RENEWABLE ENERGY TECHNOLOGIES

INSTALLİNG THE SOLAR PANEL SYSTEM MODULE

2022-2-TR01-KA210-VET-000098216

IN RENEWABLE ENERGY TECHNOLOGIES NEW APPLICATIONS ACCORDING TO 4.0 STANDARDS

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DESCRIPTIONS

FIELD	Renewable Energy Technologies
OCCUPATION	Solar Energy Systems
NAME OF THE MODULE	Installing the Solar Panel System
DESCRIPTION OF THE MODULE	This module is a learning material that provides information about installing solar panel systems in buildings and open areas.
COMPETENCE	Installing solar panel systems in buildings and open areas
PURPOSE OF THE MODULE	**General purpose** Be able to manufacture metal components determined according to the building surface conditions and turn them into a carrier system; Will be able to assemble the solar stand by determining the solar stand mounting concrete and radiation angle. **Purposes** 1. You will be able to manufacture metal components determined according to building conditions using appropriate tools. 2. You will be able to mount the metal carrier system on the roof using appropriate equipment. 3. You will be able to level the surface by pouring the solar stand mounting concrete with appropriate equipment. 4. You will be able to determine the radiation angle in the field with the appropriate tools. 5. You will be able to assemble the solar stand with the appropriate equipment.

1. INSTALLATION OF SOLAR PANELS ON BUILDING ROOFS

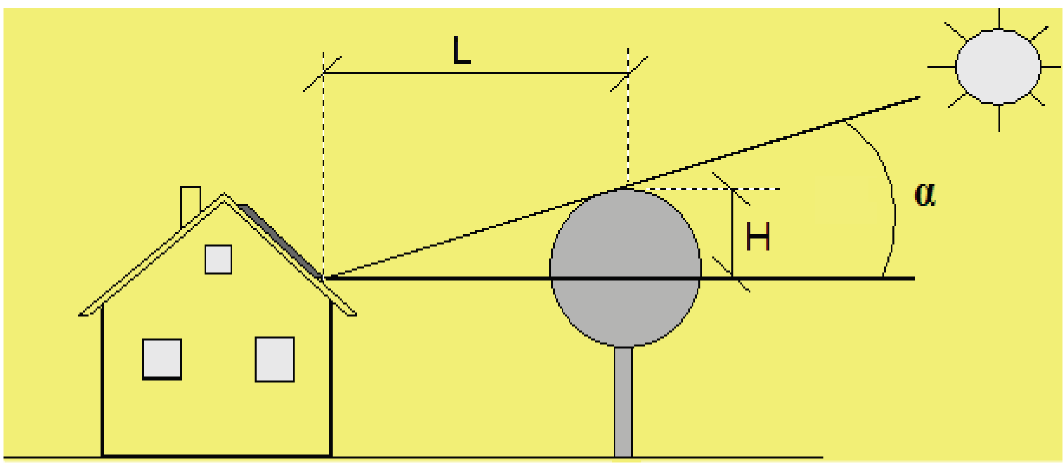
In buildings with roofs, PV panels should be installed on roof facades that can benefit from sunlight at the highest level. When installing solar panels, the panels must be mounted in a suitable direction and angle to fully receive the sun's rays. While performing this process, the direction of the panels should be determined by taking into account the solar radiation reception angle of the region. In the northern hemisphere, panels should be mounted facing south, and in the southern hemisphere, panels should be mounted facing north.

PV panels will be exposed to sunlight as well as other natural weather conditions such as wind, rain, temperature, snow, blizzard etc. For this reason, the installation of the solar panel system should be done by technical staff who are experts and competent in this field.

1.1. Roof Mounting Location Determination

In order for the system we will install to be efficient and to work smoothly for many years, the roof installation location must be determined correctly. For this purpose, attention should be paid to the shadow cast due to obstacles and the distance between solar panels (modules) in facilities installed on flat surfaces.

Shadows falling on solar panels (modules) reduce the efficiency of that module group and sometimes cause it to be completely disabled. When planning the placement of solar panels, the oblique incidence of sunlight should be taken into consideration. In Turkey, the sun's rays are most oblique (low angle) on December 21. The slope angle (α) varies depending on the region. At the same time, foothills, nearby trees and protruding windows can also create shadows. The layout plan of solar panels should be made according to these situations (Figure 1.1).



(Figure 1.1). Shadows cast on the modules due to obstacles

The situation where a shadow falls on the module due to an obstacle is checked as follows: If the distance (L) between the obstacle and the module is greater than H/tanα value, there will definitely be no shadow due to the obstacle.

L > H/tan α-

Particularly in facilities installed on flat-surface roofs, attention should be paid to the distance between modules. In the placement of the modules, incoming sunlight should not be interrupted by the previous module. The minimum distance between the modules so that they do not block each other's sunlight is calculated with the formula below (Figure 1.2).

$$A = \left[\frac{\sin \alpha}{\tan \beta} + \cos \alpha\right] \cdot L$$

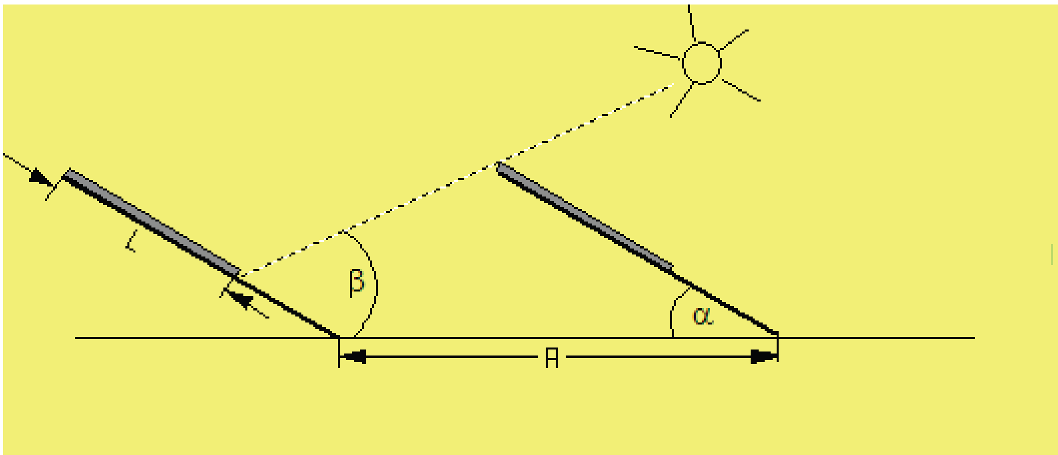


Figure 1.2: The distance to be left between two modules

1.2. Direction Determination and Latitude-Longitude Calculation Based on the Shape of the Roof

In Turkey, which is located between 36°-42° northern latitude and 26°-45° eastern longitude, the annual solar radiation is 1303 kWh/m2 and the annual sunshine duration is 2623 hours (1 year = 365 days = 8760 hours). 63% of our country's surface area can benefit from solar energy technically and economically for 10 months of the year. In order to maximize energy production from the solar panel, systems are needed so that the solar panel stand sees the sunlight at the right angle from sunrise to sunset. These solar energy systems maximize the production of electricity from solar energy by holding the solar panel at the right angle in many different ways.

