LESSON

Fixed Tilt and Dual Axis Tracker Systems

BIG IDEA(S)

Previously students learned how flush mount or ballast weight solar installation work. Fixed tilt solar is very similar to these roof mounted systems, however, when they are installed over empty ground instead of on existing buildings, they are called ground mount, fixed tilt systems.

OBJECTIVES

Students will be able to:

- Explain the advantages and disadvantages of fixed tilt and tracker based racking systems
- Demonstrate the concepts of how to install both styles of systems
- Describe how tilt is established based on seasonal need, location, distance from energy use, and angle of the sun.

TASK LIST SUBCATEGORY

506 Describe fixed tilt systems as compared to single and dual axis tracker systems

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 with appropriate comprises 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

TEXTS/REFERENCES

3D Technical Animation - Dual Axis Solar Tracking System

Worksaver Skid Steer Post Hole Digger

PD10 Pile Driver | Vermeer

PST 2AL Dual Axis Tracker

Solar PV Engineering and Installation (Sean White)

Solar Photovoltaic Basics (Sean White)

BRIGHT SOLAR FUTURES

SOLAR

TOPIC OF STUDY

Solar Installation

Year 1:
6 HOURS
(FOUR 90-MINUTE SESSIONS)
Year 2/3:
6 HOURS
(TWO 180-MINUTE SESSIONS)

KEY TERMS

single plane
inter-row shading
dual axis
single axis
trigonometry
fixed tilt
zenith
brownfields
power density
ground screw
pile driver
skid steer
ground mount

INSTRUCTIONAL - CONTINUED

MATERIALS NEEDED

Teacher Preparation:

Solar PV Engineering and Installation (Sean White) Chapter 7 Solar trigonometry

Solar Photovoltaic Basics (Sean White) Chapter 9 PV System Mechanical Design

Content:

MATERIALS

- Lights
- Cardboard
- Dark room Lights

Technology: Review the spec sheets provided (Ironridge; Soltec)

IMPLEMENTATION (LESSON PLAN)

FIXED TILT SYSTEMS

ENGAGE/EXPLORE

1. Most of what has been discussed so far is Flush mount or ballast weight solar installation. This is a form of fixed tilt solar however, when most people talk about fixed tilt solar systems they are referring to ground mounted solar.
2. What do you know about ground mount systems? What is different about installation of this kind of system? Provide a presentation based on background knowledge of ground mounted solar vs. roof mounted solar
    a. Roof mounted solar is installed in already used spaces
    b. Roof mounted solar is very efficient because it generates energy right where it's being used. There is not a long distance for the energy to travel.
    c. Ground mounted solar requires land space
        i. Is all land space the same?
        ii. Farm land, can solar and farming co-exist?
        iii. House backyard or other land related to housing
            1. Discuss trenching to house, do you have to go under anything (driveway, wall, etc.)?
        iv. Brownfields and contaminated land: there are lots of areas where the land is contaminated or otherwise unusable. Can they be good for solar?
            1. Discuss what might happen if a capped brownfield is drilled into. Contamination might leak
            2. Discuss advantages of ballast weight ground mount installation when installing on a brownfield site
    d. Orientation is important for a ground mounted solar
        i. In the northern hemisphere you want to face south
        ii. Avoid shading or obstructions
        iii. Mark the perimeter of the solar array using strings (class activity, on the floor design a solar array and then place strings on the floor around the room to mark the perimeter).

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IMPLEMENTATION (LESSON PLAN) - CONTINUED

