

# SOLA4012

Photovoltaic Systems Design

Term 2, 2022



## Course Overview

### Staff Contact Details

#### Convenors

Name	Email	Availability	Location	Phone
Baran Yildiz	<a href="mailto:baran.yildiz@unsw.edu.au">baran.yildiz@unsw.edu.au</a>	Microsoft Teams Video Chat Hours: Thursdays from 16:00 to 18:00	TETB Level 3 Room 317	(02) 9385 4284

### School Contact Information

For current students, all enquiries for The School of Photovoltaics and Renewable Energy are managed by The Nucleus:

[Engineering Student Support Services](#) – The Nucleus - enrolment, progression checks, clash requests, course issues or program-related queries

**Phone:** (+61 2) 9385 8500 – Nucleus Student Hub

For future students, all enquiries for The School of Photovoltaics and Renewable Energy are managed by the Future Student Team:

[UNSW Future Students](#) – potential student enquiries e.g. admissions, fees, programs, credit transfer

**Phone:** (+61 2) 9385 1844 – Future Students

## Course Details

### Units of Credit 6

### Summary of the Course

There is 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 (as grid connected systems) and in remote areas (as stand-alone systems), 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 provide students with tools and information on the technical and economic issues with respect to the design, installation, and operation of photovoltaic energy systems. In particular, the course aims to develop students' design, problem solving, and communication skills to implement PV systems in accordance to the Australian Standards.

### Course Aims

**Do you want to be an active part of the exciting journey to a sustainable energy future based on solar PV energy?**

This course will prepare you to be an active part of the exciting journey to a sustainable energy future because the most important component of all PV systems is the human component.

The PV industry is a multi-billion dollar industry, growing at an accelerating rate due to the cost and efficiency improvements achieved in the last twenty years, thanks in part to important contributions by UNSW SPREE researchers and alumni. Even though these improvements have resulted in massive uptake of installed PV capacity, the industry needs to grow at an even faster rate if the world is to meet its targets in carbon emission reductions. The challenge now is to achieve terawatts of capacity installed every year around the world!

This course is about you and how you can become a great designer of PV systems, taking into consideration all key design variables (technical, economical, environmental, and regulatory) under a diversity of contexts. During the course you will start developing professional skills and experience in making decisions and informed assumptions to design PV systems of different scales using real data, first working individually and then as a team.

By the end of the course you will be capable of designing high quality PV systems, optimised to provide high performance and value, while complying with all relevant Australian Standards. This will allow you to apply for the CEC (Clean Energy Council) provisional accreditation for the design of PV systems.

### Course Learning Outcomes

After successfully completing this course, you should be able to:

Learning Outcome	EA Stage 1 Competencies
1. Recommend and justify suitable PV system architecture based on the specific requirements of the application and location.	PE1.3, PE1.5, PE1.6

<b>Learning Outcome</b>	<b>EA Stage 1 Competencies</b>
2. Calculate the impact of PV systems on the local electricity network and how they can influence the power factor via reactive and active power.	PE1.3, PE2.1, PE2.2
3. Design and document a PV system fully compliant with all relevant Australian Standards for a safe and optimal operation.	PE1.6, PE2.2, PE2.3, PE3.2
4. Optimise PV designs based on technoeconomic principles using software tools	PE1.6, PE2.1, PE2.3, PE3.2
5. Develop proposals for utility scale PV projects and its associated business model.	PE2.3, PE3.2

## Teaching Strategies

The content of the course will be delivered online via lectures and studio sessions. The online lessons will be delivered via Microsoft Teams and present most of the theory related to understanding PV systems. The lecture notes will be available in Microsoft OneNote. Each week you'll have to answer an online quiz in Moodle about the theory presented in the online lessons before the online studios.

Online studio sessions will be delivered via Microsoft Teams which involve a combination of individual work, teamwork, and computer-based activities (using PV system design programs such as PVsyst and SAM, general software like Excel and design and drafting software like AutoCAD). The course lecturer and demonstrators will be present during the studio to facilitate your learning process.

## Additional Course Information

### Course pre-requisites

All students are expected to complete SOLA 2054 (9001) before enrolling in this course.

### Workload


It is recommended you design a study plan for the term, based on the learning activities and assignments of each of your courses, detailing the number of hours you will spend on each learning task. A simple example of a study plan for SOLA4012 is shown in the table below (e.g., the work related to the Commercial PV project should take you around 26 hours, while the Utility Scale project is around 20 hours for each team member or 100 hours in total).

