UNSW SYDNEY Australia's Global University

School of Electrical Engineering and Telecommunications

Term 1, 2023

Course Outline

ELEC 9719
Real-Time Digital Simulations

COURSE STAFF

Course Convener & Lecturer:	Dr. Georgios Konstantinou Senior Lecturer School of Electrical Engineering and Telecommunications Room 325, Tyree Energy Technologies Building (H6) e-mail: g.konstantinou@unsw.edu.au
Lecturer:	Dr. Felipe Arraño-Vargas Research Associate School of Electrical Engineering and Telecommunications Room 323, Tyree Energy Technologies Building (H6) e-mail: f.arranovargas@unsw.edu.au
Laboratory Demonstrators:	Ye Zhu and Shan Jiang School of Electrical Engineering and Telecommunications Office 311WS25/26, Tyree Energy Technologies Building (H6)

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.

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.

Student Support Enquiries:

For enrollment and progression enquiries please contact Student Services

Web

- Electrical Engineering Homepage
- Engineering Student Support Services
- Engineering Industrial Training
- UNSW Study Abroad and Exchange (for inbound students)
- UNSW Future Students

Phone

- (+61 2) 9385 8500 – Nucleus Student Hub
- (+61 2) 9385 7661 – Engineering Industrial Training
- (+61 2) 9385 3179 – UNSW Study Abroad and UNSW Exchange (for inbound students)

Email

- Engineering Student Support Services – current student enquiries (e.g., enrolment, progression, clash requests, course issues or program-related queries)
- Engineering Industrial Training – Industrial training questions
- UNSW Study Abroad – study abroad student enquiries (for inbound students)
- UNSW Exchange – student exchange enquiries (for inbound students)
- UNSW Future Students – potential student enquiries (e.g., admissions, fees, programs, credit transfer)

COVID19 – Important Health Related Notice

Your health and the health of those in your class is critically important. You must stay at home if you are sick or have been advised to self-isolate by NSW Health or government authorities. **You will not be penalised for missing a face-to-face activity due to illness or a requirement to self-isolate**. We will work with you to ensure continuity of learning during your isolation and have plans in place for you to catch up on any content or learning activities you may miss. Where this might not be possible, an application for fee remission may be discussed.

If you are required to self-isolate and/or need emotional or financial support, please contact the Nucleus: Student Hub. If you are unable to complete an assessment, or attend a class with an attendance or participation requirement, please let your teacher know and apply for special consideration through the Special Consideration portal. To advise the University of a positive COVID-19 test result or if you suspect you have COVID-19 and are being tested, please fill in this form.

UNSW requires all staff and students to follow NSW Health advice. Any failure to act in accordance with that advice may amount to a breach of the Student Code of Conduct. Please refer to the Safe Return to Campus guide for students for more information on safe practices.

Dates to note

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

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 favourite 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 behaviour/operation, the closed-loop testing of new equipment, and the strategic development of new protection and control functions.

The Real-Time Digital Simulations course delivers *i)* the concept of real-time digital simulation and *ii)* the application of RTS concepts and techniques in development and continued operation of modern power systems and power electronics converters. Moreover, *iii)* 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 digital simulation of power systems and power electronics.
- Introduce real-time digital simulation of power systems.
- Provide students with hands-on activities in real-time digital 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.

NOTE: Completion of the course tasks requires attendance of the open labs, to the extend of each task requires, but at your own discretion.

Session	Day	Time	Location
Laboratory	Tuesdays	1pm–4pm	RTS@UNSW (TETB H6, Room 365)
Open Labs*	Wednesdays	2pm–6pm	RTS@UNSW (TETB H6, Room 365)
	Thursdays	2pm–6pm	RTS@UNSW (TETB H6, Room 365)

Indicative Lecture – Laboratory Schedule

Period	Summary of Lecture Program
Week 1	Laboratory OH&S. The UNSW Real-time Digital Simulation Laboratory (RTS@UNSW). Introduction to real-time digital simulations, the RTDS and the RT Box simulators.
Week 2 & 3	Introduction to the RTDS simulator and power system component modelling. Development of power system models for the RTDS.
Week 4 & 5	RTDS interfacing with external hardware, protection hardware-in-the-loop (HiL). Advanced network modelling: renewable energy, HVDC systems, and large power systems.
Week 6	Flexibility Week - Open Labs
Week 7	Introduction to PLECS and PLECS RT Box for real-time digital simulations. Preparing and running a real-time digital simulation. Lab Report 1 due
Week 8	PLECS real-time simulation of power electronics. Thermal modelling of power electronics.
Week 9	Virtual prototyping in the PLECS RT Box simulator. Digital and analogue I/Os, simulation loop-back.
Week 10	PLECS control hardware-in-the-loop (CHiL) simulations. Control of power electronics with external controllers.
Week 11	Lab Report 2 due Lab Exam

