Introduction to Solar Photovoltaics Annotated Instructor's Guide

Module 57101-11

Module Overview

This module is designed for trainees who wish to pursue a career in solar energy. It covers the basic concepts of PV systems and their components. It also explains how PV systems are sized, designed, and installed. Successful completion of this module will help prepare trainees for the North American Board of Certified Energy Practitioners (NABCEP) PV Entry Level Exam.

Prerequisites

Prior to training with this module, it is recommended that the trainee shall have successfully completed *Core Curriculum*. It is also suggested that the trainee shall have completed the following modules from the Electrical curriculum: *Electrical Level One*, Modules 26101 through 26111; *Electrical Level Two*, Modules 26201, 26205, 26206, and 26208 through 26211; *Electrical Level Three*, Modules 26301 and 26302; and *Electrical Level Four*, Modules 26403 and 26413.

Objectives

Upon completion of this module, the trainee will be able to do the following:

1. Identify photovoltaic (PV) applications and advantages.
2. Identify system components and their functions.
3. Identify safety hazards associated with PV installations.
4. Trace a basic electrical circuit and perform calculations using Ohm's law.
5. List PV system sizing considerations.
6. Identify PV electrical and mechanical system design considerations.
7. Describe the tasks required to complete a site analysis.
8. Identify the effects of the environment on panel output.
9. Describe how to install a simple grid-connected PV system.
10. Explain how to assess system operation and efficiency.
11. Recognize the tasks required when performing PV maintenance and troubleshooting.
12. Identify appropriate codes and standards concerning installation, operation, and maintenance of PV systems and equipment.

Performance Tasks

This is a knowledge-based module; there are no performance tasks.

Materials and Equipment

Markers/chalk
Pencils and scratch paper
Whiteboard/chalkboard
Solar Photovoltaic Systems Installer PowerPoint® Presentation Slides (ISBN 978-0-13-257135-7)
Multimedia projector and screen
Computer
Appropriate personal protective equipment
Access to various installed PV systems
Digital AC/DC meter
Clamp-on ammeter
Pyranometer
Infrared thermal device
Torque wrench
Sun path calculator
Site survey checklist
Angle finder
Camera
Compass
Calculator
Tape measure
Ladder
Various types of solar panels and mounting system components
Inverter
Batteries

(*continued*)

Charge controller
AC and DC disconnects
Panel with breaker for inverter connection
Conduit and wire
Copy of the latest edition of the *National Electrical Code®* (*NEC®*)
Module Examination*

* Single-module AIG purchases include the printed exam and performance task sheet. If you have purchased the perfect-bound version of this title, download these materials from the IRC using your access code.

Safety Considerations

Ensure that the trainees are equipped with appropriate personal protective equipment and know how to use it properly. Ensure that all trainees are briefed on appropriate field safety procedures, including fall protection, electrical hazards, sun exposure, and battery hazards. If the training center does not have various simple PV systems set up on site, this module will require that the trainees visit one or more job sites in order to view installed PV systems. Ensure that trainees are briefed on site safety policies prior to any site visits.

Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

IEEE 1547, Standard for Interconnecting Distributed Resources with Electric Power Systems, Latest Edition. Los Alamitos, CA: Institute of Electrical and Electronics Engineers (IEEE).

National Electrical Code® (NFPA 70®), Latest Edition. National Fire Protection Association (NFPA): Quincy, MA.

Occupational Safety and Health Standard 1910.302, Electric Utilization Systems, Latest Edition. Washington, DC: OSHA Department of Labor, U.S. Government Printing Office.

Photovoltaic Systems, Second Edition. James P. Dunlop. Orland Park, IL: American Technical Publishers.

Standard for Electrical Safety in the Workplace® (NFPA 70E), Latest Edition. National Fire Protection Association (NFPA): Quincy, MA.

UL Standard 1703, UL Standard for Safety, Flat-Plate Photovoltaic Modules and Panels, Latest Edition. Camas, WA: Underwriters Laboratories.

UL Standard 1741, Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources, Latest Edition. Camas, WA: Underwriters Laboratories.

