LESSON

Installation of Racking, Modules, Inverter, and BOS

- Installing Ballast Block Systems
- Wire Management
- Penetration Systems (flashing)
- Panels (modules)
- Grounding
- Inverters
- BOS

BIG IDEA(S)

The installation of a solar system requires a series of specific steps beginning with flashing and ending with wire management and grid connection. A solar technician understands and is able to complete all the steps in this process as well as anyone pursuing the wide variety of career paths in the solar industry.

OBJECTIVES

Students will be able to:

- Fluff shingles and install flashings as well as rails
- Understand when to use mechanical attachments vs. ballast weight
- Install ballast weight systems
- Perform wire management for DC and AC systems
- Install a junction box and/or a Soladeck
- Install PVC and EMT conduit
- Pull wire through conduit
- Install solar online monitoring systems
- Interconnect solar with the utility grid

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Installation

10th grade: 4 HRS (2-3 SESSIONS)
11th grade: 8-10 HRS (4-5 SESSIONS)
12th grade: 8-10 HRS (5 SESSIONS)

TASK LIST SUBCATEGORY

501	Install roof flashings
505	Install racking, modules, inverter, BOS components
302	Demonstrate the use of Personal Fall Arrest Systems (PFAS)
303	Demonstrate the use of Personal Protective Equipment (PPE)
306	Evaluate and perform safe lifting and material handling
311	Recognize, identify and safely use hand tools and power tools

KEY TERMS

flashing
ballast
rails
stringing
wire management
branch circuits
junction box
SolaDeck (see note)
PVC
EMT
monitoring
interconnection
din rail
grid connection
Wiley clips
crimping tools
Polaris connector
terminal blocks

OVERVIEW

Students will learn about and get hands-on experience with all aspects of solar installation including: installing flashings, ballast weight racking, rails, wire management, stringing, branch circuits, junction boxes, Soladecks, PVC and EMT conduit, wiring, monitoring, interconnection. Racking system with flashing is recommended for the mock roof. Ballast system should also be demonstrated. Two of the most common ballast weight systems that are installed in Philly are Ecolibrium Eco 5D and Everest D-Dome both of which are self-squaring systems. Very little layout is required on the residential level as the system sizes are commonly within 20 panels).

NOTE: SolaDeck is a PV wire enclosure and seamless flashed product all in one. SolaDeck eliminates the multiple parts and respective labor typically needed to accomplish the roof penetration for a weather-tight wiring passageway into the home. Unique in the solar industry, SolaDeck is designed with a seamless flashing consistent with standard roofing practices for roof penetration. All SolaDeck models are third party tested by ETL to the UL50 Type 3R or UL1741 standards.

STANDARDS

PA/SDP

3.4.10.A1. Illustrate how the development of **technologies** is often driven by profit and an economic market.

3.4.10.A2. Interpret how **systems** thinking applies logic and creativity appropriately in complex real-life problems.

3.4.10.B2. Demonstrate how humans devise **technologies** to reduce the negative consequences of other **technologies.**

3.4.12.B2. Illustrate how, with the aid of **technology**, various aspects of the environment can be monitored to provide information for decision making.

3.4.12.C2. Apply the concept that engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

ETS1.B. Developing Possible Solutions: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary to HS-ESS3-2),(secondary HS-ESS3-4)

INSTRUCTIONAL

TEXT/REFERENCES

SEI Solar Electric Handbook ISBN#: 978-1-256-70166-8

How to install the Ecolibrium flat roof racking system

https://www.youtube.com/watch?v=NJFQ4y5PBbE

Overall racking training and certification program

https://www.ironridge.com/resources/on-demand-training/

MATERIALS NEEDED

Teacher Experience: Performance of 3-4 solar installations

Teacher Presentation: Mock roof; Electrical wall; all installation tools and materials for installation

MATERIALS

- Drill and impact driver with bits
- Solar Panels
- MC4 connectors
- Microinverters and optimizers
- Enphase connectors
- Wiley clips
- Zip ties
- Junction box/Soladeck
- Din rail
- Terminal blocks
- Polaris connectors
- Wire strippers
- MC4 crimp tool
- Screw drivers
- Roof safety equipment

Technology: Video projection/display

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IMPLEMENTATION (LESSON PLAN)

