Photovoltaic Installer – Level 1 (PVI1)

Competency Requirements

RENEWABLE ENERGY TECHNOLOGY

This competency serves to identify the major knowledge, skills and standards areas in which a Photovoltaic Installer (PVI) needs to be proficient in order to perform the professional tasks associated with the design, development, installation and repair of photovoltaic solar systems.

The following is a listing of the major categories and items considered necessary to be included in a course of study directed towards the education of workers needed in the photovoltaic installation industry. Certification skill demonstrations are earned through the Hands-On training required from an ETA approved school before sitting for the knowledge examination questions. Certification skill demonstration proof from prior job experiences can be reviewed by ETA in lieu of the skills learned from an ETA approved trainer.

Certification skill demonstrations are based on the topical outline provided in the Job Task Analysis list

The Photovoltaic Installer (PVI) will be required to properly do the following Job Tasks:

- Identify major components of a Photovoltaic (PV) System
- Identify types of PV systems
- Identify panel types and characteristics
- Determine proper Installation Sequence for Array and BOS
- Install basic Array and BOS components
- Determine proper Array Orientation
- Comprehend basic performance characteristics
- Comprehend basic systems sizing methods
- Troubleshoot basic systems problems and installation errors.
- Comprehend safe working practices for:
  - Electrical safety
  - Eye and ear protection
  - Working aloft (ladder, roof, lanyard and harness)
  - Working with hand and basic power tools

1.0 HISTORY AND BACKGROUND OF RENEWABLE ENERGY

- 1.1 Describe the evolution, uses, applications and function of the following renewable energy technologies:
  - 1.1.1 Photovoltaics
  - 1.1.2 Wind
  - 1.1.3 Geothermal
  - 1.1.4 Solar Thermal
  - 1.1.5 Micro Hydro
  - 1.1.6 Fuel Cells
- 1.2 Trace the evolution of photovoltaics
  - 1.2.1 Identify the historical figures involved in researching photovoltaics
- 1.3 Summarize the evolution of photovoltaic technology
- 1.4 Track the evolution of photovoltaic application
  - 1.4.1 Identify how electricity is generated by photovoltaics by explaining:
    - 1.4.1.1 PV effect
    - 1.4.1.2 PV Principles
    - 1.4.1.3 Active versus Passive
- 1.5 Explain the reasons for a dramatic decline in photovoltaic prices
- 1.6 Identify how PV systems are interconnected to the electrical grid
  - 1.6.1 Identify the concept of grid parity
  - 1.6.2 Explain Renewable Portfolio Standards (RPS)
    - 1.6.2.1 Identify how Solar Renewable Energy Certificates (SRECs) are used
  - 1.6.3 Describe a distributed energy system

