NABCEP

PV Associate Learning Objectives

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PV Associate Learning ***Objectives***

Objectives and Scope

Upon completion of the course(s) taught in accordance with the NABCEP PV Associate learning objectives, and prior to taking the NABCEP PV Associate Exam, students should have demonstrated a basic understanding of the following principles outlined in the learning objectives. A person who passes the NABCEP PV Associate Exam has demonstrated a basic, elementary knowledge of photovoltaic systems. The knowledge demonstrated by passing this test does not replace the knowledge, skills or abilities of the electrical or other construction trades, or those of other professions or degree programs that require considerably more academic and/or practical experience. It should also be noted that individuals passing the NABCEP PV Associate Exam should not be confused with NABCEP Certified PV Installers. The latter can only be achieved by highly experienced individuals who have passed a much more rigorous examination and have demonstrated the capability to supervise complete PV system installations, and who have a detailed working knowledge of the electrical codes, standards and accepted industry practice associ-ated with PV installations.

Residential PV solar installation in Minnesota

Learning Objective Categories

Listed below are the ten major categories for the NABCEP Associate Program:

1. PV Markets and Applications
2. Safety Basics
3. Electricity Basics
4. Solar Energy Fundamentals
5. PV Module Fundamentals
6. System Components
7. PV System Sizing Principles
8. PV System Electrical Design
9. PV System Mechanical Design
10. Performance Analysis, Maintenance and Troubleshooting

Students taking the NABCEP PV Associate exam will be tested to some degree in all ten categories. Consequently, in teaching pre-paratory courses for the exam, it is important that all ten categories be adequately covered. For each major category, a suggested percentage time allotment is indicated. For example, NABCEP suggests devoting 15% of training to Category 8, PV System Electrical Design (see below). In ad-dition to the suggested time allotment, a learning priority has been assigned to each learning objective. The three assigned learning priorities are *critical* (must be taught), *important* (should be taught), and *useful* (could be taught). This is to assist instructors in budgeting their time so that the most important items are covered. Please see the overall course and test specification blueprint for a typical course at the end of this document.

1. PV Markets and Applications

Suggested Percentage Time Allotment: 5% or less

		Learning Priority
1.1	Identify key contributions to the development of PV technology.	Useful
1.2	Identify common types of PV system applications for both stand-alone and utility interactive systems with and without energy storage.	Important
1.3	Associate key features and benefits of specific types of PV systems, including residential, commercial, BIPV, concentrating PV, and utility-scale.	Useful
1.4	List the advantages and disadvantages of PV systems compared to alternative electricity generation sources.	Useful
1.5	Describe the features and benefits of PV systems that operate independently of the electric utility grid.	Useful
1.6	Describe the features and benefits of PV systems that are interconnected to and operate in parallel with the electric utility grid.	Useful
1.7	Describe the roles of various segments of the PV industry and how they interact with one other.	Useful
1.8	Understand market indicators, value propositions, and opportunities for both grid-tied and stand-alone PV system applications.	Useful
1.9	Discuss the importance of conservation and energy efficiency as they relate to PV system applications.	Useful

Note: Establishing safety competencies and qualified persons are beyond the scope of the NABCEP Associate program. Refer to the OSHA Safety and Health Regulations for Construction: 29 CFR 1926 for further details on requirements for safety training and certification.

2. Safety Basics

Suggested Percentage Time Allotment: 5%

		Learning Priority
2.1	Identify the various safety hazards associated with both operating and nonoperating PV systems and components.	Critical
2.2	List different types of personal protective equipment (PPE) commonly required for installing and maintaining PV systems.	Critical
2.3	List different methods and indentify safe practices for hoisting and rigging, the use of ladders, stairways and guardrails, the use of head, feet, hearing and face protection, the use of power tools, and the use of the appropriate fall protection, including the requirements for personal fall arrest and safety-monitoring systems according to OSHA standards.	Critical
2.4	Recognize the principal electrical safety hazards associated with PV systems, including electrical shock and arc flash.	Critical

Note: The NABCEP Associate program is not a substitute for recognized electrical systems training, experience, and credentials. The electrical concepts introduced in the learning objectives are very basic, and considerable additional electrical training and experience are required of practicing PV system installers.