DAY 1: FLAT ROOF BALLAST WEIGHT SYSTEMS: SHINGLES, AND RAILS

ENGAGE

1. Review flashing installation and discuss non-ballast systems
2. Install racking system: Flat Roof Ballast Weight System: Ecolibrium EcoFoot 5D Installation
    a. Ecolibrium Eco 5D Racking System Description: Ecolibrium Solar unveils EcoFoot5D flat-roof racking solution
    b. When installing Ecolibrium eco 5D you would want a south line or a north line to follow as you build down the roof. Start by identifying an edge of the roof that is closest to the North (or South) edge of the roof.
    c. The layout process starts by obtaining the measurements of your modules (for example: 66 ⅜" X 39 ¼") and counting the number of EcoFoot bases in each row of bases on your planset, building North to South is the preferable method by most installers so you typically begin on the North side.
    d. Place a EcoFoot base in the north east corner of the array and move West placing a EcoFoot base every 66 ⅜" until you reach the number of bases for the row.
    e. Following rows, line up the bases with the row before.
    f. Now all of the bases are down it's time to move onto the next step: Slide the ballast trays into the bases.
    g. The ballast trays are coated in grease and very sharp, incorrect handling can lead to accidental penetrations of the roof so this part you must take care not to damage the roof as you attach the trays to the bases. Begin by placing a stack of trays close to the area of work, take one tray and slide one end in the base and secure the other side of the tray into the second base making sure the sharp edges do not touch the roofs' surface.
    h. Repeat until all bases are connected by ballast trays.
    i. Next, attach the panel clamp for the ballast tray.
    j. Attach this to the center of the ballast tray by sliding the two halves of the clamp under the tray and screwing a 9⁄16" bolt through the center. Do this on every tray.
    k. Then attach the 5D pressure clamps to the bases. Note: there are 2 clamps: a south clamp for the low end of the panel and a north clamp for the high end of the panel and they are almost identical, the slight difference is in the north clamp which has a bolt on the back end of it which is important for the final steps in installing this system (The Wind Deflector) so ensure you put the correct clamp on the correct base in the correct orientation.
    l. To do this take a 2 pack of clamps (north and south clamps bundled together with a rubber band) and set it on the roof in between the two rows of bases at each base, now the north clamp goes on the north base on the high end of the base and the open end of the clamp faces south, The south clamp goes on the low end of the south base with the open end facing north. do this at every base.

DAY 2: PANELS, INVERTERS

EXPLAIN

1. Review the quick install guide as an overview of the entire installation process: Quick Installation Guide North America MAN-01-00025-3.2
2. Next you will run your Cable (PV Wire or Q Cable Field Wire) from your Junction box location to the ends of each string according to your planset.

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IMPLEMENTATION (LESSON PLAN) - CONTINUED

3. Setting panels.
    a. If you are using Microinverters:
        i. Plan your microinverter attachment method and wiring.
            - Attach microinverters to the panels using rocket clips
            - Mid-clamps with MLPE attachment spaces are also available (and preferred)
            - Plan your wiring run so that you do not exceed the maximum number of microinverters per branch circuit and so that the circuit ends as close to the junction box as possible.
    b. If you are using DC optimizers
        i. Plan your optimizer attachment method and wiring
            - Attach optimizers to the panels using rocket clips
            - Mid-clamps with MLPE attachment spaces are also available (and preferred)
            - Plan your positive and negative home run so that you land one end near the junction box and you have as easy a path as possible under the array and back to the junction box. Remember, both positive and negative leads will have to enter the junction box on the roof.
    c. Next, plan the order in which you set them. Work back to your ladder: if the ladder is set up in the south-east corner of the roof, the first panel (known as the keystone panel) will be set on the north-west corner of your array. The keystone is the most important panel because if it is not set plum to your north line, as you build you will run out of square with the roof, so take your time with this keystone panel.
    d. Once it is set, secure it so it does not move while placing the next panel, you'll place 3 block on the south end and 3 block on the north end so the keystone stays in place, from there you set the rest of the north row working toward the east and checking to ensure you stay on your north line, once the north row is set you weigh it down and secure the ballast trays to the panel with the ballast tray panel clamp you installed earlier. So now set the following rows working from west to east until all panels are set.
4. While laying panels you must map the solar array. Each microinverter or DC optimizer has a serial number sticker on it. Draw a map that reflects the design of the solar array and attach the serial number sticker in the location that the panel falls on the map. This will be used later on to build the online system monitoring and will allow the person building the system online to know where all of the microinverters or dc optimizers are in the solar array. Pro tip: take a phot of the map when done so if the map is lost or damaged you have a copy of it. If the array is built in the monitoring platform prior to installation both SolarEdge and Enphase have phone apps that can scan serial numbers and place the MLPE into the online map in the correct location.
5. Once all panels are set it is time to secure the wind deflector to the north end of the panels, you start by pushing the bottom of the wind deflector into the slotted channel on the 5D base you then push the top end of the deflector onto the bolt on the north clamp and fasten it with a ½" Flange Nut. Once this is done, you have finished.