Before installing the solar stand, the direction should be checked and the system should be mounted facing south (Picture 1.1). In addition, care should be taken to place the area where the solar stand will be installed in an area that will not be shaded by other solar stands, trees and buildings. Before starting to install the system stand, direction and shadow calculations should be made with the help of a compass. In order for solar panels to work properly, they must face south. If the system to be installed is planned to be used in both summer and winter, the inclination angle of the solar stand should be the same as the latitude angle of that region. If the system is planned to be used only in summer, the latitude angle of the solar stand should be 15° lower than the latitude of the region (since the sun's rays come vertically in summer). If the system is planned to be used only in winter, the latitude angle of the solar stand should be 15° higher than the latitude of the region (since the sun's rays come horizontally in winter).

To play the video, click on the image or click the link below and open it with your browser.
https://www.youtube.com/watch?v=aGqdZ882Mvo

Picture 1.1: Solar panel system facing South

Turkey is located between 36° - 42° northern latitudes and 26° - 45° eastern longitudes. When adjusting the angle of the sun stand, the installation should be made taking into account the northern latitudes of our country (36°-42° northern latitudes). The solar panel stand should be positioned so that it faces the sunlight at noon during summer and winter. Otherwise, the efficiency of the solar panel will be low.

For example, if we accept the latitude angle of Mersin as 37° in the installation of a solar panel stand on a flat roof in Mersin (Picture 1.2);
-For the system to be used in summer and winter, the solar panel stand angle should be 37°.
-For systems that will be used only in summer, the solar panel stand angle should be 37°-15°=22°.

-For systems that will only be used in winter, the solar panel stand angle should be 37°+15°=52°.

Picture 1.2: Panel installation on a flat roof

1.3. Installation of Solar Panel System

Solar panel installation in buildings can be done on roofs and facades. Rooftop installations are more common and more cost-effective. Installations on facades provide a more aesthetic appearance. If the building is high-rise, the amount of energy production will increase since the wall surface will be larger.

Some points to consider for solar panel installation in buildings:

- The roof or facade must receive sufficient sunlight
- Panels must be mounted in accordance with the solar radiation angle.
- Panels must be mounted in a way that does not cast shadows, taking into account environmental factors.
- Panels must be of high quality and comply with standards
- During installation, appropriate mounting equipment should be used, taking into account wind and snow load.

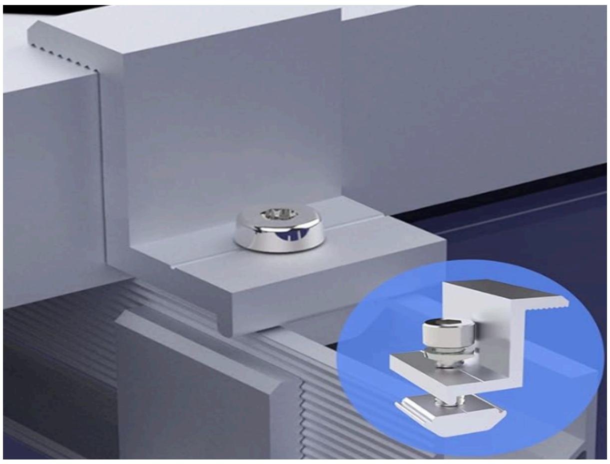
2. ROOF CARRIER SYSTEMS

2.1. Roof Carrier System Apparatus

Various mounting elements are used during the installation of solar panels on roofs and hard surfaces (Figure 1.3). Depending on the nature of the work performed, companies can produce assembly elements of different types and models. The purpose of this is to ensure that the workmanship is easy, durable, ergonomic and low-cost.

Figure 1.3: Various panel mounting elements

Edge fasteners: They are used to fix the first and last panel in the assembly of panels to sigma profiles or other metal profiles (Picture 1.3**).**

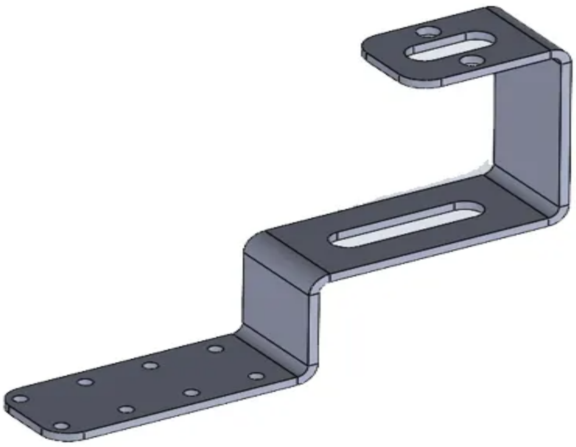


Picture 1.3: PV panel edge clamp

Intermediate fasteners: These are the intermediate assembly elements of all panels located between the first and last panel. It ensures that the panels remain stable in place against natural conditions such as wind, rain, snow and similar (Picture 1.4).

Picture 1.4: PV panel intermediate or middle clamp

Mounting hook: It is a flat-shaped iron used to attach Sigma and other PV panel mounting profiles between tiles on sloping roofs (Picture 1.5).



Picture 1.5: Solar panel mounting tile hook

Trapezoidal roof mounting element: It is mounted between the trapezoidal roof and the mounting profiles and on the trapezoidal sheet. Thus, it creates a gap between the panel and the roof. The resulting space functions as ventilation and cooling with the help of wind **(Figure 1.6).**

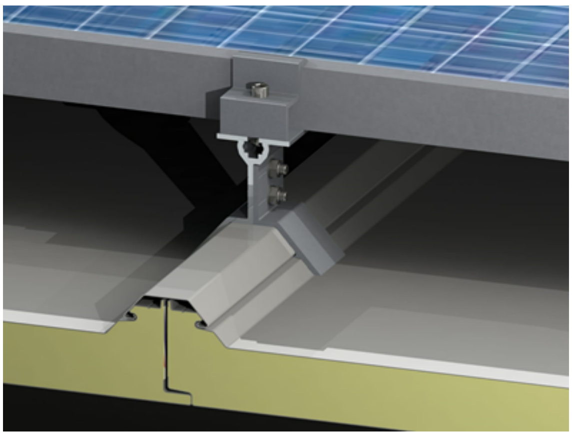
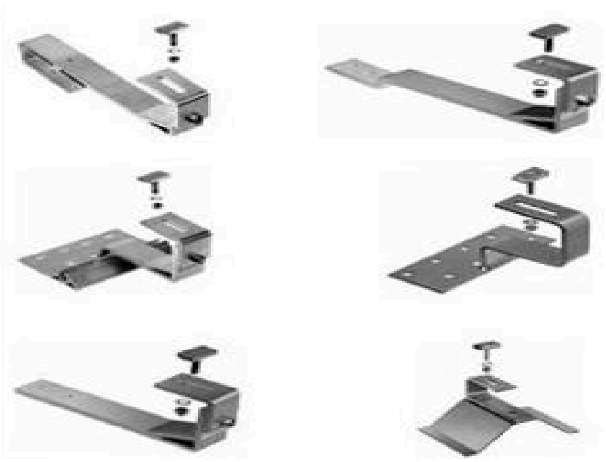


Figure 1.6: Mounting element on trapezoidal roof

Mounting elements may differ depending on the material they are manufactured from. It can be made of iron, aluminum or different alloys. They are manufactured in different patterns and models according to the producing companies and customer demands. The main point in all of these is to create the infrastructure for the panels to work soundly, regularly and efficiently.

