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Fotovoltaiklerin ve Güneş Kollektörlerinin Özel Aletler ve Yöntem ile Konumlandırılması ve Gölge Faktörünün Jeodezik Yöntemle Araştırılması

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ÖZET

Fotovoltaik panel / kolektörü kullanabilmek için, yatay düzlemde belirli bir eğim açısına sahip olacak şekilde yaklaşık olarak güney yönünde döndürülmeleri gerekir. Bu konumlandırma, yaz aylarında gün boyunca maksimum elektrik üretimi / sıcak su temini için yeterli olabilir. Güneş ışınları, Kasım, Aralık, Ocak, Şubat ve Mart aylarında yaza göre daha eğik bir açıyla Dünya'ya gelir. Bu durumda, yaz mevsimine göre konumlandırılmış fotovoltaik panel / kollektörden maksimum verimlilik elde etmek zorlaşır. Güneş FV panelleri / kollektörleri, belirtilen aylarda güneşten yararlanmak için nasıl konumlandırılmalıdır? Bu sorunun çözümleri araştırılmıştır. Yapılan araştırmalarda ülkemizde Trakya bölgesi, Doğu Akdeniz Bölgesi ve İç Anadolu Bölgesi'nde güneşten faydalanabilmek için bina cephelerinin güneş Azimut açısının 150^g ile 250^g (veya 135^o ile 225^o) arasında konumlandırılması gerektiği belirlenmiştir. Buna göre, bir binanın çatısına yerleştirilecek fotovoltaik panellerin / kollektörlerin güneş Azimut açılarının belirtilen değerlerine göre konumlandırılması incelenmiştir. Binanın çatısını örtmek için yerleştirilen fotovoltaik panellerde kısmi gölgeleme, önemli üretim kayıplarına neden olmaktadır. Panelin yerleştirileceği binanın yakınındaki uzun bir ağacın gölgesinin paneli etkileyip etkilemediği (gölge analizi) teorik olarak araştırılmaktadır. Buna ek olarak, bir panel, sahada birbirine paralel yerleştirilecek birden fazla panelde diğerini gölgede bırakmamalıdır. Bu durumda, aralarında olması gereken mesafeler önceden belirlenmelidir. Forester pusulası icat edilene kadar, Güney yönü basit bir pusula ile uygulanmıştır. Bu çalışmada, forester pusulası tanıtılmış ve panel konumlandırmada bu pusula ile gerekli yönlerin nasıl uygulanacağı açıklanmıştır. Konuyla ilgili sayısal uygulama yapılmış, elde edilen bulgular belirtilmiş ve önerilerde bulunulmuştur.

Positioning of Photovoltaics and Solar Collectors with Special Instruments and Methods and Investigation of Shadow Factor by Geodesic Method

Research Article

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ABSTRACT

In order to be able to use the PV panel / collector, they must be turned approximately to south direction so that a certain angle of inclination with the horizontal plane. Such positioning may be sufficient for maximum electricity generation / hot water supply throughout the day during summer. The sun's rays come to the earth at a more oblique angle in November, December, January, February and March compared to summer. In this case, it becomes difficult to obtain maximum efficiency from the PV panel / collector positioned according to the summer season. How should solar FV panels/collectors be positioned to take advantage of the sun in the specified months? Solutions to the question have been investigated. In the researches, it was determined that building facades should be positioned between 150ᵍ and 250ᵍ (or 135° to 225°) of the sun azimuth angle in order to benefit from the sun in the Thrace region, eastern Mediterranean region and central Anatolia region in our country. Accordingly, the positioning of the PV panels / collectors to be placed on the roof of a building in accordance with the specified values of the sun azimuth angles was investigated. Partial shadowing on PV panels placed to cover the building roof causes significant production losses. Whether the shadow of a tall tree near the building where the panel will be placed affects the panel (shade analysis) is theoretically investigated. In addition, one panel should not overshadow the other in multiple panels to be placed parallel to each other in the field. In this case, the distances that should be between them must be determined in advance. Until the forester compass was invented, the south direction was appliqued with a simple compass. In this study, the forester compass was introduced and it was explained how to apply the necessary directions with this tool and compass in panel positioning. Numerical application was made on the subject, the findings obtained were stated and recommendations were made.

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Introduction

Traditional energy sources for electricity generation are hydroelectric, fossil fuels, and nuclear energy. Increased worldwide interest in renewable energy sources, driven by increased emissions of greenhouse gases and the rapid depletion of fossil fuels. It has to make it necessary to develop and use alternative energy sources, in addition, the protection of the environment, utilization of the national resources at the highest level to ensure the supply of energy resources of the country. Among these sources, photovoltaics is among the most important renewable energy sources. Photovoltaic systems are systems that need to be used at maximum efficiency, when the costs of photovoltaic systems are taken into account, either directly connected to the network or independently of the network (Urbano et al., 2003; Šúri et al., 2007; Ünlü et al., 2015). Today, it is known that solar radiation energy is used for heating, obtaining hot water, and air conditioning. Work on using solar energy has gained momentum especially after 1970, solar energy systems have advanced technologically, but they have fallen in cost and have accepted themselves as an environmentally clean energy source (URL-1).