DAY 3: WIRING INVERTERS

1. Microinverters are a relatively new development in the industry. Rather than using high-voltage PV source circuits wired to a central string inverter, each module is paired with a single microinverter. .Microinverters mount to the rails underneath each module and haVE pre-wired connectors that mate with the module interconnects. The AC output of each inverter is then connected in parallel using special cable available from the manufacturer.

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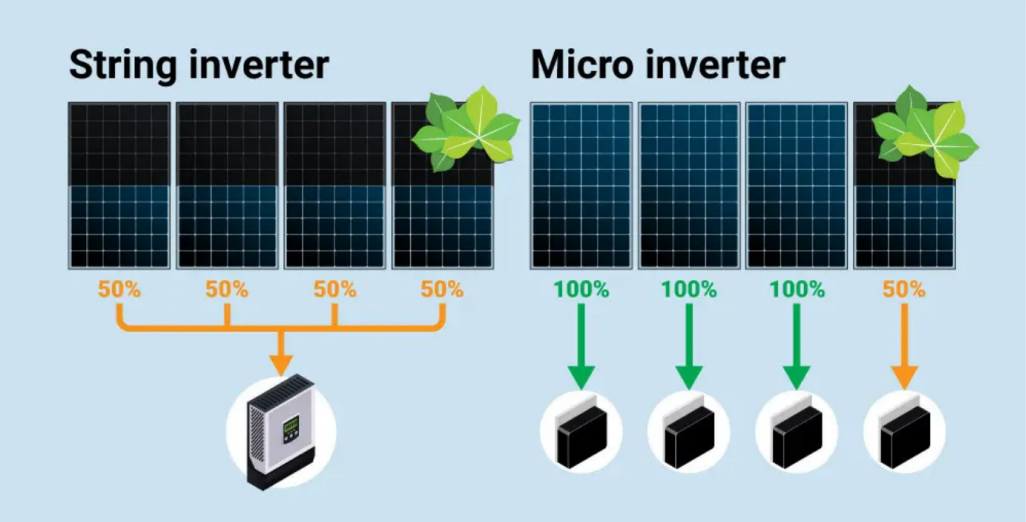
IMPLEMENTATION (LESSON PLAN) - CONTINUED

a. Microinverters usually have a good data monitoring system which allows the owner or installer to view info about each module.

b. Inverter failure does not result in complete system shutdown, as in the case of string inverters



2. Here is a sample list of materials for wiring an array using microinverters.
   a. Enphase Q cable (landscape or portrait) https://webshop.solarclarity.com/en/product/270077/enphase-q-cable-for-6096-cell-modules-
   b. Enphase IQ 7 microinverters https://enphase.com/installers/microinverters/iq7
   c. 6 enphase sealing caps
   d. Enphase terminator caps https://www.altestore.com/store/inverters/inverter-accessories/enphase-inverter-accessories/enphase-energy-sealing-cap-for-q-cable-connectors-p40743/?gclid=Cj0KCQjwrJOMBhCZARIsAGEd4VGa_QTWxV2DWuLLlig1fDaM97wTORc0xAaxs_4LJ-LzOoH254EFp18aAu-HEALw_wcB
   e. Engage cable clips Qty: 1 bag
   f. Qty: 20 each Enphase Male and Female field wireable connecters
   g. Qty: 5 - Enphase disconnect tools
   h. Qty: 3 - Breaker tie down kit
3. Teacher demonstrates how to approach the wiring task on the mock roof as the installation demonstration proceeds. The following may be used to prep for the install:

