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Design and energy performance of PV systems: a case study Kosova

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ABSTRACT

The energy and environmental crisis are increasing every day. Where the focus of energy production is being driven by renewable energy sources. Solar energy represents an inexhaustible source of energy that can be used almost anywhere. This paper presents the analysis of the energy performance of photovoltaic (PV) and photovoltaic thermal (PVT) panels for the climatic conditions of Kosovo. The site analyzed is the building of the University Clinical Center in Prishtina. The analysis included five types of photovoltaic modules from where the highest energy performance is shown by the PVT panels with a theoretical power produced during July 273 W while during December 78 W. Also, with an efficiency of 59.77% during the month of December and an efficiency of 17.08% during the month of July. While among the other types of PV panels, polycrystalline panels have the best performance with a theoretical power of 252 W during July and 72 W during December. But they showed an efficiency of 48.78 during the month of December and an efficiency of 13.94 during the month of July. The analysis made is presented in an analytical and detailed manner for certain climatic conditions of annual measurements.

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1. INTRODUCTION

Energy represents the main component of our daily life. The demand for energy is increasing every day, which is also increasing the price of energy and reducing the conventional energy reserves on which the production of energy is based in Kosovo, which has a favorable position based on the geographical position of the use of renewable energy especially solar energy [1], [2]. Electricity production in Kosovo is based on conventional sources, namely on the production of energy from lignite covering up to 92% of the energy demand [3]. Well, based on the position in which Kosovo is located, it has recorded the highest value of solar radiation of 1600 kWh/m^2 year [4]. This indicator shows the high potential of solar energy that can be used, especially solar energy [5]. When using photovoltaic (PV) systems, different technologies of solar panels are used, starting from the first generation to their third generation [6].

The performance of PV systems is influenced by the place in which they are placed, their orientation and the angle of placement [7], [8]. For this reason, the performance of these systems has been analyzed for years in order to improve their performance [9], [10]. With the introduction of new and ever-growing photovoltaic technologies, the rate of their use has increased [11], where their rapid development has also influenced the reduction of their costs in recent decades [12]. Photovoltaic thermal (PVT) panels represent a combined electrical and thermal energy production technology [13]. These technologies are considered more cost effective than other solar energy technologies since we have two types of energy produced [14]. These technologies are used for electricity and thermal energy for both air heating and water heating [15].

The production of energy from photovoltaic technologies is affected by a number of parameters that affect the reduction of the power generated by the panels from the power provided by the manufacturer for standard production conditions [16]. Where these parameters are: the adequate modeling of the system, the orientation, the placement angle of the panels and the climatic conditions to which the system is subjected [17]. The most common photovoltaic systems consist of: photovoltaic panels, inverters, connections, and energy meters if the system is connected to the grid. The connections of the panels and the structures of their placement, which represent the constructive components of the construction of the system. The use of photovoltaic systems brings various benefits in the generation of energy from renewable sources as well as benefits in the protection of the environment [18]. Photovoltaic systems represent every day more and more developed and growing systems in use in the world. Such systems are constantly improving and reducing costs, making these systems increasingly better to use [19]. Ganiyu *et al.* [20] compared the performance of a PV system with a PVT system for the state of Ghana. The energy performance of the system was analyzed and presented in detail. Vidal *et al.* [21] have presented the performance analysis of PV and PVT systems for hot water needs and for indoor heating. By using the system with PVT panels, a higher performance of the system has been achieved, making it more adequate for use. Zdyb and Gulkowski [22] have analyzed the energy performance of four different types of photovoltaic panels. They have clearly presented the performance differences between them. By presenting the analysis, the performance that can be achieved using one of these types of first and third generation PV panels is shown. Gulkowski *et al.* [23] have analyzed the performance of PVT panels. They have presented in detail the thermal performance parameters of these panels. By showing that PVT systems have the system for the utilization of thermal energy by heating the water and reducing the temperature in the PV panel, a higher performance is achieved.