<b>Period</b>	<b>Self-directed Study</b>	<b>Online Activities</b>	<b>Online Quizzes</b>	<b>Commercial PV Project</b>	<b>Utility Scale PV Project</b>	<b>Total Hours</b>
Week 01	4	5	1	2		12
Week 02	4	5	2	4		15
Week 03	4	5	2	4		15
Week 04	4	5	2	6		17

Week 05	4	5	2	6		17
Week 06	6			8		14
Week 07	4	5	2		4	15
Week 08	4	5	2		4	15
Week 09	4	5	1		4	14
Week 10	4	4			4	12
Week 11					4	4
<b>Total</b>	<b>42</b>	<b>44</b>	<b>14</b>	<b>30</b>	<b>20</b>	<b>150</b>

## Assessment

Assessment	Group Project? (group size)	Length	Weight	Learning outcomes assessed	Assessment criteria	Due date and submission requirements	Deadline for absolute fail	Marks returned
Online quizzes (x6) and video interviews (x1) (CLO)	No	Quizzes: 10 questions  Interviews: 10 minutes	15% (Pass/Fail)	CLO 1 to 3	Lecture material from weeks 2 to 9.	Quizzes: Fridays 6pm  Interview: week 9	N/A	Quizzes: One hour after the quiz due date
Commercial PV project (CLO) – Compliance submission	No	6-page report, plus attachments	30% (Pass/Fail)	CLO 1 and 3	Lecture material and studio activities from weeks 1 to 5	Week 5 Saturday 10 pm	One week after due date	Two weeks after submission deadline
Commercial PV project (ALO) – Tender submission	No	8-page report, plus attachments	15%	ALO 4	Lecture material and studio activities from weeks 1 to 5	Week 6 Saturday 10 pm	One week after due date	Two weeks after submission deadline
Utility scale PV project (ALO)	Yes (4 or 5)	10-page report and 5 min video	40%	ALO 4 and 5	All course content from weeks 1-10 inclusive.	Video: Week 10 Saturday 10 pm  Report: Week 11 Saturday 10 pm	One week after due date	Upon release of final results

Assessment task	Weight	Due Date	Course Learning Outcomes Assessed
1. Online quizzes	15%	Every Friday 6 pm	1, 2, 3, 4, 5
2. Commercial PV project-compliance submission	30%	02/07/2022 10:00 PM	1, 2, 3
3. Commercial PV project-Tender submission	15%	09/07/2022 10:00 PM	1, 2, 3, 4
4. Utility scale PV project 	40%	Video submission 01/08/2022 10:00 PM and Report submission 08/08/2022 10:00 PM	1, 2, 3, 4, 5

## Assessment 1: Online quizzes

**Due date:** Every Friday 6 pm

**Deadline for absolute fail:** Every Friday 6 pm

**Marks returned:** One hour after the quiz due date

You will have to complete six online quizzes, from weeks 2 to 5 and weeks 7 to 8. The quizzes will test your learning from the content in the online lessons. The quizzes are strictly individual and can be done online at any time after you have completed the online lessons. If you fail the quiz at first attempt, you will be given a second attempt (remedial quiz). The online quiz will be open until 6pm Friday of the respective week **after this time the quiz cannot be attempted**.

In addition, a video interview will be carried out during the term in week 9. The interviews are strictly individual between the student and the course coordinator or demonstrator. The interviews will check that you have learned the content of the course as demonstrated by the results in the online quizzes.

### Hurdle requirement

Students must demonstrate understanding of all key content of the course in the online quizzes and interviews. **A minimum average mark of 80% must be obtained in quizzes in order to pass this subject (i.e., average mark of six quizzes and interview, you won't fail if one of your quiz mark is below 80%).** The interviews will be used as check points with questions based in the online quizzes. Failure to achieve this minimum mark will result in an unsatisfactory fail (UF) grade, regardless of the performance in the rest of the course.

## Assessment 2: Commercial PV project- compliance submission

**Due date:** 02/07/2022 10:00 PM

**Deadline for absolute fail:** One week after the original submission date

**Marks returned:** Two weeks after the submission date

In this assessment task you will apply your knowledge to a real-world design challenge of a commercial grid connected PV system (Core Learning Outcome). As a part of this project, you and your team member will play the roles of 'junior engineers' in a PV company. Although this is an individual assessment, you are encouraged to collaborate with your team during this process. However, the work

submitted must be solely yours.

The project involves the use of the modelling software System Advisory Model (SAM) to design the PV system and of AutoCAD to deliver professional array layout. SAM will be used to carry out a techno-economic optimisation of the system performance and cost. The aim is to produce 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 compliance report explicitly showing all the important design criteria and considerations.

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

### **Assessment criteria**

The submission of the report to the Engineering Manager and Compliance Department of the company is due on week 5. The main body of the report should have a maximum of 6 pages plus appendices.

