www.dergipark.gov.tr
ISSN:2148-3736
El-Cezerî Fen ve Mühendislik Dergisi
Cilt: 9, No: 3, 2022 (1113-1121)
El-Cezerî Journal of Science and Engineering
Vol: 9, No: 3, 2022 (1113-1121)
DOI : 10.31202/ecjse.1121921

ECJSE

Research Paper / Makale

Solar Radiation Performance Adjusting to PV System

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Received/Geliş: 30.05.2022 **Accepted/Kabul:** 27.08.2022

Abstract: The first section of this paper presents the conditions of solar radiation orientation in Kosovo. The sheer existence of the sunlight is indeed an inexhaustible source of renewable energy having ample potential to meet all humankind’s needs for it when innovative technology is used in compliance with modern standards appropriate to economic and social environment and to the nature itself, too. The research conducted for the purpose of the present paper reveals that the greatest amount of radiant energy is focused on the absorber of the collector sensor which transmits the entire moving space at right angles to the sunlight. It is important to note that the collector angle in relation to the horizontal plane cannot be less than 20°, because there is a possibility that the collector, due to the small angle, is covered in dirt and aerosol pollution. These data ensure that best performance in high generation efficiency is reached by improving harnessing patterns in solar cell response. The objective of the Kosovo Plan in 10 years’ period has stimulated the support policy for renewable energy sources, set to be at least 10% at the national level. This paper examines radiation efficiency assessments under sensor monitoring over the absorption space where all time, high absorption power PV system panels are located. Experimental study shows that Kosovo has radiation potential due to its Geographical position equal to 1400kWh, with the optimal sensor orientation angle of 25° in the Gjakova Region. The solar radiation efficiency for one-year period has resulted in increased performance under sensor monitoring during the months of March - September, from 0.89 kWh/m^2/y to 0.92 kWh/m^2/y, when the equinox provides the longest sunlight intervals.

Keywords: Solar radiation, control system, sensor orientation, energy density, angle of solar panels.

PV Sistemine Göre Ayarlanan Güneş Radyasyonu Performansı

Öz: Bu makalenin ilk bölümü, Kosova'daki güneş radyasyonu yöneliminin koşullarını sunar. Güneş ışığının varlığı, ekonomik ve sosyal çevreye ve doğaya da uygun, modern standartlara uygun yenilikçi teknolojiler kullanıldığında, insanlığın tüm ihtiyaçlarını karşılama potansiyeline sahip tükenmez bir yenilenebilir enerji kaynağıdır. Bu makalenin amacı doğrultusunda yapılan araştırma, en büyük miktarda ışıma enerjisinin, tüm hareketli alanı güneş ışığına dik açılarda ileten kollektör sensörünün soğurucusuna odaklandığını ortaya koymaktadır. Kolektör açısının yatay düzleme göre 20°'den az olamayacağına dikkat etmek önemlidir, çünkü kollektörün küçük açı nedeniyle kir ve aerosol kirliliği ile kaplanma olasılığı vardır. Bu veriler, güneş pili tepkisindeki koşum modellerini geliştirerek yüksek üretim verimliliğinde en iyi performansın elde edilmesini sağlar. Kosova Planının 10 yıllık dönemdeki hedefi, ulusal düzeyde en az %10 olarak belirlenen yenilenebilir enerji kaynaklarına yönelik destek politikasını teşvik etmiştir. Bu makale, her zaman yüksek absorpsiyon gücüne sahip PV sistem panellerinin bulunduğu absorpsiyon alanı üzerinde sensör izlemesi altında radyasyon verimliliği değerlendirmelerini incelemektedir. Deneysel çalışma, Kosova'nın Gjakova Bölgesi'nde 25° optimal sensör oryantasyon açısı ile 1400kWh'ye eşit Coğrafi konumu nedeniyle radyasyon potansiyeline sahip olduğunu göstermektedir. Bir yıllık süre için güneş radyasyonu verimliliği, ekinoksun (gündönümü) en uzun güneş ışığı aralıklarını sağladığı Mart - Eylül aylarında 0,89 kWh/m2/y'den 0,92 kWh/m2/y'ye kadar sensör izleme altında performansın artmasıyla sonuçlandı.