The solar collector is a device designed to absorb the sun's rays and to pass it through the thermal energy that flows through it. Today, it is known that solar radiation energy is used for heating, obtaining hot water and air conditioning.

Increased worldwide interest in renewable energy sources, driven by increased emissions of greenhouse gases and the rapid depletion of fossil fuels. Among these sources, photovoltaics are among the most important renewable energy sources and these are systems that should be used with maximum efficiency (Urbano et al., 2003). In order to utilize the PV panels / collectors, it must be placed at an angle of inclination equal to the latitude angle with the horizontal plane and the collector surfaces must be turned approximately south. Such positioning may be sufficient for maximum electricity generation/hot water supply throughout the day in summer. The sun's rays come to the earth at a more oblique angle in November, December, January, February and March compared to summer. In this case, it becomes difficult to obtain maximum efficiency from the PV panel / collector positioned according to the summer season.

Alternative methods have been investigated for the positioning of solar PV panels / collectors in order to benefit from the sun in the specified months. In the researches done in our country, it has been determined that the building facades should be positioned between 150^g and 250^g (or 135° and 225°) of the sun azimuth angle in order to benefit from the sun in the Thrace region, the Eastern Mediterranean region and the Central Anatolia region.

The PV panel is usually positioned on the roof of the building or in open ground. The direction and slope of the building roof affect the efficiency of the PV panel. FV panels are positioned parallel to each other at certain intervals in open fields.

Partial shadowing on PV panels placed to cover the building roof causes significant production losses. Whether the shadow of a height tree near the building where the panel will be placed affects the panel is determined by geodetic measurements in the field. In addition, one panel should not overshadow the other in multiple panels to be placed parallel to each other in the field. In this case, the required distances between them should be determined in advance.

Until the forester compass was invented, the south direction was appliqued with a simple compass. In this study, the forester compass was introduced and it was explained how to apply the necessary directions with this tool and compass in panel positioning.

In this study, the solar angles are explained first. In order to obtain maximum benefit from PV panels / solar collectors throughout the year, it has been explained how to position them between 150^g and 250^g of the solar azimuth angle. It is explained how to make shadow analysis with geodetic methods in order to prevent partial shadow situation. Numerical application was made on the subject, the findings obtained were stated and suggestions were presented.

Material and Method

In the material method, firstly, solar angles, partial shadow situation in a PV panel, Investigation of Obstacles in Placing the Panel/Collector with Geodetic Methods, Tools Used in Application of Solar Panels and Application of South Direction will be explained.

Solar Angles

While positioning the structures to benefit from sunlight, incidence direction angles of sun rays (azimuth angles) being utilized. The azimuth angle of the sun consists of the latitude of the construction site (φ), the declination angle of the sun for a particular day of the year (δ), and the angle of the sunrise and sunset according to local noon. These angles are called azimuth (Abood 2015; Som and Pathak 2015).

Latitude (angle) φ: It is the angle of the line that combines the aboveground N point to the plumb-line, with the equatorial plane. It is marked with a (+) from the Equator to north and with a (-) to south.

Hour Angle (h): It is the angle between the line that combines the longitude of the taken into account point on earth with the centrosphere and the longitude indicated by the sun rays. Hour angle is calculated from "sun noon" when the longitude of the sun and the longitude of the point which is being taken into account are the same. The difference is marked with a (–) for before the local noon, and with a (+) for after the local noon. Every one-hour time difference is considered as an hour angle of 15^o.

Declination Angle (δ): It is the angle of the sun rays to the equatorial plane (Figure 1). This angle results from 23^o 27' degree which is between the rotational axis of the world and the normal of the orbital plane. Absolute value in solstices is maximum (June 21 summer solstice = $+23^O.45$, December 22 winter solstice = $-23^o,45$). Declination angle is obtained from the equation of:

$$\delta = 23^o,45 \sin \left(360\left(\frac{n+284}{365.25}\right)\right) \quad (1)$$

Here, n is the number of days.

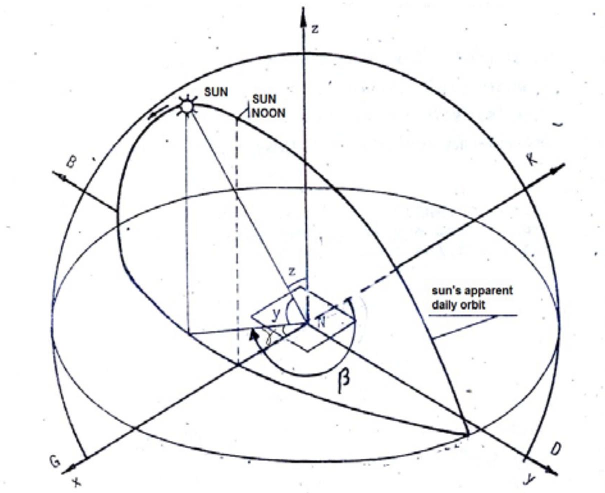

Figure 1. Schematic of the Sun Zenith Angle, Elevation and Azimuth Angle, at the Spherical Triangle from the Point on Earth of N (Abood, 2015).