Uniform Solar Energy Code, Latest Edition. Ontario, CA: International Association of Plumbing and Mechanical Officials (IAPMO).

Teaching Time for This Module

An outline for use in developing your lesson plan is presented below. Note that each Roman numeral in the outline equates to one session of instruction. Each session has a suggested time period of 2½ hours. This includes 10 minutes at the beginning of each session for administrative tasks and one 10-minute break during the session. Approximately 40 hours are suggested to cover *Introduction to Solar Photovoltaics*. You will need to adjust the time required for hands-on activity and testing based on your class size and resources.

Topic	Planned Time
Sessions I and II. Introduction; Applications	
A. Introduction	_____
B. Applications	_____
1. Standalone Systems	_____
2. Grid-Connected Systems	_____
3. Grid-Interactive Systems	_____
4. Utility-Scale Solar Generating Systems	_____
Session III. Ohm's Law and Power	
A. Ohm's Law and Power	_____
1. Applying Ohm's Law to Series and Parallel Circuits	_____
2. Ohm's Law and Power	_____
3. Series and Parallel Circuits in Solar PV Systems	_____
4. Peak Sun and Power	_____
Sessions IV and V. PV System Components	
A. PV System Components	_____
1. PV Panels	_____
2. Inverters	_____
3. Batteries	_____
4. Charge Controllers	_____
5. BOS Components	_____
Session VI. Safety Considerations in PV Systems	
A. Safety Considerations in PV Systems	_____
1. Fall Protection	_____
2. Battery Hazards	_____
3. Electrical Hazards	_____
4. Meter Safety	_____
Sessions VII and VIII. Site Assessment	
A. Site Assessment	_____
1. Customer Interview	_____
2. Power Consumption	_____
3. Roof Evaluation	_____
4. Array Orientation	_____
5. Equipment Location	_____

Topic	Planned Time
Sessions IX and X. System Design	
A. System Design	_____
1. Panel Nameplate Data	_____
2. Solar Array Sizing	_____
3. Inverter Selection	_____
4. Battery Bank Sizing	_____
5. Selecting a Charge Controller	_____
6. Adjusting PV Conductors	_____
Sessions XI and XII. Installation	
A. Installation	_____
1. Forces Exerted on the Panels/Support System	_____
2. Roof-Mounted Installations	_____
3. Ground-Mounted Installation	_____
4. Electrical System Installation	_____
5. Assessing System Output Power	_____
Sessions XIII and XIV. Maintenance; Troubleshooting	
A. Maintenance	_____
B. Troubleshooting	_____
1. Loose or Corroded System Connections	_____
2. Inverter Losses	_____
3. Heat Fade	_____
4. Burnt Terminals	_____
5. Bypass Diode Failure	_____
Sessions XV. Codes and Standards; Emerging Technologies	
A. Codes and Standards	_____
B. Emerging Technologies	_____
Session XVI. Review and Testing	
A. Module Review	_____
B. Module Examination	_____
1. Trainees must score 70 percent or higher to receive recognition from NCCER.	
2. Record the testing results on Training Report Form 200, and submit the results to the Training Program Sponsor.	

Site Assessment
Annotated Instructor's Guide

Module 57102-11

Module Overview

A thorough site assessment is essential to the installation of an efficient system that meets the customer's needs. This module introduces the trainee to the site assessment process for a photovoltaic system.

Objectives

Upon completion of this module, the trainee will be able to do the following:

1. Determine customer needs:
   - Determine electrical load and energy use by review of utility bills, meter readings, measurements, and/or customer interviews.
   - Estimate and/or measure the peak load demand and average daily energy use for all connected loads.
2. Assess any site-specific safety hazards and/or installation considerations.
3. Identify and use the tools and equipment required for conducting site surveys for PV installations.
4. Identify, select, and sketch a suitable location for PV array installation, including proper orientation, sufficient area, adequate solar access, and structural integrity.
5. Select suitable locations for installing inverters, control(s), batteries, and other components.
   - Identify essential loads for battery systems.
   - Identify opportunities for the use of energy-efficient equipment/appliances, conservation, and energy management practices.
6. Acquire and interpret site solar radiation and temperature data to establish performance expectations and use in electrical system calculations.