The efficiency of panels exposed to high temperatures decreases and their lifespan is shortened. To prevent this, necessary precautions should be taken during the installation phase as much as conditions allow. During installation, the necessary space must be left at the bottom of the panel to provide air circulation.

It consists of screws made of stainless steel, roof brackets (roof anchors) made of stainless steel (Picture 2.1), Connection legs, Metal rails (Picture 2.2), Various profiles (Picture 2.3).



Picture 2.1: Roof bracket (roof anchor)

Picture 2.2: Metal rails and solar panels

Picture 2.3: Metal profiler

2.2. Using the Apparatus

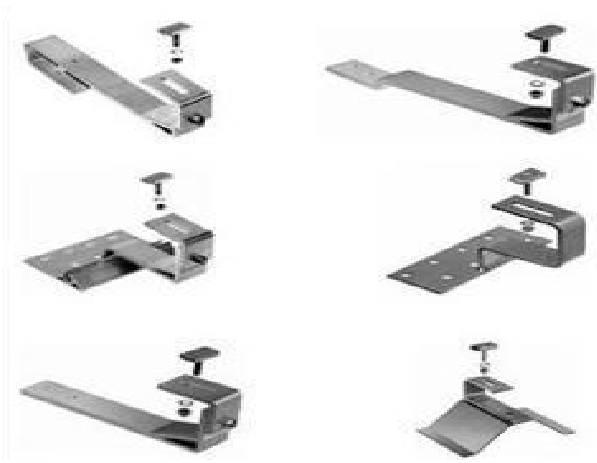
Roof brackets that will connect the panels to the roof should be mounted on the roof beams. It is not wise to drill the necessary holes directly with a drill during the installation of roof brackets to the beam. First, small, shallow holes should be opened to ensure that the feet are lined up in a straight line. With the help of chalk or laser, it should be determined that the feet are in a correct line, only after this stage the actual holes should be opened.

The screws to be used to mount the panels on the roof must be made of stainless steel and must be attached directly to the beams. In order for solar panels, which can operate for years under natural conditions, to work properly, the materials used in the assembly must also be of high quality and long-lasting.

2.3. Roof Mounting Techniques

Solar panels are devices that convert solar energy into electrical energy. Solar panels can be easily mounted on many roofs with different structures and architectures. In order to prevent the solar panels from causing any leaks on the roof, it is recommended that the installation be carried out at the same time as a renovation on the roof. It is a simple process and if the installation is done correctly, there will be no problems.

Moving around on a tiled roof during installation can also cause the tiles to break and damage the structure of the roof. For this reason, it is necessary to be more cautious and work carefully on tiled roofs. Rather than mounting the panels directly on the roof, it is smarter to put a junction point between the roof and the panel and mount the panels at that junction. Thus, removing the panels from the roof for any reason in the future can be done at low cost and without damaging the roof. One of the mounting methods of the solar panel system to be installed on the roof is the installation using a roof bracket (roof anchor). On roofs with roof slopes between 15° and 75°, where flat or slightly curved roofing elements made of clay or concrete are used, solar panel systems are installed using the roof bracket method. Roof brackets (roof anchors) are aluminum or steel components that are bolted directly to the roof joists that form the basis of the mounting system. The roof bracket to be used is determined according to the existing tile properties (Picture 2.4).



Picture 2.4: Various roof brackets (roof anchors)

With this method, flexible fixing to the roof beams is made. It does not require drilling of roofing elements. Easy and fast assembly is provided.

The installation of the solar panel system with the help of a roof bracket is as follows:

- The tiles where the roof bracket will be mounted are removed.
- Roof brackets are mounted on the beams under the removed tile (Picture 2.5).
- The removed tile is placed on the angle bracket mounted on the beam.
- A longitudinal profile is mounted on the roof hanger connected to the roof bracket (Picture 2.6).
- “T” profile is mounted on the longitudinal profile.

- The same operations above are performed in parallel on the other side (Picture 2.7).

Picture 2.5: Installation of roof brackets on beams

Figure 2.6: Mounting the "T" and longitudinal profile to the roof hanger

Picture 2.7: Final version of the solar panel system

After the solar panel system for the roof is completely installed, the direction of the system should be checked with the help of a compass. The tilt angle of the solar panel system should also be checked again with a digital protractor. Roof slope should also be taken into account when checking the slope angle. If there is any deviation, necessary corrections should be made.

2.4. Installation of Solar Panel System

Solar panel installation in buildings can be done on roofs and facades. Rooftop installations are more common and more cost-effective. Installations on facades provide a more aesthetic appearance. If the building is high-rise, the amount of energy production will increase as the wall surface will be larger.

3. INSTALLING SOLAR PANEL SYSTEM IN OPEN AREAS

Land and its structure are important factors in establishing a solar field. A solar power plant (SPP) cannot be installed on every land. The relevant legislation clearly states what land characteristics should be. First of all, your land should not have fertile soil. It should be in the status of marginal agricultural land, that is, non-productive lands on which only traditional land management can be carried out. Power plant permission is not given on fertile land.

Features that must be present on the land where solar power plant will be installed

• In marginal agricultural land status,

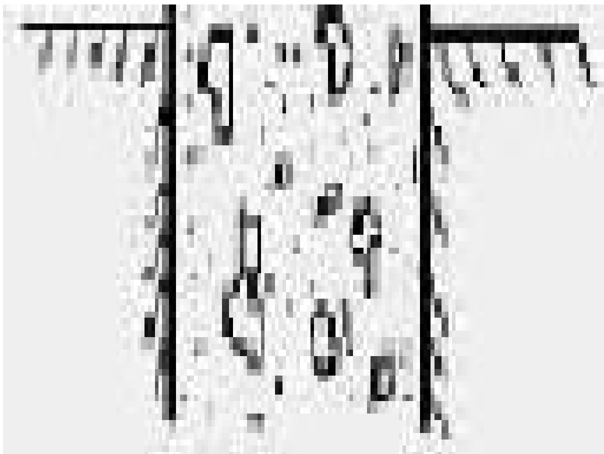
• Inclined,

• South facing (for the northern hemisphere)

3.1. Sun Stand Foundation

The concrete pit opened to mount the solar stand on the ground in order to spread the load created by the solar panel and the stand over a larger area is called the solar stand concrete pit. The solar stand concrete pit structural elements are also called the solar stand foundation. Foundations are structural elements that carry the fixed, mobile and meteorological loads of the solar stand and transmit them to the ground. The natural ground on which the foundation will sit is called the foundation bed. The concrete pit for the iron pole of the solar stand will be excavated to a depth of at least 60 cm, although this may vary depending on the size of the panels, stand and pole to be used. The dimensions of the pit to be excavated should be prepared to be at least 60x60x60cm (Picture 1.5, Picture 1.6).

Picture 1.5: Surface view of the concrete pit

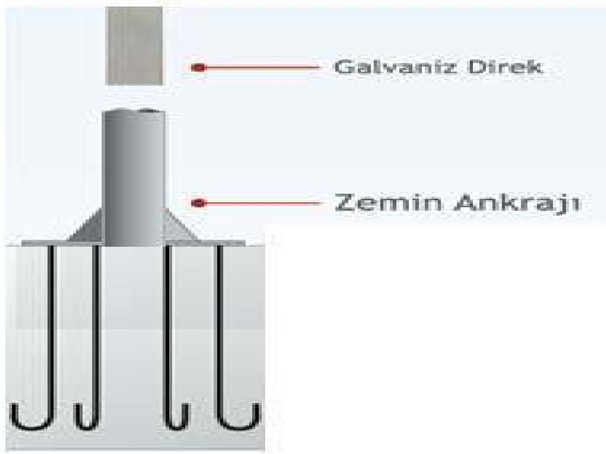


Picture 1.6: Concrete pit

3.2. Anchor Structure and Dimensions

Anchoring is the process of making a structural element work together by fastening it to another material or element by inserting it into it. In other words, if we define anchorage, we can say it as the connection of steel reinforcement into concrete in reinforced concrete structures. (Picture 1.7, Picture 1.8).