Zenith angle (z): It is the angle of direct sun rays with the normal of horizontal plane (Figure 1). At sunrise and sunset $z=90^o$. Zenith angle is obtained from the below formula;

$$\cos z = \cos \delta \cos \varphi \cos h + \sin \delta \sin \varphi \quad (2)$$

Solar elevation angle (y): It is the angle of the horizontal rays of the sun. As seen in Figure 1, $z+y=90^o$. The solar elevation angle is obtained from the formula: $y=90 - z$.

Solar azimuth angle (β): This angle represents the deviation of sun rays rotation compared to the clockwise direction of north (Figure 1). β as follows;

Before the local noon (in degrees) $\beta=180^o - \gamma^o$, (or in grade $\beta=200 - \gamma^G$) (3)

After the local noon (in degrees) $\beta=180^o + \gamma^o$, (or in grade $\beta=200+\gamma^G$) (4)

$$\cos\gamma = \frac{\cos\delta \cos\varphi \cosh - \sin\delta \cos\varphi}{\cos y} \quad (5)$$

Determination of Sun Azimuth and Elevation Angles in Shape to Provide Maximum Sunrise

In order to maximize the sunlight in many parts of Turkey, when the solar azimuth angles of sunrise and sunset at maximum sunrise times are examined, it has been found that the most favorable location for buildings is the position of solar azimuth angle between approximately 150^g and 250^g (Erdem and İnce, 2016), (Figure 2).

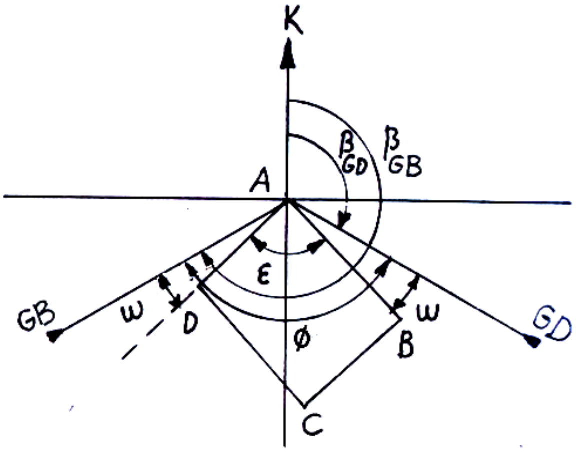

Figure 2. Positioning a rectangular structure of ABCDA between solar azimuth angles where maximum at sunrise (DD) and minimum at sunset (GB) (Erdem and İnce, 2016)

Table 1. Power loss as the amount of shadows falling on the PV panes and the percentage (URL-2).

On the solar panel falling shadow, %	Falling solar panel power lost with shadow, %
13	44
11	47
9	48
6,5	44
3	25

Partial Shading Status in the PV Panels

Photovoltaic systems are systems that need to be used at maximum efficiency, when the costs of photovoltaic systems are taken into account, either directly connected to the network or independently of the network (Ünlü et al., 2015; Karimov et al., 2005; Muntasser et al., 2000; Li et al., 2005). In a detailed study on fragmented ghosting in photovoltaic (PV) panels (Urbano et al., 2003; Ünlü et al., 2015); it has been observed that only one Maximum Power Point (MGN) is present when the radiation on the PV panels is identical, and in the case of fragmentary shadows, there are numerous local (local) MGNs due to the effect of the bypass diodes, by analyzing how the maximum power points change in different shaded states, it has first come to the conclusion that fragmented ghosting situations should be well analyzed to ensure maximum efficiency. One of the biggest mistakes in solar energy systems is the shadows falling on the solar panel. A solar panel is a device that combines multiple cells in series and parallel. The cells inside the solar panel produce electrical energy in connection with each other. No cell is independent of each other. We can think of it as a 4-wheel case of a car, if the car explodes on any wheel, the car can’t go smoothly on the road. These wheels in this example are actually the cells inside our solar panel. According to the investigations made, even if there is very little shadow on the solar panel, the current produced by the solar panel has been found to be reduced by almost half (Ramaprabha and Mathur, 2009; Haberlin 2012; Ko and Chung, 2012) (Figure 3).