Prerequisites

Prior to training with this module, it is recommended that the trainee shall have successfully completed *Core Curriculum* and *Solar Photovoltaic Systems Installer*, Module 57101-11. It is also suggested that the trainee shall have successfully completed the following modules from the Electrical curriculum: *Electrical Level One*, Modules 26101 through 26111; *Electrical Level Two*, Modules 26201, 26205, 26206, and 26208 through 26211; *Electrical Level Three*, Modules 26301 and 26302; and *Electrical Level Four*, Modules 26403 and 26413.

Performance Task

Under the supervision of the instructor, the trainee should be able to do the following:

1. Given the results of a customer interview and the sample house drawing provided, complete a site survey and checklist.

Materials and Equipment

Markers/chalk
Pencils and scratch paper
Whiteboard/chalkboard
Solar Photovoltaic Systems Installer PowerPoint® Presentation Slides (ISBN 978-0-13-257135-7)
Multimedia projector and screen
Computers with Internet access
Appropriate personal protective equipment
Selection of assessment tools
Sample electric bills
Pictures of sagging or obviously bad roofs, marginal roofs, and good roofs
Picture with roof and lot dimensions, roof angle, and number of panels
Several addresses with good aerial views available on the Internet
Compass
Solar Pathfinder™, if possible

(*continued*)

Sufficient copies of a completed customer interview
Sufficient copies of the sample house drawing
Module Examinations*
Performance Profile Sheets*

* Single-module AIG purchases include the printed exam and performance task sheet. If you have purchased the perfect-bound version of this title, download these materials from the IRC using your access code.

Safety Considerations

Ensure that the trainees are equipped with appropriate personal protective equipment and know how to use it properly. Review safety guidelines associated with working on or around photovoltaic systems, including fall protection. Emphasize the importance of proper housekeeping.

Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

Aerial photographs:
- Terraserver: www.terraserver.com.
- Google Earth: www.google.com.
- USGS: http://edcsns17.cr.usgs.gov.

AMtec Solar (combiners) website: www.amtecsolar.com.
Electric Power Glossary of Terms: www.osha.gov.
Florida Solar Energy Center website: www.fsec.ucf.edu.
National Geophysical Data Center website: www.ngdc.noaa.gov.
National Oceanic and Atmospheric Administration website: www.noaa.gov.
Solar Pathfinder™ website: www.solarpathfinder.com.
Solar Power Calculator website: www.findsolar.com.
Solar Source Institute website: www.solarsource.net.
Surrette/Rolls Battery website: www.surrette.com.
University of Oregon Solar Radiation Monitoring Laboratory website: solardat.uoregon.edu.

Teaching Time for This Module

An outline for use in developing your lesson plan is presented below. Note that each Roman numeral in the outline equates to one session of instruction. Each session has a suggested time period of 2½ hours. This includes 10 minutes at the beginning of each session for administrative tasks and one 10-minute break during the session. Approximately 10 hours are suggested to cover *Site Assessment*. You will need to adjust the time required for hands-on activity and testing based on your class size and resources. Because laboratories often correspond to Performance Tasks, the proficiency of the trainees may be noted during these exercises for Performance Testing purposes.

Topic	**Planned Time**
Session I. Introduction; Determining Customer Needs	
A. Introduction	_____
1. Assessment Tools and Equipment	_____
B. Determining Customer Needs	_____
1. Energy Loads	_____
2. Available Sunlight	_____
3. Mounting Options	_____

