Modelling of a PV system: a case study Kosovo

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ABSTRACT

The modeling of a photovoltaic (PV) system used for the needs of the industrial sector is presented in this paper. Its analysis was done analytically using real one-year measurements during the system monitoring period and software-wise using premium PV*SOL software. System generated energy, maximum power point (MPP) voltage, final yield and average generated power are included in the analysis. The highest summer energy produced for real conditions is in July with 2811.86 kWh, the highest MPP voltage also presented in July with a value of 400 V. The final yield with a value of 103.07 kWh/kWp and the highest average power 16.6 kW as well. during the month of July. Where it to let just It can be seen that due to the Mediterranean atmospheric conditions in the place of application of the PV system, during the summer months the parameters are higher than during the winter months.

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1. INTRODUCTION

The increase in the demand for energy and the presentation of shortages of fossil energy sources [1] have increased the interest in the use of renewable energy sources, especially solar energy [2]. Renewable energy sources represent energy production in a clean way which is ecological and sustainable [3]–[5]. PV technologies are the most used solar energy systems to generate cleaner [6], sustainable and cost-effective electricity in recent times [7]. Recently, the production of energy from photovoltaic (PV) systems enables the re-duction of the emission of gases harmful to the environment [8], and such systems have a relatively long lifespan [9], [10]. The main factor on which the energy produced by the PV system is based is the efficiency of the system [11], [12]. PV systems are characterized by a not very high efficiency compared to fossil energy generation systems [13].

Odeh [14] proposed the performance analysis of a small photovoltaic system which is connected to the network is presented, after the analysis of the climatic conditions, the energy produced by the system and the specific production are presented. Vidal [15] proposed the performance evaluation of the PV system in Egypt is presented, after the selection of the panels and the construction of the mathematical model, the generated energy is presented. Fetyan and Hady [16], the analysis of a PV system in Uganda is presented, after analyzing the specifics of the country, the monthly energy produced and the final yield for that system are presented. Kavuma [17] used the design and simulation of a photo-voltaic system using the PVSYST software is presented, the atmospheric conditions and the location of the panels from where the energy produced by the system is extracted are analyzed. Prasad *et al.* [18] proposed the performance of a system in Brazil was analyzed, where the losses from the photovoltaic panels as well as the losses in the system, capacity factor and performance ratio were analyzed. De Lima *et al.* [19] the modeling and simulation of a

PV system is presented, the mathematical model is built and the I-V and P-V characteristics of the system are presented. There are many technologies that use the principle of photovoltaic systems for the production of electricity, but technologies built with crystalline silicon material are the most used [20]. The performance of any photovoltaic system is affected by the real climatic conditions to which it is subjected [21]. An important factor during the performance of the system is the ambient temperature, which affects the efficiency of the system as well as the thermal losses [22]. Both the electrical efficiency and the output power depend on the temperature of the cell during the energy production [23].

In this paper, the modeling of a small PV system for specific conditions is presented, which is different from the systems analyzed so far, since it has an east-west orientation. Where the paper presents the modeling of a small PV system where all the main components of its energy performance are presented, the PV system is used to cover the electricity needs of an industrial facility.

2. PROCEDURE SPECIFICALLY DESIGNED

2.1. PV system

The analyzed photovoltaic system is a system for energy needs of an industrial facility. The system in question was created to cover the needs of a factory for the production of plastic doors and windows. The energy system of the factory is covered by the photovoltaic system and the electricity network, so the photovoltaic system represents a system connected to the network. The PV system is located in a part of the city of Suhareka, around which there are no other systems that use solar energy. The extent of which is in longitude 42.33° and in latitude 20.89°. The location is characterized by continental climatic conditions, which is characterized by hot summers and cold winters. In Figure 1. the analyzed PV system is presented.

The analyzed PV system has 88 PV modules placed in 4 strings of 22 photovoltaic panels. Real measurements for the period of one year have been made and for the system in question, its energy performance will be analyzed. The analysis of the system will be done analytically as well as software for the presentation of its energy analysis. Figure 2 presents diagram of parts and connections in the PV system.

Figure 1. PV system

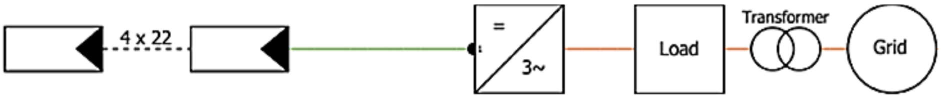

Figure 2. Scheme of parts and connections of PV system

From the diagram, it can be seen that after creating the string connections, they are connected to the inverter to convert the DC energy into AC energy for use in covering the factory's load. After the energy load from the factory is placed the current transformer which measures the energy entered into the energy network as well as the energy received from the network and of course the connection to the electricity network is made after the transformer. The analysis of the system will be done by means of PV*SOL premium software and based on real one-year measurements during system monitoring.