   EcoFoot MLPE Mounting Bracket

   Unirac Ecofoot2+ Universal Clamp Kit ES02+UNKTA

   How to install a soladeck - Soladeck install

DAY 4

1. **Wiring the junction box to DC Systems** (Teacher demonstration)
   a. PVC junction boxes are commonly used, but if using a metal junction box remember to bond and ground the junction box. Double check your positive and negative home runs to be sure they are correct (reversing polarity will cause problems!). Remember, red is positive and black is negative (note: you can purchase red PV wire so that you do not have to label the wire with tape). If you have more than a single string of panels

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IMPLEMENTATION (LESSON PLAN) - CONTINUED

you should label the wires with string numbers (ex. string 1 red and black should have a 1 labeled on it). Ensure that all positive and negative home runs have enough length to enter the junction box. Since the junction box is likely outdoors, ensure that you use a Heyco or similar connector to enter the junction box. Remember you will need a lock nut the same size as the Heyco connector to secure the Heyco connector to the junction box.

b. Inside of the junction box you will transition from one wire type to another. A typical transition is from PV wire to THHN #10 wire. You transition the wires by stripping the end of each wire (about a quarter to half of an inch) and then wire nutting or Polaris Tapping the wires together. When finished, remember to tug test your wires! We transition to THHN because it is cheaper and easier to pull through conduit.

c. Additionally you will need to make a hole in the junction box to bring in the equipment grounding conductor. This is usually bare copper wire and you will transition to green insulated wire. Use an irreversible crimp to merge these wires.

d. If you are using a Soladeck with Din Rail you can use a wire termination block (that mounts to the din rail) to transition from PV wire to THHN. Usually the Soladeck comes with a ground bar (to transition the ground wire) and lug bonded to the case to bond the metal of the case to ground using a ground wire. Lastly, always drill a small hole in the bottom of a junction box (known as a weep hole) to allow water to drain should it somehow find a way into the box.

2. **Wiring the junction box for AC systems**

a. PVC junction boxes are commonly used, but if using a metal junction box remember to bond and ground the junction box. If using Enphase Q cable use an Q Cable connector to enter the junction box. In this instance Black is L1 and Red is L2 (we are AC already so there is no positive and negative). If you have more than one branch circuit on the roof remember to label your circuits (example red and black pair are labeled branch 1, the next red and black pair are labeled branch 2).

b. Inside of the junction box you will transition from one wire type to another. A typical transition is from Q cable to THHN #10 wire. You transition the wires by stripping the end of each wire (about a quarter to half of an inch) and then wire nutting or Polaris Tapping the wires together. When finished, remember to tug test your wires! We transition to THHN because it is cheaper and easier to pull through conduit.

c. Additionally you will need to make a hole in the junction box to bring in the equipment grounding conductor. This is usually bare copper wire and you will transition to green insulated wire. Use an irreversible crimp to merge these wires.

d. If you are using a Soladeck with Din Rail you can use a wire termination block (that mounts to the din rail) to transition from Q cable to THHN. Usually the Soladeck comes with a ground bar (to transition the ground wire) and lug bonded to the case to bond the metal of the case to ground using a ground wire.

e. Lastly, always drill a small hole in the bottom of a junction box (known as a weep hole) to allow water to drain should it somehow find a way into the box.

3. **Pulling wire using a fish tape**

a. Always use the ground wire to hook onto the fish tape (the goal is to never damage any wire, but if one wire should get damaged you want it to be the ground wire and not one of the hot wires!).

b. Hook the ground wire to the fish tape and wrap electrical tape around the loop to keep the loop closed then continue taping down the ground wire and add wires every 3-4 inches. Make sure to stagger the wires when attaching them using tape so that you do not have a large bump. Wrap the tape tightly as you do not want wires to come off in the middle of a pull.

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IMPLEMENTATION (LESSON PLAN) - CONTINUED

c. If pulling a long distance, a tight pull, or there are a few turns you may want to use wire lube to allow the wires to slide through the conduit.

d. Lastly, you must have a pull point (an LB, junction box, something with a door on it) every 360º of turns. You cannot pull wire through more than 360º because you risk damaging the wire. In practice you should have a pull point at least every 270º of turns. All LB's, junction boxes, and pull points should have weep holes drilled into the bottom to allow water to escape should it enter the conduit.

