UNSW Course Outline

ELEC9719 Real-Time Digital Simulations - 2024

Published on the 22 May 2024

General Course Information

Course Code : ELEC9719
Year : 2024
Term : Term 2
Teaching Period : T2
Is a multi-term course? : No
Faculty : Faculty of Engineering
Academic Unit : School of Electrical Engineering & Telecommunications
Delivery Mode : In Person
Delivery Format : Standard
Delivery Location : Kensington
Campus : Sydney
Study Level : Postgraduate
Units of Credit : 6

Useful Links

Handbook Class Timetable

Course Details & Outcomes

Course Description

We all take electricity for granted. But have you ever considered what goes behind your outlet, when you charge your phone overnight? 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.

Relationship to Other Courses

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.

Course Learning Outcomes

Course Learning Outcomes
CLO1 : After successful completion of this course: 1. Students shall be able to assess the need for real-time digital simulation in a given application
CLO2 : 2. Students shall be able to design and implement real-time digital simulations of power systems.
CLO3 : 3. Students shall be able to prepare real-time digital simulation models of power electronics converters.
CLO4 : 4. Students shall be able to use control, protection and power hardware to interact with real-time simulators.
CLO5 : 5. Students shall be able to evaluate the results of closed-loop simulations and hardware-in-the-loop interactions.

Course Learning Outcomes	Assessment Item
CLO1 : After successful completion of this course: 1. Students shall be able to assess the need for real-time digital simulation in a given application	• Article review and Summary • Lab Exams • Report 1 - RTS in Power Electronics • Report 2 - RTS in Power Systems
CLO2 : 2. Students shall be able to design and implement real-time digital simulations of power systems.	• Article review and Summary • Lab Exams • Report 1 - RTS in Power Electronics • Report 2 - RTS in Power Systems
CLO3 : 3. Students shall be able to prepare real-time digital simulation models of power electronics converters.	• Article review and Summary • Lab Exams • Report 1 - RTS in Power Electronics • Report 2 - RTS in Power Systems
CLO4 : 4. Students shall be able to use control, protection and power hardware to interact with real-time simulators.	• Article review and Summary • Lab Exams • Report 1 - RTS in Power Electronics • Report 2 - RTS in Power Systems
CLO5 : 5. Students shall be able to evaluate the results of closed-loop simulations and hardware-in-the-loop interactions.	• Article review and Summary • Lab Exams • Report 1 - RTS in Power Electronics • Report 2 - RTS in Power Systems

Learning and Teaching Technologies

Moodle - Learning Management System

Other Professional Outcomes

Engineers Australia (EA), Professional Engineer Stage 1 Competencies

The Course Learning Outcomes (CLOs) contribute to your development of the following EA competencies:

PE1: Knowledge and Skill Base:

PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals: CLO 1, 5

PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing: CLO 1, 2

PE1.3 In-depth understanding of specialist bodies of knowledge: CLO 1, 2, 3, 4, 5

PE1.4 Discernment of knowledge development and research directions: N/A

PE1.5 Knowledge of engineering design practice: N/A

PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice: N/A

PE2: Engineering Application Ability:

PE2.1 Application of established engineering methods to complex problem solving: CLO 1, 2, 3, 4
PE2.2 Fluent application of engineering techniques, tools and resources: CLO 2, 3, 4
PE2.3 Application of systematic engineering synthesis and design processes: N/A
PE2.4 Application of systematic approaches to the conduct and management of engineering projects: N/A

PE3: Professional and Personal Attributes:
PE3.1 Ethical conduct and professional accountability: CLO 2, 3
PE3.2 Effective oral and written communication (professional and lay domains): CLO 1, 5
PE3.3 Creative, innovative and pro-active demeanour: CLO 2, 3, 4
PE3.4 Professional use and management of information: N/A
PE3.5 Orderly management of self, and professional conduct: N/A
PE3.6 Effective team membership and team leadership: N/A

Additional Course Information

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.

Assessments

Assessment Structure

Assessment Item	Weight	Relevant Dates
Article review and Summary	10%	Start Date: Not Applicable Due Date: Not Applicable
Lab Exams	20%	Start Date: Not Applicable Due Date: Not Applicable
Report 1 - RTS in Power Electronics	35%	Start Date: Not Applicable Due Date: Not Applicable
Report 2 - RTS in Power Systems	35%	Start Date: Not Applicable Due Date: Not Applicable

Assessment Details

Article review and Summary

<u>**Assessment Overview**</u>

Written feedback and presentation

<u>**Course Learning Outcomes**</u>

- CLO1 : After successful completion of this course: 1. Students shall be able to assess the need for real-time digital simulation in a given application
- CLO2 : 2. Students shall be able to design and implement real-time digital simulations of power systems.
- CLO3 : 3. Students shall be able to prepare real-time digital simulation models of power electronics converters.
- CLO4 : 4. Students shall be able to use control, protection and power hardware to interact with real-time simulators.
- CLO5 : 5. Students shall be able to evaluate the results of closed-loop simulations and hardware-in-the-loop interactions.

