ELEC4612
Power System Analysis
Course Outline – Semester 1, 2016

Never Stand Still | Faculty of Engineering | School of Electrical Engineering and Telecommunications

Course Staff

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Consultations: You are encouraged to ask questions on the course material, after the lecture class times, rather than via email. You are strongly encouraged to use the course discussion forums in Moodle. Lecturer consultation times will be advised during lectures. You are also welcome to email the lecturer or laboratory demonstrator, who can answer your questions on this course and can also provide you with consultation times. ALL email enquiries should be made from your student email address with ELEC4612 in the subject line, otherwise they will not be answered.

Keeping Informed: Announcements may be made during classes, via email (to your student email address) and/or via Moodle https://moodle.telt.unsw.edu.au/login/index.php. Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

Course Summary

Contact Hours

The course consists of 3 hours of lectures, a 1-hour tutorial, and a 3-hour laboratory session each week. The tutorial sessions commence from week 2 and laboratory sessions from week 3. Pre-recorded lecturers on selected topics will be made available. Some of the topics will be taught using the flipped-mode teaching model. The details are available in the draft teaching plan.

	Day	**Time**	**Location**
Lectures	Monday	5pm - 6pm	Design studio, L5, J17
	Wednesday	4pm – 6pm	Except on Mon 14 Mar - Ritchie Theatre, LG, G19
Laboratory	Tue, Thu, Fri	3 hours	EE214, L2, G17
Tutorials	Monday	1pm – 2pm	EE418, L4, G17
	Wednesday	11am – 12pm	MacauleyTheatre, L1, E15

Context and Aims

Context: Power systems are complex networks of generators and loads interconnected via transmission lines and various types of equipment and apparatus (transformers, switchgear, etc). An overview of modern power systems meeting present and future challenges involves understanding the fast changing structure of this system, the behaviour of its components under steady state, and dynamic and transient conditions. The course helps with an understanding to evaluate the response of this complex system to variation of loads, and to determine how this system can be controlled to supply the loads reliably, while it is economical and safe to the environment.

Aims: The course will provide students with essential knowledge in the mathematical techniques to analyse power systems, both under steady state and dynamic conditions.

Topics covered comprise: review of the basic concepts used in power system analysis: phasors, complex power, three phase systems and per-unit; application of network matrices techniques and power flow analysis to study the steady-state and dynamic behaviour of power systems; power system fault calculations including: symmetrical components, symmetrical faults, and unsymmetrical faults; power system stability by introduction of swing equation, and a single-machine-infinite-bus analysis; power system control and economic dispatch.

Indicative Lecture / Tutorial / Laboratory Schedule

Week No.	Lecture Topic	Lab exercise	Tutorial
1	Overview of power systems engineering, Three phase systems	-	-
2	Representation of power system, per unit quantities, change of base, Power system modelling	-	Even week group - Tut 1 (3-phase)
3	Types of buses, formation of power flow equations	Odd week group – Lab 1: Introduction to PowerWorld Simulator	Odd week group - Tut 1
4	Ybus matrix building – video & numerical exercises **Quiz (23/3)**	Even week group – Lab 1	-
5	Power flow studies – Gauss-Seidel	Odd week group – Lab 2: Power flow analysis	-
6	Newton-Raphson methods (**Flipped mode**)	Even week group – Lab 2	Even week group - Tut 2 (Power Flow)
7	Symmetrical Fault Analysis	Odd week group – Lab 3: Fault analysis	Odd week group - Tut 2
8	**Mid-session test (27/4)**	Even week group – Lab 3	Even week group - Tut 4 (Faults)
9	Asymmetrical Fault Analysis	Odd week group – Lab 4: Transient stability analysis	Odd week group - Tut 4
10	Power System Stability (**Flipped mode**)	Even week group – Lab 4	Even week group -Tut 5 (Stability)
11	Economic dispatch	Odd week group – Lab 5: Economic dispatch	Odd week group - Tut 5
12	Power System control (**Flipped mode**)	Even week group – Lab 5	Even week group -Tut 6 (Economic Dispatch)
13	Overview of Smart Grids / Revision	Practical test; Lab report due (1/6).	Odd week group Tut 6

Assessment

Laboratory Practical Experiments	5%
Lab Exam	10%
Lab Report	5%
Mid-Semester Exam	15%
Quiz (MCQ)	5%
Final Exam (3 hours)	60%

Course Details

Credits

This is a 6 UoC course and the expected workload is 10–12 hours per week throughout the 13 week semester.

