Evaluation Of Energy Losses And Performance Of Small-Scale Of Photovoltaics

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Abstract—The performance of a photovoltaic (PV) system, in a rigorous assessment depends on several important factors; total losses of the system are an important parameter of the evaluation of the overall operation of photovoltaic system. Energy losses can derive directly from electrical equipment, but meteorological parameters are also important. In this study small size of photovoltaics systems, for residential purposes, are investigated. Four modules types, in climatic conditions of different sites, are assumed in order to predict the energy output. Calculations are performed from the simulation tool PvPlanner. Other parameters added to losses, that affect the system performance, derive from the reduction of global in plane irradiation, from the part of global radiation reflected by surface PV, the losses that derive from the conversion of radiation into DC current, deviation from efficiency from standard test condition (STC), losses from interconnections and modules, inverter losses, losses in the AC section, losses in time due to improper maintenance. The proposed methodology can predict the values for each part of losses based on the main meteorological parameters. Maximum value among all areas for energy losses in total are 23.7% for city of Saranda. Other results analyze the energy output from different PV modules mSi, cSi, CIS, CdTE, and are carried out capacity factor (CF) and performance ratio (PR) of the system.

Keywords—Performance of PV system; PvPlanner tool, total losses; performance ratio; capacity factor

I. INTRODUCTION

Albania has a very favourable geographical position; it lies in the south-eastern part of Europe and is an important connecting part of it. Energy is a developing sector of the economy in Albania. Renewable energies are attractive to investors due to low taxes and low maintenance and operation costs. Historically, the country's electrical needs have been covered by hydropower plants; however, the demand has increased, causing interruptions in the network from time to time. Climate change will also cause negative effects on water, as well as the power produced by it; a reduction of about 15% of production is calculated according to the Albanian investment development agency (AIDA). For this reason, the energy sector will have an increasing dependence on energy imports. National Energy Agency suggests and promotes other forms of benefiting from electricity, such as solar energy and wind energy [1]. The country has very favourable solar potential for the development of photovoltaics due to its geographical position and climate, and the high intensity of solar radiation, calculated slightly more than 1,500 kWh/m2/ year. The country has an average of 2400 sunny hours, in the southern part 2500 hours and in certain areas this value reaches 2580 sunny hours. Solar energy has been developed for the part of warm water, while photovoltaics in small scale have increased in recent years, medium and large-scale projects are being implemented [2]. The data of solar radiation, of the respective networks in Albania, is difficult, due to their reformation. It is still too early to talk about the accuracy of solar radiation parameters based on ground measurements. This is directly related to feasibility projects in determination of the economic performance for the implementation of photovoltaics in Albania. Satellite measurements of solar radiation have very good accuracy and dispersion. They can also be used for the assessment of ground measurements, in cases where they are missing, incomplete, or with obvious assessment uncertainties. Photovoltaics are today a possible solution for energy complementarity, this for many reasons, technological improvement, the reduction of installation costs, in the era of energy crisis for conventional sources. In Albania, small scale installations are increasing in the last 2 years. The expansion of these occurred not only in potential climatic areas with abundant radiation, but also in mountainous areas with a climate mainly in winter that is dominated by snowfall. The performance of PV systems is influenced by many factors and specific studies are part of every project. The losses of the PV system reduce in a way that if they are not monitored, they significantly reduce the total production and therefore the price of the produced energy increases [5], [6]. The losses come as a result of PV capture losses and other electrical system and maintenance problems. Therefore, the assessment of losses and their detailed analysis in concrete case studies is very important. In the literature studies on PV system losses that use artificial intelligence or machine learning methods, the parameters that are widely used in the literature are monthly or annul production, reference of the system yield efficiency, losses from system, from radiation, radio performance, and capacity factor. Performance metrics in the studies, as performance ratio and have been widely used in the literature to present the effects of the total power losses in PV systems. Efficiency of overall system also evaluates the PV system in the face of total losses [4]. Different tools for PV simulation are used in some papers to calculate the values for different types of losses in PV systems as System Advisor Model, SAM and PVsyst, SolarGIS and HelioScope [7], [8], [9]. The types of PV system losses are numerous and can be analyzed in a detailed study; total system losses, losses from radiation, capture losses, climatic conditions, snow in mountain climates, dust in urban industrial areas, humidity, and drought at high temperatures above 40^{o} C [10], [11], [12]. The performance of a small scale of photovoltaic systems for a wide territory in Albania is evaluated. This paper aims to present typical losses in a PV system in different climatic conditions for 12 sites in different parts of Albania, comparison of values and the difference between different climates. Comparison are made for performance ratio and capacity factor in different sites, Proposal regarding a method for calculating losses for different PV systems, starting from the method of calculating losses, software tools that can be used, suggested tools for monitoring losses, starting from equipment, inverter, types of modules , cables, MPPT controllers. In the first part of the paper, the results for different parameters as the energy losses and the calculations for PR, CF are presented. The first part suggests a method for calculating the system losses, the second part summarizes the predicted results, and the third part compares the results. The goal is to summarize and discuss an approach for detailed power losses on calculation for PV systems, a standard method that can help in the feasibility projects, taking into consideration all the losses of the PV system