2.2. Meteorological data analysis

Taking into account the analyzed location and its atmospheric conditions, the climatic conditions that affect the performance of the PV system at that location were measured and presented. Figure 3 shows horizontal radiation, diffuse radiation and global radiation. From the diagram, a higher potential of global radiation can be seen in the horizontal plane, the month with the highest radiation potential is July with

203.92 kWh/m^2, while the one with the lowest radiation is December with 38.95 kWh/m^2. The windy months are characterized by a higher radiation potential than the winter months. It can be seen that the month with the highest horizontal irradiance potential is the month of July with 203.92 W/m^2. From the figure can be seen that from May to August in the analyzed country, the potential of diffuse radiation is higher. In August, diffuse radiation is higher during the year compared to other months with 87.40 W/m^2. Figure 4 presents the PV generation potential at that location.

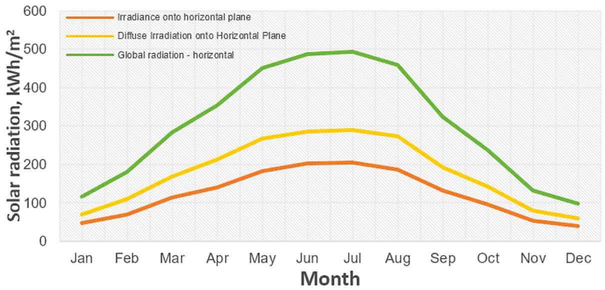

Figure. 3. Horizontal plane irradiance, diffuse irradiance and global irradiance, kWh/m^2

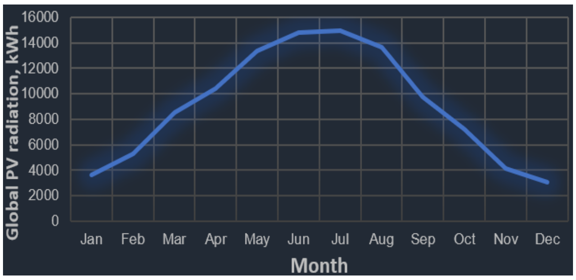

Figure 4. Global PV radiation, kWh

PV potential which can be used throughout the year is high. The global PV radiation potential is higher in the summer months than in the winter months based on the Mediterranean atmospheric conditions of the location. Global PV radiation has the highest value during the month of July with 14966 kWh of energy, while the lowest is during December with 3063 kWh of energy. Figure 5 shows the ambient temperature, that of the PV module and the wind speed.

The external ambient temperature reaches the highest value in August with 22.944 °C, while the lowest in January with -0.11809 °C. The temperature of the photovoltaic module is also affected by the external temperature of the environment, which has the highest values during the month of July with 30.5 °C while it is the lowest during the month of January 1.8 °C. The high temperatures of the PV modules also negatively affect their performance, in this aspect the wind speed can be seen as a positive component, which has the highest values during the month of March 1.8 m/s while the lowest during the month of November 1.1 m/s.

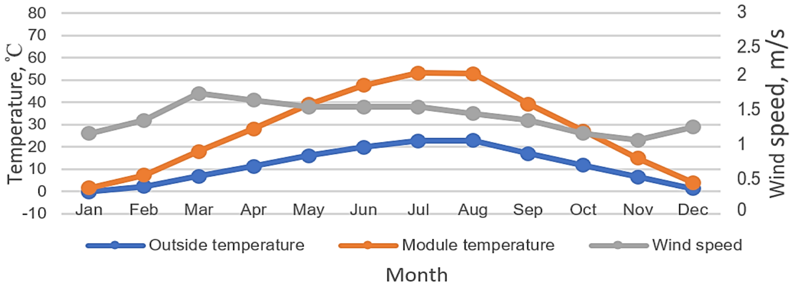

Figure 5. Outside and module temperature °C and wind speed m/s

3. METHOD

For the most realistic presentation of the performance of the PV system, all the elements related to its performance have been analyzed, such as: solar radiation, ambient temperature and wind speed. All these parameters are important for an adequate operation of the PV system. In the real operating conditions of the system, the power given by the manufacturer is not always reached, for this reason we get a theoretical power in reality, which can be calculated using the formula:

$$P_{theoreticla} = P_{peak} \cdot \frac{G}{1000} \quad (1)$$

where: $P_{theoretical}$: theoretical power given from module [W]; P_{peak}: peak power from solar modules [W]; G: direct solar irradiance [W/m^2] [24].

