Palau Community College
School of Technical Education
ELECTRICAL TECHNOLOGY

COURSE OUTLINE

Grid-connected Solar PV System, Design and Installation	**ET 214**
Course Title	Dept & Course No.

COURSE DESCRIPTION

This course covers technical knowledge and practical skills relevant in designing, installation, troubleshooting, repair and maintenance of grid-connected solar photovoltaic system. It deals with designing a PV generating system according to customer's need and requirements. It includes undertaking one or two simulated installations on dummy roof or ground mounted PV arrays. It also deals with safety work practices applicable to sustainable energy industry.

SEMESTER CREDIT: 4

I. CONTACT HOURS PER WEEK:

2	6	8
Lecture	Lab	Total

II. PREREQUISITE: ET 103, BP 116, ET 122

III. COURSE LEARNING OUTCOME:

Upon completion of the course, the students will be able to, with 65% accuracy to;

1. Design grid-connected PV system according to customer's requirements.

IV. COURSE CONTENT

A Understanding Energy Concepts
- 1) Power and Energy
- 2) Unit conversions
- 3) Prefixes
- 4) Identifying power rating of electrical appliances
- 5) True power, apparent power and reactive power calculations
- 6) Calculating effective energy consumptions

B Determining solar resources
- 1) Irradiance
- 2) Irradiation and peak sun hours
- 3) Solar radiation data
- 4) Sun path diagram
- 5) Defining position of the sun
- 6) Solar altitude
- 7) Geometric effects
- 8) Tilting solar modules
- 9) Magnetic north and true north

C Determining customer's energy requirements
- 1) Customer's reason for installing grid-connected solar PV

D Local billing method
- 1) Local utility energy metering
- 2) Understanding on how metering equipment is installed

E Undertaking system design
- 1) PV modules
  - a) Characteristics of solar cell

b) Fill factor and equivalent solar cell circuit
c) STC and NOTC
d) Types of solar cell
e) Electrical protection
f) Module reliability
g) Technical specification and output characteristic of PV module
h) Factors that influence the output characteristic of PV module
i) Connecting modules in series/parallel configuration
j) Effects of combining dissimilar modules
k) Blocking and bypass diodes
l) Impact of dirt and shading on PV module

2) Balance of system - Inverter
   a. Purpose of inverter
   b. Types of inverter
   c. Maximum power point tracking feature of grid-connected inverter
   d. Factors affecting the efficiency and reliability of inverter
   e. Understanding inverter's specifications and features
   f. Balance of Systems - System cabling, circuit protection and metering
   g. Cable routes and length
   h. Current carrying capacity of conductor
   i. Effects of excessive voltage drop in the system
   j. Calculating cables voltage drop
   k. Determining circuit protection rating
   l. Determining size of switches/isolators and their location/placement within the system
3) System performance-component matching
4) Matching PV array current, voltage and power to inverters operating window
5) System yield and performance
6) Yearly energy yield
7) Specific yield
8) Performance ratio

F Undertaking economic analysis
1) Capital cost of the system
2) Expected running cost
3) Expected replacement cost
4) Life cycle cost

2. Prepare PV system documentations

G PV system documentation for the customer
1) List of equipment supplied
2) System wiring diagram
3) System performance estimates
4) Operating instructions
5) Shutdown and isolation procedure
6) Maintenance procedure and time table
7) Commissioning record and installation checklist
8) Monitoring system
9) Warranty information

10) Equipment manufacturer's documentation and handbooks

3. Install grid-connected PV systems

H Working Safely with Photovoltaic Systems
1) Carry out a Job Safety analysis:-
   a) Identifying job tasks
   b) Identifying hazards
   c) Identifying the risk class
   d) Nominating risk control measures
   e) Nominating a person responsible for carrying out each measure
2) OHS legislation and its application to the sustainable energy industry
3) Safety work practices in installing PV system
   a) Safety practices in working with ladders/scaffolds
   b) Disabling array during installation
   c) Safe techniques in laying and securing cables

I Installing grid-connected PV system
1) Undertaking a site assessment
2) Identifying installation hazards and risk
3) Determining the maximum number of modules that can fit on the roof
4) Installation techniques on different types of roof
5) Wind loading requirements
6) Avoiding corrosion problems in contacting dissimilar metals
7) Layout, positioning, fixing and securing system components
8) Mounting design and techniques in attaching modules
9) Cabling techniques
   a) Laying and securing cables
   b) Physical protection for cables (ducting/raceway)
10) Label and signage
11) Interconnection of PV to the grid
12) System installation and pre-commissioning checklist

