 - Sep 12/14th L9 - Sep 14th	Three-Phase network analysis, per-phase, per-unit, transformer basics. LTCs, 3-winding transformers, Factory Tests, Binary SC Impedance, star equivalent. | xls example More on 3-winding transformers, Followup on CKTS | Intro to Matlab Assignment
4 - Ch.3	L10 - Sep 19th L11 - Sep 19/21st L12 - Sep 21st	Transformers: PSs, paralleling, etc. Office Hr#2 Off-nominal turns ratio, paralleling, circuit analysis methods. Hand-written notes/examples Circuit analysis methods (cont'd); Ch.3 Sychronous Machines. SYNC Hmwk, P1 (Due Oct __th 9am) Synchronous Machines study problems (Ch.3 Soln)
5 - Ch. 3	SM - Notes L13 - Sep 26th L14 - 26th/28th L15 - Sep 28th	Ch.3 - Synchronous Machines a-b-c -- d-q-0 analysis methods (Video of Dr. Bohmann guest lecture) Synchronous Machines - d-q circuit analysis | Capability Curves Synch Machine Wrapup - physical construction, more on d-q Synch Machines recap: Over- vs. Underexcited, control via Ea and δ, Cap Curves, Faults.
6 - Ch. 4,5	L16 - Oct 3rd L17 - Oct 3/5th L18 -0 Oct 5th	Term Project Guidelines - Send short e-mail with Term Project idea by Week 7. Transmission Lines, T-Line Configs, Overhead Conductors, Overview of RLC effects, pi-equivalent, etc. Suggested Probs: 4.2, 4.5, 4.6, 4.12, 4.13, 4.14, 4.15, 4.17, 4.18, 4.21, 4.22 (Ch.4 Soln) Suggested Probs: 5.2, 5.4, 5.6, 5.8, 5.9, 5.11 (Ch.5 Soln) Self-Inductance & Mutual Inductance recap; Series Impedance: Resistance, Self Ind, Mutual Ind. Inductance for 3-phase systems of conductors using Line Constants of ATPDraw Use of Line Constants (from EMTP, Aspen, CAPE, etc) | TLIN Homework - Due Oct 25th 9am
7 - Ch. 5	L19 - Oct 10th L20 - Oct 10/12th L21 - Oct 12th	By Week 8: Submit formal outline of project with key references. Capacitance, Double-circuit lines, Zero Sequence Coupling (Ch.6 Soln) Line Charging Current, Nov 1st, 9am: TLIN2 | Answrs Hmwk (all problems + supplemental prob) Transmission Lines as a two-port network, ABCD parameters, etc.
8 - Ch. 5,6 §5.1, 5.2 ATP Quickstart ATP Tutorial Video (skip first 5:30)	L22/23 - Oct 17th Trav Wave Notes Oct 19th	ABCD parameters, shunt and series compensation, Ferranti Rise, Voltage Regulation Transmission Line Performance Issues. Short-, medium-, and long-line models Long line behaviors, Zc, propagation constants, Adding lines, xmfrs, loads, into [Y] . (Ch.7 Soln) Traveling waves - ATP Video - Sample Case in ATP Fall Break - No Lecture
9 - Ch. 6 §6.1 §6.2	L25 - Oct 24th L26 - Oct 24/26th L27 - Oct 26th	Admittance Formulations in General, [Y] vs. [Z] considerations Switching lines and equipment in and out of system, off-nominal transformers Mutual Inductance of Double-Ckt Lines; network reduction (Kron method) Network Calculations with [Y] and [Z] (Ch.8 Soln) Term Project - Submit detailed outline and nearly-complete reference list by end of week.
10 - Ch. 8,9,10	L28 - Oct 31st L29 - Oct 31/Nov 2nd L30 - Nov 2nd Fault Studies	Fault Calculation using [Z], Current contributions using [Y]. X/R Ratio, Circuit Breaker Ratings, Practical [Ybus] method for SC calculation. Practical [Ybus] and Z[bus] methods for SC calculation. (Ch.10 Soln) (Ch.11 Soln) Wrapup on balanced 3-ph fault calcs, circuit breaker ratings, fuses. Sequence Networks, unsymmetrical faults (Short Circuit Exercises) Due Tues Nov 15th, 9am. Intro to Planning Studies (Loadflow Exercises due 9am Nov 30th), Contingencies (Ch.14 Soln) Calculation Methods for Fault Studies (Dr. Bohmann video lecture is also in Modules area of Canvas) Term Project - Journal paper outline (and begin analysis) by Mon Nov 8th.
11 - Ch. 7 NR Details Aspen Tutorial Aspen Video	L31 - Nov 8th L32 - Nov 8/10th L33 - Nov 10th	Intro to Loadflow, see also "NR Details" and 17-bus New Zealand case (Example Cases below) Intro to Loadflow, Aspen software, : [Sample 5-bus system | Ch.9 Soln Wrapup on Loadflow - Remedial actions for planning study, Contingencies, Security.
12 - Ch. 12 Gen/Grid Operation	L34 - Nov 15th L35 - Nov 15/17th L36 -Nov 17th	Term Project - By Mon Dec 5th (end of Week 13), submit final draft of journal paper analysis Frequency control, droop, AGC, unit commitment (Ch.13 Soln) Generator Paralleling and other operational issues. Homework Syst_Op - due Dec __th. Economic Dispatch - lossless; Intro to Dispatch - Hand Notes

Fall Break	Nov 20st - 24th	Thanksgiving Recess - Enjoy. Come back refreshed and ready
13 - Ch. 12	L37 - Nov 29th L38 - Nov 29th/Dec 1st L39 - Dec 1st	Economic Dispatch derivation and calculatioins. Dispatch Exercises - Team Exercise. Accepted latest Dec10th 9am Economic Dispatch, example of simplistic lossless case; Economic Dispatch including losses. Economic Dispatch including losses. System Stability (Ch.12 Soln) Submit final Journal Paper Analysys and short .ppt presentation or "mini-lecture" by Mon Dec 5th.
14 - Ch. 11 System Stability	L40 - Dec 6th L41 - Dec 6/8th L42 - Dec 8th	(Ch.16 Soln) Full Set of Stability Notes | Stability Exercises (not collected) | Stability Exer Soln System Stability, Swing Equation, Out-of-Step problem Power System Protection (EE5223) - basic overview, building on EE5200. Overview of Smart Grid Technologies. Term Project - Final Report is due Wed Dec 13th 10am; PowerPoint slides due 5pm Wed Dec 13th.
Finals Week	Thurs Dec 14th	Term Project Presentations TBC, Thurs Dec 14th, 8:00 am, Online: Zoom. Attendance mandatory.