SOLA4012-9007
Grid-Connected Photovoltaic Systems

Course Outline – Semester 1, 2016

Never Stand Still | Engineering | School of Photovoltaic and Renewable Energy Engineering

1 Course Staff

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Consultations: Monday 3-4 pm (open door, no appointment needed). For all enquiries about the course please contact the course convener. For all other questions or enquiries you are encouraged to ask the lecturer after class or post your question on Moodle. https://moodle.telt.unsw.edu.au/login/index.php

Keeping Informed: All course material and announcements will be posted on Moodle. Please note that it's your responsibility to check the site regularly for any updates and that you should take careful note of all announcements.

2 Course Details

2.1 Credits

This is a 6 UoC course; the expected workload is 10-12 hours per week during the 13 weeks.

2.2 Pre-requisites and Assumed Knowledge

Students should have a good working knowledge of university level introductory physics, circuit theory and mathematics. Furthermore, it is expected that students have taken SOLA2540 Applied PV and hence have an understanding of the technical components of PV systems, including how solar cells work and the effect of mismatch, shading and temperature on the operation of photovoltaic modules, including the mathematical analysis.

2.3 Relationship to Other Courses

SOLA4012 is a 4th year course in the School of Photovoltaic and Renewable Energy Engineering School. It is a compulsory course for the Photovoltaics and Solar Energy (BE Hons) program and a professional elective for the Renewable Energy Engineering (BE Hons) program. SOLA4012/9007 is a compulsory course for the Photovoltaic and Solar Energy (SOLAES5341), the Masters of Engineering Science in Photovoltaic and Solar Energy (SOLACS8338), and for the Masters of Engineering Science in Renewable Energy (SOLADS8338).

2.4 Context and Aims

There is currently increasing need in generating electricity from renewable energy sources and reducing greenhouse gas emissions. Photovoltaic (PV) systems are one of the few distributed renewable electricity generation options that can be readily used in urban areas with little environmental impact at the site and potential economic benefits for the user and the network operator. The aim of the course is to give the students an understanding of basic technical and economic issues with respect to the operation of distributed photovoltaic energy systems on the electricity network. In particular to prepare students with design skills to implement basic systems and to develop students' problem solving, design, creative thinking and communication skills, with emphasis on developing problem solving skills.

2.5 Learning outcomes

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

1. Explain the fundamentals of operating grid connected PV systems on an electricity network.
2. Demonstrate knowledge of the components of a grid connected PV system and their characteristics, including hybrid systems.
3. Appreciate the benefits and limitations of PV distributed generation and apply that understanding within an engineering design framework.
4. Determine the best solution available for a grid connected PV system depending on load assessment, site location, solar resource, and economic principles.
5. Design a grid connected PV system for an electricity network with an awareness of the relevant safety and installation standards and procedures.
6. Perform economic analysis of grid connected PV systems and optimize designs based on techno-economic analysis.
7. Identify and apply the relevant Australian standards in designing grid connected PV systems.
8. Write a complete technical report that assesses the performance and economics of a grid connected PV system and documents the best solution.

This course is designed to achieve the above learning outcomes which address the specific UNSW and Faculty of Engineering graduate capabilities listed in ***Appendix A***. This course also addresses the Engineers Australia (National Accreditation Body) Stage I competency standard as outlined in ***Appendix B***.

2.6 Syllabus

This course familiarizes students with issues relevant to the use of photovoltaic systems connected to the electricity distribution network with the aim of attaining competency in design and specification. The types of systems considered include residential, building integrated, distributed grid support and central station. System components, design, operation, safety principles, and standards are addressed making extensive use of past experience.

2.7 Indicative Lecture Schedule

Period	Summary of Lecture Program	Tutorials	Deadlines
Week 01 – 27 Feb	Course overview; refresh on PV strings and array		
Week 02 – 06 Mar	Intro to inverters; Inverter sizing	Array Basics	
Week 03 – 13 Mar	Inverter system configuration; Site specific design	Design Tutorial 1 - Inverter	
Week 04 – 20 Mar	DC design and protection; Earthing and faults	PVsyst Basics	
Week 05 – 27 Mar	Losses and performance; AC circuit basics	Design Tutorial 2 - Arrays	*Assignment 1*
Week 06 – 03 Apr	Inverters and grid integration; Quality of Supply	Earthing	
Week 07 – 10 Apr	Grid integration and 3 phase systems; Standards	Design Tutorial 3 - Cabling	
Break			
Week 08 – 24 Apr	PV systems with storage; Grid connected storage	AC Power	
Week 09 – 01 May	Grid connected economics	*Project Presentation*	
Week 10 – 08 May	Installation of PV systems (guest lecture)	PV-Battery Basics	
Week 11 – 15 May	Large scale solar systems (guest lecture)	3 Phase Systems	
Week 12 – 22 May	PV markets; Wider grid issues	Power Quality	
Week 13 – 29 May		Multiple Inverters	*Project Report*

2.8 Contact Hours

The course consists of 2 hours of lectures and a 2 hour tutorial session each week as listed below. This course requires you to use a number of software packages that will be available on student computers in LG34 and LG35 in TETB.

