ELEC4611
Power System Equipment

Course Outline – Semester 1, 2017

Australia's Global University | Faculty of Engineering | School of Electrical Engineering and Telecommunications

1. Course Staff

Course Convener: A/Prof. Toan Phung, Room MSEB547, toan.phung@unsw.edu.au
Tutor: A/Prof. Toan Phung
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Consultations: You are encouraged to ask questions on the course material, after the lecture class times in the first instance, rather than via email. In addition, you can make use of the open consultation time between 12-1pm daily. You may seek consultation at other times by prior appointment. All email enquiries should be made from your student email address with ELEC4611 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 online learning and teaching platforms – in this course, we will use 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.

2. Course Summary

Contact Hours

The course consists of 3 hours of lecture each week, a 1-hour tutorial each fortnight, and a 3-hour laboratory session each fortnight.

	Day	Time	Location
Lectures	Monday Thursday	15-17 14-15	CLB 8 CLB 8
Tutorials	Thursday (even weeks) Thursday (even weeks) Thursday (odd weeks)	15-16 16-17 16-17	Mat 310 Mat 103 TETB G17
Labs	Monday (even, odd weeks) Monday (even, odd weeks) Tuesday (even, odd weeks) Tuesday (even, odd weeks) Wednesday (even, odd weeks) Wednesday (even, odd weeks) Friday (even, odd weeks)	09-12 12-15 09-12 15-18 09-12 13-16 09-12	ElecEng 115 ElecEng 115 ElecEng 115 ElecEng 115 ElecEng 115 ElecEng 115 ElecEng 115

Context and Aims

Context: Power Engineering is concerned with the generation, transmission, distribution and utilization of electrical energy. Large power systems are interconnected physical networks of many different types of equipment and apparatus: synchronous generators for generating electricity, power transformers for changing the voltage levels, overhead transmission lines, underground cables, metering and control equipment, switchgear for connection/disconnection, high-voltage insulators, etc. Because of operating conditions (different voltage and power levels) each equipment type in turn comprises many different designs.

Aims: The course aims to provide the student with essential knowledge in high-voltage power system components and equipment such as their functions, physical design, factors affecting their operation, and diagnostic techniques to monitor their condition.

Indicative Schedule

Period	Activities
Week 1	Course overview Topic 1: Equipment and components used in electrical power systems
Week 2	Topic 2: Insulation of HV equipment - electric stress calculation, field grading
Week 3	Topic 2 (cont.) Lab 1: Fuses and circuit breakers (odd week group); Tutorial set 1.
Week 4	Topic 3: Overcurrents - electrodynamic forces, thermal effects, protection. Lab 1 (even week group); Tutorial set 1.
Week 5	Topic 3 (cont.) Lab 2: Surge propagation in electrical systems; Tutorial set 2.
Week 6	Topic 4: Overvoltages - steady-state and transient, recovery voltage, current chopping. Lab 2 (even week group); Tutorial set 2.
Week 7	Topic 4 (cont.): surge propagation on transmission lines or cables, overvoltage protection, insulation coordination. Lab 3 (Non-destructive HV testing); Tutorial set 3. Mid-Semester Exam
Mid-semester break	
Week 8	Topic 5: Equipment rating: thermal equivalent circuit, steady-state temperature rise calculation Lab 3 (even week group); Tutorial set 3.
Week 9	Topic 5 (cont.) Lab 4 (Impulse voltages in electrical systems); Tutorial set 4.
Week 10	Topic 6: High-voltage testing techniques and insulation assessment. Lab 4 (even week group); Tutorial set 4.
Week 11	Topic 6 (cont.) Lab 5 (Electric stress finite element analysis); Tutorial set 5.
Week 12	Topic 7: Insulation materials, dielectric properties. Practical case studies. Lab 5 (even week group); Tutorial set 5.
Week 13	Revision Catch-up lab Lab report due (15 June)

Note that depending on your enrolment, laboratory and tutorial classes start from week 3 for odd classes or week 4 for even classes. The above schedule is provisional and may be updated during the semester (this version is dated 20/2/17). You should attend lectures and regularly check the course website for possible updates.

Assessment

Laboratory Practical Experiments	10%
Laboratory Report	5%
Mid-Semester Exam	25%
Final Exam (2 hours)	60%

Assessment task due dates are given in the course schedule above except for the final exam (TBA). Note that there are no marks awarded for tutorial work.