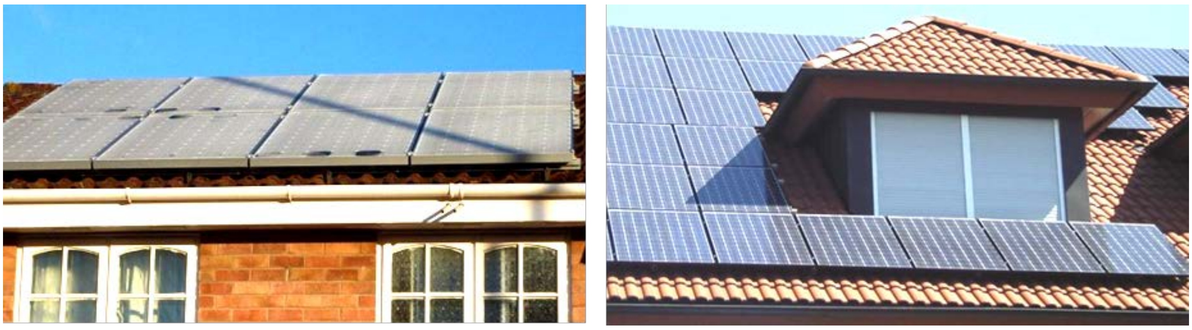

Figure 3. Partial shadow state of the PV panes in the building roof (URL-2)

Shadow quantities falling on a solar panel and power loss rates as a percentage of loss are given in Table 1 (Qiu and Rıffat, 2003; Gunerhan and Hepbasli, 2007; Ramaprabha and Mathur, 2009) When the data in Table 1 is taken into account; how important is the shadow that falls on the solar panels, in six serial and parallel solar panels, it is understood that even if one of them is in the shadows and the shaded panel loses efficiency, the others lose efficiency in the same way (URL-2; Qiu and Rıffat, 2003; Wang and Hsu, 2009).

Solution of the obstacles that can occur when the panel/collector is placed

Suggestions for the obstacles and conventions that may arise when the solar panels are placed on the building roof are given below (Qiu and Rıffat, 2003; MEB);

- For the system to be installed to be efficient and to work smoothly for many years, the direction check must be done before the installation of the solar platform and the system should be installed facing south.
- Attention should be paid to the shadows caused by obstacles and the distance between the solar panels in installations on flat surfaces.
- The high buildings on the arrival side of the sun rays and trees and protruding windows the nearby building where the solar panel will be placed can create a shadow on the panel.
- In Turkey, the sun's rays come with the most oblique (low angle) on December 21 when winter solstice.
- In the case of shadow over the solar panels, the efficiency of the panel drops.
- When the layout of the solar panels is made; the most oblique state of sunlight must be considered.
- Solar panels should also be taken into account when planning the layout of the sun's rays. In Turkey, the sun's rays are the most tilted (low angle) date of December 21.

If there is a shadow on the panel due to an obstruction near the building (the upper branches of a tree near the building), for control, the electronic takeometer is installed a P-point so that it can see the roof of the building to be built with a solar panel and the top of the tree near the building. An electronic tachometer is directed to the point (F) of the building and the junction point (H) to the floor, to the top of the tree (G), and the bottom (J) (Figure 4 and 5).

Z_B ', Z_B, Z_A', Z_A vertical angles are measured along with the S_B, $S_{P,}$ and S_A horizontal distances to the building corner, the solar panel direction, and the tree's body (Figure 4 and 5).

GJ tree height with FH building height is derived from the following relations (Anderson and Mikhail, 1998; Bannister et al., 1982);

$Z_{B'}<100^g$ ve $Z_B<100^g$ ise $FH=S_B*(\tan(100-Z_{B'})-\tan(100-Z_B))$ (6)

$Z_{B'}<100^g$ ve $Z_B>100^g$ ise $FH=S_B*(\tan(100-Z_{B'})+\tan(Z_B-100))$ (7)

$Z_{A'}<100^g$ ve $Z_A<100^g$ ise $GJ=S_B*(\tan(100-Z_{A'})-\tan(100-Z_A))$ (8)

$Z_{A'}<100^g$ ve $Z_A>100^g$ ise $GJ=S_B*(\tan(100-Z_{A'})+\tan(Z_A-100))$ (9)

If ZB '<100g and ZB <100g, FH = SB * (tan (100-ZB') - tan (100-ZB)

If $Z_{B'}<100^g$ and $Z_B>100^g$, $FH=S_B*(\tan(100-Z_{B'})+\tan(Z_B-100))$

If $Z_{A'}<100^g$ and $Z_A<100^g$, $GJ=S_B*(\tan(100-Z_{A'})-\tan(100-Z_A))$

If $Z_{A'}<100^g$ and $Z_A>100^g$, $GJ=S_B*(\tan(100-Z_{A'})+\tan(Z_A-100))$

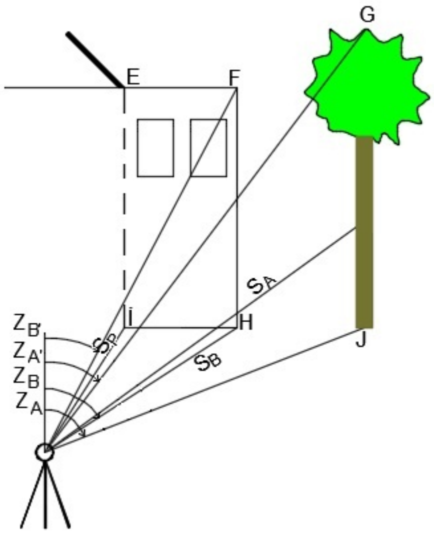

Figure 4. Measurement of vertical angles and horizontal distances.