	Day	Time	Location	Delivered by
Lectures	Tuesday	10 am – 12 pm	Electrical Engineering G25	Dr. Jose Bilbao
Tutorials	Tuesday	12 pm – 02 pm	Red Centre 2035	Navid Haghdadi
	Tuesday	02 pm – 04 pm	Quad G052	Iskra Zafirovska
	Tuesday	04 pm – 06 pm	Block G15	Samiul Amin
	Wednesday	03 pm – 05 pm	Law 275	Baran Yildiz

3 Assessment

Assessment	Percentage of Total Mark	Date Due
Assignment 1	10%	Friday Week 5
Assignment 2	10%	Progress check on tutorials
Major Project	30%	
Presentation	*10%*	*Tutorial Time Week 9*
Final Report	*20%*	*Wednesday Week 13*
Final Exam (2 hours)	50%	UNSW Exam Period

The assessment scheme in this course reflects the intention to assess your learning progress throughout the semester. The assignment and project submission will be via Moodle – PDF files ONLY – no hard copy submission. The final examination will cover all material in the course.

Late submissions of any of the assignments and project will attract a penalty of 0.4% per hour (including weekends). Work submitted after the marks have been released will incur the maximum penalty.

3.1 Assignment 1 (Total 10%)

This assignment will comprise a number of questions based on material presented in the first 4 weeks of the course, including a simple grid connected system design exercise. The assignment will include topics like site assessment, array design and orientation, and inverter matching. You'll need to learn how to work with PVsyst for this assignment. This is an individual assignment submitted electronically via Moodle. Marks will be assigned according to how completely and correctly the problems have been addressed.

3.2 Assignment 2 (Total 10%)

As part of this assignment you will need to develop an excel model for a PV system following the Australian Standards. The spreadsheet must include calculations to select cable size and length, voltage drop, protection size, degradation, system performance, and some simple economic metrics, assuming a system with a lifetime of 25 years. You'll need to develop this model during the semester as part of some relevant tutorials. The model will be checked during the last tutorial. The model can be used as a helping tool for the final project. A spreadsheet template with a basic structure will be provided as a starting point.

3.3 Major Project (Total 30%)

The project is designed to give you a chance to apply your knowledge to a real-world design challenge of a commercial grid connected PV system. The project involves the use of modeling software (SAM or PVsyst) to design the system. The software will also be used to carry out a techno-economic optimization of the system performance and cost.

Students will be arranged in groups of 3 or 4 to complete the project. As part of this project, your group will play the role of a team of engineers in a PV installing company. The project will run through the whole semester aiming at producing a comprehensive design of a grid connected PV system for a location and load to be selected. The project report will be prepared as a ‘Tender submission’, i.e., your engineering team is preparing a full tender submission in order to ‘win’ a contract for the installation of a new PV system.

3.3.1 Presentation (10%)

A presentation of the progress achieved for the major project will be carried out during week 9 at tutorial time. The presentation is aimed to show a summary of your results, the objective and context of your project, the state of the design and a clear idea of your procedures and workings. The groups will receive feedback from a panel of experts regarding the status of the ‘tender application’. Presentations will last a maximum of 10 min with an extra 5 min for questions.

3.3.2 Final Report (20%)

A final project report is to be handed in during week 13 via Moodle. The report should be presented in the format of a tender submission, including a complete design, performance and shading analysis, storage option, list of equipment, estimated costs, and a system schematic. Students within the group will be asked to assess each other’s contribution to the project to ensure fairness in mark allocation for each student.

3.4 Final Exam (Total 50%)

The exam in this course will be carried out in a digital format, as a first Faculty trial. The exam will be very similar to a ‘standard closed-book 2 hours written examination’ except for the fact that it will be carried out in a computer lab and your answers will be submitted via a computer containing the digital exam. The computers will be locked so no internet access will be possible.

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, unless specifically indicated otherwise by the lecturer. Marks will be assigned according to the correctness of the responses. The undergraduate and postgraduate examination papers will be different. <u>Students must achieve at least a 40% mark on the final examination paper to pass this course</u>.

3.5 Relationship of Assessment Methods to Learning Outcomes

	Learning Outcomes							
Assessment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Assignment 1	✓	✓	✓	✓	-	-	-	-
Assignment 2	-	✓	✓	-	✓	-	✓	-
Project Presentation	-	✓	✓	✓	✓	-	-	-
Project Report	✓	✓	✓	✓	✓	✓	✓	✓
Final Exam	✓	✓	✓	✓	✓	✓	✓	-

4 Teaching Strategies

4.1 Delivery Mode

The teaching strategy for this course comprises a series of lectures and tutorial sessions. The lecture series will present theory related to understanding energy and lighting.