Efficiency is the main indicator of the conversion of solar energy into electrical energy, which can be calculated using the formula:

$$P_{max} = V_{oc} \cdot I_{sc} \cdot FF \quad (2)$$

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

where: V_{OC}: is the open-circuit voltage; I_{SC}: is the short-circuit current; FF: is the fill factor; Pin: is the input power [W]; η: is the efficiency [25].

4. RESULTS AND DISCUSSION

The presented results are from the real measurements of the system performance as well as the simulations which were made with the PV*SOL premium software. The real data measured includes the period July 2021 to June 2022. In the following, the components analyzed during the modeling of the system, including its performance, are presented. Figure 6 presents the annual energy generated by the PV system, energy which is provided by the PV*SOL premium software.

The PV potential which can be used throughout the year is high. The main component analyzed when designing a PV system is the energy that can be generated by that system. From the simulation done in our software, a larger energy production can be predicted during the months of June-August. The month with the largest production is June with a production of 4706 kWh, while the lowest production of energy is during the month of December with 949.5 kWh. Figure 7 presents the annual MPP voltage.

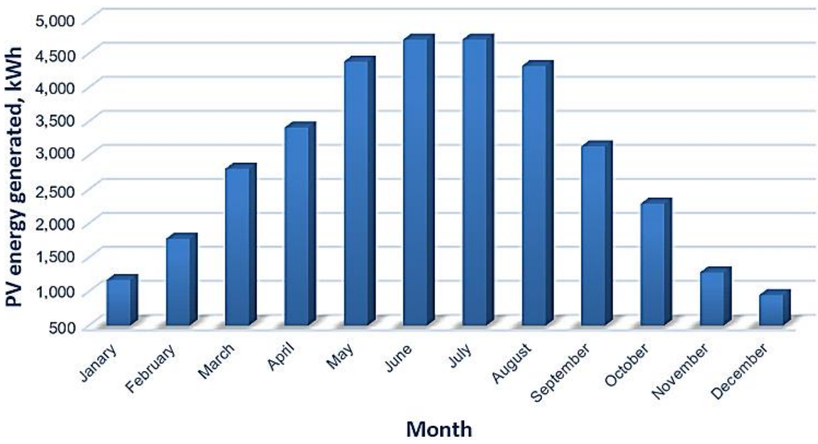

Figure 6. PV energy generated

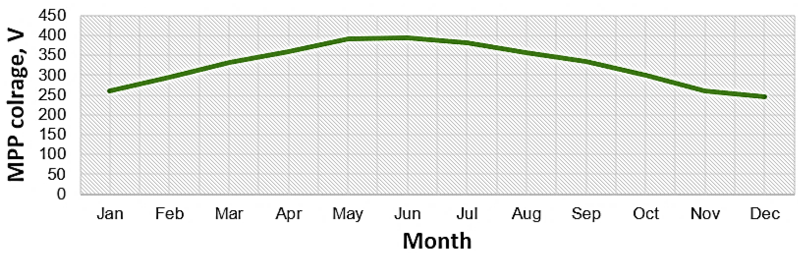

Figure 7. The annual MPP voltage

Similar to the energy generated by the system, which changes depending on the seasons, that change also affects in the voltage change as well. MPP voltage in winter season is lower while in summer season it is higher. The months with the highest solar radiation also have the highest potential. The highest voltage is reached during the month of July with around 400 V, while the lowest during the month of December with around 250 V. Figure 8. presents the annual DC energy produced.

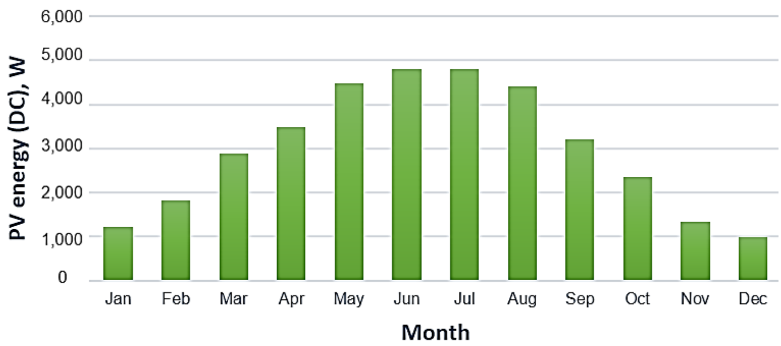

Figure 8. The annual PV energy (DC)

The largest production of DC energy is also seen from May to August. In the month of May, the production reaches 4482.6 W, in June 4815.1 W, in July 4812.9 W, while in August 4411.6 W. Which means that the month with the largest production is the month of June. In the following, the data from the real measurements during the year of the performance of the system will be presented. Figure 9 presents the annual energy produced by the PV system.