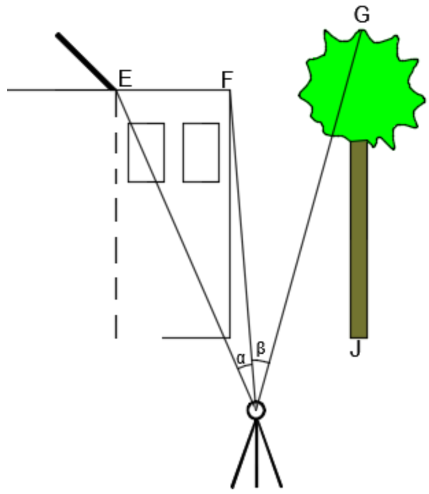

Figure 5. The horizontal distance between G and E.

There is no shadow problem if GJ <FH. But;

If $GJ>FH$, $\Delta HFG=GJ-FH$ (10)

The horizontal distance between G and E (Figure 5) is derived from the following relation (Bannister et al., 1982);

$$EG=\sqrt{(S_P^2+S_A-2*S_P*S_A*\cos(\alpha+\beta))} \qquad (11)$$

Every year on December 21, the solar zenith angle (Z_G) at a time close to the sunset, starting from local lunch time, is calculated in relation to (2). Taking into account the calculated Z_G angle and the ΔH_{EG} obtained from the relation (10), the L shadow size (Figure 6), which will form ΔH_{EG} difference, is obtained from the following relation.

$$L= \Delta H_{FG} *\tan Z_G \qquad (12)$$

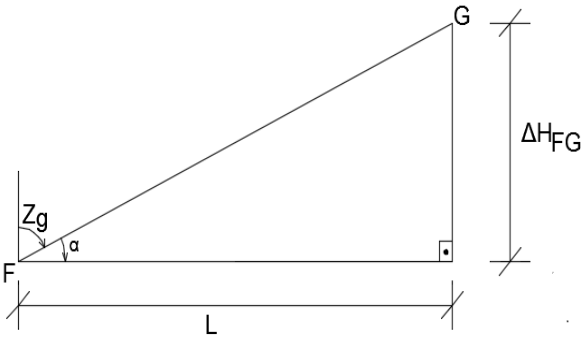

Figure 6. Calculation of L shadow length.

If; If EG> L, the shadow length due to ΔH_{FG} difference does not affect the solar panel. If EG <L, the shadow length due to ΔH_{FG} difference affects the solar panel. In this case, the position of the solar panel is changed to EG> L. In particular, the distance between panels should be considered in installations installed on flat roofs. The solar rays coming into the installed panels must not be cut by the previous panel. In order for panels to not interfere with each other's sunlight, it is necessary to calculate the minimum distance the solar zenith angle (Z_G) at the time of sunset near the sun setting is taken into account on December 21st of the year (Figure 7). In Figure 7;

L_P: The length of the solar panel,

φ: Angle of the solar panel with the horizontal plane (latitude at which it is located),

H_P: Height of the top of the panel from the floor (from the roof of the building)

S_1: The projection of the L_P oblique length on the time axis,

S_2: Shadow length of the panel at the height of Hp from the ground to be formed in the ground according to Z_G zenith angle,

S: The horizontal distance between the Panels.

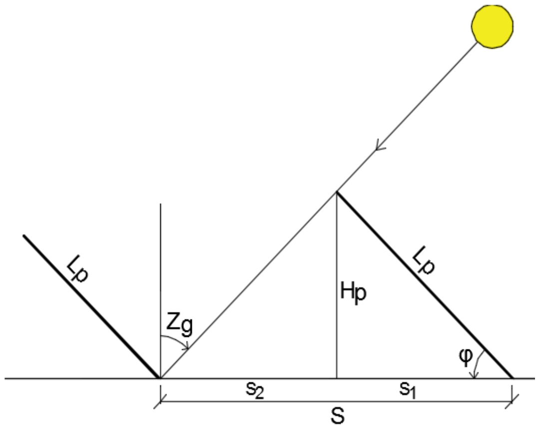

Figure 7. Distance between two PV panels/collectors that are parallel to each other.

According to this; S_1, S_2, S are obtained from the following relations;

$$S_1=H_P/\tan\varphi \quad (13)$$

$$S_2=H_P*\tan Z_G \quad (14)$$

$$S=S_1+S_2 \quad (15)$$

In order for the PV panel/collectors to be installed in parallel to each other on the roof of a building not to cut off the sun's rays, the distance between them must satisfy the following condition.

$$S>(S_1+S_2) \quad (16)$$

Appliances Used in Sun Panels Application and Applied to the South

A compass (Figure 8A) and a forester compass (Figure 8B) are used in the southward direction of the solar panels in the roof of the building. The digital angle meter (Figure 8C) is used to measure the angle of the solar panel with the horizontal plane.