Topic	Planned Time
Session II. Mounting Surface Information; Acquiring and Interpreting Site Solar Data	
A. Mounting Surface Information	_____
1. Inspecting Proposed Installation Areas	_____
2. Inspecting Attic Spaces	_____
3. Roofing Materials	_____
4. Spacing	_____
5. Anchoring	_____
B. Acquiring and Interpreting Site Solar Data	_____
1. Identifying Sun Paths and Intensity Levels	_____
2. Shading at the Customer's Location	_____
Session III. Locations for BOS Components; Documenting Site Assessment; New Technology	
A. Locations for BOS Components	_____
1. Support and Security Structures	_____
2. Combiners	_____
3. Charge Controllers	_____
4. Batteries	_____
5. Inverters	_____
6. Disconnects	_____
7. Grounding	_____
B. Documenting Site Assessment	_____
C. New Technology	_____
D. Laboratory	_____
Given the results of a customer interview and the sample house drawing provided, have the trainees complete a site survey and checklist. This laboratory corresponds to Performance Task 1.	
Session IV. Review and Testing	
A. Review	_____
B. Module Examination	_____
1. Trainees must score 70 percent or higher to receive recognition from NCCER.	
2. Record the testing results on Training Report Form 200, and submit the results to the Training Program Sponsor.	
C. Performance Testing	_____
1. Trainees must perform each task to the satisfaction of the instructor to receive recognition from NCCER. If applicable, proficiency noted during laboratory exercises can be used to satisfy the Performance Testing requirements.	
2. Record the testing results on Training Report Form 200, and submit the results to the Training Program Sponsor.	

System Design
Annotated Instructor's Guide

Module 57103-11

Module Overview

This module describes system design considerations, including array configurations, component selection, and wire sizing. It also covers bonding, grounding, and the selection of overcurrent protection and disconnects.

Prerequisites

Prior to training with this module, it is recommended that the trainee shall have successfully completed *Core Curriculum* and *Solar Photovoltaic Systems Installer*, Modules 57101-11 and 57102-11. It is also suggested that the trainee shall have successfully completed the following modules from the Electrical curriculum: *Electrical Level One*, Modules 26101 through 26111; *Electrical Level Two*, Modules 26201, 26205, 26206, and 26208 through 26211; *Electrical Level Three*, Modules 26301 and 26302; and *Electrical Level Four*, Modules 26403 and 26413.

Objectives

Upon completion of this module, the trainee will be able to do the following:

1. Identify appropriate system designs and array configurations based on user loads, customer expectations, and site conditions.
2. Determine the size and capacities for major system components based on user load, desired energy production, autonomy requirements, and costs.
3. Determine the PV module layout, orientation, and mounting method for optimum system production and integrity.
4. Determine the ampacity requirement for all components and wiring of the PV system.
5. Select the appropriate conductor types and sizes for each portion of the electrical circuit.
6. Identify the appropriate size, rating, and location of required overcurrent protection and power disconnect devices.
7. Determine the appropriate size, rating, and location for bonding, grounding, and surge suppression.

Performance Task

Under the supervision of the instructor, the trainee should be able to do the following:

1. Given a completed site assessment, design a grid-connected PV system.

Materials and Equipment

Markers/chalk
Pencils and scratch paper
Whiteboard/chalkboard
Solar Photovoltaic Systems Installer PowerPoint® Presentation Slides (ISBN 978-0-13-257135-7)
Multimedia projector and screen
Computers with Internet access
Appropriate personal protective equipment
Several multimeters
A list of battery requirements including:
- Current load
- Inverter efficiency
- DC system voltage
- Days of autonomy
- Battery design discharge limit

Several battery catalogs
Several solar panel specification sheets
PV system, working
Photos of several site locations, with their city, state, and insolation factors
Two or three copies of the *NEC*®
A couple of wire specifications for the trainees to determine wire sizes
An electrical diagram of a PV system with the grounding and disconnects removed
Factor values for determining array size
Completed site assessment
Module Examinations*
Performance Profile Sheets*

* Single-module AIG purchases include the printed exam and performance task sheet. If you have purchased the perfect-bound version of this title, download these materials from the IRC using your access code.

Safety Considerations

Ensure that the trainees are equipped with appropriate personal protective equipment and know how to use it properly. Review safety guidelines associated with working on or around solar PV systems. Emphasize the importance of proper housekeeping.

Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

IEEE 1547, Standard for Interconnecting Distributed Resources with Electric Power Systems, Latest Edition. Los Alamitos, CA: Institute of Electrical and Electronics Engineers (IEEE).

National Electrical Code® (NFPA 70®), Latest Edition. National Fire Protection Association (NFPA): Quincy, MA.

Occupational Safety and Health Standard 1910.302, Electric Utilization Systems, Latest Edition. Washington, DC: OSHA Department of Labor, U.S. Government Printing Office.

Photovoltaic Systems, Second Edition. James P. Dunlop. Orland Park, IL: American Technical Publishers.

Standard for Electrical Safety in the Workplace® (NFPA 70E®), Latest Edition. National Fire Protection Association (NFPA): Quincy, MA.

Solar insolation for U.S. major cities: www.solar4power.com.

Solar panels, solar power generation, and photovoltaic system comparison chart: www.bdbatteries.com.

UL Standard 1703, UL Standard for Safety, Flat-Plate Photovoltaic Modules and Panels, Latest Edition. Camas, WA: Underwriters Laboratories.

UL Standard 1741, Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources, Latest Edition. Camas, WA: Underwriters Laboratories.

Uniform Solar Energy Code, Latest Edition. Ontario, CA: International Association of Plumbing and Mechanical Officials (IAPMO).

Teaching Time for This Module

An outline for use in developing your lesson plan is presented below. Note that each Roman numeral in the outline equates to one session of instruction. Each session has a suggested time period of 2½ hours. This includes 10 minutes at the beginning of each session for administrative tasks and one 10-minute break during the session. Approximately 25 hours are suggested to cover *System Design*. You will need to adjust the time required for hands-on activity and testing based on your class size and resources. Because laboratories often correspond to Performance Tasks, the proficiency of the trainees may be noted during these exercises for Performance Testing purposes.

Topic	**Planned Time**
Sessions I–VII. Introduction; Stand-Alone System Design; System Wiring	
A. Introduction	_____
B. Stand-Alone System Design	_____
1. The Electrical Load	_____
2. Battery Selection	_____
3. Solar PV Panel Selection	_____
4. Charge Controller Selection	_____
5. Inverters	_____
6. System Design and Equipment Review	_____

Topic	Planned Time
C. System Wiring	_____
1. Wire, Cable, and Raceway	_____
2. Wiring Diagram	_____
3. Solar Array Wiring	_____
4. Battery and Controller Wiring	_____
5. Inverter Wiring	_____
6. Overcurrent Protection and Disconnects	_____
Sessions VIII–IX. Grid-Tied Systems	
A. Grid-Tied Systems	_____
1. Grid-Tied System Component Selection	_____
2. PV System Grid Interface	_____
B. Laboratory	_____
Given a completed site assessment, have trainees design a grid-connected PV system. This laboratory corresponds to Performance Task 1.	
Session X. Review and Testing	
A. Review	_____
B. Module Examination	_____
1. Trainees must score 70 percent or higher to receive recognition from NCCER.	
2. Record the testing results on Training Report Form 200, and submit the results to the Training Program Sponsor.	
C. Performance Testing	_____
1. Trainees must perform each task to the satisfaction of the instructor to receive recognition from NCCER. If applicable, proficiency noted during laboratory exercises can be used to satisfy the Performance Testing requirements.	
2. Record the testing results on Training Report Form 200, and submit the results to the Training Program Sponsor.	

System Installation and Inspection Annotated Instructor's Guide

Module 57104-11

Module Overview

This module explains the process of installing a solar photovoltaic (PV) system, inspecting the entire system, and then activating the system.

Prerequisites

Prior to training with this module, it is recommended that the trainee shall have successfully completed *Core Curriculum* and *Solar Photovoltaic Systems Installer*, Modules 57101-11 through 57103-11. It is also suggested that the trainees shall have successfully completed the following modules from the Electrical curriculum: *Electrical Level One*, Modules 26101 through 26111; *Electrical Level Two*, Modules 26201, 26205, 26206, and 26208 through 26211; *Electrical Level Three*, Modules 26301 and 26302; and *Electrical Level Four*, Modules 26403 and 26413.