II. METHODS OF STUDY

A. *PvPlanner Tool*

Objectives of the study is to determine the radiation in different areas of Albania, then calculate the output energy of the photovoltaic system for a certain technology of photovoltaic cells chosen in this study. In order to determine the energy from photovoltaic systems, small size of PV installed is assumed in this study. Some important performance parameters are: the energy generated by the photovoltaic system, the performance ratio of the photovoltaic system, the capacity factor. These normalized indicators are important because they establish a basis from which photovoltaic systems can be studied and compared under different operating conditions. Is assumed in this study that the efficiency of the inverter is 95%, 5.5% are losses in direct current, 1.5% in alternating current. The energy obtained from the photovoltaic systems has been estimated with the PvPlanner tool, combining the photovoltaic cells with the inverter efficiency. Local radiation and temperature values are also taken into account in this model. The use of appropriate performance parameters facilitates the comparison of photovoltaic systems connected directly to the grid. Photovoltaic systems can vary in terms of design, technology or geographic location. PvPlanner is a simulation tool for optimization of photovoltaic (PV) systems using high performance algorithms, with data specifically in the selected location, with high temporal and spatial resolution from SolarGis database. The infrastructure of this tool is built with high-level algorithms, combining satellite and atmospheric images with specific data of the selected location. The output energy from PV System depends on many external factors besides the technological specifications of the modules themselves. The dependence comes from the surface occupied by the modules, climatic conditions, final mounting of the PV system, depends on type, fixed or tracking system, shading, snow, humidity and other factors as maintenance during the whole lifetime of the system. In PvPlanner long degradation is not taken into account. Below are the steps in calculating the losses according to the steps of this software [13] [14].

The performance parameters generally define the system based on the energy produced, the solar energy resources, as well as the effects that losses have on the system:

I. Calculation in the input data with Standard Test Conditions (STC)

II. Reduction of global in-plane irradiation due to the location of PV,

III. Global radiation reflected from the surface of PV cells type, cSI, mSi CdTe, CIS

IV. The losses that come from the conversion of radiation into DC current, the deviation of the yield of the cells by comparing it with the reference value.

V. Heat losses, connections between modules

VI. Losses in the inverter,

VII. Losses assumed due to deficiencies in the maintenance function.

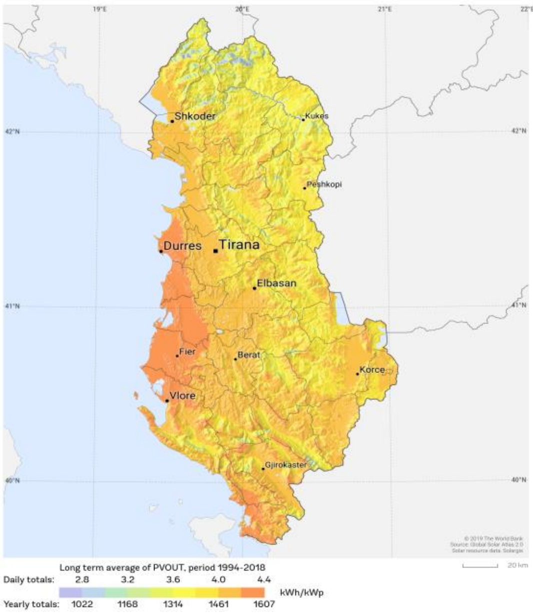

Fig. 1. Photovoltaic power potential (source Global Solar Atlas)

B. *Potential of solar energy*

Table 1 gives the average daily radiation on a horizontal surface as well as for an inclined surface, also gives the output energy of the photovoltaic system for two photovoltaic modules c-Si and a-Si, CIS and CdTe. It can be seen from the table that the energy potential is high, for Fier 5.15 kWh/m2 per day, for Kukës it has the smallest value 3.96 kWh/m2 per day. Figure 2 shows the annual changes in air temperature as well as daily global radiation for one of the areas under consideration, the city of Shkodra, while figure (b) shows the prediction for electricity produced every month as well as the performance report for a certain technology c-Si, calculated with PvPlanner software for the city of Vlora. The performance ratio is lower in June, July and August due to the influence of high temperatures.