**This report is only for design option 1 without storage.**

Your system design must include all the aspects required for a system compliant to Australian Standard:

- Selection of components (PV, inverter, frame, protection, etc.)
- Sizing of all components including cables and protection, and calculation of voltage drops (this will be delivered as an excel input sheet).
- Lightning protection assessment.
- Wind load assessment.
- Drawing with the physical layout of modules, inverters, wiring, switching and protection gear required by AS/NZS5033, including earthing and lightning protection.

The report must include the following sections:

1. Context and site assessment
2. System design and calculations (includes Excel Design Spreadsheet to be submitted separately)
3. Lightning and wind load assessments
4. Estimated cost and performance
5. Estimated project plan
6. Appendices (workshop drawings and reference datasheets)

### **Hurdle requirement**

Students must demonstrate they can design a full PV system for optimum performance and in conformance to all the relevant Australian Standards. **A minimum mark of 80% must be obtained in the Commercial PV Project – Compliance report to pass this subject.** Failure to achieve this minimum mark will result in an unsatisfactory fail (UF) grade, regardless of the performance in the rest of the course.

Students will be given a second attempt if they fail to obtain above the 80% mark in their first attempt which they need to re-submit their final report within a week.

### **Assessment 3: Commercial PV project- Tender submission**

**Due date:** 09/07/2022 10:00 PM

**Marks returned:** Two weeks after submission

In this assessment task you will apply your knowledge to a real-world design challenge of a commercial grid connected PV system (Core Learning Outcome) including a storage option (Advanced Learning Outcome). As a part of this project, you and your team member will play the roles of 'junior engineers' in a PV company. Although this is an individual assessment, you are encouraged to collaborate with your team during this process. However, the work submitted must be solely yours.

In addition to the modelling and professional PV outline developed for the compliance report, you will need to deliver professional level single line diagrams (SLD) for the tender submission. SAM will be used to carry out a techno-economic optimisation of the system performance and cost. The aim is to produce 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., you are preparing a full tender submission in order to 'win' a contract for the installation of a new PV system.

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

### **Assessment criteria**

The main body of the tender report should have a maximum of 8 pages plus appendices. The appendices should include a full set of drawings and data sheets for all the components used in the design.

Your system design must include all the items included in the compliance report plus the system techno optimisation (for both design options: with and without battery) as well as the complete single line diagrams of both design options.

The report must include the following sections:

1. Executive summary (1 page max)
2. Context and site assessment
3. Summary of system design with and without battery
4. System optimization based on economic assessment
5. Project plan
6. Performance guarantee
7. Recommendations and conclusions
8. Appendices
  1. Tender return forms (see this document appendices)
  2. Workshop drawings
  3. Data sheets and warranties.

### **Assessment 4: Utility scale PV project (Group)**

**Due date:** Video submission 01/08/2022 10:00 PM and Report submission 08/08/2022 10:00 PM

**Deadline for absolute fail:** One week after the original submission date

**Marks returned:** Two weeks after submission

This project is based on utility scale PV systems, meaning that your team will be working on a solar farm. As part of this project, your team will play the role of a 'PV developer' trying to setup a new solar farm project in Australia. The project will run through the last half of the term aiming at producing a comprehensive project that can be presented to investors for funding during week 10 and 11. The team will have to select the location of the solar farm taking into consideration aspects like irradiance and grid connection. The final submission will be prepared as an investment brochure (video presentation with

commercial information plus drawings and marketing material) so your company can obtain funding for your project. This project will allow you to implement all the knowledge gained through the course involving the use of Australian standards, modelling software, together with engineering and economic principles to design a solar farm.

As part of the utility scale PV project, you will need submit the project report (30%) and video submission 10% (each team member presents).

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

### **Assessment criteria**

The submission of the final project report to the company board is due on Monday week 11. The main body of the report should have a **maximum of 12 pages** plus appendices. The appendices should include a full set of drawings and data sheets for all the components used in the design.

Your system design must include:

- The physical layout of modules, inverters, and wiring.
- Complete single line diagram showing estimated cable lengths.
- Selection of cable sizes and estimates of voltage drops in cables.
- Lightning protection assessment.
- Wind load assessment.
- The layout of all switching and protection required by AS/NZS5033 (shown on physical layout and single line diagram), including earthing and lightning protection.

The report (business plan) must include the following section:

1. Executive summary (1 page max)
2. Context (business opportunity)
3. Site assessment and selection
4. Connection point description and analysis
5. System design and optimization (technical solution)
6. Full economic assessment (costs and benefits)
7. Project risks
8. Project plan
9. Recommendations and conclusions
10. Appendices
  1. Workshop drawings
  2. Data sheets and warranties.

## Attendance Requirements

Students are strongly encouraged to attend all classes and review lecture recordings.