This paper presents an analysis of the energy performance of five types of photovoltaic, PV and PVT technologies for the climatic conditions of Kosovo. For the presented analysis, measured one-year data were used, on which all the components that can affect the energy performance of these photovoltaic technologies were analyzed. Such analysis represents a clear way of designing photovoltaic systems by analyzing several types of panels in order to achieve better energy performance. Currently, in the studied location, there is a small photovoltaic system with polycrystalline panels, the need to expand this system is presented, for this reason, the need to analyze the performance of different types of photovoltaic panels in order to achieve a better performance is presented. of the system in that location. Such an analysis can also serve as an example for creating similar analyzes for other locations, taking into account that climatic conditions change depending on the location.

2. PROCEDURE SPECIFICALLY DESIGNED

2.1. System description

The analyzed location is the facility at the University Clinical Center in Pristina (latitude 42.38°N, longitude 21.09°E) Kosovo. The climatic conditions of the analyzed country are characterized by continental climatic conditions. The one-year data measured for this location are included in the analysis. A section of mono and polycrystalline panels is installed in the facility facing south at a slope of 45. The view of the location is shown in Figure 1. The analysis will include the analysis of PV and PVT panels for the given location. The existing system on the presented building is a system with polycrystalline panels which have been in place for several years.

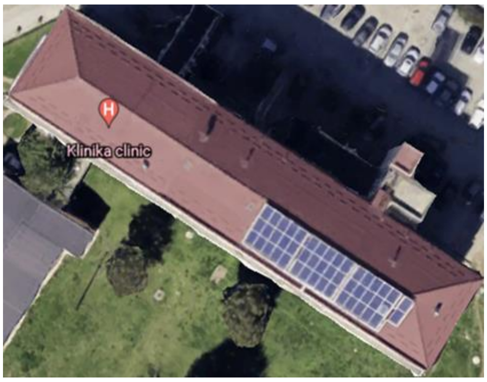

Figure 1. University Clinical Center

From the figure it can be seen that the analyzed location already has two types of photovoltaic panels installed and the placement angle is determined by the slope of the roof of the clinic. In the vicinity, there is no other object with a greater height that could have shaded the summit and affected the performance of the installed panels. Due to the need to expand the system, there is a need to study different types of panels that can be used to achieve a better performance. This paper presents the design as well as the analysis of the performance of four types of PV technologies to determine the use of which technology in the analyzed location achieves the best performance from the system.

2.2. Meteorological data analysis

To analyze the performance of the PV system, meteorological data recorded and monitored for one year were carefully analyzed and studied. Such data include: solar radiation, temperature of ambient, and wind speed. Data collected from April 2022 to March 2023. Figure 2 presents the measured data for the one-year period. Solar radiation is the main parameter which plays an important role towards the proper and reliable operation of the PV module, in its performance as well as in the performance of the whole PV system. Figure 2 shows the solar radiation per square meter at the analyzed location.

Figure 2 shows that solar radiation is reached higher in the summer months than in the winter months due to the continental climate that reigns in this location. The data presented are taken from the measurements performed and the analysis of the data at the analyzed location. The highest solar radiation is reached in July with 1050 W/m^2 while the lowest in December with 300 W/m^2. The average monthly variation of the total solar radiation within the plane reaching the surface of the PV modules (45° tilted) during the monitored period is shown in Figure 3.

The average monthly solar radiation varies from a minimum of 45 kWh/m^2 in December to a maximum of 209 kWh/m^2 in July as can be seen in Figure 3. Solar radiation is highest during the spring, summer and autumn months (March, April, May, June, July, August, September, October, and November) and lowest in the winter months (January, February, and December). Changes in ambient temperature and wind speed are shown in Figure 4.