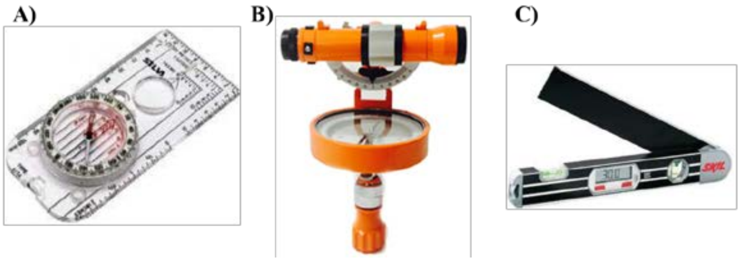

Figure 8. A) Compass, B) Forester compass and C) Digital angle meter

Applied to the South by Compass

When the solar panels are placed facing south, they are injured from the compass. The direction of the pipe connecting the endpoints near the checkers of the panels to be placed on the roof of a building inclined to the south direction is in the east-west direction. Utilizing this feature, a small nail is struck on the eastern side of the roof of the underground building where the solar panel stand will be placed (A), the nail is connected to a thin white rope of 2 m, the person gripping the other end of the rope directs the compass that he puts on the floor to the north to show the red-purple north of the compass. The tensioned rope in this position of the compass is turned in the appropriate direction, passing through the east (E) and west (W) points of the compass. When the specified condition is satisfied, a nail is caught in the trace (B), the other end of your thread is connected to the spiked nail. The right side of the rope in the AB direction is north and the left side is south (Figure 9). Thus, the south-facing direction is applied to the solar panel.

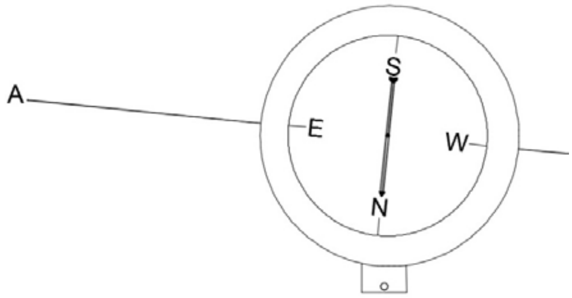

Figure 9. Compass

The Application of the Orientation with the Forester Compass

When the instrument is installed on a specified point on the roof, the feet of the instrument stand is placed so as not to slip, the instrument is fixed to the stand with the aid of a fixing screw (Figure 10). Two cylindrical levels perpendicular to each other in the dial of the tool, after the dial is brought to the setting position by hand, the clamping ring at the top of the fixing screw is fixed in the appropriate direction and the dial is fixed. The dial's general motion screw is loosened and the dial is rotated in the appropriate direction with the north arrow of the compass in the middle and the north (N) direction. When the desired condition is satisfied, the north direction is fixed and the horizontal angle value at the north arrow is read and recorded. By adding 90^o the read angle, the angle of the north-south direction perpendicular to the west-east direction is obtained. The dial's general motion screw is loosened, the northern arrow of the magnet is rotated until the calculated angle is reached, when the desired condition is satisfied, the dial's general motion screw is compressed. Looking at the binoculars, an element on the roof at a distance of about 2.5 m. is inserted in the direction of the jalon and the point on the roof of the jalousie is marked when full direction is provided. Thus, the east-west direction of the panel stand is marked on the roof, the left side of this direction shows the north, and the right side shows the south direction (URL-3).

Figure 10. General view of the forecaster

Application of the angle of the panel with a digital anglemeter

The digital anglemeter, before being placed on a roof or roof of a building with a solar panel, is used to mount the panel pipes on the horizontal plane, at the latitude of that location, while mounting the panel pipes on the upper and lower connection pipes. The digital anglemeter is a movable two-arm instrument connected to a first joint, the other being connected to each other (Figure 8C). On the fixed arm, there are two cylindrical gauges placed perpendicular to each other and an indicator showing the angle of the movable arm with the fixed arm. When the panel tilt angle is applied, the calculated panel tilt angle is moved by the moving arm until it is visible on the screen in the fixed cradle, when the desired condition is satisfied, the fixed arm is tilted to the side, and the tubes of the solar panel are moved to the position parallel to the rocking arm (Duffie et al., 2020).

Positioning the Solar Panel / Collector according to the Solar Azimuth Angles 150^g-250^g Values

In Turkey, for the utmost benefit from the sun of the building to be constructed in the region of Thrace Eastern Mediterranean and Central Anatolia, the minimum and maximum sun time were investigated (Erdenedavaa et al., 2018; İnce and Erdem, 2019). The most suitable location for sunbathing buildings is where the solar azimuth angle is between approximately 150^g to 250^g (or 135^o to 225^o) (Figure 11).