Picture 1.7: Various anchor bars



Picture 1.8: Solar stand pole ground anchor

3.3. Leveling the Concrete Surface

After the pole location is marked according to the project, it is opened according to its size. The concrete mold is prepared to be placed in the opened pit. A few days before placing the anchor bar in the hole of the pole, 10 cm thick mortar is poured. If the mortar will not be poured, the soil should be compacted.

The anchor bar suitable for the solar panel stand pole is placed on the pit floor on a suitable scale. After the anchor iron is placed in the pit, the anchor foundation must be made in accordance with the technological rules. In order to ensure that the anchor remains in its position for a long time, the anchor is filled with mortar in accordance with the procedures and a foundation is made. The anchor bar is definitely placed in concrete mortar. The mortar to be prepared for this job consists of 70% aggregate (sand, gravel, gravel), 10% cement and 20% water. When necessary, additive material can be added, provided that it is not more than 5% of the cement weight. The mortar is compressed to spread the concrete poured into the mold all over the mold, to ensure that it covers the anchoring reinforcement thoroughly, and to increase the filling by removing air gaps. The concrete should be placed in homogeneous layers. The formation of piles and inclined layers should be prevented during placement. To prevent evaporation and sudden water loss of the concrete after pouring. Wrapping it with a wet cover or applying cure (protection) is important to reduce the risk of cracking.To prevent the accumulation of water, snow, etc. at the bottom of the pole, projecting concrete is created in the form of raincoat concrete up to 15cm above the soil level.

4. RADIATION ANGLE IN THE LAND

4.1. Determination of Radiation Angle

The first question that comes to mind when installing a solar-powered lighting system or any other system that gets its power from the sun is what the solar panel direction and angle should be. The solar panel will operate at its highest efficiency when oriented directly towards the sun. When we look around us, we can observe differences in the mounting directions of solar panels. This is due to the lack of information about which direction and how inclined the solar panel will be facing.

The tilt angle of the panels affects the efficiency of the panels in the following ways

The angle at which the sun rays hit the panel: As the inclination angle of the panels increases, the angle at which the sun rays hit the panel also increases. This causes the panels to capture more sunlight and therefore increases the efficiency of the panels.

Reflection of sun rays: As the angle of inclination of the panels increases, the possibility of reflection of sun rays from the panel also increases. This causes the panels to capture less sunlight, thus reducing the efficiency of the panels.

Shadowing: The angle of inclination of the panels also affects the risk of panel shadowing. As the angle of inclination of the panels increases, the risk of shading the panels also increases. This causes the panels to capture less sunlight, thus reducing the efficiency of the panels.

Other factors affecting the efficiency of solar panel tilt angle

The angle of inclination of the panels is not the only factor that affects the efficiency of the panels. Other factors affecting the efficiency of panels are:

Quality of panels: The quality of panels directly affects the efficiency of panels. Quality panels capture more sunlight and therefore work more efficiently.

Cleaning of panels: Cleaning of panels indirectly affects the efficiency of panels. Dirty panels capture less sunlight and therefore operate less efficiently.

Position of the panels: The position of the panels indirectly affects the efficiency of the panels. Panels should be placed in a location that receives direct sunlight.

Taking these factors into consideration, the inclination angle of the panels should be determined.

The angle of sunlight reaching the earth at different angles at different times of the day. Systems that track sunlight can be installed. This is a more technical installation to make maximum use of sunlight. However, it is generally not preferred due to high installation costs. We can calculate the most suitable sun exposure angle by taking into account our latitude and longitude. There are various calculation methods on this subject. We will use the following method, which is not very complicated.

4.2. Compass and Its Use

The most important part of the compass is a magnetic needle. This needle is mounted on the compass body so that it can move freely. The needle always points in the same direction when released. This is because there is a force on earth that pulls the needle. The earth is like a big magnet with one end in the north and the other in the south. The Earth's magnetism causes the compass needle to rotate towards magnetic north. The tip of the needle pointing north is painted red or black. In some compass needles, the tip is pointed like an arrowhead. Some even have the letter "N" on the tip of the needle pointing north. The compass has a 4-cornered surface. These show the cardinal directions: North, south, west, east. These directions divide the compass into 4 quadrants. These are divided among themselves as: northeast, northwest, southeast and southwest.

The compass below is different. See the figure below (Figure 4.1). You will see a red and black arrow.

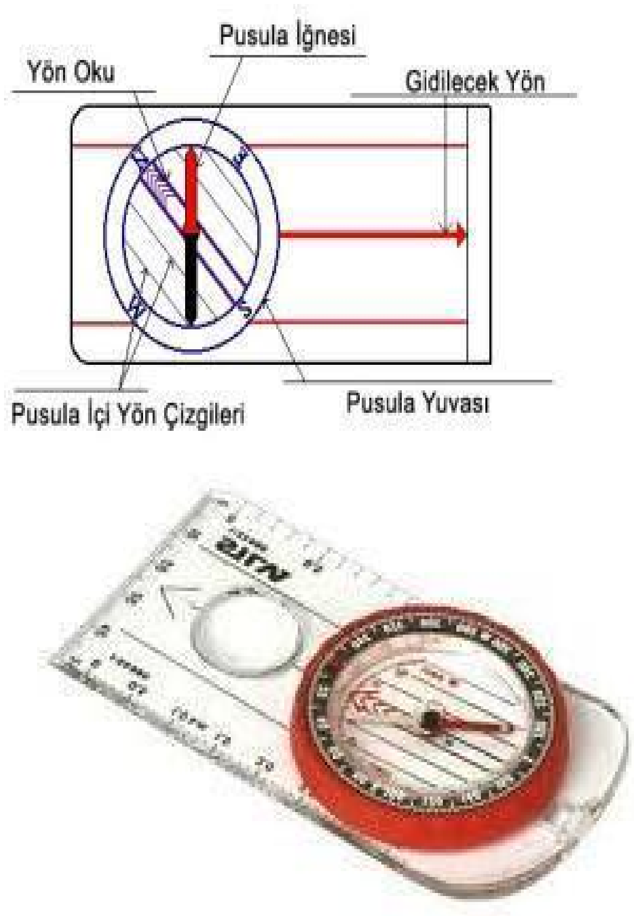


Figure 4.1: Compass

In some compasses, the color of the compass needle may be red and white. The important thing you need to know here is that red indicates "Magnetic North". But let's say; You want to detect another direction rather than north. In this case, there is a rotating collar on the compass. This is called the compass housing (angle dial). There is a ruler with a scale on the compass housing that shows degrees (between 0 and 360 degrees). This ruler shows numbers from 0 to 360. Additionally, directions are indicated on this ruler with the letters N (North), S (South), W (West) and E (East). If you are going to go somewhere in the middle of two of these directions, you need to say the names of both directions.