2.0 PHOTOVOLTAICS TERMINOLOGY

- 2.1 Define the following key solar power terms:
  - 2.1.1 Active Solar Energy
  - 2.1.2 Passive Solar Energy
  - 2.1.3 Insolation
  - 2.1.4 Irradiance
  - 2.1.5 Kilowatt-hours per square meter
  - 2.1.6 Photon
  - 2.1.7 Balance of System (BOS)
  - 2.1.8 Pyranometer
  - 2.1.9 Pyroheliometer
  - 2.1.10 Solar Constant
  - 2.1.11 Solar noon
  - 2.1.12 Solar Pathfinder
  - 2.1.13 Zenith Angle
  - 2.1.14 Air Mass
  - 2.1.15 Ambient Temperature
  - 2.1.16 Cell Temperature
  - 2.1.17 Days of Autonomy
  - 2.1.18 Cloud Enhancement
- 2.2 Identify the three major types of Solar cells and how they are manufactured:
  - 2.2.1 Monocrystalline silicon modules
  - 2.2.2 Polycrystalline silicon modules
  - 2.2.3 Amorphous or thin-film modules
- 2.3 Identify key chemical components used in photovoltaic technology:
  - 2.3.1 Boron (B)
  - 2.3.2 Cadmium (Cd)
  - 2.3.3 Copper Indium Diselenide (CuInSe2, or CIS)
  - 2.3.4 Gallium (Ga)
  - 2.3.5 Gallium Arsenide (GaAs)
  - 2.3.6 Hydrogenated Amorphous Silicon
  - 2.3.7 Indium Oxide
- 2.4 Describe the following photovoltaic cell characteristics:
  - 2.4.1 Semiconductor/silicon
  - 2.4.2 P-N junction
  - 2.4.3 Band gap
  - 2.4.4 Insulator
  - 2.4.5 Doping
  - 2.4.6 Diodes
    - 2.4.6.1 Distinguish between Blocking Diode and Bypass Diode
- 2.5 Define the following system application terminology for renewable PV energy
  - 2.5.1 Integrated Photovoltaics
    - 2.5.1.1 Roof integrated
    - 2.5.1.2 Wall integrated
  - 2.5.2 Battery Backup Systems
  - 2.5.3 Hybrid Systems
    - 2.5.3.1 PV plus solar thermal
    - 2.5.3.2 PV plus wind
    - 2.5.3.3 PV plus hydro
    - 2.5.3.4 PV plus electric generator
  - 2.5.4 Grid Tied PV System (also “Grid Connected” or “Utility Connected”)
  - 2.5.5 Off Grid PV System (also stand-alone)
  - 2.5.6 Seasonal loads
  - 2.5.7 Small PV Applications
- 2.6 Define the following PV panel terms:
  - 2.6.1 I-V Curve
  - 2.6.2 Maximum Power Point (MPP)
  - 2.6.3 Nominal Operating Cell temperature (NOCT)
  - 2.6.4 Standard Test Conditions (STC)
  - 2.6.5 Nominal Voltage

- 2.6.6 Open Circuit Voltage (Voc – volts open circuit)
- 2.6.7 Rated Module Current (Referred to as “Ipm” [Amps panel Max])
- 2.6.8 ISC (Amp Short Circuit)
- 2.6.9 Voltage at Maximum Power (there is only a theoretical maximum for panels)
- 2.6.10 PVWatts Test Conditions (PTC)
- 2.6.11 Volts Panel Max (Volts at STC - 1,000wm2 @ 77degrees F) aka Vpm
- 2.6.12 Temperature Coefficient
- 2.6.13 Combiner box
- 2.6.14 Concentrator

2.7 Define the following terms for energy storage:

- 2.7.1 Kinetic storage
  - 2.7.1.1 Spiral spring storage
  - 2.7.1.2 Flywheel storage
- 2.7.2 Battery storage
  - 2.7.2.1 Identify types of batteries including:
    - 2.7.2.1.1 Flooded Lead Acid (FLA)
    - 2.7.2.1.2 Sealed
    - 2.7.2.1.3 Absorbed glass matt (AGM)
    - 2.7.2.1.4 Lithium Ion (L-Ion)
    - 2.7.2.1.5 Salt Water (alkaline)
  - 2.7.2.2 Identify battery terminology
    - 2.7.2.2.1 Deep cycle
    - 2.7.2.2.2 Depth of discharge (DoD)
    - 2.7.2.2.3 Overcharge
    - 2.7.2.2.4 Trickle charge
    - 2.7.2.2.5 Vented cell
    - 2.7.2.2.6 Amp Hour (Ah) Capacity
    - 2.7.2.2.7 State of Charge
      - 2.7.2.2.7.1 Bulk
      - 2.7.2.2.7.2 Absorption
      - 2.7.2.2.7.3 Float
    - 2.7.2.2.8 Charging characteristics
- 2.7.3 Thermal mass storage

