Term 2, 2019
Course Outline

ELEC9711
Power electronics for renewable and distributed generation

COURSE STAFF

Course Convener:	Prof. Faz Rahman, Room 405, EE building, f.rahman@unsw.edu.au
Tutor:	Dr. Kazi Saiful Alam, Room 115, kazisaiful.alam@unsw.edu.au
Laboratory Contact:	NA

Consultations: You are encouraged to ask questions on the course material, after the lecture class times in the first instance, rather than via email. Lecturer consultation times will be advised during lectures. You are welcome to email the tutor, 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 ELEC9711 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.

COURSE SUMMARY

Contact Hours

The course consists of 2x2 hours of lectures/tutorials sessions each week. Tutorial classes will be conducted during these 4 hours on topics covered prior.

Lectures/Tutorials	Day	Time	Location
"	Tuesday	6 - 8pm	Rex Vowels Theatre
"	Wednesday	6 - 8pm	Physics Theatre

Context and Aims

Power electronic converters are an essential part of renewable and distributed energy systems which include wind turbines, photovoltaics, and energy storage systems. These are also used in connecting renewable energy systems to utility grids, incorporating ability to extract the maximum available power from various sources to the grid, and address the regulation of active and reactive powers, and voltage and frequency of the grid. Distributed energy sources often are transmitted through HVDC transmission systems and then connected to the AC grid using power electronic converters. Power electronic converters in these applications also provide the means to control the flow of active and reactive powers to the electrical grid and its generation sources.

The course is aimed at students who have already been introduced to a first course in Power Electronics which covers steady-state characteristics of various AC-DC, DC-DC, and DC-AC converter circuits. The fourth year elective course ELEC4614 – Power Electronics offered by EE&T, UNSW, is such a course. The objective of ELEC9711 builds on the knowledge of these converter topologies, and a few other converters that are utilized in renewable and distributed energy systems (wind and PV), in utility applications (for example HVDC) and to further study these converters in terms of their efficiency, control characteristics, description of dynamics and their closed-loop control. Some advanced converter topologies, especially in the context of large and complex applications, which are beyond the scope of a first course in power electronics, are also treated.

The course also introduces students to computer modelling of power electronic converters and their control circuits using modern simulation platforms like LTSpice, PLECS, PSIM or SimPower in Matlab-Simulink.

Indicative Lecture Schedule

Period	Summary of Lecture Program	Hours
Week 1	Introduction to course; Review of DC-DC converter	3
Week 2	DC-DC converters continued; the Dual Active Bridge (DAB); Non-ideal switches and components and conversion efficiency;	4
Week 3	Dynamic model of converters; review of AC-DC converters. Assignment 1 on materials in weeks 1-3, **due on end week 5**	4
Week 4	Review of 2-level single and three phase inverter; Multi-level converters, CHB, MMC;	3
Week 5	Multi-level converters, CHB, MMC continued	3
Week 6	Grid connection of converters: axes transformations; PQ theories, PLLs for grid connection; Assignment 2 on materials in weeks 4-6; **due on end week 8**	3
Week 7	Grid connection of converters continued: Controller designs	3
Week 8	PV energy conversion systems; HVDC	3
Week 9	PV energy conversion systems; HVDC	3
Week 10	Wind energy conversion systems (WECS) Assignment on materials in 7-10; **due on end week 11**	3
	Total hours	**32**

Assessment

Assignments (3 in total)	40%
Final Exam (2 hours, answer 3 out of 4 questions)	60%

COURSE DETAILS

Credits

This is a 6 UoC course and the expected workload is 15 hours per week throughout the 10-week term.

Relationship to Other Courses

This is a postgraduate course in the School of Electrical Engineering and Telecommunications.

Assumed Knowledge

The assumed knowledge for this course is ELEC4614 – Power Electronics and ELEC4613 – Electric drive Systems or equivalent courses covered elsewhere. It is essential that you are familiar with the content of ELEC4614-Power Electronics which includes analysis of DC/DC, DC-AC inverter (single and three-phase) and AC-DC (single and three-phase) rectifier circuits. A good grasp of DC, AC and transient circuit analysis will assist with the course. A good understanding of Electric Drive Systems (covered in course ELEC4613) will also be presumed for further understanding of wind power conversion systems. It is further assumed that you will be familiar with computer simulations on MATLAB-Simulink and PSIM platforms.

Following Courses

NA

Learning outcomes

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

1. understand the use of power converters in PV applications
2. understand the use of power converters in wind turbines
3. understand the concept of maximum power point tracking
4. understand how real and reactive power flow can be controlled from a renewable or distributed energy resource to the utility network
5. understand the basic components of an HVDC system and the control of real power flow
6. understand power converters with non-ideal devices and elements
7. develop analytical techniques for analysing the steady-state and dynamic characteristics of converters.
8. understand the quadrant operation of various types of converters and their control requirements, selection of converters, components, etc.
9. understand how to design the hierarchical control structures for power converters and systems.
10. be able to select and design important elements of a power converter system.
11. be able to apply the theories of power electronic converters and control system design to implement power converter systems which are appropriate for specific applications.