Relationship to Other Courses

The course is a fourth year professional elective offered to students following a BE (Elec. Eng.) course at UNSW. The course gives the foundations for power system network analysis and design; as such, the course would normally be taken concurrently with thesis work in the energy systems area.

Pre-requisites and Assumed Knowledge

The pre-requisite for the course is ELEC3105, Electrical Energy. It is further assumed that the students have good computer literacy and mathematical skills.

Following Courses

Some of the topics covered in this course are expanded in more details in a post-graduate course ELEC9715, Electricity Industry Operation and Control. This is one of the specialization courses for a Master degree in Engineering Science (Energy Systems).

Learning outcomes

After successful completion of this course, you should be able to:

1. Model major types of components used in electrical power systems.
2. Calculate the steady-state power flow in a power system.
3. Analyse different types of short-circuit faults.
4. Calculate the power system dynamics and its stability.
5. Determine the economic dispatch in a power system.
6. Understand power system control.
7. Understand smart grid structure and operation.

This course is designed to provide the above learning outcomes which arise from targeted graduate capabilities listed in ***Appendix A***. The targeted graduate capabilities broadly support the UNSW and Faculty of Engineering graduate capabilities (listed in ***Appendix B***). This course also addresses the Engineers Australia (National Accreditation Body) Stage I competency standard as outlined in ***Appendix C***.

Syllabus

An overview of modern power systems. Review of the basic concepts used in power system analysis: phasors, complex power, three phase systems and perunit methodology. Modelling circuit of power system components including transformers, generators, transmission lines and loads. Steady state and dynamic behaviour of power systems. Network matrices and power flow analysis. Power system fault calculations: symmetrical components, symmetrical faults, unsymmetrical faults. Power system stability: swing equation, multimachine applications. Power system control, economic dispatch. Smart Grid Overview.

Teaching Strategies

Delivery Mode

The course consists of the following elements: lectures, laboratory work, home work, and tutorials.

The teaching in this course aims at establishing a good fundamental understanding of the areas covered using:

- Formal face-to-face lectures, which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding;
- Tutorials, which allow for exercises in problem solving and allow time for you to resolve problems in understanding of lecture material;
- Laboratory sessions, which support the formal lecture material and also provide you with practical construction, measurement and debugging skills;
- Flipped mode teaching with related quiz and group exercises on selected topics (as outlined in the draft schedule), which help in prior learning and sound understanding of the topics.
- In addition, on 16/3/16 and 21/3/16, the face-to-face lectures will be replaced by video content and related numerical analysis to be completed by students at their own pace. The students are expected to go through these materials that will be followed by a MCQ test on 23/3.

Learning in this course

You are expected to attend <u>all</u> lectures, tutorials, labs, and mid-semester exams in order to maximise learning. You must prepare well for your laboratory classes and your lab work will be assessed. In addition to the lecture notes/video, you should read relevant sections of the recommended text. Reading additional texts will further enhance your learning experience. Group learning is encouraged and organised during the flipped mode teaching sessions. UNSW *assumes* that self-directed study of this kind is undertaken in addition to attending face-to-face classes throughout the course.

Tutorial classes

You should attempt all of your problem sheet questions in advance of attending the tutorial classes. The importance of adequate preparation prior to each tutorial cannot be overemphasised, as the effectiveness and usefulness of the tutorial depends to a large extent on this preparation. Group learning is encouraged. Answers for these questions will be discussed during the tutorial class and the tutor will cover the more complex questions in the tutorial class. In addition, during the tutorial class, 1-2 new questions that are not in your notes may be provided by the tutor, for you to try in class. These questions and solutions may not be made available on the web, so it is worthwhile for you to attend your tutorial classes to gain maximum benefit from this course.