ASSESSMENT

Brief Assessment Description

1. Lab Reports:	**80%**
Lab Report 1	30%
Lab Report 2	30%
Oral Exam 1	10%
Oral Exam 2	10%
2. Lab Exam:	**15%**
3. Advanced Applications Report (Week 5):	**5%**

You are expected to attend all labs and also make use of the open-lab hours of the course in order to maximise 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 **5% penalty** per day of delayed submission. The soft deadline will be followed by a hard deadline five 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**
Lab Reports	✓	✓	✓	✓	✓
Lab Exam	✓	✓	✓	✓	✓
Advanced Applications 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 10-week term.

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.

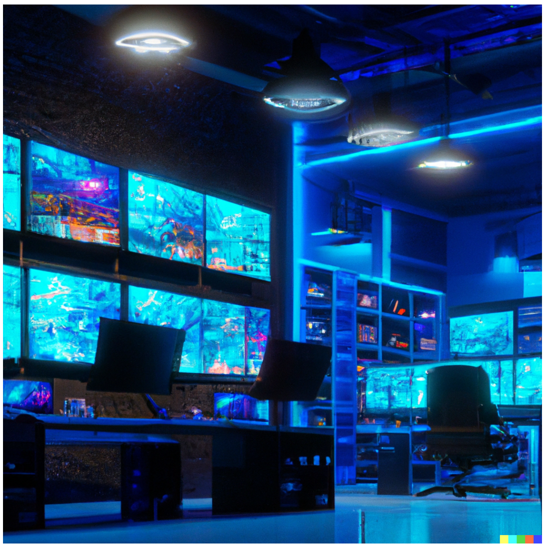
The course delivery methods and course content address a number of core UNSW graduate attributes; these include:

- 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

Online 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 oral exams 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] A. Monti and A. Benigni, *Modeling and Simulation of Complex Power Systems*, 1st ed. London, United Kingdom: IET, 2022.

[2] H . 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. 1968.

[3] H. W. Dommel, "Nonlinear and Time-Varying Elements in Digital Simulation of Electromagnetic Transients," *IEEE Trans. Power App. Syst.*, vol. PAS-90, no. 6, pp. 2561–2567, Nov. 1971.

[4] 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.

[5] 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.

[6] 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.

[7] O. Cwikowski, H. R. Wickramasinghe, G. Konstantinou, J. Pou, M. Barnes and R. Shuttleworth, "Modular Multilevel Converter DC Fault Protection," *IEEE Trans. Power Del.*, vol. 33, no. 1, pp. 291–300, Feb. 2018.

[8] 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," *IEEE Trans. Power Del.*, vol. 34, no. 1, pp. 149–159, Feb. 2019.

[9] F. Arraño-Vargas and G. Konstantinou, "Development of Real-Time Benchmark Models for Integration Studies of Advanced Energy Conversion Systems," *IEEE Trans. Energy Convers.*, vol. 35, no. 1, pp. 497–507, Mar. 2020.

[10] F. Arraño-Vargas and G. Konstantinou, "Real-Time Models of Advanced Energy Conversion Systems for Large-Scale Integration Studies," in *2019 IEEE 10th Int. Symp. Power Electron. Distrib. Gen. Syst. (PEDG)*. Xi'an, China, Jun. 2019, pp. 756–761.

[11] 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," in *2017 Australasian Universities Power Eng. Conf. (AUPEC)*. Melbourne, VIC, Australia, Nov. 2017, pp. 1–6.

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.

Some changes made in Term 1, 2023 in response to previous feedback include:

- New and expanded theory notes to further support the topics covered in the course.

ACADEMIC HONESTY AND PLAGIARISM

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.

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.

STUDENT RESPONSIBILITIES AND CONDUCT

Students are expected to be familiar with and adhere to all UNSW policies, and particular attention is drawn to the following:

Workload
It is expected that you will spend at least **16 to 18 hours per week** studying a 6 UoC course over the term, 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.

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.

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.

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:
Policies and Procedures
https://student.unsw.edu.au/guide

Disclaimer
This Course Outline sets out description of classes at the date the Course Outline is published. The nature of classes may change during the Term after the Course Outline is published. Moodle should be consulted

for the up-to-date class descriptions. If there is any inconsistency in the description of activities between the University timetable and the Course Outline (as updated in Moodle), the description in the Course Outline/Moodle applies.

Thanks DALL-E for the images. No animals were hurt during the production of this course outline.

CRICOS
CRICOS Provider Code: 00098G

Acknowledgement of Country
We acknowledge the Bedegal people who are the traditional custodians of the lands on which UNSW Kensington campus is located.

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	