Anahtar Kelimeler: Güneş radyasyonu, kontrol sistemi, sensör yönelimi, enerji yoğunluğu, güneş paneli açısı.

How to cite this article
Sofiu V., Sofiu M., Gashi S., “Solar radiation performance adjusting to PV system”, El-Cezerî Journal of Science and Engineering, 2022, 9 (3); 1113-1121.

Bu makaleye atıf yapmak için
Sofiu V., Sofiu M., Gashi S., “PV sistemine göre ayarlanan güneş radyasyonu performansı”, El-Cezerî Fen ve Mühendislik Dergisi, 2022, 9 (3); 1113-1121.
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1. Introduction

Demand for electricity and sustainable development is a priority of Kosovo's energy strategy [1]. Gjakova region having its geographical position on the coordinates 42° 23′N 20 °26′E is the most suitable place in Kosovo for harnessing of the natural resources of solar energy. Analyses and outcome of numerous studies have made possible the construction of the largest plant of the PV system in our country and southeaster Europe. Investments made during 2018 with an installation power of 6 MW with the classical installation system of solar panels, with the possibility of expanding generating capacities to 20 MW by 2025 [2]. Production input of solar energy provides increased efficiency of electricity generation by rotating sensor system in support of absorption stability providing beneficial performance of investments in PV projects [3]. The incidence angles with the adaptability of the spatial positioning on the earth's surface create the quantities of energy transferred from sunlight to electricity. The surveillance and communication operations are realized through the Low Power Wide Area Network (LPWAN) wireless computer operation system, which enhances the qualitative performance of the generating efficiency [4]. The actual paper has investigated external environmental factors which affect the performance of PV panels. Innovative technology provides the possibility of self-elimination of these absorption barriers to generate and provide stable quantities into the system [5]. The light absorbing material is a semiconductor material with a radiant power of 0.92 kWh/m^2, the core component of the solar cell that is used to absorb sunlight and under actual conditions of generating potential of the existing plant is 2500 kWh/ m^2 [6].

The purpose of our paper is to demonstrate that sensor monitors create suitable conditions for increasing the absorption efficiency which is then adapted to the seasonal solstices [7].

The northern hemisphere expression includes the angle of solar radiation directly on the surface of the PV system. In the Formula (1) are presented the parameters: Normal radiation (DNI) length global horizontal length (GHI) and horizontal diffuse radiation (DHI) are featured simply, whose position required be optimal with the angle of alignment (given Ref. Vasihtha S., 2013).

$$GHI = DHI + DNIx\ cos\theta \tag{1}$$

Solar energy is the biggest source renewable energy in our country that suits the climatic conditions and brings sustainable economic development. The investment incentives according to feed in tariffs that presents perspective to CO_2 decommissioning according to the strategic plan of European energy [9].

2. Experimental Methods and Materials

Solar radiation absorption measurements were conducted in the area of Gjakova Region which is classified as a suitable area for the installation of solar panels, where temperatures in this area are quite high - according to the seasonal equinox ranging from 25 °C to 35 °C. The sensor used is of a Spectral response: 400 - 1100 nm, Illumination range: 10 - 1300W/m² and dimension 160x54 mm [10]. The solar energy in Kosovo is the only natural resource that can be used to cover all consumption demand for all consumers in the country [11]. PV system in Gjakova is associated by increasing necessity to enhance sunlight absorption efficiency and increase generating performance for new plants implemented equipped with a monitoring system of radiation space tracking by an electronic instrument and orienting the rotational motion on its own axis [12]. The following methods have been applied in this paper:

- Measurement methods with pyrometer instrument with sensory tracking of solar radiation within a one-year period January - December 2021.
- Feasibility plan with simulation for ECO-Park in R. Kosovo using MATLAB platform.