J Preparing and interpreting system drawings and system design
1) Identifying system components
2) Preparing procurement list of system components from the drawing
3) Identifying actual locations of system components and equipment

K Applying relevant guidelines and standards
1) Local regulatory requirements
2) SEAPI Guidelines
3) National Electrical Code (NEC)

4. Test and commission grid-connected PV system

L Testing and commissioning the system
1) Visual inspection of the entire installation
2) Structural integrity and weather sealing
3) Measuring system current and voltage
4) Checking proper wiring practices, polarity and

integrity of terminations
5) Earthing system
6) Procedures in connecting and disconnecting the system from all sources
7) Verifying system overall functionality
8) System start-up and shut down procedure
9) Commissioning test sheets

M Safety issues associated with testing and commissioning of PV system

5. Troubleshoot, repair and maintain grid-connected PV system

N Troubleshooting the system
1) Dealing with customer's complaint about system not working
2) Troubleshooting PV arrays
3) Troubleshooting inverters

O System maintenance
1) Inverter
2) PV arrays
3) System integrity

P Maintenance schedule and log book

Q Tools and equipment in troubleshooting and repair of the system

R Measuring system performance and operating parameters

S Safety issues associated with operations and maintenance of the system

V. TOOLS, MATERIALS AND EQUIPMENT

1. PV modules
2. Module railings
3. Module clamps and brackets
4. Railing mounting
5. Roof mounting
6. Fastening devices
7. Ducting/raceways
8. Grounding rod
9. Grounding lug with star tooth washers
10. Isolating sheets
11. UV rated corrugated conduits
12. UV rated cable ties
13. AC cable
14. DC cable
15. cable clamps
16. conduit clamps
17. adapters
18. Power maximiser
19. Charge controller/monitor
20. Inverter for stand alone PV system
21. Inverter for grid-connected PV
22. Variable resistance
23. AC isolator
24. DC isolator
25. M4 plugs
26. Deep cycle battery
27. Solar irradiance meter
28. Clamp ammeter with DC and AC rating
29. PV module tester
30. Multi-meter
31. Crimping tool
32. Solar pathfinder
33. Cable cutters
34. Cable strippers
35. Pliers
36. Screwdrivers
37. Allen keys
38. Battery powered electric drill
39. Body harness
40. First aid kit
41. Sun block
42. Spanners
43. Mounting structure for ground mounted PV modules
44. Mock-up trainer for testing string/array
45. Mock-up trainer for small stand-alone PV system
46. kWh meter

VI. TEXT AND REFERENCES

A. *Required Text*

GSES Pty. Ltd. ***GRID-CONNECTED PV SYSTEMS-DESIGN AND INSTALLATION 1st Ed USA Version,*** Global Sustainable Energy Solutions Pty Ltd. December 2013. *ISBN*: 978-1-921932-03-8

B. *References*

Latest Edition of ***National Electrical Code***,
SEIAPI ***System Design Guidelines*** on Grid-connected PV systems.
SEIAPI ***System Installation Guidelines*** on Grid-connected PV systems.

VII. METHOD OF INSTRUCTION

A. Lecture-discussion
B. Demonstration
C. Video Presentation
D. Laboratory Performance/Field activities

VIII. METHOD OF EVALUATION

A. Knowledge will be evaluated using the following methods:
   1. Written test
   2. Graded recitation/Oral presentation
   3. Instructor-student one-on-one interview

B. Skills will be evaluated using the following criteria:
   1. Accuracy
   2. Quality of work
   3. Safety, use of tools, materials and equipment
   4. Timeliness/Completion

C. Midterm and final grade are computed and weighted using the following criteria:

Class participation.....	15%
Quizzes/Short Tests.....	20%
Midterm/Final Exams.....	25%
Lab Performance/Projects.....	40%
TOTAL	100%

D. Transmutation of total percent to letter grade:

90-100%.....	A
80-89%.....	B
70-79%.....	C
65-69%.....	D
00-64%.....	F

Palau Community College
School of Technical Education
Electrical Technology

TASK LISTING

ET 214 - Grid-connected Solar PV System, Design & Installation	Credit:	2	2	96
Course No. & Title		Lec	Lab	Total Lab Hrs