3. Electrical Basics *Suggested Percentage Time Allotment: 10%*

		Learning Priority
3.1	Understand the meaning of basic electrical parameters including electrical charge, current, voltage, power and resistance, and relate these parameters to their hydraulic analogies (volume, flow, pressure, hydraulic power and friction).	Important
3.2	Explain the difference between electrical power (rate of work performed) and energy (total work performed).	Important
3.3	Describe the function and purpose of common electrical system components, including conductors, conduits/raceways and enclosures, overcurrent devices, diodes and rectifiers, switchgear, transformers, terminals and connectors, grounding equipment, resistors, inductors, capacitors, etc.	Useful
3.4	Identify basic electrical test equipment and its purpose, including voltmeters, ammeters, ohmmeters and watt-hour meters.	Useful
3.5	Demonstrate the ability to apply Ohm's Law in analyzing simple electrical circuits, and to calculate voltage, current, resistance or power given any other two parameters.	Important
3.6	Understand the fundamentals of electric utility system operations, including generation, transmission, distribution and typical electrical service supplies to buildings and facilities.	Important

4. Solar Energy Fundamentals *Suggested Percentage Time Allotment: 10%*

		Learning Priority
4.1	Define basic terminology, including solar radiation, solar irradiance, solar irradiation, solar insolation, solar constant, air mass, ecliptic plane, equatorial plane, pyranometer, solar declination, solstice, equinox, solar time, solar altitude angle, solar azimuth angle, solar window, array tilt angle, array azimuth angle, and solar incidence angle.	Critical
4.2	Diagram the sun's apparent movement across the sky over any given day and over an entire year at any given latitude, and define the solar window.	Important
4.3	For given dates, times and locations, identify the sun's position using sun path diagrams, and determine when direct solar radiation strikes the north, east, south and west walls and horizontal surfaces of a building.	Important
4.4	Differentiate between solar irradiance (power), solar irradiation (energy), and understand the meaning of the terms peak sun, peak sun hours, and insolation.	Critical
4.5	Identify factors that reduce or enhance the amount of solar energy collected by a PV array.	Important
4.6	Demonstrate the use of a standard compass and determine true geographic south from magnetic south at any location given a magnetic declination map.	Important

Continued

4.7	Quantify the effects of changing orientation (azimuth and tilt angle) on the amount of solar energy received on an array surface at any given location using solar energy databases and computer software tools.	Important
4.8	Understand the consequences of array shading and best practices for minimizing shading and preserving array output.	Critical
4.9	Demonstrate the use of equipment and software tools to evaluate solar window obstructions and shading at given locations, and quantify the reduction in solar energy received.	Important
4.10	Identify rules of thumb and spacing distances required to avoid inter-row shading from adjacent sawtooth rack mounted arrays at specified locations between 9 am and 3 pm solar time throughout the year.	Important
4.11	Define the concepts of global, direct, diffuse and albedo solar radiation, and the effects on flat-plate and concentrating solar collectors.	Important
4.12	Identity the instruments and procedures for measuring solar power and solar energy.	Important