<u>**Detailed Assessment Description**</u>

Guided assesement where models are provided and students need to analyse results.

<u>**Assignment submission Turnitin type**</u>

This assignment is submitted through Turnitin and students can see Turnitin similarity reports.

Lab Exams

Assessment Overview

2 exams, 1 on each part of the course

Course Learning Outcomes

- CLO1 : After successful completion of this course: 1. Students shall be able to assess the need for real-time digital simulation in a given application
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- CLO3 : 3. Students shall be able to prepare real-time digital simulation models of power electronics converters.
- CLO4 : 4. Students shall be able to use control, protection and power hardware to interact with real-time simulators.
- CLO5 : 5. Students shall be able to evaluate the results of closed-loop simulations and hardware-in-the-loop interactions.

Detailed Assessment Description

Verbal examination for each part of the course (power systems and power electronics) in which students need to demonstrate how the simulation was implemented, the assumptions made, while explaining the results.

Assignment submission Turnitin type

Not Applicable

Report 1 - RTS in Power Electronics

Assessment Overview

Presubmission for feedback - Final submission / written feedback

Course Learning Outcomes

- CLO1 : After successful completion of this course: 1. Students shall be able to assess the need for real-time digital simulation in a given application
- CLO2 : 2. Students shall be able to design and implement real-time digital simulations of power systems.
- CLO3 : 3. Students shall be able to prepare real-time digital simulation models of power electronics converters.
- CLO4 : 4. Students shall be able to use control, protection and power hardware to interact with real-time simulators.
- CLO5 : 5. Students shall be able to evaluate the results of closed-loop simulations and hardware-in-the-loop interactions.

Detailed Assessment Description

Written report as part of designing, preparing and building a real-time digital simulation of power electronics, and the analysis of its results.

Assignment submission Turnitin type

This assignment is submitted through Turnitin and students can see Turnitin similarity reports.

Report 2 - RTS in Power Systems

Assessment Overview

Presubmission for feedback - Final submission / written feedback

Course Learning Outcomes

- CLO1 : After successful completion of this course: 1. Students shall be able to assess the need for real-time digital simulation in a given application
- CLO2 : 2. Students shall be able to design and implement real-time digital simulations of power systems.
- CLO3 : 3. Students shall be able to prepare real-time digital simulation models of power electronics converters.
- CLO4 : 4. Students shall be able to use control, protection and power hardware to interact with real-time simulators.
- CLO5 : 5. Students shall be able to evaluate the results of closed-loop simulations and hardware-in-the-loop interactions.

Detailed Assessment Description

Written report as part of designing, preparing and building a real-time digital simulation of power system, and the analysis of its results.

Assignment submission Turnitin type

This assignment is submitted through Turnitin and students can see Turnitin similarity reports.

General Assessment Information

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*.

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.

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

<u>**Grading Basis**</u>

Standard

Course Schedule

Teaching Week/Module	Activity Type	Content
Week 1 : 27 May - 2 June	Lecture	• Laboratory OH&S. • UNSW's Real-Time Simulations Laboratory (RTS@UNSW). • Introduction to real-time digital simulations: RTDS and PLECS RT Box simulators.
Week 2 : 3 June - 9 June	Lecture	• Introduction to the RTDS simulator and power system component modelling.
Week 3 : 10 June - 16 June	Lecture	• Development of power system models for the RTDS.
Week 4 : 17 June - 23 June	Lecture	• RTDS interfacing with external hardware, protection hardware-in-the-loop (HiL).
Week 5 : 24 June - 30 June	Lecture	• Advanced network modelling: renewable energy, HVDC systems, and large power systems.
	Assessment	• Article review and Summary --> Advanced Applications Report
Week 6 : 1 July - 7 July	Activity	• Flexibility week. • Open labs.
Week 7 : 8 July - 14 July	Lecture	• Introduction to PLECS and PLECS RT Box for real-time digital simulations. • Preparing and running a real-time digital simulation.
	Assessment	• Report of RTS in Power Systems. • Verbal examination of RTS in Power Systems.
Week 8 : 15 July - 21 July	Lecture	• PLECS real-time simulation of power electronics. • Thermal modelling of power electronics.
Week 9 : 22 July - 28 July	Lecture	• Virtual prototyping in the PLECS RT Box simulator. • Digital and analogue I/Os, simulation loop-back.
Week 10 : 29 July - 4 August	Lecture	• PLECS control hardware-in-the-loop (CHiL) simulations. • Control of power electronics with external controllers.
Week 11 : 5 August - 11 August	Assessment	• Report of RTS in Power Electronics. • Verbal examination of RTS in Power Electronics. • Article review and Summary --> written lab exam

Attendance Requirements

Please note that lecture recordings are not available for this course. Students are strongly encouraged to attend all classes and contact the Course Authority to make alternative arrangements for classes missed.