Now let's learn how to use a compass. But before moving on to this subject, we need to touch upon an important point. Since our compass is a magnetic device, it may be affected by metal objects around it. Metal watches, bag straps, rings, cars around the compass; We should know that devices that emit magnetic fields, such as mobile phones, computers and televisions, will confuse our compass. For this reason, we should use our compass away from these objects.

In order to find direction with our compass, we will first need to learn to take bearings. Bearing: Simply the angle between magnetic north and our target. Example: Let's say 320° northwest. The first thing you need to do is to find the location of 320° northwest on the compass housing. Then you will position the part of the compass housing that points 320° northwest over the “arrow” indicating the “Direction To Go” (Figure 4.2).

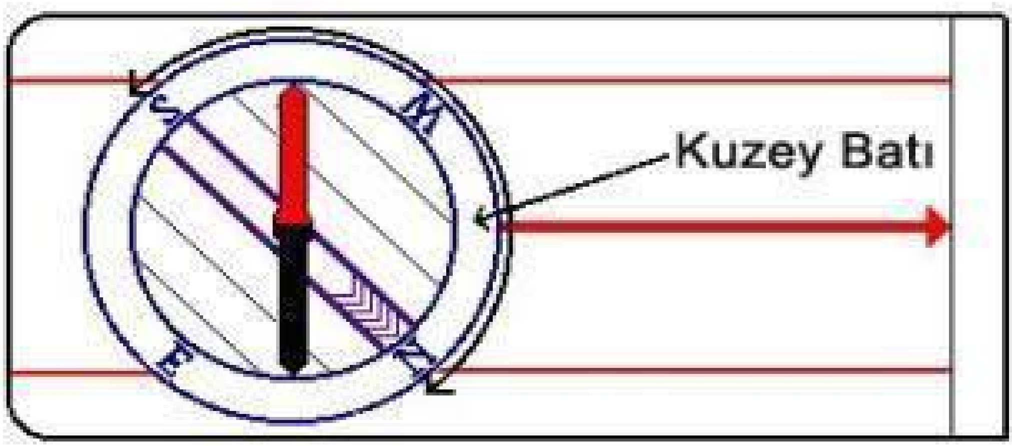
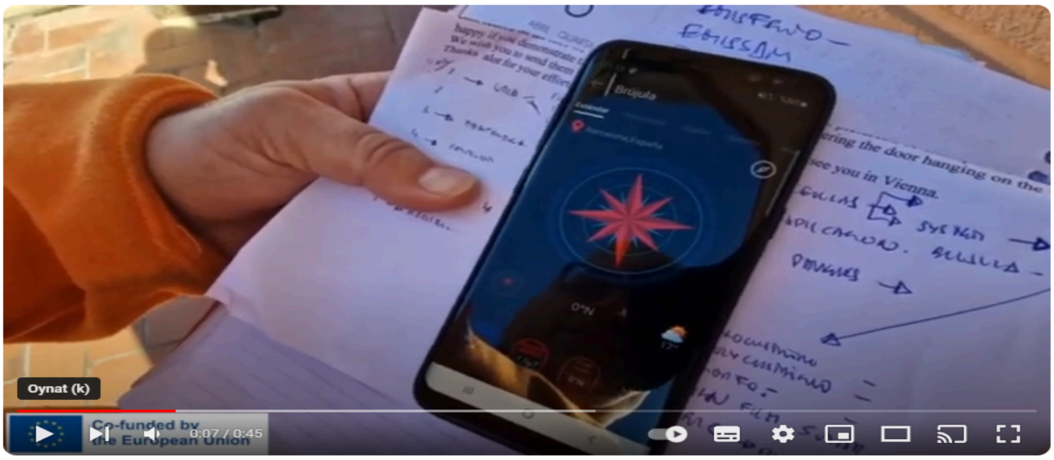


Figure 4.2: Positioning the part of the compass housing pointing northwest over the arrow showing the "Direction to Go"

Hold the compass in your hand. You need to hold the compass flat in your hand so that the compass needle can rotate easily. Then, with the compass in your hand, turn your whole body until the north of the compass needle coincides with the north inside the compass slot (Figure 4.3).

Figure 4.3: Turning until the north of the compass needle coincides with the north inside the compass slot

If you're sure you've done everything right up to this point, the arrow will point in the direction you want.



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https://www.youtube.com/watch?v=haTnxZH9kN8

4.3. Using the Irradiance Angle Determiner

Thin beams of light that originate from a light source and reach us in a straight line are called rays. This type of energy emitted from different energy sources is called radiation or radiation. The term radiation, which is the equivalent of radiation in western languages, is also widely used.

In solar energy applications, since the surfaces where solar energy is converted into light or electricity are placed inclined, the solar radiation reaching the inclined surface is an important and basic parameter in the calculations. Total solar radiation incident on any surface on earth; consists of direct, diffuse and reflected radiation (Figure 4.4).

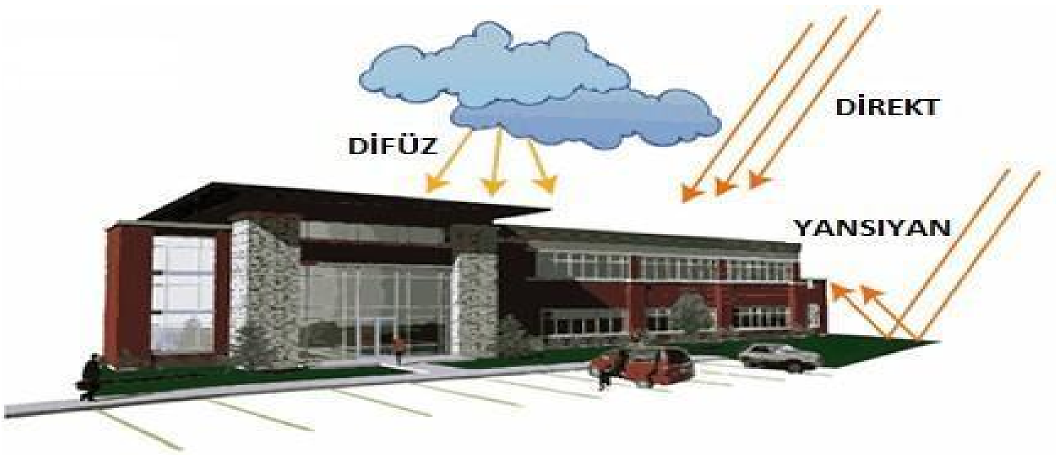


Figure 4.4: Total solar radiation types reaching any surface on earth

Direct solar radiation: Direct solar energy comes to the surface.

Diffuse (diffuse) solar radiation: It is the component of the radiation coming from the sun, which is absorbed by clouds and dust after passing through the atmosphere and comes back to the surfaces from there.

Reflected solar radiation: It is the component of solar radiation falling on the earth that comes to the surface from the environment around the surface.

Total solar radiation is measured with devices such as pyranometer (Figure 4.1), actinograph or solarimeter (Figure 4.3). Direct solar radiation intensity is measured with pyranometer devices (Figure 4.3) and diffuse solar radiation intensity is measured with pyranometer devices using shadow balls or tapes (Figure 4.4).

Resim 4.1: Piranometre

Resim 4.2: Solarimetre

Resim 4.3: Pirhelyometre

Total hourly solar radiation incident on the inclined surface; It is calculated as the sum of the hourly direct, diffuse and reflected radiation incident on the inclined surface. In order to calculate these components, the total, diffuse and direct solar radiation incident on the horizontal surface must be known.