Tutorial sessions will involve a combination of computer based sessions (where students will learn how to use programs such as PVsyst and SAM) as well as problem sets and demonstrations which cover all topics for this course. Students will also develop an excel model during the tutorials as part of Assignment 2. A tutor will be available to give assistance during each of the scheduled tutorial sessions.

4.2 Learning in this course

You are expected to attend all lectures and tutorials in order to maximize learning. You will need to complete some pre-work for each of your tutorial classes. In addition to the lecture notes, you will be expected to read relevant papers and texts as required.

Group learning is encouraged but PLAGIARISM IS NOT. UNSW *assumes* that self-directed study of this kind is undertaken in addition to attending face-to-face classes throughout the course.

4.3 Tutorial classes

Attendance at the tutorial classes is compulsory from Week 2 to 13. There will be no tutorials in Week 1.

4.4 Tutorial exemption

You must attend all tutorials. If, for any reason you cannot attend your tutorial please contact the course convener and check whether it would be possible to attend another tutorial class.

5 Course Resources

5.1 Reference Books (copies available in the library)

- Grid-Connected PV Systems, Design and Installation - GSES
- Grid-Connected PV Systems with Battery Storage - GSES

5.2 On-line Resources

Climate Information

- Australian Bureau of Meteorology - http://www.bom.gov.au/climate/
- NASA - eosweb.larc.nasa.gov/sse/
- NREL National Solar Radiation Database (weather data) - https://nsrdb.nrel.gov/

Design Tools (all in TETB computer labs)

- PVSYST - Software for photovoltaic Systems http://www.pvsyst.com/
- SAM - System Advisory Model https://sam.nrel.gov/
- HOMER Energy - Hybrid Renewable and Distributed Generation Power System Design and Optimization http://www.homerenergy.com/
- RETScreen - Clean Energy Management Software system for energy efficiency http://www.retscreen.net/ang/home.php
- SMA Sunny Design - http://www.sunnydesignweb.com/sdweb/#/Home

Standards (via UNSW Library)

- Building Code of Australia (BCA)
- AS/NZS 1170.2:2011 - Structural design actions - Wind actions
- AS/NZS 1768:2007 - Lightning Protection
- AS/NZS 3000:2007 - Electrical Wiring Rules
- AS/NZS 3008.1.1:2017 - Electrical installations - Selection of cables
- AS/NZS 4777.1:2016 - Grid connection of energy systems via inverters - Installation requirements
- AS/NZS 4777.2:2015 - Grid Connections of Energy Systems via Inverters - Inverter requirements
- AS/NZS 5033:2014 - Installation and safety requirements for photovoltaic (PV) arrays

General Resources

- APVI Solar Maps - http://pv-map.apvi.org.au/
- Nearmap tool (via UNSW Network) - http://au.nearmap.com/
- Clean Energy Council - http://www.cleanenergycouncil.org.au/
- PVeducation - http://www.pveducation.org/pvcdrom

Drawing Tools

- LucidChart - https://www.lucidchart.com/
- SmartDraw - https://www.smartdraw.com/
- MS Visio – try https://dreamspark.eng.unsw.edu.au/
- Autocad - http://www.autodesk.com/education/free-software/featured
- Sketchup - https://www.sketchup.com/

Gant Chart Tools

- MS Project - try https://dreamspark.eng.unsw.edu.au/
- Ganttpro - https://ganttpro.com/

5.3 Moodle

As a part of the teaching component, Moodle will be used to disseminate teaching materials. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.

5.4 Announcements and Discussion Board

Announcements concerning course information will be given in the lectures and/or on Moodle. A Discussion Board will also be established on the Moodle course page for you to post questions or initiate course-related discussions.

6 Other Matters

6.1 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.

6.2 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:

6.3 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.

6.4 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.

6.5 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.

6.6 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.

6.7 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.

6.8 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 RESOC 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.

6.9 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:
http://www.engineering.unsw.edu.au/electrical-engineering/policies-and-procedures
https://my.unsw.edu.au/student/atoz/ABC.html

7 Appendix A: 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 through students working through the Problem Sets and use of modelling software for the assignment.
- 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.

8 Appendix B: Engineers Australia (EA) Professional Engineer Competency Standard

	Program Intended Learning Outcomes		Relevant LO
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	✓	LO1 to LO7
	PE1.4 Discernment of knowledge development and research directions		
	PE1.5 Knowledge of engineering design practice	✓	LO4 to LO7
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice	✓	LO1, LO3, LO5, LO6, LO7
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving	✓	LO4, LO5, LO6
	PE2.2 Fluent application of engineering techniques, tools and resources	✓	LO4, LO5, LO6
	PE2.3 Application of systematic engineering synthesis and design processes	✓	LO4 to LO7
	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)	✓	LO8
	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		