General Schedule Information

The course consists of 3 hours of combined lecture/lab time and open-lab sessions. The expected average workload, including Lab attendance, open labs, and self-study is approximately

16-18 hours per week during the 10-week term.

Course Resources

Prescribed Resources

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

Recommended Resources

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.

Staff Details

Position	Name	Email	Location	Phone	Availability	Equitable Learning Services Contact	Primary Contact
Lecturer	Felipe Arrano Vargas		Room 323, Level 3, TETB (H6)		By appointment via email	Yes	Yes
	Georgios Kon stantinou		Room 325, Level 3, TETB (H6)			No	No

Other Useful Information

Academic Information

I. Special consideration and supplementary assessment

If you have experienced an illness or misadventure beyond your control that will interfere with your assessment performance, you are eligible to apply for Special Consideration prior to, or within 3 working days of, submitting an assessment or sitting an exam.

Please note that UNSW has a Fit to Sit rule, which means that if you sit an exam, you are declaring yourself fit enough to do so and cannot later apply for Special Consideration.

For details of applying for Special Consideration and conditions for the award of supplementary assessment, please see the information on UNSW's Special Consideration page.

II. Administrative matters and links

All students are expected to read and be familiar with UNSW guidelines and polices. In particular, students should be familiar with the following:

- Attendance
- UNSW Email Address
- Special Consideration
- Exams
- Approved Calculators
- Academic Honesty and Plagiarism
- Equitable Learning Services

III. Equity and diversity

Those students who have a disability that requires some adjustment in their teaching or learning environment are encouraged to discuss their study needs with the course convener prior to, or at the commencement of, their course, or with the Equity Officer (Disability) in the Equitable Learning Services. Issues to be discussed may include access to materials, signers or note-takers, the provision of services and additional exam and assessment arrangements. Early notification is essential to enable any necessary adjustments to be made.

IV. Professional Outcomes and Program Design

Students are able to review the relevant professional outcomes and program designs for their streams by going to the following link: https://www.unsw.edu.au/engineering/student-life/student-resources/program-design.

Note: This course outline sets out the 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 or your primary learning management system (LMS) 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/Moodle/LMS, the description in the Course Outline/Moodle/LMS applies.

Academic Honesty and Plagarism

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW students have a responsibility to adhere to this principle of academic integrity. Plagiarism undermines academic integrity and is not tolerated at UNSW. *Plagiarism at UNSW is defined as using the words or ideas of others and passing them off as your own.*

Plagiarism is a type of intellectual theft. It can take many forms, from deliberate cheating to accidentally copying from a source without acknowledgement. UNSW has produced a website with a wealth of resources to support students to understand and avoid plagiarism, visit: student.unsw.edu.au/plagiarism. The Learning Centre assists students with understanding academic integrity and how not to plagiarise. They also hold workshops and can help students one-on-one.

You are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting and the proper referencing of sources in preparing all assessment tasks.

Repeated plagiarism (even in first year), plagiarism after first year, or serious instances, may also be investigated under the Student Misconduct Procedures. The penalties under the procedures can include a reduction in marks, failing a course or for the most serious matters (like plagiarism in an honours thesis or contract cheating) even suspension from the university. The Student Misconduct Procedures are available here:

www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf

Submission of Assessment Tasks

Work submitted late without an approved extension by the course coordinator or delegated authority is subject to a late penalty of five percent (5%) of the maximum mark possible for that assessment item, per calendar day.

The late penalty is applied per calendar day (including weekends and public holidays) that the assessment is overdue. There is no pro-rata of the late penalty for submissions made part way through a day. This is for all assessments where a penalty applies.

Work submitted after five days (120 hours) will not be accepted and a mark of zero will be awarded for that assessment item.

For some assessment items, a late penalty may not be appropriate. These will be clearly indicated in the course outline, and such assessments will receive a mark of zero if not completed by the specified date. Examples include:

- Weekly online tests or laboratory work worth a small proportion of the subject mark;
- Exams, peer feedback and team evaluation surveys;
- Online quizzes where answers are released to students on completion;
- Professional assessment tasks, where the intention is to create an authentic assessment that has an absolute submission date; and,
- Pass/Fail assessment tasks.

Faculty-specific Information

Engineering Student Support Services – The Nucleus - enrolment, progression checks, 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

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)

School-specific Information

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.

Use of AI for assessments

Your work must be your own. If you use AI in the writing of your assessment, you must acknowledge this and your submission must be substantially your own work. More information can be found on this website.

Workplace Health & Safety (WHS)

WHS for students and staff is of utmost priority. Most courses involve laboratory work. You must follow the rules about conduct in the laboratory. About COVID-19, advice can be found on this website.

School Contact Information

Consultations: Lecturer consultation times will be advised during the first lecture. You are welcome to email the tutor 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 ELEC/TELExxxx 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 enrolment and progression enquiries please contact Student Services

Web

Electrical Engineering Homepage