From the data recorded by the modeling of the PV system and the one-year period of its observation, the graph shows the largest production during the summer months than during the winter months. Where in July 2021 the energy production from the system was 2811.86 kWh, in August it was 2648.04 kWh, while in June 2022 it was 2576.32 kWh. The largest energy production during the year in which the measurements were made was achieved in July. Figure 10 presents the final yield.

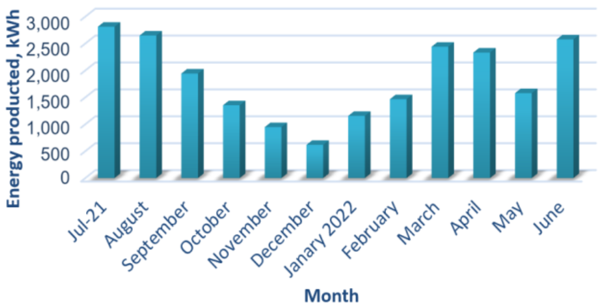

Figure 9. The annual energy produced

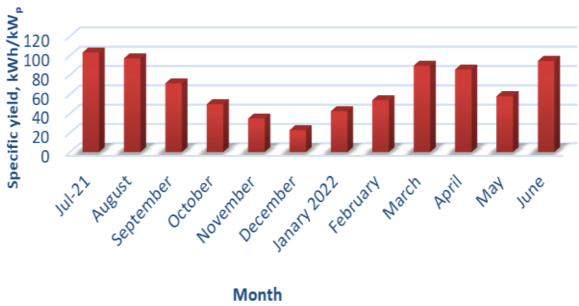

Figure 10. Specific yield

To know how much energy is generated for each installed kilowatt point of photovoltaic panels, their efficiency serves. On the basis of which the solar energy that has been used in a beneficial way is determined. The final yield during the months of June, October and August is greater. In June it reaches the value of 94.44 kWh/kWp, in July 103.07 kWh/kWp, while in August 97.07 kWh/kWp. The largest production was achieved during the month of July. Figure 11. presents the average power.

Based on the solar potential in the analyzed location, the continuous power generated by the PV system can be determined. Well, it is important to know what power is generated during each month of the year. Average power produced in June, July and August. The average power produced in June is 15.81 kW, in July 16.66 kW, while in August it reaches 15.79 kW. In this way we can conclude that the month with the highest average power produced is the month of July.

The analyzed system is a small photovoltaic system which is used to cover the energy requirements of an industrial facility. The results obtained from the analysis are satisfactory since the system in most of the time achieves the coverage of more than half of the energy requirements. The system is more non-specific than the case studies that have been carried out so far, which represents an innovation since its design was not made according to the basic principles of system design and we have a large deviation from the azimuth angle. In the future works, it is envisaged to carry out the optimization of this system and to present the performance analysis after the optimization in order to observe the change in its performance.

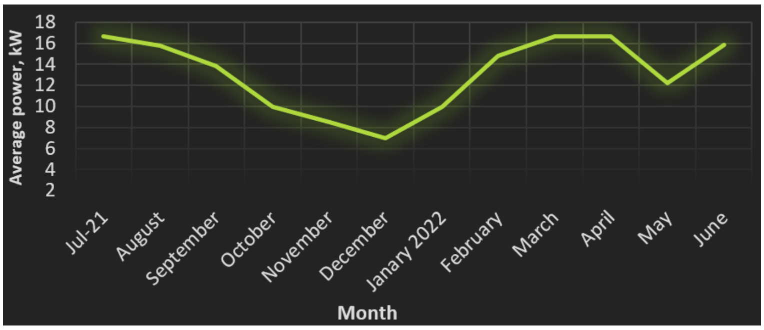

Figure 11. Average power

5. CONCLUSION

Considering that the energy crisis is deepening every day and the industrial sector is among the sectors that consume large amounts of energy, renewable sources, especially photovoltaic systems, are seen as the best opportunity to be used to minimize the demand for energy in this sector. In this paper, the modeling of a small PV system for the energy needs of an industrial facility is presented. Modeling of the system is done analytically and software using real one-year measurements from July 2021 to June 2022 and using PV*SOL premium software. The evaluated parameters of the PV system are: energy production, final yield and average power. From the energy produced, the largest amount of energy produced was in the month of July with 2811.86 kWh, while it decreased the most in December with 617.01 kWh. The final yield during 2021 was 103.07 kWh/kWp, while during December it decreased to 22.62 kWh/kWp. The average production power during the month of July was 16.6 kW, while the lowest was in December with 7.01 kW. Such energy production systems are very profitable to use, especially with the emergence of the energy crisis and for the independence of the facility from the electricity grid. Such systems enable independence from the energy grid by producing energy in a cleaner and more economical way. This work can be used as a model for the analysis of other similar systems in different locations with other climatic conditions.

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