2.8 Define the following terms used in PV wiring:

- 2.8.1 Ampacity
- 2.8.2 Conductor
- 2.8.3 Grounded conductors
- 2.8.4 Load Resistance
- 2.8.5 Short Circuit Current
- 2.8.6 Direct Current (DC)
- 2.8.7 Alternating Current (AC)
- 2.8.8 Bonding
- 2.8.9 Ground
- 2.8.10 Type of Wiring (THWN, THHN, PV Wire, RHW)
- 2.8.11 American Wire Gauge (AWG)
- 2.8.12 Overcurrent Protection
- 2.8.13 Electrical Isolation
- 2.8.14 Touch Potential (also in safety section)

2.9 Define the following terms used in PV panel installation:

- 2.9.1 Tracking Array
  - 2.9.1.1 Single-axis tracking
  - 2.9.1.2 Dual-axis tracking
- 2.9.2 Fixed Tilt Array
- 2.9.3 String
- 2.9.4 System Operating Voltage
- 2.9.5 Solar Path diagram
  - 2.9.5.1 Define the following terms that affect cell energy:
    - 2.9.5.1.1 Altitude
    - 2.9.5.1.2 Azimuth
    - 2.9.5.1.3 Angle of incidence

2.9.5.1.4 Latitude
2.9.5.1.4.1 Equinox / Solstice
2.9.5.1.5 Magnetic Declination
2.9.5.1.6 Peak Sun Hours
2.9.5.1.7 Shading
2.9.5.1.8 Air Mass
2.9.5.1.9 Weather
2.9.5.1.10 Ambient Temperature

2.10 Explain the Electromagnetic Power Spectrum
2.11 Define the Balance of System (BOS) terms
2.11.1 Identify the different types of charge controllers
2.11.1.1 Pulse Width Modulation (PWM)
2.11.1.2 Series charge controller
2.11.1.3 Maximum Power Point Tracking (MPPT)
2.11.1.4 Shunt charge controller (Diversionary charge controller)
2.11.2 Describe how activation voltage for a charge controller protects batteries
2.11.3 Describe types of inverters and how they work
2.11.3.1 Pure sine wave inverter
2.11.3.2 Modified wave form inverter
2.11.3.3 Grid Tied Inverter (Utility Interactive Inverter)
2.11.3.4 String inverter
2.11.3.5 System inverter
2.11.3.6 Micro-inverter
2.11.4 Explain the importance of anti-islanding for inverter installation
2.11.5 Generator
2.11.6 Voltage regulator

3.0 INSTALLATION AND SAFETY

3.1. Describe Basic Safety practices
3.1.1. Summarize the safe work practices and requirements of Occupational Safety and Health Administration (OSHA)
3.2. Explain Battery Safety practices
3.3. Explain precautions for testing High Voltage
3.4. Describe best safety practices for:
3.4.1. Hearing and eye safety
3.4.2. Ladder climbing and safety procedures
3.4.3. Roof (working at heights) safety
3.4.3.1. Describe how to implement a fall protection plan
3.5. Describe equipment use safety including:
3.5.1. tools
3.5.2. personal protection
3.6. Discuss Site Safety
3.6.1. Explain how to install safety barriers
3.6.2. Identify existing and potential site hazards
3.6.3. Identify safe staging and access locations
3.6.4. Ensure material safety data sheets are on-site
3.6.5. Explain how to implement a vehicle safety plan
3.7. Explain Mounting Procedures including:
3.7.1. Roof Mounting
3.7.1.1. Structural Issues
3.7.1.2. Wind load
3.7.2. Ground Mounting
3.7.2.1. Pole Mounting
3.8. Discuss Battery Installation including:
3.8.1. battery venting
3.8.2. charging stages
3.8.3. settings for Charge Controller types

3.9. Describe PV system wire management
  3.9.1. Describe electrical metallic tubing (Type EMT)
  3.9.2. Describe tube bending, take-up