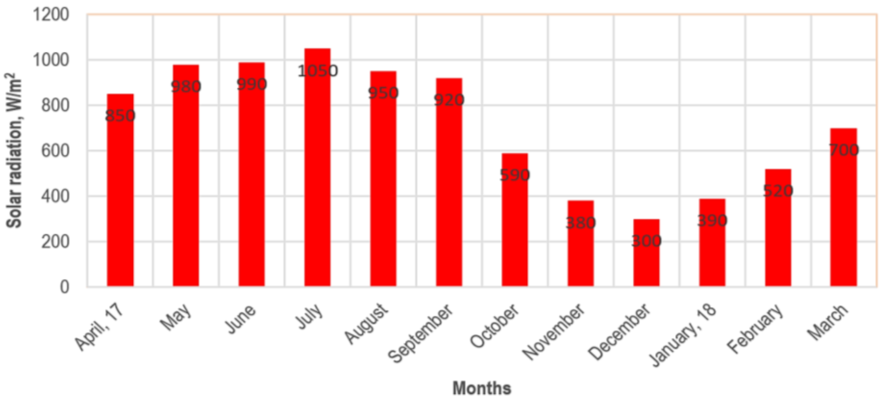

Figure 2. Solar radiation at the analyzed location

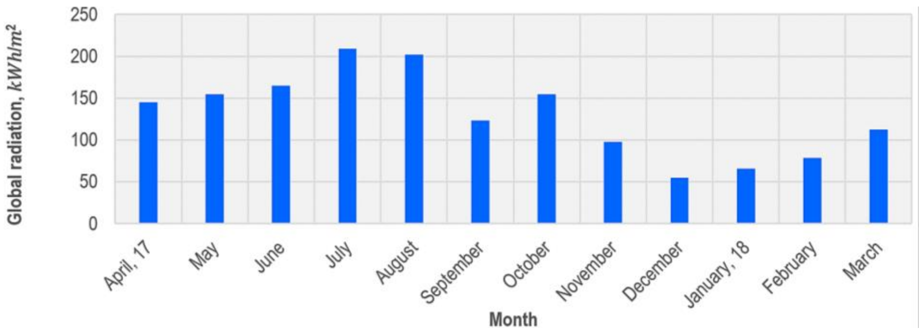

Figure 3. Solar radiation that falls on one square meter at an angle of 45° in relation to the horizontal surface when the surface is oriented to from south

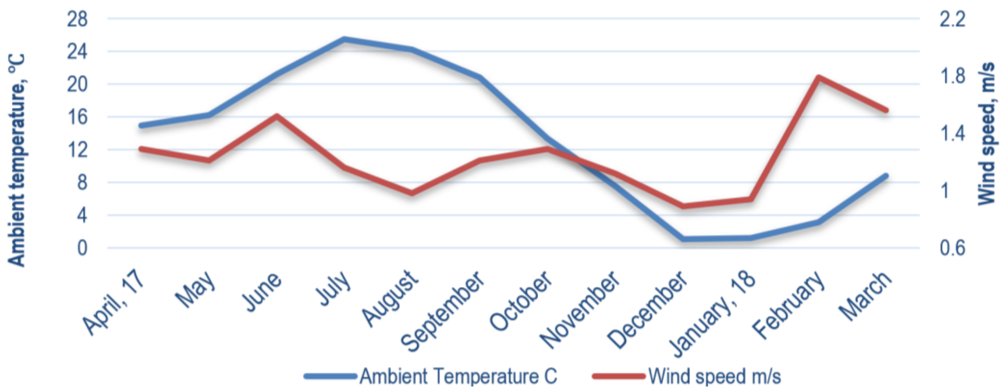

Figure 4. Monthly variation of daily average ambient temperature and wind speed

The daily average temperature of ambient varies from a minimum of 1.16 ℃ in January to a maximum of 25.5 ℃ in July as can be seen from Figure 4. Furthermore, the figure shows the monthly variation of the daily average of wind speed. The latter varies from a minimum of 0.94 m/s in January to a maximum of 1.79 m/s in February. This paper presents the design as well as the analysis of the performance of four types of PV technologies to determine the use of which technology in the analyzed location achieves the best performance from the system.

3. METHOD

The analysis of all parameters related to the photovoltaic system is necessary for a more adequate functioning of the system. Its energy performance is the main indicator that shows what percentage of the system is used efficiently. The presented analysis is an analytical analysis which takes into account the main components that affect the energy performance of photovoltaic systems. In this way, the design and performance of the photovoltaic system for the building presented in this case study was analyzed.