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

Topics to be covered in this course will include: Advanced topics in DC-DC converters, inverters, AC-DC converters and AC-AC converters for use in utility interfacing; Multi-level converters; Grid integration of electrical power from renewable sources; Current and voltage control; Resonant converters for DC-DC conversion; Converter circuit and system modelling using MATLAB-Simulink, PSim or other simulation platforms, device selection and their modelling, magnetic core and other component selection and design, and case studies of converter system designs.

TEACHING STRATEGIES

Delivery Mode

The teaching in this course aims at establishing an 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;
- Design, control and simulation work, which supports the formal lecture material and also provides you with skills necessary to perform a design task.

Learning in this course

You are expected to attend all lectures and tutorials. In addition to the lecture notes, you should read relevant sections of the recommended text. Reading additional texts will further enhance your learning experience. UNSW *assumes* that self-directed study of this kind is undertaken in addition to attending face-to-face classes throughout the course.

Tutorial classes

Lectures will be supplemented with problem solving tutorial sessions. Five to six tutorial sheets may be expected. The problem-solving sessions will be on most recently covered topics. Additionally, PSIM or LTSpice sessions may be arranged in room EE214. Students will be expected to participate vigorously during these sessions, in the form of questions, suggested solutions and methods. Participation by students should be viewed as desirable aspects of these sessions. You should attempt all of your problem sheet questions in advance of attending any tutorial classes. The importance of adequate preparation prior to each tutorial cannot be overemphasized, as the effectiveness and usefulness of the tutorial depends to a large extent on this preparation. Group learning is encouraged. Solutions will be discussed during the tutorial class and the tutor may 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.

ASSESSMENT

The assessment scheme in this course reflects the intention to assess your learning progress through the Term. Ongoing assessments using three Assignments will take place as indicated in the table in page 2.

Assignment

The three assignments allow self-directed study leading to the solution of partly structured problems. Marks will be assigned according to how completely and correctly the problems have been addressed, the quality of the code written for the assignment (must be attached to the report), and the understanding of the course material demonstrated by the report. Assignments 1 and 2 are for 10 marks each. Assignment 3 is for 20 marks; the total for Assignment reports is 40% of the final assessment for the course. All assignments must be submitted into a collection box at the School Office, with a front page downloaded from:

Due dates for the three assignment reports are indicated in the table in page 2 in **Indicative Lecture Schedule**. *Late reports will attract a penalty of 10% per day* (including weekends).

Final Exam

The exam in this course is a standard closed-book 2 hour written examination, comprising five compulsory questions. University approved calculators are allowed. The examination tests analytical and critical thinking and general understanding of the course material in a controlled fashion. Questions may be drawn from any aspect of the course (including laboratory), unless specifically indicated otherwise by the lecturer. Marks will be assigned according to the correctness of the responses. *Please note that you must pass the final exam in order to pass the course.* The final exam will be held over two hours and is worth 60 marks (i.e., 60% of the final assessment for the course).

Relationship of Assessment Methods to Learning Outcomes

Assessment	**Learning outcomes**
Assignment 1	1 - 3
Assignment 2	3 - 7
Assignment 3	1 - 8
Final exam	1 - 11

Course Resources

Textbooks

Power Electronics

1. N. Mohan, T. M. Undeland & W. P. Robins, "Power Electronics; Converters, Applications and Design", John Wiley, Second Edition, 1995, New York.

2. J. G. Kassakian, M.F. Schlecht & G.C. Verghese, "Principles of Power Electronics", Addison Wesley, 1991.

Grid Connection

3. Remus Teodorescu, Marco Liserre and Pedro Rodriguez, "Grid Converters for Photovoltaic and Wind Power Systems", John Wiley and IEEE, 2011

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

Dates to note

Important Dates available at: https://student.unsw.edu.au/dates

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/guide), and particular attention is drawn to the following:

Workload

It is expected that you will spend at least **15 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 can apply for special consideration when illness or other circumstances beyond your control interfere with an assessment performance. If you need to submit an application for special consideration for an exam or assessment, you must submit the application **prior to the start** of the exam or before the assessment is submitted, except where illness or misadventure prevent you from doing so. Be aware of the "fit to sit/submit" rule which means that if you sit an exam or submit an assignment, you are declaring yourself well enough to do so and cannot later apply for Special Consideration. For more information and how to apply, see 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 online student survey myExperience. 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.

You are also encouraged to provide feedback via Moodle, which will help improve the course for current and future students in the course.

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 assignments and 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 digital and information literacy and lifelong learning skills through assignment work.
- Developing ethical practitioners who are collaborative and effective team workers, through group activities, seminars and tutorials.
- Developing independent, self-directed professionals who are enterprising, innovative, creative and responsive to change, through challenging design and project tasks.
- Developing citizens who can apply their discipline in other contexts, are culturally aware and environmentally responsible, through interdisciplinary tasks, seminars and group activities.

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	✓