Laboratory program

The laboratory schedule is deliberately designed to provide practical, simulation-based exposure to the concepts conveyed in lectures soon after they are covered in class. You are required to attend laboratory from Week 3 to Week 12. Laboratory attendance WILL be kept, and you MUST attend at least 80% of labs.

Laboratory Exemption

There is no laboratory exemption for this course. Regardless of whether equivalent labs have been completed in previous courses, all students enrolled in this course for Semester 1, 2016 must take the labs. If, for medical reasons, (note that a valid medical certificate must be provided) you are unable to attend a lab, you will need to apply for a catch-up lab during another lab time, as agreed by the laboratory demonstrator.

Assessment

The assessment scheme in this course reflects the intention to assess your learning progress through the semester. Ongoing assessment occurs through the lab checkpoints (see lab manual), lab exams and the mid-semester exam.

Laboratory Assessment

Laboratories are primarily about learning, and the laboratory assessment is designed mainly to check your knowledge as you progress through each stage of the laboratory tasks. You are required to maintain a lab book for recording your observations. A lab book is an A4 size notebook containing a mix of plain pages and graph sheets. You can purchase your own lab book from any stores.

It is essential that you complete the laboratory preparation before coming to the lab. You are required to write the aim of the experiment and complete all theoretical calculations. This will be verified and signed by your demonstrators in the lab. You will be recording your observations/readings in your lab book first and then completing and showing the results on the PC screen before leaving the lab.

After completing each experiment, your work will be assessed by the laboratory demonstrator. Both the screen and your lab book will be assessed by the laboratory demonstrator.

Assessment marks will be awarded according to your preparation (completing set preparation exercises and correctness of these or readiness for the lab in terms of pre-reading), how much of the lab you were able to complete, your understanding of the experiments conducted during the lab, and your understanding of the topic covered by the lab.

Laboratory Exam

To check that you have achieved the practical learning outcomes for the course, you will be examined in the laboratory. Laboratory Exams are closed book practical exams that include simulations and analytical calculations. The exam questions will be based on what you have learned in your laboratory classes and lectures, and marks will be awarded for the correct understanding of practical and relevant theoretical concepts, correct simulation of the experiment, and correct interpretation of measured results.

Lab Report

There will be only one laboratory report to submit for the course. This is a group report (3 in a group) and is worth 5% of the total mark. The following are to be noted.

- The report can be on any of the experiments (2, 3, 4 or 5).
- The report should follow the usual format, i.e. introduction, background theory, experimental results, analysis, discussion, conclusion, and reference.
- The report is to be submitted before **5 pm Wednesday June 1st, 2016**. Submission is via the assignment submission chute at the EE&T School Office.
- Since this work counts toward your formal assessment for this course, you are required to complete the details on the assignment cover sheet and sign the declaration. This form

must be attached to the front of your report. The form can be downloaded from the School web site.
- Please ensure that individual contributions for the report are clearly marked. Although this is a group report, marks will be allotted as per individual contributions. So make sure there is equal team work.
- Marks are allocated as follows: background theory (10%), experimental results (30%), analysis and discussion (30%), presentation (15%), and language (15%).
- Any report submitted after the due date/time is liable to have marks deducted (10% for every day late, including weekends). Delays on medical grounds are accepted on submission of special consideration.

Also be aware that plagiarism is considered a very serious academic misconduct which will result in zero marks for the course!

MCQ Quiz

The quiz is based on multiple choice questions. This helps to test the basic understanding of the course material, especially the fundamentals. Questions may be drawn from any course material up to the end of week 4 (topics include up to Ybus building). This may be paper based or online and the test has to be undertaken in person in the venue allocated (attendance will be monitored). The test is of 60 minute duration, closed-book, held during lecture time in **Week 4 Wednesday (23/3)**. Announcement regarding the test venue and other details will be available in the Moodle near to this time.

Mid-Semester Exam

The mid-session examination tests your general understanding of the course material, and is designed to give you feedback on your progress through the analytical components of the course. Questions may be drawn from any course material up to the end of week 7 (topics include up to Symmetrical Fault Analysis). It may contain questions requiring some (not extensive) knowledge of laboratory material, and will definitely contain numerical and analytical questions. Marks will be assigned according to the correctness of the responses. The test is of 75 minute duration, closed-book, held during lecture time in **Week 8 Wednesday (27/4)**. Announcement regarding the test venue will be available in the Moodle near to this time.