The overall performance global horizontal irradiance GHI measurement is in line with satisfactory deviation ± 25 Wm−2 (±10 %). Diffuse Horizontal Irradiance DHI shows deviations ± 20 Wm-2 (± 13%). For direct normal radiation (DNI), the extended error range for RSIs is ranging for e±40 Wm−2 (±5–6 %). GHI and DHI errors showed similar amplitude and dependence on solar altitude, while DNI errors were significantly slighter under relative terms than GHI or DHI errors [13]. Experimental measurements of solar irradiance were made using the Pyrometer instrument within a one-year period, in the area of Eco Park in Gjakova [14]. Analytical modulations of global horizontal irradiance (GTI) and horizontal distribution, correspondingly maximizing the inclination angle and increasing the absorption efficiency are conducted according to the equations It, Id, Ig [15]. Solar cells are semiconductor materials that convert sunlight directly into electricity [16]. A very cautious approach and attention must be showed when installing solar panels or when setting the inclination degree with orientation to a suitable angle in order to maximize the solar energy efficiency of the incident [17]. In such situations it is necessary to calculate the Global Tilted Irradiance (GTI or IT) and the average values of global tilt, global irradiance, horizontal irradiance and horizontal distribution. Irradiances are denoted by It, Id, Ig and are related by the following equation. In the formula (2) shows the absorption parameters of the sun's rays and the degree of inclination of the solar panels [18].

$$\frac{I_t}{I_g} = r_b \left[1 - \frac{I_d}{I_g}\right] + r_d \left[\left[\frac{I_r}{I_g}\right]\right] + r_r \qquad (2)$$

where: I_t - Global Inclined Radiation, I_d- Horizontal diffuse radiation and I_r - Perpendicular radiation.

It is clear that due to the large reduction in DHI efficiency, the GTI value is significantly reduced when compared to the GHI shown in Figure 1.

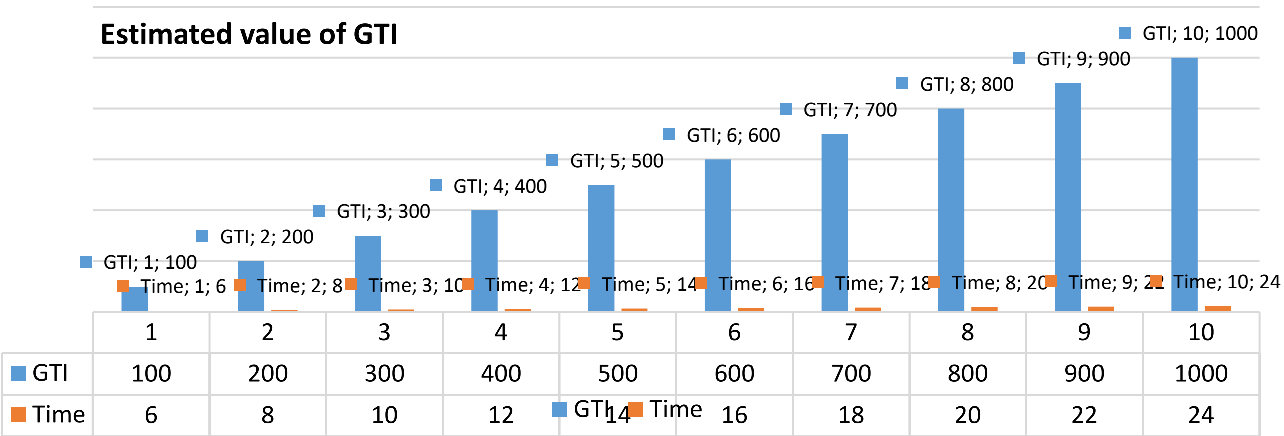

Figure 1. Evaluating of solar energy measured of global irradiance on time

The degree of inclination of the solar panels is the basic component of sunlight absorption which must be taken into account [19-20].