Total hourly solar radiation incident on the inclined surface; It is calculated as the sum of the hourly direct, diffuse and reflected radiation incident on the inclined surface. Hourly total solar radiation (ITE) incident on the inclined surface is found by the following equation;

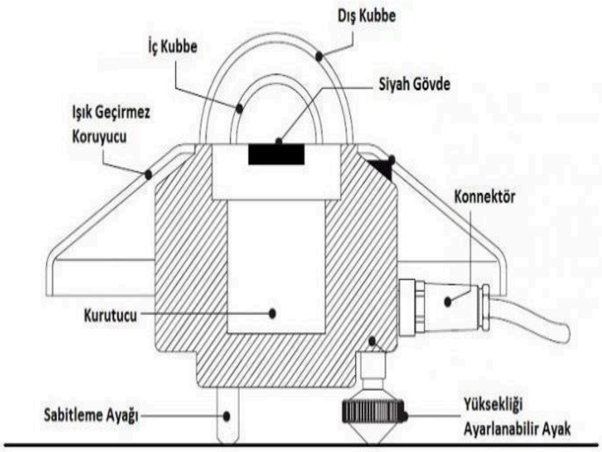
ITE = Ibe + Ide + Ire. Here;

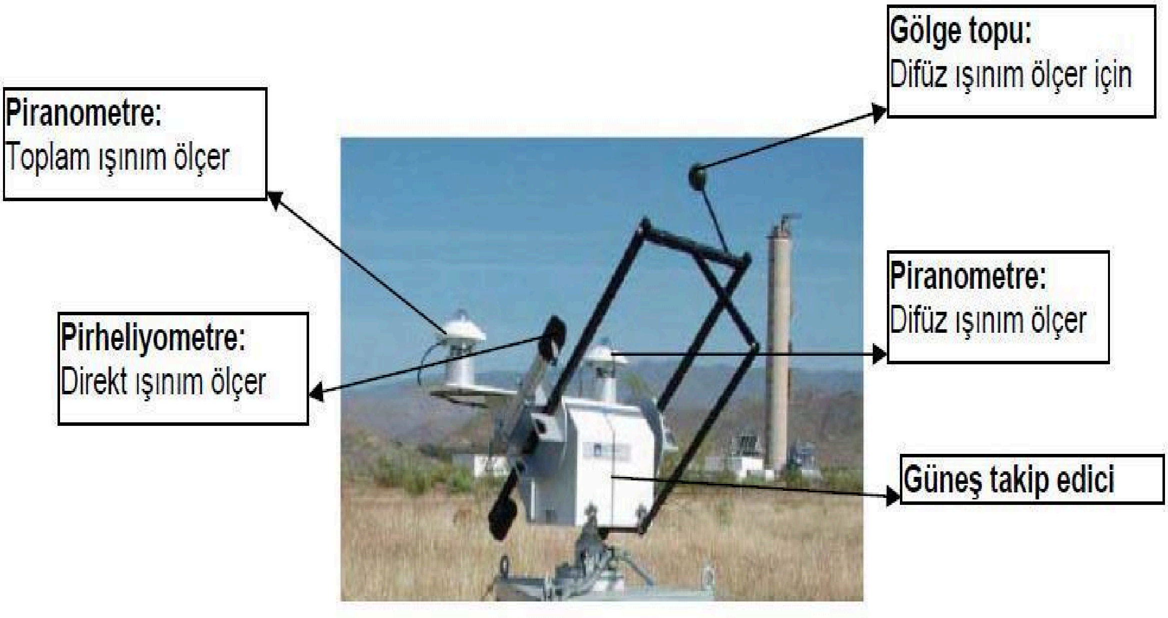
ITE= Total hourly solar radiation incident on the inclined surface,

Ibe= Direct radiation incident on the inclined surface,

Ide = diffuse radiation incident on the inclined surface,

Ire = Refers to the reflected radiation incident on the inclined surface. Direct, diffuse and reflected radiation values are calculated using various models.





Picture 4.4: System that measures all components of solar radiation incident on the horizontal plane

4.4. Latitude-based methods

Latitude-based methods calculate the tilt angle of the panels using the latitude value of the place where the panels will be installed. These methods are widely used because they are simple and practical. However, these methods do not fully calculate the efficiency of the panels because they do not take into account the season in which the panels will be used.

Advantages of latitude-based methods:

• They are simple and practical.

• They can be easily applied.

• They do not require complex calculations.

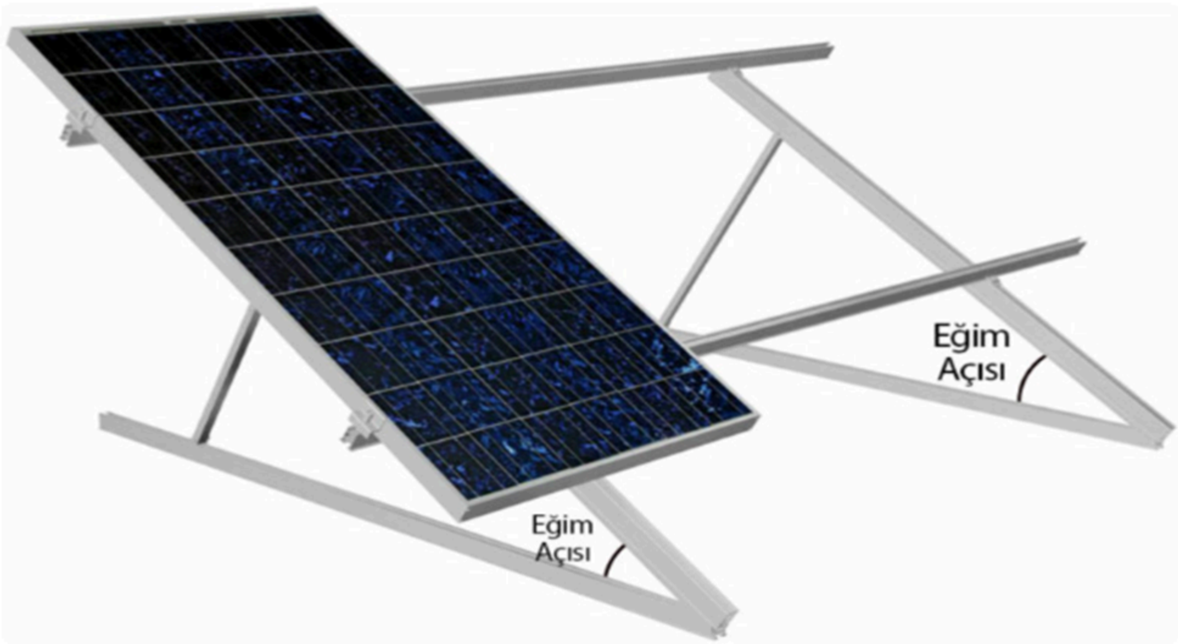
Disadvantages of latitude-based methods:

• They do not take into account the season in which the panels will be used.

• They do not calculate the efficiency of the panels exactly.

The solar panel tilt angle is calculated using the latitude value (Picture 4.5). If the latitude value is between 25 and 50, it is multiplied by 0.87 and 3.1 degrees is added to the result. Since Turkey is located between 36 and 42 degrees latitude, this calculation method should be used for all installations in our country.

