School of Electrical Engineering and Telecommunications

Term 3, 2019

Course Outline

ELEC 9719
Real-Time Digital Simulations

COURSE STAFF

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Consultations: Consultations: You are encouraged to ask questions on the course material, after the lecture class times in the first instance, rather than via email. You can also post questions in the Moodle discussion forums. **ALL** email enquiries should be made from your student email address with "ELEC9719" in the subject line, otherwise they will not be answered.

Consultation times for the course are **During Open Labs**.

Keeping Informed: The main announcements regarding the course and its assignments will be made through Moodle https://moodle.telt.unsw.edu.au/login/index.php. Announcements may also be made during classes but everything will be formally announced in the relevant sections of Moodle.

Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

COURSE SUMMARY

We all take electricity for granted!!

But have you ever considered what goes behind your outlet, when you charge your phone overnight or when you turn on your PC to play your favorite game? Electricity networks are the largest "machines" humans have ever built and the complex nature of modern power electronics converters and power systems necessitates modern approaches to their design and analysis.

Real-time digital simulations (or RTS); the solution and execution of a computation model in the same rate as actual "real-life" time; offer a modern and powerful tool that allows engineers and researchers to design, develop and troubleshoot in a safe, time- and cost-effective manner.

The main advantages of RTS in power systems and power electronics are i) very fast simulation of extended and complicated networks, ii) easy access to voltages and currents in all nodes iii) the interface with measurements, external control and power hardware and iv) the ability to run multiple test cases simultaneously and consecutively.

In this course, you will have the opportunity to explore and experiment hands-on with concepts, methodologies and practical applications of RTS across multiple modern power engineering areas. You will be able to work in a research-oriented environment and in state-of-the-art facilities that will prepare you for the future of power engineering.

Context and Aims

Over the past years electric power systems have changed and evolved substantially. With paramount requirements to improve economic efficiency and reduce environmental impact, modern electricity networks are being pushed towards the boundaries of reliable, flexible, and resilient operation. This includes more interconnections in electricity networks and adding more power electronics-based equipment to networks. Real time digital simulations have become more commonplace as a critical technology for utilities and manufacturers in this demanding and dynamic environment to support the study of power system behavior/operation, the closed-loop testing of new equipment, and the strategic development of new protection and control functions.

The Real-Time Digital Simulations (RTS) course delivers i) the concept of real time digital simulation, ii) the application of RTS concepts and techniques in development and continued operation of modern power systems and power electronics converters. Moreover, the students are provided with the opportunity to engage with the up to date research and dynamic research groups in the field.

The aims of the course are to:

- Introduce concepts, approaches and applications of real-time digital simulation in power engineering.
- Demonstrate modelling for real-time simulation of power systems and power electronics.
- Introduce real-time digital simulation of power systems
- Provide students with hands-on activities in real-time simulation of power electronics
- Offer an opportunity for interaction with research-level hardware-in-the-loop applications for power electronics and power systems.

Contact Hours
The course consists of 3 hours of combined lecture/lab time.

It is essential to note that completion of the course tasks requires attendance of the open labs as well, to the extend of each task requires, but at your own discretion.

Session	Day	Time	Location
Laboratory	Mondays	2pm - 6pm	TETB RTS Lab (Room 365)
Open Labs*	Wednesdays	9am - 2pm	TETB RTS Lab (Room 365)
	Thursdays	12pm - 5pm	TETB RTS Lab (Room 365)
	Fridays	9am - 2pm	TETB RTS Lab (Room 365)

Indicative Lecture - Laboratory Schedule

Period	Summary of Lecture Program
Week 1	Laboratory OH&S, Software Installation and Use. The UNSW Real-time Digital Simulation Laboratory. Introduction to Real-Time Digital Simulations, the RTDS and OPAL-RT Simulators.
Week 2	Familiarisation with Real-time Simulations. Simulating Power Electronics, Analysing Results of RTS.
Week 3	OPAL-RT Real-time Simulation of Power Electronics, CPU level Simulations. Preparing and running a Real-time Digital Simulation.
Week 4	OPAL-RT Power Electronics, FPGA level Simulations - eHS. Digital and Analog IOs, Simulation Loop-back and connection to external hardware.
Weeks 5 & 6	OPAL-RT Hardware-in-the-loop Simulations. Control of Power Electronics with external controllers - (CHiL).
Week 7	Introduction to the RTDS Simulator and Power System Simulations. Power System Component Modeling and Development for the RTDS.
Week 8 & 9	Extended network simulations RTDS Interfacing with external hardware, Protection Hardware-in-the-Loop (HiL).
Week 10	Advanced Network modeling Microgrids, HVDC systems and other Applications.

ASSESSMENT

Brief Assessment Description

1. Power Electronics Simulation (Week 2):	**10%**
2. Lab Reports:	**80%**
Lab Report 1	30%
Lab Report 2	30%
Oral Exam 1	10%
Oral Exam 2	10%
3. Lab Exam:	**5%**
4. Advanced Applications Report (Week 10):	**5%**

You are expected to attend all labs and also make use of the open-lab hours of the course in order to maximize learning. It is important to prepare in advance of attending the laboratories each week; this includes preparing your own simulations and results. In addition to the lecture notes, you should read relevant sections of the recommended textbooks, articles and other provided material. Reading additional texts would further enhance your learning experience. *Group learning is strongly encouraged.*

Final Exam

There is no Final Exam for this course.

Submission of Assessment Tasks

Assessment tasks will be submitted via the Moodle page of the course. Each Report **must follow** the style of the template provided and explained at the first week of classes. Each assessment task will have two deadlines, a soft deadline for the submission of each assignment after which submissions will incur a **10% penalty** per day of delayed submission. The soft deadline will be followed by a hard deadline three days later, after which no marks will be given to an assignment.