## Course Schedule

<b>Week</b>	<b>Topic</b>	<b>Delivery Mode</b>	<b>Suggested Readings</b>	<b>Date</b>
1	<i>Course introduction, PV basics, design thinking and team creation</i>	Online	OneNote online lesson	30 May – 5 Jun
2	<i>PV site specific design and modelling, component matching, cables, and protections</i>	Online	OneNote online lesson	6 Jun – 12 Jun
3	Array circuit protection, AC power, waves, phasors, and power factor	Online	OneNote online lesson	13 Jun - 19 Jun
4	PV architecture, inverters, and grid connection, earthing and faults	Online	OneNote online lesson	20 Jun – 26 Jun
5	Tendering for PV projects, installation of PV systems, wind loads and mounting	Online	OneNote online lesson	27 Jun – 3 Jul
6	<b><i>Flexibility week</i></b>			4 Jul – 10 Jul
7	Large scale PV systems, the grid, islanding and inverter safety	Online	OneNote online lesson	11 Jul – 17 Jul
8	Solar farm virtual site visit, quality of supply, voltage and frequency regulation	Online	OneNote online lesson	18 Jul – 24 Jul
9	PV financing & business models, three phase systems	Online	OneNote online lesson	25 Jul – 31 Jul
10	HV grid connection, operation and maintenance of power plants	Online	OneNote online lesson	1 Aug – 7 Aug

# Resources

## Prescribed Resources

Weekly OneNote online lecture notes

Reference Books:

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

Online resources:

- UNSW Library website - <https://www.library.unsw.edu.au/>
- Australian Bureau of Meteorology - <http://www.bom.gov.au/climate/>
- NASA (weather data) - <https://eosweb.larc.nasa.gov/>
- NREL National Solar Radiation Database (weather data) - <https://nsrdb.nrel.gov/>
- Renewables Ninja - <https://www.renewables.ninja/>
- 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>

Design Tools

- PVSYST - Software for photovoltaic Systems
- SAM - System Advisory Model
- RETScreen - Clean Energy Management Software system for energy efficiency

Standards (via UNSW Library)

- Building Code of Australia
- 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

## Submission of Assessment Tasks

Work submitted late without an approved special consideration or extension by the course coordinator or delegated authority is subject to a late penalty of 5% mark reduction per day, capped at five days (120 hours) from the assessment deadline, after which a student cannot submit an assessment, consistent with UNSW Assessment Implementation Procedure.

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.

Work submitted after the 'deadline for absolute fail' is not 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 are clearly indicated in the course outline, and such assessments receive a mark of zero if not completed by the specified date. Examples include:

- a. Weekly online tests or laboratory work worth a small proportion of the subject mark, or
- b. Online quizzes where answers are released to students on completion, or
- c. Professional assessment tasks, where the intention is to create an authentic assessment that has an absolute submission date, or
- d. Pass/Fail assessment tasks.

## Academic Honesty and Plagiarism

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](http://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.

If plagiarism is found in your work when you are in first year, your lecturer will offer you assistance to improve your academic skills. They may ask you to look at some online resources, attend the Learning Centre, or sometimes resubmit your work with the problem fixed. However more serious instances in first year, such as stealing another student's work or paying someone to do your work, may be investigated under the Student Misconduct Procedures.

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) even suspension from the university. The Student Misconduct Procedures are available here:

[www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf](http://www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf)

## Academic Information

### Course Evaluation and Development

Feedback on the course is gathered periodically using various means, including the UNSW myExperience process, informal discussion in the final class for the course, and the School's Student/Staff meetings. Your feedback is taken seriously, and continual improvements are made to the course based, in part, on such feedback.

In this course, recent improvements resulting from student feedback include changes in the assessment tasks and the online content.

### Important Links

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

- [Attendance](#)
- [Special Consideration](#)
- [Equitable Learning Services](#)
- [Exams](#)
- [Approved Calculators](#)
- [UNSW Email Address](#)

### 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.*

### 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.

## Appendix: Engineers Australia (EA) Professional Engineer Competency Standard

Program Intended Learning Outcomes	
Knowledge and skill base	
PE1.1 Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline	
PE1.2 Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline	
PE1.3 In-depth understanding of specialist bodies of knowledge within the engineering discipline	✓
PE1.4 Discernment of knowledge development and research directions within the engineering discipline	
PE1.5 Knowledge of engineering design practice and contextual factors impacting the engineering discipline	✓
PE1.6 Understanding of the scope, principles, norms, accountabilities and bounds of sustainable engineering practice in the specific discipline	✓
Engineering application ability	
PE2.1 Application of established engineering methods to complex engineering 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	
Professional and personal attributes	
PE3.1 Ethical conduct and professional accountability	
PE3.2 Effective oral and written communication in 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	