For latitude values of 50 degrees and above, the ideal angle can be taken as approximately 45 degrees**.**

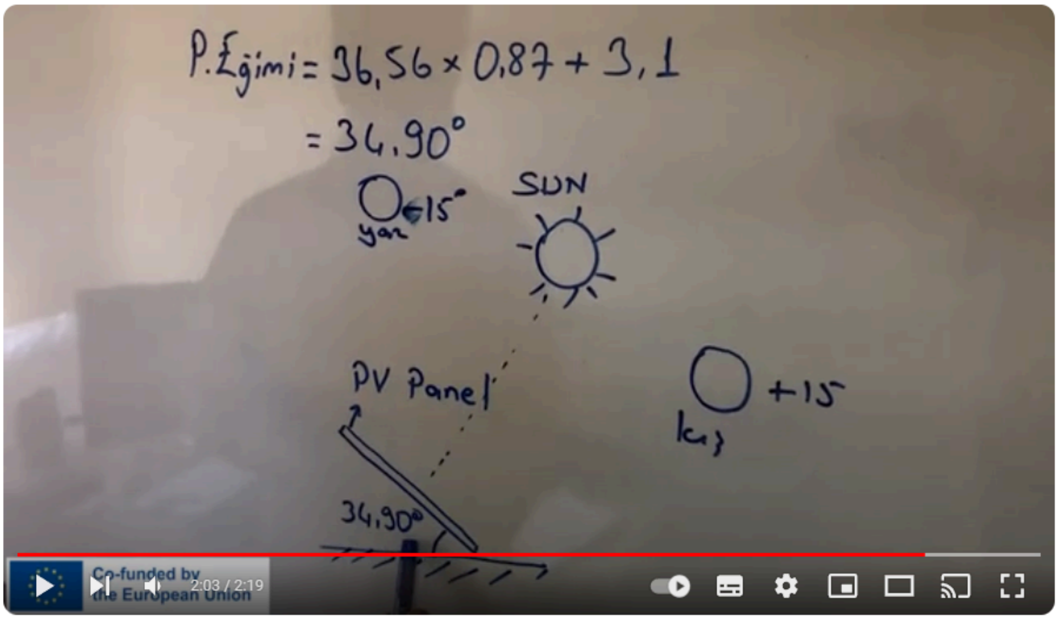


Picture 4.5: Solar panel tilt angle

You can use the formula below to calculate the solar panel tilt angle for use in all cities in Turkey.

Panel Tilt = Latitude x 0.87 + 3.1

The angle of inclination to be found with the help of calculation refers to the angle between the panel and the ground. In other words, zero degree panel inclination means completely horizontal positioning, and 90 degrees panel inclination means full vertical positioning.



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https://www.youtube.com/watch?v=3jr0GuRDrOU&t=62s

According to these data,
Example-1: Let's calculate the panel angle for the solar panels to be installed in Turkey / Mersin-Tarsus Chamber of Commerce and Industry Vocational and Technical Anatolian High School.

Latitude for Tarsus = 36°56′N ⇒ Panel Slope = 36.56 x 0.87 + 3.1 = 34.90°

Example-2: Let's calculate the panel angle for the solar panels to be installed in Spain/Barcelona-Eshia Energia S.L.

Latitude for Barcelona= 41°23′N ⇒ Panel Tilt = 41.23 x 0.87 + 3.1 = 38.97°

Example-3: Let's calculate the panel angle for the solar panels to be installed in the Austria/Vienna-N2 ANIMA GMBH facility.

Latitude for Vienna= 48°12′N ⇒ Panel Tilt = 48.12 x 0.87 + 3.1 = 44.96°

As a result, although all three cities are in the northern hemisphere, panel installation angles vary depending on latitude. These angles are valid for four-season use, and in certain seasonal uses, installation angles may vary depending on the characteristics of the season.

– For systems to be used in summer, the solar panel stand angle should be 15° less than the calculated value.

– For systems to be used in winter, the solar panel stand angle should be 15° more than the calculated value.

4.5. Zenith angle based slope angle calculation

Maximum absorption of sunlight occurs when the panels are perpendicular to the falling sunlight (Figure 4.5).

Zenith angle (zenith angel): It is the angle between direct solar radiation and the perpendicular to the horizontal plane. It is denoted by the Greek letter (ϑ). It is pronounced with a lispy "t" sound, produced by slightly protruding the tip of the tongue beyond the front teeth.

Elevation angle: It is the angle between the Sun and the horizontal plane. It is denoted by the Greek letter (α). It is pronounced alpha.

Tilt angle: It is the angle of PV panels with the horizontal. It is expressed with the letter (t).

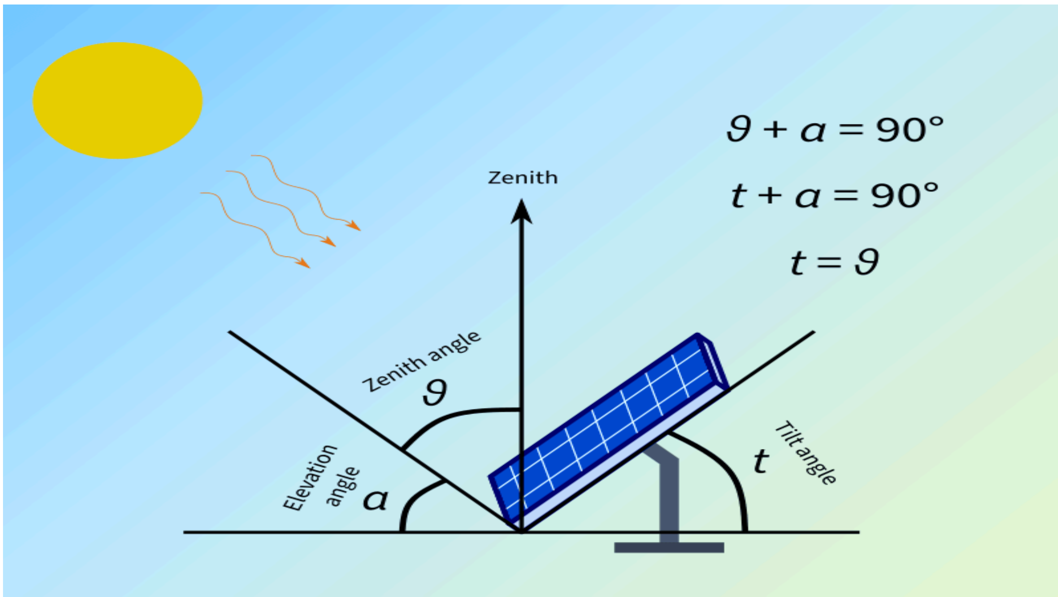
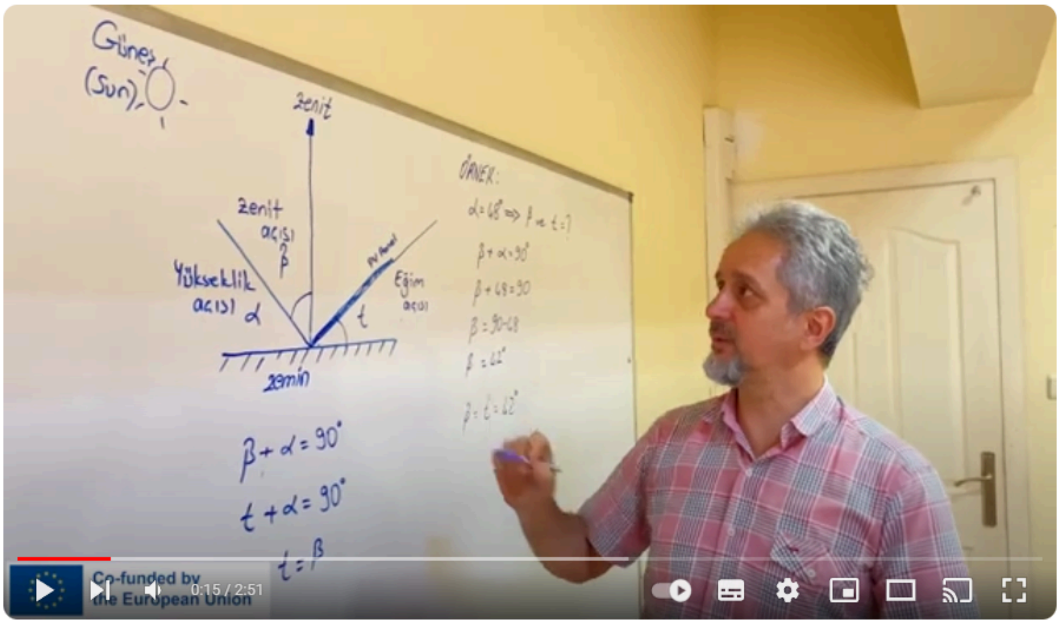