Looking at the monthly and annual data graphics presented on the Table 1 average angle for the whole year the maximum of solar energy in the solar collector is 25.5°. Therefore, the decrease in power due to aerosol particles is expected to be of the same extent [21-22]. Special layers called Anti-reflection coatings (commonly silicon nitride (SiN), which makes solar cells appear bluish) [23]. The load distribution (p-n junction) has an integrated voltage that is an energy for electrons transferred by sunlight in order to be transferred to conductors [24]. The average daily solar radiation is 253.1 kWh/m2/d, while the average annual radiation is 1390.3 kW m2 [25]. There are several variations of the contact structure used in photovoltaic panels [26].

Table 1. Measurements of solar radiation on optimum angle within the period of one year

Month	Angle(⁰)	Solar energy/ month kWh/m²	Solar energy/year kWh/m²
January	20.5	166.8	1082.7
February	22.4	189.1	1109.2
March	24.9	222.7	1286.9
April	25.2	257.5	1396.5
May	25.9	263.3	1492.5
June	26.9	280.3	1609.2
July	26.5	327.4	1619.5
August	27.3	355.2	1696.6
September	26.1	333.3	1616.6
October	25.3	255.6	1391.8
November	24.8	220.5	1299.4
December	23.4	165.3	1082.4
Year	**25.5**	**253.1**	**1390.3**

Table 2. The optimal tilt angle of solar radiation with electromotor rotation MATLAB simulation kWh/m²/y

Measurements of solar radiation kWh / m² according to solstices from 10° to 90°

(°)Angle	**10°**	**15°**	**20°**	**25°**	**30°**	**35°**	**40°**	**45°**	**50°**	**55°**	**60°**	**65°**	**70°**	**75°**	**80°**	**85°**	**90°**
kWh/m²	**0.75**	**0.82**	**0.89**	**0.92**	**0.98**	**0.98**	**0.95**	**0.92**	**0.89**	**0.85**	**0.83**	**0.81**	**0.8**	**0.78**	**0.76**	**0.75**	**0**

The Direct Normal Radiation for IQBAL model W/m²/y											
136.8	159.2	182.7	207.5	233.3	260	287.4	315.3	343.2	366.5	399.5	427.4
The beam Radiation for IQBAL W/m²											
50.4	63.1	77.5	93.79	111.7	131.2	152.4	174.4	198.8	223.5	248.6	274.1
The Diffuse Radiation for IQBAL W/m²/y											
55.12	62.17	69.04	75.61	81.8	87.58	92.85	97.62	101.5	105.8	108.9	111.78
IBAL Hourly total kWh/m²/y											
108.9	125.2	146.5	169.8	193.5	218.6	245.9	272.7	300.5	328.5	357.4	385.7
IQBAL Hourly total radiation kWh/m²											
23.55											
The Global Radiation for IQBAL model W/m²/y											
102.5	125.2	146.3	169.2	193.5	218.2	245.6	272.5	300.2	328.4	357.5	385.7

Most silicon solar cells have a contact structure that can be considered the standard applied for the same operating system conditions [27]. A part of the PV plant design includes the analysis on energy losses calculation [28]. The Table 2 in our paper presents the simulation of data with the MATLAB platform by comparing the direct electronic measurements made by Solar meter instrument (pyrometer) connected to a computer, which monitors and manages the real time data generated in a period of one year [29]. The measurements made (as per the feasibility plan) are detailed in relation to the supporting data of the geographical position of the location and orientation of the tilt is 25° and the azimuth angle of 4° [30].

From the table 3, are presented the functional components aiming to increase the generation efficiency with the rotary system SMART in its own axis. Figure 2 shows the data simulation with the MATLAB platform of Global Radiation Distribution tilted by the inclination scale and the efficiency of the solar absorption performance with sensor tracking [32].