5. PV Module Fundamentals *Suggested Percentage Time Allotment: 10%*

		Learning Priority
5.1	Explain how a solar cell converts sunlight into electrical power.	Useful
5.2	Distinguish between PV cells, modules, panels and arrays.	Useful
5.3	Identify the five key electrical output parameters for PV modules using manufacturers' literature (Voc, Isc, Vmp, Imp and Pmp), and label these points on a current-voltage (I-V) curve.	Critical
5.4	Understand the effects of varying incident solar irradiance and cell temperature on PV module electrical output, illustrate the results on an I-V curve, and indicate changes in current, voltage and power.	Critical
5.5	Determine the operating point on a given I-V curve given the electrical load.	Important
5.6	Explain why PV modules make excellent battery chargers based on their I-V characteristics.	Useful
5.7	Understand the effects of connecting similar and dissimilar PV modules in series and in parallel on electrical output, and diagram the resulting I-V curves.	Critical
5.8	Define various performance rating and measurement conditions for PV modules and arrays, including STC, SOC, NOCT, and PTC.	Critical
5.9	Compare the fabrication of solar cells from various manufacturing processes.	Useful
5.10	Describe the components and the construction for a typical flat-plate PV module made from crystalline silicon solar cells, and compare to thin-film modules.	Important
5.11	Given the surface area, incident solar irradiance and electrical power output for a PV cell, module or array, calculate the efficiency and determine the power output per unit area.	Important
5.12	Discuss the significance and consequences of PV modules being limited current sources.	Useful
5.13	Explain the purpose and operation of bypass diodes.	Important
5.14	Identify the standards and design qualification testing that help ensure the safety and reliability of PV modules.	Important

6. System Components *Suggested Percentage Time Allotment: 15%*

		Learning Priority
6.1	Describe the purpose and principles of operation for major PV system components, including PV modules and arrays, inverters and chargers, charge controllers, energy storage and other sources.	Critical
6.2	List the types of PV system balance of system components, and describe their functions and specifications, including conductors, conduit and raceway systems, overcurrent protection, switchgear, junction and combiner boxes, terminations and connectors.	Important
6.3	Identify the primary types, functions, features, specifications, settings and performance indicators associated with PV system power processing equipment, including inverters, chargers, charge controllers, and maximum power point trackers.	Important
6.4	Understand the basic types of PV systems, their major subsystems and components, and the electrical and mechanical BOS components required.	Important

7. PV System Sizing Principles *Suggested Percentage Time Allotment: 10%*

		Learning Priority
7.1	Understand the basic principles, rationale and strategies for sizing stand-alone PV systems versus utility-interactive PV systems.	Important
7.2	Given the power usage and time of use for various electrical loads, determine the peak power demand and energy consumption over a given period of time.	Important
7.3	Beginning with PV module DC nameplate output, list the de-rating factors and other system losses, and their typical values, and calculate the resulting effect on AC power and energy production, using simplified calculations, and online software tools including PVWATTS.	Critical
7.4	For a specified PV module and inverter in a simple utility-interactive system, determine the maximum and minimum number of modules that may be used in source circuits and the total number of source circuits that may be used with a specified inverter, depending upon the expected range of operating temperatures, the inverter voltage windows for array maximum power point tracking and operation, using both simple calculations and inverter manufacturers' online string sizing software tools.	Critical
7.5	Given a stand-alone application with a defined electrical load and available solar energy resource, along with PV module specifications, size and configure the PV array, battery subsystem, and other equipment as required, to meet the electrical load during the critical design period.	Critical

Note: Qualified electrical contractors and engineering approvals are required for many PV installations. The NABCEP Associate program is not intended as a substitute for recognized training, competencies and qualifications of electrical contractors or design professionals. The PV system electrical design and installation concepts covered in the learning objectives are intended to provide a very basic overview of the considerations involved, and are not intended to imply an in-depth understanding of the electrical codes and their application.