Final Exam

The exam in this course is a standard closed-book 3 hours written examination, covering all aspects of the course that have been presented in the lectures and tutorials. The exam format will be similar to the previous years' examinations. The examination tests analytical and critical thinking and general understanding of the course material in a controlled fashion.

Please note that you must pass the final exam in order to pass the course.

Relationship of Assessment Methods to Learning Outcomes

	Learning outcomes						
Assessment	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Laboratory practical assessments	✓	✓	✓	✓	✓	-	-
Lab exam	✓	✓	✓	✓	✓	-	-
Lab Report	✓	✓	✓	✓	✓	-	-
MCQ Quiz	✓	-	-	-	-	-	-
Mid-semester exam	✓	✓	✓	-	-	-	-
Final exam	✓	??	✓	✓	✓	✓	✓

Course Resources

Textbooks

Prescribed textbook

- J.D. Glover, and M.S Sarma, T.J. Overbye, *Power System Analysis and Design*, 5th Edition (SI), Cengage Learning, 2012.

Reference books

- Stevenson, W D: *Elements of Power System Analysis,* 4th edition, McGraw-Hill, 1982
- P.Kundur, "Power System Stability and Control", McGraw, 1994.
- Olle. I. Elgerd, 'Electric Energy Systems Theory – An Introduction', McGraw Hill, 2003.
- B.M. Weedy, and B. Cory, *Electric Power Systems*, 4th edition, Wiley, 1998.
- N. Mohan, *First Course on Power Systems*, Minneapolis, 2006.
- T.R. Bosela, *Electrical Power System Technology*, Prentice-Hall, 1997.
- J. Eaton, and E. Cohen, *Electric Power Transmission Systems,* 2nd ed., Prentice-Hall.
- M.E. El-Hawary, *Electrical Power System Design and Analysis*, Prentice-Hall, 1983.
- T. Gonen, *Electric Power Distribution System Engineering*, McGraw-Hill, 1986.
- P. Hasse, *Overvoltage Protection in Low Voltage Systems*, Peter Peregrinus, 1992.
- F. Kussy, and J. Warren, *Design Fundamentals for Low Voltage Distribution and Control*, Marcel Dekker, 1987.
- J.C. Whitaker, *AC Power Systems Handbook*, CRC Press, 1991.
- Greenwood, A: *Electrical Transients in Power Systems*. John Wiley.
- Wood, A & Wollenberg, B: *Power Generation Operation & Control*, Wiley,1984

On-line resources

Moodle

As a part of the teaching component, Moodle will be used to disseminate teaching materials, host forums and occasionally quizzes. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.

Mailing list

Announcements concerning course information will be given in the lectures and/or on Moodle and/or via email (which will be sent to your student email address).

Other Matters

Academic Honesty and Plagiarism

Plagiarism is the unacknowledged use of other people's work, including the copying of assignment works and laboratory results from other students. Plagiarism is considered a form of academic misconduct, and the University has very strict rules that include some severe penalties. For UNSW policies, penalties and information to help you avoid plagiarism, see http://www.lc.unsw.edu.au/plagiarism. To find out if you understand plagiarism correctly, try this short quiz: https://student.unsw.edu.au/plagiarism-quiz.

Student Responsibilities and Conduct

Students are expected to be familiar with and adhere to all UNSW policies (see https://my.unsw.edu.au/student/atoz/ABC.html), and particular attention is drawn to the following:

Workload

It is expected that you will spend at least **ten to twelve hours per week** studying a 6 UoC course, from Week 1 until the final assessment, including both face-to-face classes and *independent, self-directed study*. In periods where you need to need to complete assignments or prepare for examinations, the workload may be greater. Over-commitment has been a common source of failure for many students. You should take the required workload into account when planning how to balance study with employment and other activities.

Attendance

Regular and punctual attendance at all classes is expected. UNSW regulations state that if students attend less than 80% of scheduled classes they may be refused final assessment.