3. 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

This is a fourth year course in the EE&T School. It is a professional elective course for students following a BE (Electrical or Telecommunications) program and other combined degree programs. The course gives the foundations in power system equipment design and technology; as such, it may be taken concurrently with thesis work in the energy systems area

Pre-requisites and Assumed Knowledge

The pre-requisite for this course is ELEC3105, Electrical Energy. It is essential that you are familiar with ELEC3105, in particular fundamental aspects of electrical energy transmission and distribution systems; basic concepts used in power circuit analysis. It is further assumed that the students are familiar with MatLab, and have a good computer literacy.

Following Courses

Many of the topics covered in this course are expanded in more details in a post-graduate course ELEC9712, High Voltage Systems. This is one of the specialisation courses in Energy Systems for a Master of Engineering or Engineering Science program.

Learning outcomes

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

1. Understand the functions of various types of equipment and major components used in electrical power systems.
2. Understand the different effects (thermal, mechanical, electrical) caused by short-circuit faults and over-voltage transients.
3. Calculate the steady-state thermal ratings of power cables and overhead lines.
4. Calculate the electric stress and explain the dielectric design of high-voltage components.
5. Apply appropriate electrical/physical/chemical test methods for insulation assessment.

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

Overview of electricity supply network infrastructure; Electrical insulation in power system equipment and components: materials and dielectric properties, electric stress calculation, field grading; Overcurrent: electrodynamic forces, offset current transient, short-circuit thermal effects, protection (fuses, circuit breakers); Overvoltage: steady-state and transient, recovery voltage, surge propagation, protection (arresters), insulation coordination; Equipment rating: thermal equivalent circuit, steady-state temperature rise; High-voltage testing: power frequency overvoltage, lightning and switching impulse; Diagnostic methods for insulation assessment: insulation resistance, dielectric dissipation factor, partial discharge, dissolved gas-in-oil analysis.

4. Teaching Strategies

Delivery Mode

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;

Learning in this course

You are expected to attend all lectures, tutorials, labs, and mid-semester exams in order to maximize 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 also encouraged. UNSW *assumes* that self-directed study of this kind is undertaken in addition to attending face-to-face classes throughout the course.

- **Lectures**: Students are expected to prepare themselves for the lectures. The lectures provide the students with a focus on the core material in the course. Generic features and functions of various types of major equipment and apparatus required in a typical power system network are explained. This is further illustrated with practical examples from Australian power utility installations. Mathematical tools and computer-aided analysis are then used to convey a qualitative understanding of critical issues affecting the operation of power system equipment. This in turn leads students to an appreciation of the equipment ratings, choice of particular insulation materials and designs. The basic principles covering the high-voltage testing and condition monitoring of equipment are presented and then illustrated by examining a wide array of diagnostic devices that are currently being used in the power industry.
- **Tutorial classes**: The tutorial sessions provide personal assistance to students in solving problems. A total of 5 problem sets will be presented throughout the semester and some of these will be worked through during the tutorials. The tutorials take the student through all critical course topics and aim to exercise the students' analytical and critical thinking skills. Students are strongly encouraged to complete all the tutorial problems as these help to develop in-depth quantitative understanding of the course materials. During tutorials, students will also be invited to raise any concepts or topics covered in lectures with which they are experiencing difficulty and required another explanation. Tutorials are also opportunities for interactive discussion on any questions, issues or topics relevant to the course.
- **Laboratory work**: The laboratory work provides the student with hands-on experience and exposure to practical high-voltage testing, measurement and reporting. Students will work in groups of three. There will be five three-hour experiments in total. The experiments will contain material that may not be covered in lectures until after the experiment is done. This requires that the laboratory sheets must be read thoroughly before the laboratory session. Students must come prepared for the laboratory sessions; the laboratory sessions are short, so this is only possible way to complete the given tasks. Laboratory attendance WILL be kept, and you MUST attend all 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 coordinator.
- **Home work**: The class lectures can only cover the course material to a certain depth; students must down-load the lecture notes (from the course web site) and reflect on its content as preparation for the lectures to fully appreciate the course material. Further research and reading

from the recommended list of text/reference books are also required. The ability to read the literature, identify relevant parts and extract critical information with the aid of the lectures is regarded as an essential component of this course. Also, a significant component of homework is preparation for laboratory, tutorials, and writing laboratory reports.