Figure 4.5: Tilt angle based on zenith angle



To play the video, click on the image or click the link below and open it with your browser.
https://www.youtube.com/watch?v=TBru3QuRMjo

The sum of the zenith angle (ϑ) and the elevation angle (α) is 90°. ⇒ $\vartheta + \alpha = 90°$

The sum of the inclination angle (t) and the elevation angle (α) is 90°. ⇒ $t + \alpha = 90°$

Accordingly, the Slope angle (t) and the Zenith angle (ϑ) are equal to each other. ⇒ $t = \vartheta$

Example: If the elevation angle is 52°, calculate the zenith angle and inclination angle in degrees.

Solution: $\vartheta + \alpha = 90°$

$\vartheta + 52° = 90° \Rightarrow \vartheta = 90° - 52°$

$\vartheta = 38°$ $\vartheta = t = 38°$ tilt angle.

The sun's elevation angle is at its minimum in the morning and evening. We should make zenith angle measurements at noon, when the sun is directly overhead, in the middle of the day.

Zenith angle based methods

Zenith angle-based methods calculate the tilt angle of the panels using the latitude of the place where the panels will be installed and the season in which the panels will be used. These methods calculate the efficiency of the panels more accurately. However, these methods are less commonly used than latitude-based methods due to their greater complexity.

Advantages of zenith angle based methods:

• They take into account the season in which the panels will be used.

• They calculate the efficiency of the panels more accurately.

Disadvantages of zenith angle based methods:

• They are more complex.

• They require more calculations.

In order to get maximum efficiency from PV panels, sunlight must reach the panels at a 90° angle. For this, we must mount our solar panels at an angle of inclination equal to (90° - elevation angle). This value changes every hour of the day.

Which method should be used depends on the purposes and conditions in which the panels will be used.

If the panels are to operate efficiently throughout the year, it would be better to use zenith angle-based methods. However, if the panels will be used only in a certain season, latitude-based methods can also be used.

In general, latitude-based methods are widely used because they are simple and practical. However, to fully calculate the efficiency of the panels, it would be more accurate to use zenith angle-based methods.

4.6. Things to Consider in Photovoltaic System Selection and Installation

Work experience in engineering calculations for the installation of solar panels for electricity generation from solar energy is at least as important as the quality of the products used. Incorrect system installation and incorrect installation of panels not only cause efficiency losses, but also lead to various malfunctions and increased maintenance costs. However, the system that produces less than the need cannot achieve the desired efficiency, while overproduction causes additional costs. Therefore, care should be taken when installing solar panels.

4.7. Solar Panel Mounting on the Roof

It is generally installed on the roof in businesses, residences and villas. Systems installed on roofs are less costly because installation labor is less than on land**.** In the installation of solar panels on roofs, additional construction is required for the connection of the panels after the steel substructure. Although the direction and slope of the panels are important on the roofs, the west part to be installed must bear the weight of the panels. At the same time, ventilation should be ensured by leaving a distance between the panel and the roof (Picture 4.6).)

Picture 4.6: Solar panel installation in open area

Some points to consider for solar panel installation in buildings:

• The roof or facade must receive sufficient sunlight
• Panels must be mounted in accordance with the solar radiation angle.
•Panels must be mounted in a way that does not cast shadows, taking into account environmental factors.
• Panels must be of high quality and comply with standards
• When mounting, appropriate mounting equipment should be used, taking into account wind and snow load.

Example-4: 10 kW rooftop solar energy system SPP installation quantity is listed below.
44 pieces of 270W Polycrystalline Silicone
1 string ON-GRID inverter (10kw)
1 piece 400 v wall type LV distribution panel
330 meters 1*6mm2fIex-sol-xl
5 meters 5x4 mm2 NYY
1 bidirectional counter
Roof solar construction
4 pairs of connectors
30 meters1*4mm2 NYA (for grounding)
1 piece of 1.5 meter copper ground stake

4.8. Solar Panel Installation in Outdoor

First of all, the differences between the location, slope, direction and durability of the place where the system installation needs to be done and the need for driving or concreting on the field as infrastructure during installation should be analyzed well. At the same time, hot-dip galvanized aluminum construction should be used for the assembly of the panels. It should be decided whether the panels to be installed in the field will be 2, 3 or 4 panels and how the panels will be installed in the field after calculating the distance between them (Picture 4.7).

Resim 4.7: Açık alanda güneş paneli kurulumu

After deciding on the land and installation type for electricity production from solar energy, a single line electricity plan should be prepared by projecting, the placement of the panels, the number of panels, inverters and kiosks, cables, security system, wire double entry point energy lines, direct current and alternating current lines should be determined and the most In addition to obtaining good efficiency, the energy produced must be transmitted with the least loss.

Some points to consider for outdoor solar panel installation:

Land Status: The first condition is that the land has the status of marginal land (land other than absolute agricultural lands, special product lands and planted agricultural lands).

Irradiance Values: One of the main factors that has a great impact on efficiency is the solar energy potential of the region. High radiation values in the region where the land is located will also increase the amount of energy the power plant will produce. In terms of solar energy potential, it should be suitable for solar power plant installation.

Facade: It is of great importance that the land where the installation will be located faces south. If it faces other directions, the efficiency of the solar power plant decreases and the return on investment period increases. Therefore, lands facing south are the best choice.

Shade: Shading can significantly reduce the efficiency of solar panels. Therefore, it is of great importance that the land on which it will be installed is selected to minimize shading that may occur due to nearby structures, vegetation or other obstacles. Conducting a shading analysis beforehand can help identify potential shading problems and select a site accordingly.

Distance to Energy Transmission Lines and TEİAŞ Substation Capacities: The distance of the land on which the installation will be made to the energy transmission lines of the distribution company is an important criterion for obtaining a solar power plant connection permit. The distance to the lines may prevent you from obtaining installation permission on your land. In addition, increasing the distance between the installation site and the energy transmission lines will increase the investment cost and thus prolong the payback period.

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