4.0 CODES AND STANDARDS

4.1 Describe Authorities Having Jurisdiction (AHJ)- Local, State and Federal Codes
4.2 Discuss the National Electrical Code® (NEC®) distributed by the NFPA (Nat'l Fire Protection Assc)
  4.2.1 Article 250 Grounding and Bonding
  4.2.2 Article 685 Integrated Electrical Systems
  4.2.3 Article 690 Solar Photovoltaic Systems
    4.2.3.1 Table 310.15. b16 wire selection
    4.2.3.2 PV conductors
    4.2.3.3 AV inverter conductors
    4.2.3.4 Rapid Shutdown
      4.2.3.4.1 Multi-level power electronics (MLPE)
    4.2.3.5 Critical space (NEC 2017)
  4.2.4 Article 700 Emergency Systems
  4.2.5 Article 100 General Wiring
  4.2.6 Article 358 Electrical Metallic Tubing (Type EMT)
  4.2.7 Article 445 Generators
4.3 Discuss NFPA 5000 Building Construction and Safety Code
4.4 Discuss ANSI/ASHRAE/IESNA Standard 100-1995
4.5 Discuss ANSI/ASHRAE/IESNA Standard 90.1 – 1989
4.6 Discuss ANSI/ASHRAE/IESNA Standard 90.2 – 2001
4.7 Discuss ANSI/ASHRAE/IESNA Standard 105 – 1984
4.8 Discuss IEEE 1547, Standard for Interconnecting Distributed Resources with Electric Power Systems
4.9 Discuss UL 1703, Standard for Flat-plate Photovoltaic Modules and Panels
4.10 Discuss UL 1741 Standard for Static Inverters, Converters & Controllers for use in Photovoltaic Power Systems
4.11 Discuss Independent Power Systems
4.12 Discuss Interconnection Agreements
4.13 Describe NREL-STC (Nat'l Renewable Energy Lab Standard Test Conditions)
4.14 Explain Net Metering
4.15 Compare PV USA-PTC

5.0 THEORY OF OPERATION

5.1 Describe the photovoltaic system types identified in 2.5
5.2 Describe the individual components of a photovoltaic system
5.3 Explain the following photovoltaic principles:
  5.3.1 Series modules
  5.3.2 Parallel modules
  5.3.3 Series – Parallel arrays
5.4 Describe module characteristics and functions
5.5 Explain photovoltaic module performance of specific items defined in 2.6 and 2.8:
  5.5.1 Maximum power point
  5.5.2 Short circuit current
  5.5.3 Open circuit voltage
  5.5.4 Temperature Coefficient
  5.5.5 Load resistance
  5.5.6 External performance factors:
    5.5.6.1 Temperature
    5.5.6.2 Dirt on panels
    5.5.6.3 Solar Intensity
5.6 Explain PV system installations
  5.6.1 Explain how to do Site Selection using:
    5.6.1.1 Solar Radiation measurements
    5.6.1.2 Gathering Site Data
    5.6.1.3 Performing Solar Site Analysis
  5.6.2 Describe PV Array Installation types defined in 2.8.1:

- 5.6.2.1 Tracking
  - 5.6.2.1.1 Single-axis
  - 5.6.2.1.2 Dual-axis
- 5.6.3 Explain how to do a Battery Installation
- 5.6.4 Describe the PV System's Electronics including:
  - 5.6.4.1 System control characteristics
  - 5.6.4.2 Describe inverter characteristics:
    - 5.6.4.2.1 Theory of Operation
      - 5.6.4.2.1.1 Wave forms
    - 5.6.4.2.2 Types
    - 5.6.4.2.3 Features
    - 5.6.4.2.4 Sizing
    - 5.6.4.2.5 Safety Issues
- 5.6.5 Explain PV system wiring
  - 5.6.5.1 Explain wire sizing characteristics
    - 5.6.5.1.1 Explain derating factors
  - 5.6.5.2 Explain over-current/overload protection
  - 5.6.5.3 Explain separately derived systems
    - 5.6.5.3.1 Describe electrical disconnects
    - 5.6.5.3.2 Explain electrical bonding and grounding
    - 5.6.5.3.3 Describe surge suppression
- 5.6.6 Describe Grid-Tied systems types and advantages
- 5.6.7 Explain Stand-Alone PV systems types