The power given by the manufacturer for certain panels is not always achieved due to changing climatic conditions and solar radiation, for this reason in reality we get the theoretical power produced by the panel which is calculated as (1).

$$P_{theoretical} = P_{peak} \cdot \frac{G}{1000} \tag{1}$$

Where add are: $P_{theoretical}$: theoretical power given from module [W]; P_{peak}: peak power from solar modules [W]; G: direct solar irradiance [W/m^2] [24]. Efficiency represents the degree of conversion of solar energy into electricity by the solar panel and which is calculated by (2) and (3).

$$P_{max} = V_{oc} \cdot I_{sc} \cdot FF \tag{2}$$

$$\eta = \frac{V_{oc} \cdot I_{sc} \cdot FF}{P_{in}} \tag{3}$$

Where: V_{oc}: is the open-circuit voltage [V], I_{sc}: is the short-circuit current [A], FF: is the fill factor, P_{in}: is the input power [W], and η: is the efficiency [25].

4. RESULTS AND DISCUSSION

Any PV panel that is used as well as PVT ones know that the power given by the manufacturer is not always achieved as in reality the climatic conditions in which the photovoltaic panel operates change. Using the analytical analysis as well as annual measurements for the analyzed location, the generation of this energy analysis was done. From the one-year data obtained from the meter using the analytical method, they were analyzed and the results are presented in the figure below in this paper. Figure 5 shows the theoretical performance achieved by these panels. The theoretical power represents the power which is achieved in reality by exposing the used panel to real climatic conditions.

Because the current generated power is analyzed based on the measured data for the meteorological conditions to which the system is subjected in order to present the most realistic values of the analysis. It can be seen from Figure 5 that the highest performance of all panel types is achieved during the summer months while the lowest performance occurs during the cold winter months. Polycrystalline panels produce the highest theoretical power in July 252 W and the lowest in December 72 W. Monocrystalline panels produce the highest theoretical power in July 204.75 W and the lowest in December 58.5 W. α-Si photovoltaic panels of the generation of third and those CIGS reach the highest theoretical power in July with 136.5 and 194.25 W while the lowest in December with 39 and 55.5 W. While the PVT panels reach the highest theoretical power in July 273 W while the lowest theoretical power in December is 78 W. Figure 6 shows the efficiency of the panels depending on the change in solar radiation. Figure 6 shows the efficiency of PV and PVT panels for climate conditions analyzed.

The best indicator of the use of panels is their efficiency in order to know what percentage of solar energy is actually used to produce useful energy. The analysis shows that polycrystalline panels have the highest efficiency during December 48.78% while the lowest during July 13.94%. Monocrystalline panels reach the highest efficiency during December 50.78% while the lowest during July 14.51%. The α-Si panels as seen reach the highest efficiency during December 30.31% while the lowest during July 8.66%. While the second type of third generation PV panels CIGS panels achieve the highest efficiency during December 38.54% while the lowest during July 11.01%. PVT panels have a higher efficiency than PV panels in the analysis made which have the highest efficiency during December 59.77% while the lowest during July 17.08%. PVT technologies produce thermal as well as electrical energy. Knowing that the weakness of PV systems is high temperature, the fluid that flows in PVT systems affects the reduction of panel heat thus producing thermal energy which, as two types of energy together, achieve this efficiency. As can be seen in the presented analysis, PVT panels have a higher efficiency than PV panels for the geographical position and climatic conditions analyzed in this paper. Figure 7 shows the energy that can be generated for each month during the year for each type of panel which is used for this location.

Figure 7 shows that most of the energy is generated by PVT solar panels. These panels reach the maximum energy production during the month of July 326 kWh of energy generated while the minimum during the month of December 85.64 kWh. While the panels that produce the lowest amount of energy are the α-Si panels which reach the maximum output during July 209 kWh while the minimum during December 54.9 kWh.