TABLE I. RADIATION ON HORIZONTAL SURFACE, RADIATION ON INCLINED SURFACE, DAILY ELECTRICITY

Area	*Average Daily Radiation (kWh/m2 d)*	*Radiation on inclined surfaces* (kWh/m2 d)	Optimal Angle (°)	Daily energy Produced [kWh/kWp] c-Si	a-Si	CIS	CdTe
Vlora	4.48	5.11	32	4.01	4.16	4.21	4.07
Fier	4.49	5.15	33	4.10	4.20	4.15	4.27
Kuçova	4.40	5.06	33	4.02	4.12	4.08	4.20
Korça	4.26	4.85	32	3.92	3.95	3.97	4.06
Kukës	3.96	4.45	31	3.58	3.60	3.63	3.71
Himara	4.39	4.99	31	3.95	4.07	4.39	4.13
Gjirokastër	4.26	4.80	31	3.84	3.91	3.89	4.00
Durrës	4.43	5.11	33	4.06	4.15	4.13	4.23
Tirana	4.29	4.95	33	3.93	4.02	3.99	4.09
Shkodra	4.21	4.90	34	3.82	4.04	3.89	4.01
Elbasan	4.28	4.92	33	3.92	4.00	3.97	4.07
Saranda	4.54	5.17	32	3.96	4.26	4.05	4.21

The energy performance provides information on the difference between the installed capacity of the photovoltaics and the energy received by the system. The output energy of the PV system is calculated with the PvPlanner program tool, combining the PV cells with the efficiency of the inverter, losses in direct current DC and alternating current AC, local radiation and temperature values. The energy performance provides information on the difference between the installed capacity of the photovoltaics and the energy received by the system. The output energy of the PV system is calculated with the PvPlanner program, combining the PV cells with the efficiency of the inverter, losses indirect current DC and alternating current AC, local radiation and temperature values. Fier is the site with the most potential of average daily radiation. Optimal angle for yearly produced energy is predicted between 31^{0} and 34^{0} degrees. Solar cells technologies Cd Te is the mos efficient comparing with other technologies. Energy Losses Energy losses in a PV system are difficult to predict accurately, it depends on designing and installing a properlysized PV system considering all the factors that influence the performance reduction. All factors taken into consideration are calculated below. PvPlanner tool simulates according to inputs data, and predicts possible losses. The degradation of the modules is not taken in account because this would depend specifically on the chosen technology.

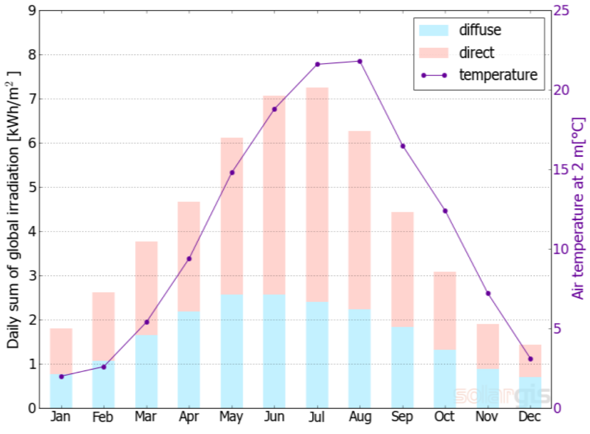

Fig. 2. Annual variations of air temperature and daily global radiation,

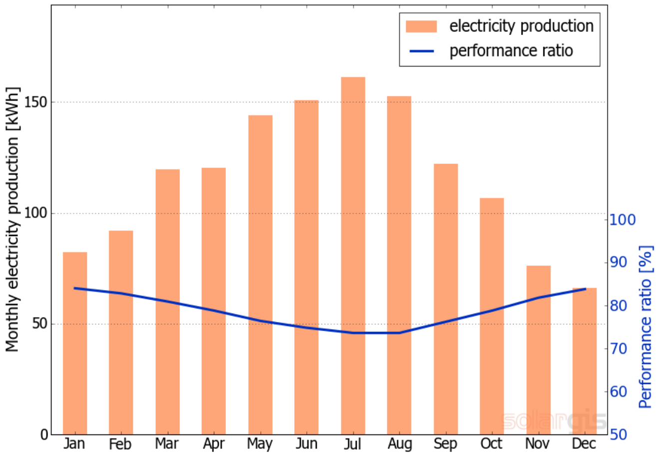

Fig. 3 Monthly produced electricity, Shkodra

C. Performance Ratio and Capacity factor

Performance ratio [4]:

$$PR = \frac{Energy \quad Produced}{Expected \quad Energy} = \frac{E_{AC}}{G_h * S * \eta_{St}} \quad (1)$$

The capacity factor is given：

$$CUF = \frac{Energy \quad Produced \quad (Kwh)}{Installed \quad Power\,(kWp) * 24 * 365} = \frac{E_{AC}}{P_{pv} * 8760} \quad (2)$$

III. RESULTS AND DISCUSSION

Losses from different factors are summarized in the following tables for the two cities, Vlora and Saranda. The simulations performed with the PvPlanner software tool are given below. All possible factors, such as shading due to terrain, reflectivity, which reduces global radiation, further DC losses in modules, losses in other parts of the electrical circuit, losses caused by DC/AC conversion, transformer and cabling losses are all added up to give the total system performance.