8. PV System Electrical Design *Suggested Percentage Time Allotment: 15%*

		Learning Priority
8.1	Draw and prepare simple one-line electrical diagrams for interactive and standalone PV systems showing all major components and subsystems, and indicate the locations of the PV source and output circuits, inverter input and output circuits, charge controller and battery circuits, as applicable, and mark the directions of power flows through the system under various load conditions.	Critical
8.2	Understand how PV modules are configured in series and parallel to build voltage, current and power output for interfacing with inverters, charge controllers, batteries and other equipment.	Critical
8.3	Identify basic properties of electrical conductors including materials, size, voltage ratings and insulation coverings and understand how conditions of use, such as location, other conductors in the same conduit/raceway, terminations, temperature and other factors affect their ampacity, resistance and corresponding overcurrent protection requirements.	Critical
8.4	Understand the importance of nameplate specifications on PV modules, inverters and other equipment on determining allowable system voltage limits, and for the selection and sizing of conductors, overcurrent protection devices, disconnect means, wiring methods and in establishing appropriate and safe interfaces with other equipment and electrical systems.	Critical
8.5	Determine the requirements for charge control in battery-based PV systems, based on system voltages, current and charge rates.	Important
8.6	Identify the labeling requirements for electrical equipment in PV systems, including on PV modules, inverters, disconnects, at points of interconnection to other electrical systems, on battery banks, etc.	Important
8.7	Understand the basic principles of PV system grounding, the differences between grounded conductors, grounding conductors, grounding electrode conductors, the purposes of equipment grounding, PV array ground-fault protection, and the importance of single-point grounding.	Critical
8.8	Apply Ohm's Law and conductor properties to calculate voltage drop for simple PV source circuits.	Important
8.9	Identify the requirements for plan review, permitting, inspections, construction contracts and other matters associated with approvals and code-compliance for PV systems.	Critical
8.10	Demonstrate knowledge of key articles of the National Electrical Code, including Article 690, Solar Photovoltaic Systems.	Important

Note: Roofing systems and structural engineering expertise are required for many PV installations. The NABCEP Associate program is not intended as a substitute for recognized training, competencies and qualifications of roofing contractors or professional engineers. The PV system mechanical design and installation concepts covered in the learning objectives are intended to provide a very basic overview of the considerations involved.

9. PV System Mechanical Design *Suggested Percentage Time Allotment: 10%*

		Learning Priority
9.1	Identify the common ways PV arrays are mechanically secured and installed on the ground, to building rooftops or other structures, including rack mounts, ballasted systems, pole mounts, integral, direct and stand-off roof mounts, sun tracking mounts and for other building-integrated applications.	Important
9.2	Compare and contrast the features and benefits of different PV array mounting systems and practices, including their design and materials, standardization and appearance, applications and installation requirements, thermal and energy performance, safety and reliability, accessibility and maintenance, costs and other factors.	Important
9.3	Understand the effects on PV cell operating temperature of environmental conditions, including incident solar radiation levels, ambient temperature, wind speed and direction for various PV array mounting methods.	Important
9.4	List various building-integrated PV (BIPV) applications and compare and contrast their features and benefits with conventional PV array designs.	Useful
9.5	Identify desirable material properties for weathersealing materials, hardware and fasteners, electrical enclosures, wiring systems and other equipment, such as UV, sunlight and corrosion resistance, wet/outdoor approvals and other service ratings appropriate for the intended application, environment and conditions of use, and having longevity consistent with the operating life expectancies of PV systems.	Important
9.6	Understand the requirements for roofing systems expertise, and identify the preferred structural attachments and weathersealing methods for PV arrays affixed to different types of roof compositions and coverings.	Critical
9.7	Identify the types and magnitudes of mechanical loads experienced by PV modules, arrays and their support structures, including dead loads, live loads, wind loads, snow loads, seismic loads, in established combinations according to ASCE 7-05 Minimum Design Loads for Buildings and Other Structures.	Important
9.8	Identify PV system mechanical design attributes that affect the installation and maintenance of PV arrays, including hardware standardization, safety and accessibility, and other factors.	Important
9.9	Identify mechanical design features that affect the electrical and thermal performance of PV arrays, including array orientation, mounting methods and other factors.	Important
9.10	Review and recognize the importance of PV equipment manufacturers' instructions with regard to mounting and installation procedures, the skills and competencies required of installers, and the implications on product safety, performance, code-compliance and warranties.	Critical