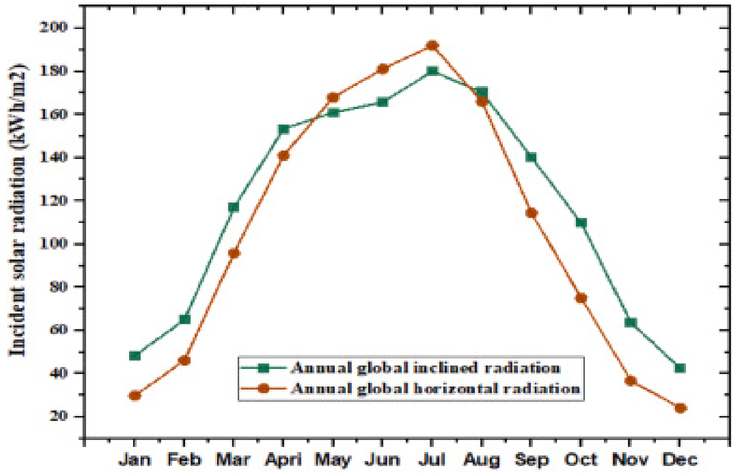

Figure 2. Simulative representation of global radiation as variable components

Table 3. Grid-Connected System: Project simulation parameters

Grid-Connected System: Simulation parameters			
Geographical Site	**City**	**Country**	
	Gjakova	Kosovo	
Situation:	Latitude 42.39° N	Longitude 20.43° E	
Time defined:	Time zone UT+1		
Altitude	364 m		
Albedo	0.2		
Collector Plane Orientation:		Tilt 25°	Azimuth 4°
PV Arrays Characteristics		Model CS6K-275P	
Number of PV modules:	23 (in series)	1888 strings (in parallel)	
Total number of PV modules:		Nb. Modules 20424, 275Wp	
Array global power:	Nominal; 5617 kWp	At operating cond; 5044 kWp (50°C)	
Array operating characteristic (50°C)		Umpp 637 V	I mpp; 7923 A
Total	Arrays global power	Nominal (STC) 6000 kWp	
	21792 modules	Cell area : 31825 m^2	
PV Array Loss Factors			
Thermal Loss factor:	Uc (const) 29.0 W/m^2K	Uv (wind) 0.0 $W/m^2K/m/s$	
Wiring Ohmic Loss:	1.4 m Ohm	Loss	
	Fraction 1.5% at STC		
	Fraction 1.5% at STC LID - Light Induced Degradation		

The solar radiation angle varies from 360° in 24 hours, so in order to be accurate, the estimation of the *i %HS* solar angle is calculated based on the following [33]:

$$HS = HSR - 360°/24h \cdot DR \cdot t \tag{3}$$

where HS- Hour angle of Sun, DR- During the time, and t- Time.

The performance of solar collectors within the diffusion field has also eliminated shading simulations on its axis based on calculations made by direct sensory measurements of solar radiation with the Pyrometer instrument [34].

During our research work, we have observed that the optimal radiation angle of the solar panels located in the ECO-park ranges from 10° - 90°. In table 3 shows the measurements of the radiant follower where the reaches an efficiency of 0.998% or an increase of 8%. The angle of inclination of the solar panels in the park of Gjakova is 25°.The overall performance for measuring global horizontal irradiance GHI is in line with satisfactory deviation of ±25 Wm−2 (±10 %). Diffuse Horizontal Irradiance DHI exhibits deviations ± 20 Wm-2 (± 13%). For direct normal irradiance (DNI), the extended error range for RSIs is in the extend of e±40 Wm−2 (±5–6 %). GHI and DHI errors showed similar amplitude and dependence on solar altitude, while DNI errors were significantly smaller in relative terms than GHI or DHI errors [35].