General Conduct and Behaviour

Consideration and respect for the needs of your fellow students and teaching staff is an expectation. Conduct which unduly disrupts or interferes with a class is not acceptable and students may be asked to leave the class.

Work Health and Safety

UNSW policy requires each person to work safely and responsibly, in order to avoid personal injury and to protect the safety of others.

Special Consideration and Supplementary Examinations

You must submit all assignments and attend all examinations scheduled for your course. You should seek assistance early if you suffer illness or misadventure which affects your course progress. All applications for special consideration must be **lodged online through myUNSW within 3 working days of the assessment**, not to course or school staff. For more detail, consult https://my.unsw.edu.au/student/atoz/SpecialConsideration.html.

Continual Course Improvement

This course is under constant revision in order to improve the learning outcomes for all students. Please forward any feedback (positive or negative) on the course to the course convener or via the Course and Teaching Evaluation and Improvement Process. You can also provide feedback to ELSOC who will raise your concerns at student focus group meetings. As a result of previous feedback obtained for this course and in our efforts to provide a rich and meaningful learning experience, we have continued to evaluate and modify our delivery and assessment methods. The lecture hours have retained at three hours per week similar to last year. Additional Quiz and assessments have been introduced. Based on the feedback from previous year on flipped mode teaching, this year the learning space is organised in a collaborative environment in the design studio (J17). This will enable peer-to-peer interaction during the problem solving sessions.

Administrative Matters

On issues and procedures regarding such matters as special needs, equity and diversity, occupational health and safety, enrolment, rights, and general expectations of students, please refer to the School and UNSW policies:
http://www.engineering.unsw.edu.au/electrical-engineering/policies-and-procedures
https://my.unsw.edu.au/student/atoz/ABC.html

Appendix A: Targeted Graduate Capabilities

Electrical Engineering and Telecommunications programs are designed to address the following targeted capabilities which were developed by the school in conjunction with the requirements of professional and industry bodies:

- The ability to apply knowledge of basic science and fundamental technologies;
- The skills to communicate effectively, not only with engineers but also with the wider community;
- The capability to undertake challenging analysis and design problems and find optimal solutions;
- Expertise in decomposing a problem into its constituent parts, and in defining the scope of each part;
- A working knowledge of how to locate required information and use information resources to their maximum advantage;
- Proficiency in developing and implementing project plans, investigating alternative solutions, and critically evaluating differing strategies;
- An understanding of the social, cultural and global responsibilities of the professional engineer;
- The ability to work effectively as an individual or in a team;
- An understanding of professional and ethical responsibilities;
- The ability to engage in lifelong independent and reflective learning.

Appendix B: UNSW Graduate Capabilities

The course delivery methods and course content directly or indirectly addresses a number of core UNSW graduate capabilities, as follows:

- Developing scholars who have a deep understanding of their discipline, through lectures and solution of analytical problems in tutorials and assessed by written examinations.
- Developing rigorous analysis, critique, and reflection, and ability to apply knowledge and skills to solving problems. These will be achieved by the laboratory experiments and interactive checkpoint assessments and lab exams during the labs.
- Developing capable independent and collaborative enquiry, through a series of tutorials spanning the duration of the course.
- Developing ethical practitioners who are collaborative and effective team workers, through group activities, lab work and tutorials.

Appendix C: Engineers Australia (EA) Professional Engineer Competency Standard

	Program Intended Learning Outcomes	
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals	✓
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing	✓
	PE1.3 In-depth understanding of specialist bodies of knowledge	✓
	PE1.4 Discernment of knowledge development and research directions	✓
	PE1.5 Knowledge of engineering design practice	
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice	
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving	✓
	PE2.2 Fluent application of engineering techniques, tools and resources	✓
	PE2.3 Application of systematic engineering synthesis and design processes	
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects	
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability	✓
	PE3.2 Effective oral and written communication (professional and lay domains)	✓
	PE3.3 Creative, innovative and pro-active demeanour	✓
	PE3.4 Professional use and management of information	✓
	PE3.5 Orderly management of self, and professional conduct	
	PE3.6 Effective team membership and team leadership	✓