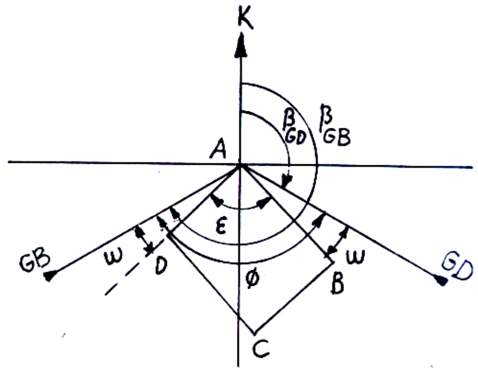

Figure 11. Positioning a rectangular structure of ABCD between solar azimuth angles where maximum at sunrise (DD) and minimum at sunset (GB) (Erdem ve İnce, 2016).

The sun's rays come to the earth at a more oblique angle in November, December, January, February and March. In this case, it becomes difficult to obtain maximum efficiency from the PV panel / collector positioned for the summer season. 150^g to 250^g (or 135^o to 225^o) values of the solar azimuth angles should be taken into account in the positioning of solar PV panels / collectors in order to benefit from the sun in the specified months. In order to apply these angles, first, the bearing angle is calculated by considering the coordinates of the corner points of the building facade where the PV panel will be placed. On the roof of the building, a parallel direction to the facade of the building is created by taking equal distances from two separate points on the facade of the building, in the middle of the roof. The tachometer is set up at the starting point of this direction and the scope of the instrument is directed to the other end of the line, from this direction, the angle equal to the difference of 150^g or 250^g from the parallel direction is applied in the appropriate direction (İnce ve Erdem, 2019). The end points of the PV panel in contact with the ground are placed in the direction of the application of the specified angle. Thus, the panel direction is positioned above the specified direction of the sun azimuth angle. Solar panels to be used all year round should be positioned according to the directions specified in the following seasons. Accordingly, the panel surface is;

-In the spring, it should be positioned so that it faces south-east in a direction perpendicular to the south-west north-east direction.

- It should be positioned to face south in summer.
- In the autumn, it should be positioned so that it faces southwest in a direction perpendicular to the north-west south-east direction.

Solar panels are generally placed on the building roof in a fixed position. A separate mechanical layout should be created for the change of position of the panel that will occur according to the seasons (Koçer et al., 2016).

Applications

Sun azimuth and zenith angles will be determined to provide maximum insolation in Thrace region where the application is made. The most suitable location for buildings in sunbathing in the Thrace region is where the sun azimuth angle is approximately 150^g to 250^g (or 135^o to 225^o) (Figure 12).

Figure 12. Solar panel to be placed on the building roof

Solar zenith angle required for minimum spacing is taken into account when placing multiple panels in parallel to each other and at certain intervals. This angle is the sun zenith angle at h = 3 hours from local noon on December 21 of the year for the Thrace region. In order to calculate this angle, first the solar declination angle, hour angle and geographic latitude angle are required. In the calculation of the declination angle δ the day of the year for December 22 was taken as n = 355, and from equation (1), the declination angle = -23,449878 was obtained. And on this date, the hour angles for sunrise and sunset for Edirne in the Thrace region from the local noon time were calculated and shown in Table 2.

Table 2. Values of solar zenith lines between h = 0 and h = 4 on December 21 in the Thrace region.

Date of year	Day of Year (n)	δ^0	Sun Clock Angles (h)^o						
			Sunrise	Sunset	0	1	2	3	4
21 December	355	23,4498	4:42	4:35	64.44459	65.98062	70.3845	77.15718	85.72365

The calculation of the angle clock, has benefited from leafy calendar published by the Turkey Religious Foundation. This calendar includes local noon, sunrise and sunset times for each day of the year in designated cities. In solar PV / panels, the zenith angle stated above is calculated as $Z_G = 77^o,15818$; taking into account the equation (2) h = 3, $\varphi = 41^o,6667$ and the calculated equation value. For Edirne in Trakya region, the angle of inclination of a solar panel to be used in summer and winter with a horizontal plane to be made on a roof of a building is $\varphi = 41^o,40$. The solar panels to be used in the Thrace region are manufactured in a way that the pipes in the panel provide the latitude angle of the region with the horizontal plane. In placing the panel mounted in this way on the building roof; First, the east-west direction was applied with the compass as indicated in section 2.1. The foot points of the panel (points that touch the building roof) shown in Figure 12, with the surface of the panel formed by pipes facing south, were placed on the panel roof, staying on the east-west line. The pipe length in inclined position in the panel placed is = 2045 mm. The projection length of the inclined panel on the horizontal plane is S_1= 2,045 * cosφ = 1,528 m. The height of the upper part of the panel from the building roof is H_P = 2,045 * sinφ = 1,360 m. The shadow length of the upper part of the panel at H_P height according to the zenith angle (Z_G) calculated for December 21 is $S_2 = H_P$ * tanZ_G = 5,966 m. The distance between parallel panels to be placed on the roof is according to Figure 7; S = $S_1 + S_2$ = 7,326 m.

It has been investigated whether a tree located near the building where the solar panel is placed affects the solar panel. In accordance with Figure 4, a P point was determined to see the E point, the F corner of the roof and the top G point of the tree. An electronic tacheometer was installed at the P point and the geodetic measurements made are given in Table 3. Considering the data, it has been investigated whether there is ghosting on the solar panel.