3. Results and Discussion

This paper presents and discusses performance indicators along with losses of solar radiation systems GTI and GHI in line with the climatic conditions that prevail in our country. The measured solar radiation conditions of the installation of static solar panels are optimized with electronic measurements. The measurements were made with the pyrometer instrument during the period of one year and showed that the slope angle is 25°. The average annual solar radiation is equal to 253.1 kWh/m^2. Annual solar radiation is 1390.5 kW according to Table 1; which analytically confirms the feasibility plan according to table 2. Comparing the data to the solar Global Horizontal Irradiance and Global Tilted Irradiance, the simulated electronic measurements have recorded a value of 1418.6 kWh/m^2, see Ref [35].

These measured values of radiation are slightly higher than the obtained values of the area where we have conducted the research. The tilted solar radiation varies from 166.8 kWh /m^2 in January to 355.2 kWh m^2 in July. Compared to [35], the measurements recorded for the purpose of our paper, they have resulted higher in the first part of the spring solstice, while in the summer solstice we have approximate values. Global horizontal irradiance in the country ranges from 50.4 kWh/m^2 to 274.1kWh/m^2 compared to [34] measured recorded values that range from 24.4 kWh/m^2 to 192 kWh/m^2. For the purpose of analyzing the performance of radiation efficiency increase, we have added the sensor monitoring with electric motor. In this case have been analyzed parameters of the quantities measured at the same time and in the same system of characteristics of the solar panels.
On this occasion it has been found that the global horizontal GHI irradiation is suitable in accordance with the deviations of ± 25 Wm - 2 (± 10 %), while horizontal diffusion ± 20 Wm-2 (± 10%). Integrated errors among systems showed a differentiating amplitude between GHI and DHI error measurement systems at an efficiency of 8%.

4. Conclusions

The performance of a solar PV system connected to the network in the Gjakova Region for a period of one year is analyzed. Kosovo is a suitable area to generate electricity yet is has not been developed enough compared to other countries of the region and the Europe. The power capacity of the installation is 6 MW, while the target of the strategic plan of Kosovo to 2025 will be 30 MW applying feed in tariff. The strategic investment plan has no legislative restrictions. The experimental results of the PV system are compared with the 3D sensor system and determine the tilt angle for installation of solar panels as provided for in the feasibility plan. Investment orientation on electricity generation should be focused on the maximum sunlight transmission systems. The feasibility plan provides construction of another 20 MW PV system will be implemented in the ECO Park of Gjakova and in the future it should be focused on the sensor radiation monitoring system of the rotary electric motor (dish system) of PV. Deriving from the results obtained, we have concluded that such projects can be a model of investment in other regions providing investment opportunities to public institutions (schools, hospitals, municipal buildings) and private (residential and industrial) because we are a developing country. The system of static parabolic PV plants with suction mirror presents the possibility of increasing the efficiency for future plants. The inclination or tilt angle of the radiation in the static PV system is 25° and it is possible to increase the efficiency with the support of absorption tracking technology.

Horizontal correlation coefficients for the period April-September have been successful in absorbing sunlight, but there is potential for increased efficiency if we adhere to future investment conditions and environmental investments. The subject of our future research on this particular topic remains pollution prevention measures that hinder the efficiency of solar radiation. Dust caused by polluting particles prevents the absorption of rays. To be more efficient, we recommend to use the SMART technologies for their cleaning. During our research, we have noticed that if one pays maximum caution during the feasibility plan then this investment model would motivate public and private investments in other cities in order to meet the demand for alternative electricity supplies in our country.

Acknowledgments

We co-author(s) thank you for your support for our work to be published in the journal. This work was supported by the Scientific Research of lab. University for Business and Technology in Prishtina, Kosova.

Authors' Contributions

All authors have worked together on this paper. Laboratory measurements were performed at the University of Business and Technology, while project measurements were performed at the PV Gjakova plant. All authors read and approved the final manuscript.

Competing Interests

The authors declare that they have no competing interests.

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