Objectives

Upon completion of this module, the trainee will be able to do the following:

1. Review the site assessment report, system design documents, and permits, and inspect the installation site.
2. Perform a job safety analysis (JSA) and deploy safety systems as needed.
3. Use system drawings and manufacturer's instructions to plan the installation and to inventory the project materials and tools needed for the job.
4. Locate structural members and install mounting hardware and raceway.
5. Inspect photovoltaic (PV) system components prior to installation.
6. Install the mechanical parts of the PV modules (panels) and balance-of-system components.
7. Install, label, and terminate electrical wiring and devices in accordance with local and national codes.
8. Activate and test the system to verify overall system operation.

Performance Task

Under the supervision of the instructor, the trainee should be able to do the following:

1. Install and commission a system.

Materials and Equipment

Markers/chalk
Pencils and scratch paper
Whiteboard/chalkboard
Solar Photovoltaic Systems Installer PowerPoint® Presentation Slides (ISBN 978-0-13-257135-7)
Multimedia projector and screen
Computers with Internet access
Appropriate personal protective equipment
Roof anchors
Harnesses and lanyards
Air-filtering respirator
ESD protection
Sufficient drills, torque wrenches, and tools for panel installation
Stud finder
Multimeter
Hydrometer
Set of panel output specifications
Bill of Materials for a PV system installation
Charge controller and user manual
Inverter and user manual
Combiner and user manual
Disconnect switches
Wiring diagram for solar PV system
Wire and raceway catalogs
Job safety analysis for each task in an installation
Site design plans
Section of a roof with shingles
Roofing sealant

(*continued*)

FLA batteries, dry
Electrolyte
Flange connections, both good and slightly damaged
Sufficient standoffs, mounting beams, grounding lugs, sliders, and associated hardware
End clamps, 16 sets
Mid clamps, 6 sets
Solar panels, boxed
Module Examinations*
Performance Profile Sheets*

* Single-module AIG purchases include the printed exam and performance task sheet. If you have purchased the perfect-bound version of this title, download these materials from the IRC using your access code.

Safety Considerations

Ensure that the trainees are equipped with appropriate personal protective equipment and know how to use it properly. Review safety guidelines associated with working on or near PV systems. Emphasize the importance of proper housekeeping.

Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

AMtec Solar (combiners) website: www.amtecsolar.com.

Florida Solar Energy Center website: www.fsec.ucf.edu.

Sample wiring diagram for solar PV system: www.freesunpower.com.

Solar panel terms: www.osha.gov.

Surrette/Rolls Battery website: www.surrette.com.

Solar Source Institute website: www.solarsource.net.

University of Oregon's Solar Radiation Monitoring Laboratory website: http://solardat.uoregon.edu.

Teaching Time for This Module

An outline for use in developing your lesson plan is presented below. Note that each Roman numeral in the outline equates to one session of instruction. Each session has a suggested time period of 2½ hours. This includes 10 minutes at the beginning of each session for administrative tasks and one 10-minute break during the session. Approximately 60 hours are suggested to cover *System Installation and Inspection*. You will need to adjust the time required for hands-on activity and testing based on your class size and resources. Because laboratories often correspond to Performance Tasks, the proficiency of the trainees may be noted during these exercises for Performance Testing purposes.

Topic	**Planned Time**
Session I. Introduction; Job Preparations	
A. Introduction	_____
B. Job Preparations	_____
1. Reviewing Site Assessment Reports	_____
2. Reviewing System Design Plans	_____
3. Inspecting Building Permits	_____
4. Inspecting Installation Sites	_____