10. Performance Analysis, Maintenance and Troubleshooting

Suggested Percentage Time Allotment: 10%

		Learning Priority
10.1	Discuss various potential problems related to PV system design, components, installation, operation or maintenance that may affect the performance and reliability of PV systems.	Useful
10.2	Identify and describe the use and meaning of typical performance parameters monitored in PV systems, including DC and AC voltages, currents and power levels, solar energy collected, the electrical energy produced or consumed, operating temperatures and other data.	Important
10.3	Compare PV system output with expectations based on system sizing, component specifications and actual operating conditions, and understand why actual output may be different than expected.	Important
10.4	Describe typical maintenance requirements for PV arrays and other system components, including inverters and batteries, etc.	Important
10.5	Understand the safety requirements for operating and maintaining different types of PV systems and related equipment.	Critical
10.6	Identify the most common types of reliability failures in PV systems and their causes due to the equipment, quality of installation and other factors.	Important
10.7	Review component manufacturers' instructions for operation, maintenance and troubleshooting for PV modules and power processing equipment, and develop a simple maintenance plan for a given PV system detailing major tasks and suggested intervals.	Important
10.8	Understand basic troubleshooting principles and progression, including recognizing a problem, observing the symptoms, diagnosing the cause and taking corrective actions leading from the system, subsystem to the component level.	Important

Course and Test Specification

The following provides a blueprint for courses taught to the NABCEP Associate Program, including the primary learning objectives and suggested percentage time allotment. NABCEP recognizes the diversity of training programs offered and their participants, including short courses, continuing educa-tion programs, and more in depth and lengthy programs of study, including formal apprenticeship, multicourse certificate programs, and degree-track programs. The NABCEP PV Associate is not intended as an installer in-training credential, but rather as an important first step in preparing individuals to become highly skilled, qualified and experienced tradespersons and professionals in the PV industry.

Category	Course Time By %	Exam Items	Level of Testing	Study Materials
1. PV Markets & Applications	5%	3	Comprehension	References 1 and 5 below
2. Safety Basics	5%	3	Comprehension Application	References 1, 2 and 3 below
3. Electricity Basics	10%	6	Comprehension Problem Solving	References 1 and 5 below
4. Solar Energy Fundamentals	10%	6	Comprehension Application Problem Solving	References 1, 4 and 5 below
5. PV Module Fundamentals	10%	6	Comprehension Application Problem Solving	References 1, 4 and 5 below
6. System Components	15%	9	Comprehension Application Problem Solving	References 1, 4 and 5 below
7. PV System Sizing Principles	10%	6	Application Problem Solving Design	References 1, 4 and 5 below
8. PV System Electrical Design	15%	9	Application Problem Solving Design	References 1, 2, 4 and 5 below
9. PV System Mechanical Design	10%	6	Application Problem Solving Design	References 1, 4 and 5 below
10. Performance Analysis, Maintenance and Troubleshooting	10%	6	Analysis Problem Solving	References 1, 4 and 5 below
Totals	**100%**	**60**		

Notes: Prerequisite or bridge training and/or experience in electrical systems, mathematics, and other subjects may be required for some students to fully comprehend and satisfactorily demonstrate knowledge of all of the learning objectives. Also, for intensive short courses (e.g., 40-hour, one-week workshops) students should be encouraged to spend approximately 2-3 additional hours outside of class (for each hour in class) to review the subject matter, solve problems, and study reference materials prior to taking the PV Associate Exam. This will usually require the student to take the exam at a later date rather than immediately following the course.

Suggested References and Study Materials

1. Photovoltaic Systems, 2nd Edition, by James P. Dunlop, ISBN 978-0-8269-1287-9. ©July 2009 National Joint Apprenticeship and Training Committee and American Technical Publishers: www.jimdunlopsolar.com

2. Code of Federal Regulations, Chapter 29 Part 1926 - Safety and Health Regulations for Construction, Occupational Safety and Health Administration: www.osha.gov

3. 2008 National Electrical Code®, NFPA 70 or 2008 National Electrical Code® Handbook, National Fire Protection Association®: www.nfpa.org

4. Study Guide for Photovoltaic System Installers, North American Board of Certified Energy Practitioners, Version 5.1.2, December 2011: www.nabcep.org

5. Solar Electric Handbook, Photovoltaic Fundamentals and Applications, Second Edition, 2013, Solar Energy International, www.solarenergy.org/bookstore/solar-electric-handbook-photovoltaic-fundamentals-and-applications-media-bundle-textbook-e

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