All submissions will be checked for originality and plagiarism with Turnitin (https://student.unsw.edu.au/how-use-turnitin-within-moodle). Assessments deemed to have an unacceptable level of similarity will not be marked.

Relationship of Assessment Methods to Learning Outcomes

	Learning Outcomes				
	LO1	**LO2**	**LO3**	**LO4**	**LO5**
P.E. Simulation	✓			✓	✓
Lab Reports	✓	✓	✓	✓	✓
Lab Exam	✓	✓	✓	✓	✓
A.a. Report	✓	✓		✓	✓

COURSE DETAILS

Credits
ELEC9719 is 6 UOC course. The expected average workload, including Lab attendance, open labs, and self-study is approximately **16-18 hours per week** during the normal semester.

Relationship to Other Courses
Pre-requisites and Assumed Knowledge
Students are expected to have prior knowledge of Power Systems and Power Electronics. Recommended courses are:

- Power Electronics (ELEC4614) or Power Electronics for Renewables (ELEC9711) or equivalent,
- Power System Equipment (ELEC4611) or Power Systems Analysis (ELEC4612) or equivalent.

Those without these prerequisite courses will be enrolled on a discretionary basis and WAM.

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

LO-1: Assess the need for real-time digital simulation in a given application.
LO-2: Design and implement real-time digital simulations of power systems.
LO-3: Prepare real-time digital simulation models of power electronics converters.
LO-4: Use control, protection and power hardware to interact with real-time simulators.
LO-5: Evaluate the results of closed-loop simulations and hardware-in-the-loop interactions.

The course delivery methods and course content address a number of core UNSW graduate attributes; these include:

- The capacity for analytical and critical thinking and for creative problem solving.
- The ability to engage in independent and reflective learning.
- Information Literacy – the skills to locate evaluate and use relevant information.
- The capacity for enterprise, initiative and creativity.
- The skills of effective communication.

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**.

Laboratories
Students are required to attend the laboratories as outlined in the Contact hours.

COURSE RESOURCES

On-line resources

Moodle

As a part of the teaching component, Moodle will also be used. Lab assessment marks will also be available via Moodle https://moodle.telt.unsw.edu.au/login/index.php. As the course progresses, students' marks from assessments such as labs and the quizzes are available for personal viewing on this website.

Textbooks

Prescribed textbook

There is no prescribed textbook for the course. All material will be provided in class and in the form of notes.

For Further Reading:

[1] . W. Dommel, "Digital computer solution of electromagnetic transients in single-and multiphase networks," IEEE Trans. Power App. Syst. , vol. PAS-88, no. 4, pp. 388–399, Apr. 1969.

[2] H. W. Dommel, "Nonlinear and time-varying elements in digital simulation of electromagnetic transients," IEEE Trans. Power App. Syst. , vol. PAS-90, no. 4, pp. 2561–2567, Nov. 1971.

[3] Mahseredjian, S. Dennetière, L. Dubé, B. Khodabakhchian, and L. Gérin-Lajoie, "On a new approach for the simulation of transients in power systems," Electr. Power Syst. Res. , vol. 77, no. 11, pp. 1514–1520, 2007.

[4] G. McLaren, R. Kuffel, R. Wierckx, J. Giesbrecht, and L. Arendt, "A real time digital simulator for testing relays," IEEE Trans. Power Del., vol. 7, no. 1, pp. 207–213, Jan. 1992.

[5] M. Foley, Y. Chen, and A. Bose, "A real time power system simulation laboratory environment," IEEE Trans. Power Syst. , vol. 5, no. 4, pp. 1400–1406, Nov. 1990.

[6] O. Cwikowski, H. R. Wickramasinghe, G. Konstantinou, J. Pou, M. Barnes and R. Shuttleworth, "Modular Multilevel Converter DC Fault Protection," in IEEE Transactions on Power Delivery, vol. 33, no. 1, pp. 291-300, Feb. 2018.

[7]H. R. Wickramasinghe, G. Konstantinou, Z. Li and J. Pou, "Alternate Arm Converters-Based HVDC Model Compatible With the CIGRE B4 DC Grid Test System," in IEEE Transactions on Power Delivery, vol. 34, no. 1, pp. 149-159, Feb. 2019.

[8] F. Arraño-Vargas and G. Konstantinou, "Development of Real-Time Benchmark Models for Integration Studies of Advanced Energy Conversion Systems," in IEEE Transactions on Energy Conversion.

[9] F. Arraño-Vargas and G. Konstantinou, "Real-Time Models of Advanced Energy Conversion Systems for Large-Scale Integration Studies," 2019 IEEE 10th International Symposium on Power Electronics for Distributed Generation Systems (PEDG), Xi'an, China, 2019, pp. 756-761.

[10] Z. Jiang, G. Konstantinou, Z. Zhong and P. Acuna, "Real-time digital simulation based laboratory test-bench development for research and education on solar pv systems," 2017 Australasian Universities Power Engineering Conference (AUPEC), Melbourne, VIC, 2017, pp. 1-6.

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

Workload

It is expected that you will spend at least twelve to fourteen hours per week studying a 6 UoC course over the semester, from Week 1 until the final assessment, including both face-to-face classes and independent, self-directed study. In periods where you 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.

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 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.

Administrative Matters

On issues and procedures regarding such matters as special needs, equity and diversity, occupational health and safety, enrollment, rights, and general expectations of students, please refer to the School and UNSW policies:
https://www.engineering.unsw.edu.au/electrical-engineering/resources/undergraduate-resources/policies-and-procedu
https://student.unsw.edu.au/guide

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 <select those which apply (maybe 3-5) and adapt to suit course>:

- 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	