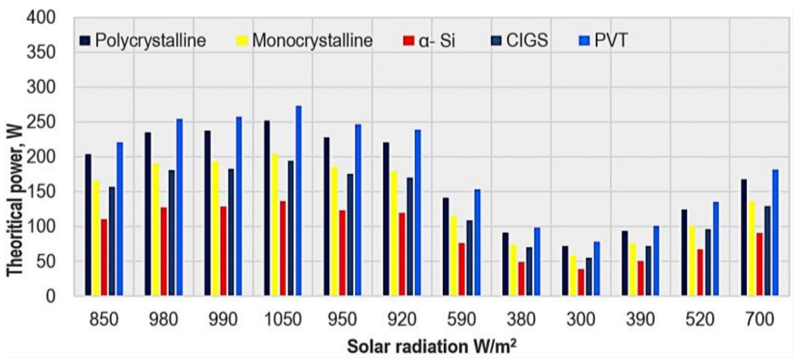

Figure 5. Theoretical power of PV and PVT panels depending of solar radiation

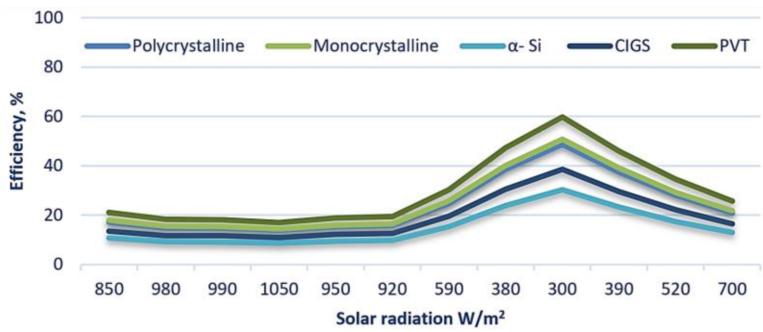

Figure 6. Efficiency of PV and PVT panels

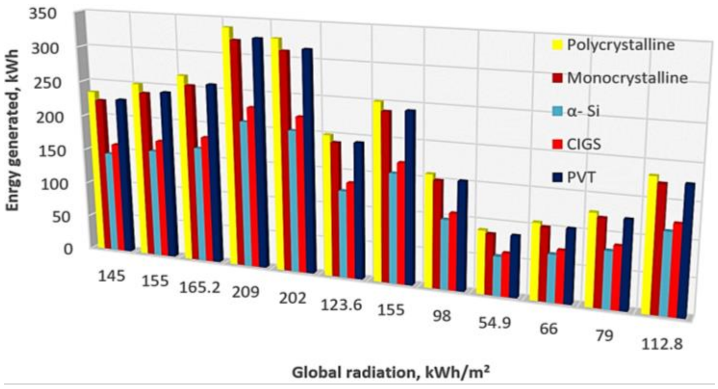

Figure 7. Monthly energy generated from panels

5. CONCLUSION

Solar energy represents an inexhaustible source of energy which can be used for the production of thermal energy as well as electricity. PV technologies are improving every day and are becoming more and more attractive for use in different locations using different systems for the use of energy from the sun. In this paper is presented the energy performance of solar panels PV and those PVT for showed climatic conditions. The results obtained are the monitoring of climatic conditions during a year in northeastern Kosovo. The analysis includes two types of first-generation PV panels, two types of third generation PV panels or thin-film panels and PVT panels. From the analysis made it can be seen that PVT panels manage to have a large theoretical power produced as well as a greater efficiency compared to other PV panels and which occurs because these panels during high temperatures which negatively affect the efficiency of PV panels, PVT panels during this time are cooled by the working medium which takes the thermal energy that can be used for thermal energy. PVT panels reach the highest theoretical power during July 273 W while the lowest during December 78 W. While the highest efficiency reaches during December 59.77% while the lowest during July 17.08%. While from other types of PV panels the highest theoretical power is achieved by polycrystalline panels, the highest output of which is reached in July 252 W while the lowest during December 72 W. Their height efficiency from 48.78% in December at lowest 13.94% in July.

The data obtained from this paper are also useful for analyzes that can be done for other countries and other climatic conditions. From the analysis carried out, it was expected that PVT panels have a greater performance than other photovoltaic technologies, knowing that high temperature is a weakness of photovoltaic technologies, while in PVT panels it is used to heat water for sanitary purposes and thus affects in reducing the temperature of the panel. The earlier analyzes with photovoltaic technologies have shown that they are very favorable for use in Kosova, similarly it can be seen in the study carried out above, seeing that there is a high potential that can be used both for the production of thermal and photovoltaic energy. The work presents an innovation in the field of study that has not been done so far in Kosovo. The use of such systems is seen as increasingly necessary taking into account the reduction of fossil fuel reserves and the large pollution of the environment caused by the use of conventional fuels for energy production and not the use of renewable energy sources. The analysis presented for the design and energy performance of the studied system can also serve for other analysis in the future for similar analyzes in different countries with different climatic conditions.

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