How to Attach Wire to a Fish Tape: How To Attach Wire To A Fish Tape

Fish Tape Wire Pulling: Electrician Pro Tip: Fish Tape Wire Pull Prep

4. **Landing wires**

a. DC Systems

i. SolarEdge Installation Guide: How to Install SolarEdge | RENVU

ii. Once you have pulled your wire from the junction box on the roof through to the inverters DC disconnect it is time to land the DC wires. Make sure to pull more wire than you will need into the DC disconnect. You will want to leave slack in the wire for expansion and contraction so do not pull wires tight. Keep your wires organized and tidy so if a service tech needs to come back and work inside the DC disconnect they will have an easy time determining what is what. Strip your wires about ¼" on the end. In a SolarEdge inverter there are DC terminal blocks. You will stick a small flat head screwdriver into the hole just above where the wire is to be landed and slightly twist the screwdriver. This will open the jaws on the terminal block. NOTE: Make sure you understand which terminals are for negative and which are positive, do not reverse the polarity! When the stripped end of the wire is in the terminal block remove your screwdriver from the top of the terminal block to close the terminal jaws on the wire. Tug test your wires to ensure they are installed correctly.

iii. Interconnection

b. AC Systems

ENPHASE IQ Combiner Box + IQ Envoy Installation Manual

Introducing the Enphase IQ Combiner Plus

i. Once you have pulled your wire from the junction box on the roof through to the AC combiner box it is time to land the AC wires. Make sure to pull more wire than you will need into the AC combiner. You will want to leave slack in the wire for expansion and contraction so do not pull wires tight. Keep your wires organized and tidy so if a service tech needs to come back and work inside the AC combiner they will have an easy time determining what is what. Strip your wires about ¼" on the end. In an Enphase IQ AC combiner you are going to land the wires in 2 pole 20 Amp breakers. You will need to run the black wire (and ONLY the black wire) through the CT (the round doughnut) and then land them in the appropriate breaker. To land wire in the breaker strip the end about ¼" and screw it into the breaker. Make sure to tug test when done! Important: L1 and L2 matter! Make sure to follow the wiring diagram on the inside of the door of the IQ combiner. Black and red (L1 and L2) must remain the same throughout the install or the monitoring will show strange results.

Wiring the AC disconnect: Installing a Solar AC Disconnect

Wiring the interconnection: Solar panel wiring connection in house wiring diagram

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IMPLEMENTATION (LESSON PLAN) - CONTINUED

DAY 5

For Everest D-Dome East-West systems on a residential level (informational, not for demo-install)

Everest D-Dome Racking System: Everest D Dome R^2 Quick Install Video (full demo of install in a lab setting)

Intro D-Dome: Everest D Dome R^2 System Introduction

1. Begin by popping east-west lines at the measurement of the width of a row of panels, 66 ⅜ strike them down the length of the array, let's say this array is 2 rows wide, strike three lines the length of the array that are parallel with each other and square to the roofs edge the array will be walking along.
2. Next place the base pads on the lines 39 ¼" from each other, as you place down the pads another crew member places down the bases.
    a. There are two bases for D-dome: the foot and the dome. They alternate foot, dome, foot, until the pads are filled.
    b. After the bases are placed they are connected together with the leg, a bar intended to slot into the base of the dome and bolt into the foot. This provides a place to attach the ballast bars for the racking,
    c. After all the legs are installed you must refer to your ballast plans to identify where and how many ballast block should be placed, you then walk around your array placing the ballast bars into the slotted channel on the legs and draw a number for how many block go in each ballasted section.
3. Once this is done you may load the number of blocks near each section for later and lay out your cable (PV Wire to homeruns or Q Cable Field Wire) to the projected ends of each string of panels.
4. Begin to set the panels: your Keystone panel is going to be the most important.
    a. With D-Dome you can use multiple panels as a keystone. To do this you can set four panels square to each other at either the east or west end of the array
    b. By doing this a larger keystone section is made and will run along a further distance on your east-west lines, ensuring a straight array.
    c. As you work down your array you'll need to wire manage and place block. Note: it is far easier to do this as you work down the array then to go back after all panels have been set and wire manage.
5. The final step is grounding your array. Everest requires one single ground lug as the array provides its own ground path, so you'll place a ground lug on the end of your array and run Bare #6 Cu from the lug to your Junction Box.

Remember, a backfeed breaker must be installed on the opposite end of the bus bar from the main service disconnect.

RESOURCES/LINKS

https://unboundsolar.com/blog/step-by-step-diy-solar-installation

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