COURSE LEARNING OUTCOMES	Allotted Hours
1. Design grid-connected PV system according to customer's requirements	20
A. Survey the customer to determine what are their reasons for installing a PV Grid Connects System	
B. Identify what month, time and day of a year a certain location will experience shading using sun path diagram and solar pathfinder.	
C. Quantify the daily total peak sun hours to array orientation, inclination and time of the year	
D. Demonstrate basic electric circuit theory and be able to identify series and parallel circuits	
E. Demonstrate the effect on array output (current, voltage and power) of connecting modules in series and parallel configurations	
F. Illustrate the effects of using dissimilar modules in an array	
G. Demonstrate the use of blocking and bypass diodes with the different classes of PV modules, and make appropriate decisions about their use or otherwise and quantify the effect of diodes on array output.	
H. Demonstrate the impact of shading and implement a program to periodically check for shading effects by cleaning panels, removing debris (leaves bird droppings etc.), trimming trees	
I. Determine the design currents for any part of a PV system electrical circuit	
J. Explain the reasons why excessive voltage drop can be detrimental to system performance	
K. Discuss current carrying capacity and the implications for cable selection	
L. Demonstrate the calculation and measurement of voltage drop in a conductor	
M. Demonstrate the measurement of current through a conductor	
N. Demonstrate the use of tables to calculate the current carrying capacity of a conductor and the factors which influence CCC	
O. Apply voltage drop and current carrying capacity calculation to select cables for all circuits in a grid connect PV system	
P. Specify appropriate protection for all conductors in a circuit	
Q. Determine appropriate size, ratings, and locations for earthing, surge suppression, and associated equipment	
R. Determine appropriate size, ratings, and locations for all system overcurrent and disconnect devices.	
S. Carry out an economic analysis of the system design and its projected performance.	
1) Capital cost of the system	
2) Expected running cost	
3) Expected replacement cost	
4) Life cycle cost	
2. Prepare PV system documentation for customer	10
A. State and prepare the system documentation that should be provided to the system owners	
1) List of equipment supplied	
2) System wiring diagram	

	3) System performance estimates 4) Operating instructions 5) Shutdown and isolation procedure 6) Maintenance procedure and time table 7) Commissioning record and installation checklist 8) Monitoring system 9) Warranty information 10) Equipment manufacturer's documentation and handbooks	
3.	***Install grid-connected PV systems*** A. Fill-out job task checklist B. Fill-out risk analysis checklist C. Maintain safe work habits and a clean, orderly work area D. Demonstrate safe and proper use of required tools and equipment E. Demonstrate safe and accepted practices for personnel protection F. Demonstrate how the modules are connected in series and parallel to suit the inverter chosen G. Prepare and interpret system drawings and system design H. Apply relevant guidelines and standards I. Demonstrate sound mounting design and techniques for attaching modules to the array frame and the array frame to its supporting structure J. Use appropriate bolts or screws, including gauge, penetration K. Fix external timber or metal battens to the roof sub frame L. Perform weather sealing of array to building or other support mechanism M. Assess a site in relation to information from published wind data, and the suitability of the array frame and mounting techniques to meet wind loading requirements N. Assemble modules, panels, and support structures as specified by module manufacturer or design O. Demonstrate a working knowledge of the pitch and condition of different roof claddings systems, and apply appropriate mounting techniques the roofs typical within the country of installation P. Recognize and avoid corrosion problems arising from contacting dissimilar metals in mounting systems / roof claddings Q. Use of rubber grommets, non-metallic membranes R. Use of appropriate bolts (stainless steel etc.) S. Visually inspect and quick test (measure open-circuit voltage) PV modules as required T. Demonstrate the positioning and fixing of all system components (eg Inverter and meters) in place to: minimize cable lengths between all components; layout and secure system components in position U. Demonstrate diagrammatically and in practice the layout of system components in ergonomic and economic positions V. Demonstrate the use of appropriate fixing systems to secure system components in place W. Demonstrate cable termination techniques X. Demonstrate the installation and replacement of circuit protection Y. Demonstrate safe techniques for laying and securing cables in place Z. Demonstrate the use of appropriate physical protection for installed cables AA. Install module array interconnect wiring; implement measures to disable array during installation BB. Install cabling between modules , inverter and switchboard CC. Complete final assembly, structural attachment, and weather sealing of array to building or other support mechanism DD. Install and provide required labels on inverters, controls, disconnects and overcurrent devices, surge suppression and earthing equipment, junction boxes, batteries and enclosures, conduit, and other electrical hardware	30