5.7 Describe PV system testing procedures defined back in 2.6 area

5.8 Explain System commissioning procedures including:

- 5.8.1 Initiate start-up procedures
- 5.8.2 Program set points
- 5.8.3 Monitor start-up process
- 5.8.4 Compare measured values to expected values
- 5.8.5 Verify system labeling
- 5.8.6 Perform any required corrective actions

6.0 APPLIED CALCULATIONS AND FORMULAS

6.1 Explain Ohms Law

- 6.1.1 Define Voltage
- 6.1.2 Define Current
- 6.1.3 Describe Resistance

6.2 Identify Power Formulas

- 6.2.1 Define Watts

6.3 Compare Series and Parallel Calculations

6.4 Explain Kirchhoff's Rules

6.5 Apply Raceway and Box Calculations

6.6 Use Voltage-Drop Calculations

6.7 Identify Dwelling Unit Calculations

6.8 Identify Transformer Calculations

7.0 ESTIMATING HOME ENERGY NEEDS

7.1 Explain how to use energy efficiently

- 7.1.1 Identify electrical loads that may be shifted to a more appropriate energy source
- 7.1.2 Identify electrical appliances that may be replaced by more energy efficient ones
- 7.1.3 Explain the appliance Energy Star rating system.

7.2 Calculate electrical load requirements

- 7.2.1 Explain how to compile load calculation information
- 7.2.2 Explain the standard load calculation method
- 7.2.3 Identify the optional load calculation method
- 7.2.4 Explain how to use a load summary worksheet
- 7.2.5 Identify peak consumption periods
- 7.2.6 Identify the maximum projected load
- 7.2.7 Calculate the whole home monthly and yearly projected load

7.3 Explain sizing and economics of energy use

8.0 PROJECT MANAGEMENT

- 8.1 Recognize and use plans and blue prints
  - 8.1.1 Explain elevation drawings
  - 8.1.2 Recognize grid lines
  - 8.1.3 Explain the use of a legend
  - 8.1.4 Identify a revision block
  - 8.1.5 Explain drawing scale
  - 8.1.6 Identify schematics
  - 8.1.7 Explain sectional drawings
  - 8.1.8 Recognize specifications
  - 8.1.9 Define structural drawings
  - 8.1.10 Identify drawing symbols
  - 8.1.11 Identify the title block
- 8.2 Explain a request for information (RFI)
- 8.3 Discuss electrical estimating
  - 8.3.1 Identify material costs and labor hours
    - 8.3.1.1 Comprehend how to use Labor Units (LU)
  - 8.3.2 Explain take offs (estimating totals materials and labor)
  - 8.3.3 Explain the bid summary

End of Photovoltaic Installer – Level 1 Competency

Find An ETA Approved School and Test Site: https://etai.org/test_sites.html

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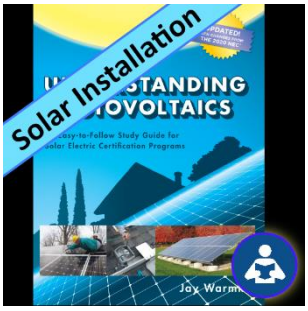
Suggested Additional Resource and Study Material:

Understanding Photovoltaics, 8E; Jay Warmke



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- https://solarpvtraining.com/product/understanding-photovoltaics/
- www.etai.org has editions also
- 1st edition, 2014, still available.

Green Technology, Concepts and Practices by Jay and Annie Warmke

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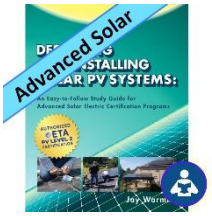
Designing & Installing Solar PV Systems



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Photovoltaic Systems, 3rd Edition, James Dunlop

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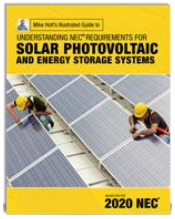
Mike Holt's Illustrated Guide to Understanding the NEC Requirements for Solar Photovoltaic Systems, 2020 NEC



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