Topic	Planned Time
Sessions II and III. Safety	
A. Safety	_____
1. Housekeeping	_____
2. Fall Protection	_____
3. Containment	_____
4. PPE and Heat or Sun Protection	_____
5. Material Handling	_____
6. Batteries	_____
7. Electrical Safety	_____
Sessions IV–VII. Job Planning and Inventory of Materials and Tools; Installing Mounting Hardware and Raceways	
A. Job Planning and Inventory of Materials and Tools	_____
1. Mounting Hardware	_____
2. Panels, Combiners, and Wiring to BOS Components	_____
3. BOS Components	_____
B. Installing Mounting Hardware and Raceways	_____
1. Preparing Installation Site	_____
2. Installing Mounting Hardware	_____
Sessions VIII and IX. Inspections of PV Components Prior to Installation	
A. Inspections of PV Components Prior to Installation	_____
1. Inspecting PV Panels	_____
2. Inspecting Combiner and DC Disconnect Switch	_____
3. Inspecting Charge Controller and Batteries	_____
4. Inspecting Inverters and AC Circuit Breakers	_____
5. Inspecting Raceway and Wiring	_____
Sessions X–XXIII. Installing PV Modules and BOS Components; Installing, Labeling, and Terminating Wiring per Code; Activating and Testing PV System to Verify Operations	
A. Installing PV Modules and BOS Components	_____
1. Installing the Combiner	_____
2. Installing a DC Disconnect Switch	_____
3. Installing the Batteries	_____
4. Installing the Charge Controller	_____
5. Installing the Inverter	_____
6. Installing the PV Panels	_____
B. Installing, Labeling, and Terminating Wiring per Code	_____
1. Labeling	_____
2. Checking Terminations	_____
C. Activating and Testing PV System to Verify Operations	_____
1. Final System Walkdown	_____
2. System Activation and Testing	_____
D. Laboratory Have trainees install and commission a system. This laboratory corresponds to Performance Task 1.	_____

Topic	Planned Time

Session XXIV. Review and Testing

A. Review _____

B. Module Examination _____

1. Trainees must score 70 percent or higher to receive recognition from NCCER.
2. Record the testing results on Training Report Form 200, and submit the results to the Training Program Sponsor.

C. Performance Testing _____

1. Trainees must perform each task to the satisfaction of the instructor to receive recognition from NCCER. If applicable, proficiency noted during laboratory exercises can be used to satisfy the Performance Testing requirements.
2. Record the testing results on Training Report Form 200, and submit the results to the Training Program Sponsor.

Maintenance and Troubleshooting Annotated Instructor's Guide

Module 57105-11

Module Overview

This module introduces the trainee to the components and operation of PV systems and describes how to maintain and troubleshoot them.

Prerequisites

Prior to training with this module, it is recommended that the trainee shall have successfully completed *Core Curriculum* and *Solar Photovoltaic Systems Installer*, Modules 57101-11 through 57104-11. It is also suggested that the trainees shall have successfully completed the following modules from the Electrical curriculum: *Electrical Level One*, Modules 26101 through 26111; *Electrical Level Two*, Modules 26201, 26205, 26206, and 26208 through 26211; *Electrical Level Three*, Modules 26301 and 26302; and *Electrical Level Four*, Modules 26403 and 26413.

Objectives

Upon completion of this module, the trainee will be able to do the following:

1. Identify the tools and equipment required for maintaining and troubleshooting PV systems.
2. Measure system performance and compare to expected performance.
3. Perform system maintenance as recommended by the PV equipment manufacturer.
4. Perform diagnostic procedures, interpret the results, and implement corrective measures on a malfunctioning system.
5. Verify system functionality, including startup, shutdown, normal operation, and emergency/bypass operation.
6. Compile and maintain records of system operation, performance, and maintenance.

Performance Tasks

Under the supervision of the instructor, the trainee should be able to do the following:

1. Demonstrate typical maintenance procedures on an installed PV system and document the results.
2. Troubleshoot a malfunctioning system and document the results.