EXPLAIN

1. Digging and Mounting Systems
    a. Always call the local Dig Safe authority before digging in the ground!
    b. Soil conditions
        i. Soft sandy soil (not good uplift strength)
        ii. Harder clay-like soil
        iii. Rocky soil (depending on the size of the rocks you may not be able to dig deep enough) Be careful using an auger with a Skid Steer in rocky soil, you can flip the Skid Steer!
    c. Digging tools
        i. Hand dig using a shovel
        ii. Ditch Witch trenching tool
        iii. Skid Steer with digging attachments (different types of attachments available: bucket shovel, auger, shovel of different widths)
        iv. Mini-excavator
        v. Excavator
    d. Ground mount racking systems that penetrate the earth
        i. Ground Screw
        ii. Concrete sono tube
        iii. Pile Driver installed piles
        iv. Vibration installed piles
    e. Figuring out how much solar can be installed using a fixed tilt system
        i. Discuss land area available for solar
        ii. Are there local AHJ requirements about ground mount solar (Does it need to be fenced in? How close to the property line can it go? Etc.)
        iii. Are there any land use issues to be considered
            1. Will animals be using the same space? If so, what types? NOT GOATS! Cows can work.
            2. Will plants be grown underneath? If so how, will they be maintained and cut back?
            3. If plants are not wanted how will the ground be treated to prevent plants from growing? Using tarps or other covers such as mulch or stone.
            4. How will water run-off be collected? Does it need to be?
        iv. Will the solar fit in a single row of panels that are all coplanar? Or will there need to be multiple rows?
        v. What is the ideal tilt angle for the solar? Ideal production tilt is always your latitude. However, if there are multiple rows you must consider inter-row shading!
            1. Discussion of Trigonometry and how you can calculate inter-row shading. Reference Solar PV Engineering and Installation Chapter 7 (pg. 99).
            2. IN CLASS ACTIVITY. Have students cut out to scale versions of solar panels using cardboard (1"= 1'). Use toothpicks, cut straws or other methods to angle the cardboard up on a surface. hang a light a known height and distance away from

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IMPLEMENTATION (LESSON PLAN) - CONTINUED

the cardboard. Can you calculate the length of the shadow? Shine the light and turn off all other lights. Measure the shadow.

3. Could you get more power out of the area available by sacrificing the ideal tilt to allow for more panels to fit in the area (Lower tilt shrinks the inter-row shading and allows for greater power density!)

SINGLE AND DUAL TRACKER SYSTEMS

EXPLAIN

What is a single axis tracking system? What is a dual axis tracker and how does it work?

a. Single axis tracker:
   i. Advantages: A single axis tracker is a solar racking system that tracks the sun in a single direction. Sometimes, single axis trackers track east to west throughout the day if they are motor powered (but this is rare). Single axis trackers can be installed with driven piles and do not necessarily require concrete footers.
   ii. Functionality: Most single axis trackers adjust the tilt of the panels manually or with a very simple motor. This means there is little to no maintenance. If using a single axis manually powered tracker the tilt adjustment typically happens twice per year. A sharper angle in the winter and a flatter angle in the summer. This allows you to gain solar production throughout the year.
   iii. Disadvantages: Even with very few moving parts there are still moving parts and potentially motors involved. These create points of failure. Also, since the solar is only tracking in a single axis some potential solar energy gains are being lost. They are not as efficient as dual axis trackers.

b. Dual axis tracker:
   i. Advantages: Dual axis trackers allow for the most possible solar energy production because they are always optimizing the angle of the array to be perpendicular to the sun. They are good to use in environments where there is not a lot of sun throughout the year. They are also good to use in environments prone to storms as they will move to a flat position for protection when wind speeds get above a set threshold.
   ii. Functionality: The dual axis tracker moves east to west throughout the day and also slightly adjusts the angle of the panel throughout the year to match the height of the sun. These types of trackers usually have an electric motor and there can be a special solar panel on the tracker that is used to charge a battery that powers the tracker. Additionally, since in the winter they can be at a very steep angle, dual axis trackers usually have wind speed indicators on them. If the wind speed gets too high they will move to the flat position in order to shed wind load.
   iii. Disadvantages: As with anything with moving parts there is a higher probability of something breaking. Most dual axis trackers require some sort of regular maintenance. Dual axis trackers usually require a concrete footer that goes at least six feet deep (and perhaps much more) in order to counter strong wind and snow loads. Lastly, the spacing between trackers can be quite large as they need space to move in every direction and lay flat (don't forget that we don't want them to shade each other!)

EXTEND

Utility Scale solar: Almost all VERY large solar systems (10 MW and above) are ground mount systems. A 10 MW solar system may consist of 30,000+ solar panels and this requires a lot of space. These types of systems are usually fixed tilt and located in the southern areas of the United States. Solar Developers look for big, wide open, unused spaces that are near utility infrastructure so the power can be transmitted to urban areas where it will be used.

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MEETING INDIVIDUAL NEEDS

Do in-class activities to demonstrate how inter-row shading works. Allow visual learners to watch YouTube videos in resources.

HOMEWORK

Look for a piece of land (big open space or backyard) where you could design a ground mount solar system. What would work best in this location: Fixed tilt? Single axis tracker? Dual axis tracker? Remember the further north you go the more important it is to optimize power output when the sun is shining since there will be fewer sun hours per year as compared to southern locations.

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