Table 3. Geodetic measurements carried out to investigate the shading of the panel from the station point P

Station Point	Connection Point	Horizontal Angle	Horizontal Distance	Vertical Angle	Height of Reflector
P	E	0,0000	-	-	-
a=1,55m	F	5,2556	-	85,7020	-
	G	10,1284	-	83,5030	-
	İ	0,0000	67,836	101,6480	1,55
	H	5,2556	69,836	101,6480	1,55
	J	13,4284	75,345	101,5040	1,55

Solution:

FH=69,836*(tan(100-85,7020)+tan(101,6480-100))=17,762 m

GJ=75,345*(tan(100-83,5030)+tan(101,5040-100))=21,754 m

$\Delta H_{FG} = \Delta H_{EG}$=GJ-FH=3,992 m

$Z_G = 77^o,15818 = 85^g,7313$

L= ΔH_{FG} *tanZ_G=*tan85,7313=17,512 m

EG=$\sqrt{(S_P^2+S_A^2-2*S_P*S_A*\cos(\alpha+\beta))}$ =$\sqrt{(75,345^2+69,836^2-2*75,345*69,836*\cos 13,4284)}$=16,236

Since L> EG, there is a shadow effect. The panel must be moved so that EG> L.

Results

The panel pipe length in the inclined position, for example 2045 mm, to be placed on a building roof in the Thrace region, at an angle of inclination of $\varphi=41^o,666$;

- the projection length in the horizontal plane is S1=2,045*cosφ=1,528 m.
- the height of the upper part of the sampled panel from the building roof is HP =2,045*sinφ=1,360 m The

distance between these parallel panels to be placed on a building roof, according to Figure 6; It should not be less than S=S1+S2=7,326 m. In the placement of multiple panels in parallel position and at certain intervals in the Thrace region; for the solar zenith angle on December 21, h=3 should be taken as the hour angle. When h> 3, the distance between the panels to be created increases. Due to global climate change, the average temperatures in the Northern hemisphere have tended to increase by about 0,07°C in annual temperatures and 0,074°C in winter temperatures every 10 years (Koçer et al., 2016; Lobaccaro et al., 2019).

Discussion

In the placement of multiple panels in parallel position and at certain intervals in the Thrace region; for the solar zenith angle on December 21, h=3 should be taken as the hour angle. When h> 3, it is not possible to benefit from the sun that comes very obliquely near the evening hours in winter. For this reason, h=3 as the hour angle for the sun zenith angle in the Thrace Region on December 21 is the most suitable time. When h>3, the distance between the panels parallel to each other increases. This will cause a decrease in the number of panels to be placed on a building roof and a decrease in the efficiency to be provided by solar energy. The effects of global climate change on renewable energy sources such as wind and sun in our country may differ according to regions, wind speed and sunshine duration and intensity may vary (Türkeş at al., 2000). This may require repositioning of the solar panels to be placed on the roof of the building in our country. In order to benefit from the sun in the above-mentioned seasons, in addition to positioning the solar panel between the maximum and minimum values of the tilt angle, the maximum sunlight effect can be increased by changing the angle of the panels in winter and summer with the support of a mobile system and an autonomous software.

Conclusions

- In the Thrace region, the sun azimuth angles specified in the positioning of the buildings to benefit from sunlight during the day should also be taken into account in the positioning of the solar panels to be placed on the roofs of the buildings.
- The sun's rays come to the earth at a more oblique angle in November, December, January, February and March. In this case, it becomes difficult to obtain maximum efficiency from the PV panel / collector positioned for the summer season. 135º to 225º values of the solar azimuth angles should be taken into account in the positioning of solar PV panels / collectors in order to benefit from the sun in the specified months.
- Solar panels to be used all year round should be positioned according to the directions specified in the following seasons.
- Accordingly, the panel surface is
- In the spring, it should be positioned so that it faces south-east in a direction perpendicular to the south-west north-east direction. It should be positioned to face south in summer.
- In the autumn, it should be positioned so that it faces southwest in a direction perpendicular to the north-west south-east direction.

- Solar panels are generally placed on the building roof in a fixed position. A separate mechanical layout should be created for the change of position of the panel that will occur according to the seasons.
- Partial shadowing on PV panels placed on the building roof causes significant production losses. Whether the shadow of a tall tree located near the building where the panel will be placed affects the panel should be determined by geodetic measurements to be made in the field by a technical cartographer.
- To direct the solar panel to the south direction on the building roof, the east-west direction is determined with a compass with an accuracy of ± 1^o. However, on the roof of the building, the south direction is applied more precisely (± 0^o,01) with a forester's compass by a mapping technician or engineer.
- In order to benefit from the sun in the above-mentioned seasons, in addition to positioning the solar panel between the maximum and minimum values of the tilt angle, the maximum sunlight effect can be increased by changing the angle of the panels in winter and summer with the support of a mobile system and an autonomous software.

Statement of Conflict of Interest

Authors have declared no conflict of interest.

Author's Contributions

The contribution of the authors is equal.

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