Materials and Equipment

Markers/chalk
Pencils and scratch paper
Whiteboard/chalkboard
Solar Photovoltaic Systems Installer PowerPoint® Presentation Slides (ISBN 978-0-13-257135-7)
Multimedia projector and screen
Computer
Appropriate personal protective equipment
PV system, working
Solar panel, clean and working
Solar panel, working but dirty with dust and debris
Manufacturer's specifications and cleaning instructions
Appropriate soap and cleaning equipment
Solar panel, visibly worn or slightly damaged, and the manufacturer's specifications
Cat III/IV multimeter
Pyranometer
Archimedes and refractive index hydrometers
Water cart, filler gun, and distilled water
Current-limiting battery charger
Noncontact IR thermometer
Batteries, including both sealed and flooded lead acid (FLA)
Sufficient electrolyte
PV system performance evaluation form
PV system maintenance record
Data from an actual PV system check

(*continued*)

Selection of mounting hardware, some good and some damaged or corroded
Sufficient batteries for cleaning
Sufficient inverters for cleaning and any necessary tools, such as soft brushes or cloths
Manufacturer's troubleshooting chart
Manufacturer's maintenance and lubrication charts
Two or three actual maintenance records and logs
Module Examinations*
Performance Profile Sheets*

* Single-module AIG purchases include the printed exam and performance task sheet. If you have purchased the perfect-bound version of this title, download these materials from the IRC using your access code.

Safety Considerations

Ensure that the trainees are equipped with appropriate personal protective equipment and know how to use it properly. Review safety guidelines associated with working on or around photovoltaic systems, including fall protection and lockout/tagout. Emphasize the importance of proper housekeeping.

Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

Canadian Solar website: www.canadian-solar.com.

Florida Solar Energy Center website: www.fsec.ucf.edu.

Outback Power Systems website: www.outbackpower.com.

Solar panel terms: www.osha.gov.

Solar Source Institute website: www.solarsource.net.

Surrette/Rolls Battery website: www.surrette.com.

Teaching Time for This Module

An outline for use in developing your lesson plan is presented below. Note that each Roman numeral in the outline equates to one session of instruction. Each session has a suggested time period of 2½ hours. This includes 10 minutes at the beginning of each session for administrative tasks and one 10-minute break during the session. Approximately 10 hours are suggested to cover *Maintenance and Troubleshooting*. You will need to adjust the time required for hands-on activity and testing based on your class size and resources. Because laboratories often correspond to Performance Tasks, the proficiency of the trainees may be noted during these exercises for Performance Testing purposes.

Topic	**Planned Time**
Session I. Introduction; Preventive Maintenance	
A. Introduction	_____
B. Preventive Maintenance	_____
1. Tools and Test Equipment	_____
2. Cleaning and Inspecting PV Equipment	_____
3. Evaluating Performance of PV Systems	_____

Topic	Planned Time
Session II. Manufacturer-Recommended Maintenance Activities	
A. Manufacturer-Recommended Maintenance Activities	_____
1. Recommended Panel and Mounting Hardware Maintenance	_____
2. Recommended Combiner, DC Disconnect Switch, and Conduit Maintenance	_____
3. Recommended Charge Controller Maintenance	_____
4. Recommended Battery Maintenance	_____
5. Recommended Inverter Maintenance	_____
B. Laboratory Have trainees demonstrate typical maintenance procedures on an installed PV system and document the results. This laboratory corresponds to Performance Task 1.	
Session III. Troubleshooting	
A. Troubleshooting	_____
1. Alarms and Indicators	_____
2. Baseline Data	_____
3. Breaking Down a PV System	_____
4. Inverters	_____
5. Charge Controllers	_____
6. Combiners and Panels	_____
7. Manufacturer's Troubleshooting Data	_____
8. Record Keeping	_____
B. Laboratory Have trainees troubleshoot a malfunctioning system and document the results. This laboratory corresponds to Performance Task 2.	_____
Session IV. Review and Testing	
A. Review	_____
B. Module Examination	_____
1. Trainees must score 70 percent or higher to receive recognition from NCCER.	
2. Record the testing results on Training Report Form 200, and submit the results to the Training Program Sponsor.	_____
C. Performance Testing	
1. Trainees must perform each task to the satisfaction of the instructor to receive recognition from NCCER. If applicable, proficiency noted during laboratory exercises can be used to satisfy the Performance Testing requirements.	
2. Record the testing results on Training Report Form 200, and submit the results to the Training Program Sponsor.	