EE. Label, install, and terminate electrical wiring; verify proper connections, voltages, and phase/polarity relationships FF. Verify continuity and measure impedance of earthing system GG. Program, adjust, and/or configure inverters and controls for desired set points and operating modes	
4. *Test and commission grid-connected PV system* A. Visually inspect entire installation, identifying and resolving any deficiencies in materials or workmanship B. Check system mechanical installation for structural integrity and weather sealing C. Demonstrate the use of multimeters and other test equipment when undertaking the testing D. Check electrical installation for proper wiring practice, polarity, earthing, and integrity of terminations E. Activate system and verify overall system functionality and performance; compare with expectations F. Demonstrate procedures for connecting and disconnecting the system and equipment from all sources G. Identify and verify all required markings and labels for the system and equipment H. Identify and explain all safety issues associated with operation and maintenance of system I. Identify what documentation is required to be provided to the PV system owner/operator by the installer	20
5. *Troubleshoot, repair and maintain grid-connected PV system* A. Identify tools and equipment required for maintaining and troubleshooting PV systems; demonstrate proficiency in their use B. Identify maintenance needs and implement service procedures for modules, arrays, power conditioning equipment, safety systems, structural and weather sealing systems, and balance of systems equipment C. Measure system performance and operating parameters; compare with specifications and expectations, and assess operating condition of system and equipment D. Perform diagnostic procedures and interpret results E. Identify performance and safety issues, and implement corrective measures F. Verify and demonstrate complete functionality and performance of system, including start-up, shut-down, normal operation, and emergency/bypass operation G. Prepare, compile and maintain records of system operation, performance, and maintenance	16
	96

Palau Community College

ET 214 SOLAR PV SYSTEM, DESIGN AND INTALLATION

Course Learning Outcomes

During the course experience, the ***course learning outcomes*** (CLO) will be assessed through the use of signature assignments. A rating scale will be used to determine the students' proficiency level of each CLO using specifically aligned assignments. The numerical rating of 4,3,2 and 1 are not intended to represent the traditional school grading system of A, B, C, D and F. The descriptions associated with each of the numbers focus on the level of student performance for each of the course learning outcome listed below.

Rating Scale:

5. Excellent
4. Above average
3. Average
2. Below Average
1. Unacceptable

1. Design grid-connected PV system according to customer's requirements

5	The student is able to design grid-connected PV system according to customer's requirements without any supervision and instruction
4	The student is able to design grid-connected PV system according to customer's requirements with limited supervision but no instruction
3	The student is able to design grid-connected PV system according to customer's requirements with limited supervision and limited instruction
2	The student has difficulty to design grid-connected PV system according to customer's requirements
1	The student is unable to design grid-connected PV system according to customer's requirements.

2. Prepare PV system documentation

5	The student is able to interpret local regulatory requirement and prepare PV system documentation without any supervision and instruction
4	The student is able to interpret local regulatory requirement and prepare PV system documentation with limited supervision but no instruction
3	The student is able to interpret local regulatory requirement and prepare PV system documentation with limited supervision and limited instruction
2	The student has difficulty to interpret local regulatory requirement and prepare PV system documentation and requires considerable supervision and instruction
1	The student is unable to interpret local regulatory requirement and prepare PV system documentation.

3. Install grid-connected PV systems

5	The student is able to install grid-connected PV systems without any supervision and instruction
4	The student is able to install grid-connected PV systems with limited supervision but no instruction
3	The student is able to install grid-connected PV systems with limited supervision and limited instruction
2	The student has difficulty to install grid-connected PV systems and requires considerable supervision and instruction
1	The student is unable to install grid-connected PV systems.

4. Test and commission grid-connected PV system

5	The student is able to test and commission grid-connected PV system without any supervision and instruction
4	The student is able to test and commission grid-connected PV system with limited supervision but no instruction

3	The student is able to test and commission grid-connected PV system with limited supervision and limited instruction
2	The student has difficulty to test and commission grid-connected PV system and requires considerable supervision and instruction
1	The student is unable to test and commission grid-connected PV system.

5. Troubleshoot, repair and maintain grid-connected PV system

5	The student is able to troubleshoot, repair and maintain grid-connected PV system without any supervision and instruction
4	The student is able to troubleshoot, repair and maintain grid-connected PV system with limited supervision but no instruction
3	The student is able to troubleshoot, repair and maintain grid-connected PV system with limited supervision and limited instruction
2	The student has difficulty to troubleshoot, repair and maintain grid-connected PV system and requires considerable supervision and instruction
1	The student is unable to troubleshoot, repair and maintain grid-connected PV system.