5. Assessment

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

Laboratory Work

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

Assessment of the laboratory work will be on the basis of (i) an oral examination conducted by the demonstrators during each laboratory session, and (ii) a detailed written report to be submitted at the end of the semester on one of the experiments

Students are required to attend all the scheduled laboratory sessions. After completing each experiment, your work will be assessed by the laboratory demonstrator. Assessment marks will be awarded according to your preparation (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, the quality of the information you write during your lab work, and your understanding of the topic covered by the lab.

A group report on an experiment is to be submitted (see due date on schedule). Late submissions carry a 50% penalty for the first week and will not be accepted beyond one week delay. Delays on medical grounds are accepted. The reports must be submitted online via the course Moodle as one pdf file including a cover-page declaring that the work detailed in the report is entirely that of the named student(s) only. Marks are awarded based on sound explanation of the experiment concept and theoretical analysis, correct measurement results and their interpretation.

A satisfactory performance (50% or greater) in the laboratory work is a necessary requirement to pass this course, irrespective of the marks obtained in the other components.

Mid-Semester Exam

This is a closed-book 1.5-hour written examination, held during the lecture time in week 7. The test is intended to get early feedback on student performance. It will definitely have numerical and analytical questions as well as descriptive type questions, drawn from any course material up to the end of week 5. Assessment is a graded mark according the correct fraction of answers to the test questions.

Final Exam

The exam in this course is a standard closed-book 2-hour written examination, covering all aspects of the course that have been presented in the lectures, laboratory experiments and tutorials. University approved calculators are allowed. 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. Assessment is a graded mark according to the correct fraction of the answers to the exam questions. *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**
Laboratory practical assessments	✓	✓		✓	✓
Written report	✓	✓		✓	✓
Mid-semester exam	✓	✓	✓	✓	✓
Final exam	✓	✓	✓	✓	✓

6. Course Resources

Textbooks

Prescribed textbook: there are no prescribed textbooks for the course. A set of lecture notes developed by the convener will be made available for download from the course web site.

Reference books: the following references will each cover parts of the course only. They are listed in no particular order of importance:

- E. Kuffel, W.S. Zaengl, and J. Kuffel, *High Voltage Engineering: Fundamentals*, 2nd ed., Butterworth-Heinemann, 2000.
- P. Gill, Electrical *Power Equipment Maintenance and Testing*, 2nd ed., CRC Press, 2008.
- H.M. Ryan (ed.), *High Voltage Engineering and Testing*, 2nd ed., London : Institution of Electrical Engineers, c2001.
- R.E. James and Q. Su, *Condition Assessment of High Voltage Insulation in Power System Equipment*, IET, 2008.
- W. Hauschild and E. Lemke, *High-Voltage Test and Measuring Techniques*, Springer Berlin Heidelberg, 2014.
- F.A.M. Rizk and G.N. Trinh, *High Voltage Engineering*, CRC Press, 2014.
- C.L. Wadhwa, *High Voltage Engineering*, 2nd ed., New Age International, 2007.
- T.J. Gallagher and A.J. Pearmain, *High Voltage: Measurement, Testing, and Design*, Chichester [Sussex] ; New York : Wiley, c1983.
- N.H. Malik, et al, *Electrical Insulation in Power Systems,* Marcel Dekker, 1998.
- M.S. Naidu and V Kamaraju, *High Voltage Engineering*, 2nd ed., McGraw-Hill, 1996.
- J.D. Glover, M.S. Sarma and T.J. Overbye, *Power System Analysis and Design*, 5th ed., Cengage Learning, 2012.
- B.M. Weedy, and B. Cory, *Electric Power Systems*, 4th ed., 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.

On-line resources

Moodle

The website for this course is on UNSW Moodle. It contains lecture notes, tutorials, laboratory materials, past exam papers, as well as other relevant information and announcements about this course: 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).

7. 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 https://student.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://student.unsw.edu.au/policy), 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://student.unsw.edu.au/special-consideration

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 myExperience 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 increased lecturing hours to 3 hours per week. Also, a suite of video recordings explaining laboratory experiments are produced and made available on Moodle to help students preparing before they come to laboratory classes.

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:
https://student.unsw.edu.au/guide
https://www.engineering.unsw.edu.au/electrical-engineering/resources

Appendices

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 oral assessments during the labs.
- Developing capable independent and collaborative enquiry, through a series of tutorials spanning the duration of the course.
- Developing digital and information literacy and lifelong learning skills through written report work.
- Developing ethical practitioners who are collaborative and effective team workers, through group activities (laboratory 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	✓