TABLE II. LOSSES FOR DIFFERENT FACTORS SIMULATED IN PVPLANNER SOFTWARE (CSI MODULES) ARE SUMMMERISED FOR VLORA AND SARANDA.

Energy conversion step	Energy output	Energy loss	Energy loss	Performance ratio	
Vlora	[kWh/kWp]	[kWh/kWp]	[%]	[partial %]	[cumul. %]
Global in-plane irradiation (input)	1877			100.0	100.0
Global irradiation reduced by terrain shading	1864	-13.0	-0.7	99.3	99.3
Global irradiation reduced by reflectivity	1814	-51.0	-2.7	97.3	96.6
Conversion to DC in the modules	1655	-159.0	-8.8	91.2	88.1
Other DC losses	1564	-91.0	-5.5	94.5	83.3
Inverters (DC/AC conversion)	1525	-39.0	-2.5	97.5	81.2
Transformer and AC cabling losses	1502	-23.0	-1.5	98.5	80.0
Reduced availability	1487	-15.0	-1.0	99.0	79.2
Total system performance	1487	-391.0	-20.8		79.2

Energy conversion step	Energy output	Energy loss	Energy loss	Performance ratio	
Saranda	[kWh/kWp]	[kWh/kWp]	[%]	[partial %]	[cumul. %]
Global in-plane irradiation (input)	1895			100.0	100.0
Global irradiation reduced by terrain shading	1886	-9.0	-0.5	99.5	99.5
Global irradiation reduced by reflectivity	1835	-51.0	-2.7	97.3	96.8
Conversion to DC in the modules	1610	-225.0	-12.2	87.8	85.0
Other DC losses	1522	-89.0	-5.5	94.5	80.3
Inverters (DC/AC conversion)	1484	-38.0	-2.5	97.5	78.3
Transformer and AC cabling losses	1461	-22.0	-1.5	98.5	77.1
Reduced availability	1447	-15.0	-1.0	99.0	76.3
Total system performance	1447	-449.0	-23.7		76.3

TABLE III. THE MAIN LOSSES OF THE PHOTOVOLTAIC SYSTEM, FOR DIFFERENT CITIES

District	Total Energy output [kWh/kWp]	Total system performance [kWh/kWp]	Total Energy loss [kWh/kWp]	Total Energy loss %	Performance ratio[cumul. %]
Tirana	1814	1436	-378.0	-20.8	79.2
Vlora	1877	1487	-391.0	20.8	79.2
Fier	1887	1496	-392.0	-20.8	79.2
Kuçova	1857	1467	-390.0	-21.0	79.0
Korça	1786	1433	-353.0	-19.8	80.2
Kukës	1661	1308	-353	21.2	78.8
Himara	1824	1443	-381.0	-20.9	79.1
Shkodra	1794	1394	-400.0	-22.3	77.7
Elbasan	1807	1431	-377.0	-20.8	79.2
Saranda	1895	1447	-449.0	-23.7	76.3

Table 2 gives a summary illustration of the losses of a photovoltaic system installed in the city of Vlora and Shkodra, as well as the performance report. Input parameters for the modules is c-Si technology, the total loss energy by the system is also estimated with the PvPlanner program. It can be seen from the table that the losses are around the value of 20.8% for the city of Vlora, and 23.7% for Saranda.

Calculations have also been developed for some major cities in Albania, from table 3; the percentage difference of losses does not change much in some cities. The smallest values for energy losses are performed in Korça, where the radiation is lower during the year, this site is characterized by a colder climate.

IV. CONCLUSION

The solar energy potential in different areas of Albania was studied. For a small-scale system, the energy produced by 1kWp was calculated. Calculations are also given for the average energy produced by the photovoltaic system, the performance ratio of the installed system and capacity factor. Kukës is the area with the lowest output energy of the photovoltaic system, 1308kWh, and in Fier the highest value of 1496kWh. The capacity factor of the system is 14.9% for Kukës and 17.0% for Fier. From (PvPlanner) simulations, in different locations in Albania the losses predicted from PvPlanner the maximum value is predicted for the city of Saranda, and the minimum value for Korça. Total energy losses predicted are between 19.8% 23.7%. Energy losses from conversion to DC in the modules are 12.2%, which is also the most significant part of the total losses. Another parameter to evaluate the total performance of the system is the performance ratio of the installed system, from the table values ranging from 76.3 % in Saranda and the maximum value is 80.2% in Koca. While in Kukës, the energy output of the photovoltaic system is 1308Wh, and as it is expected in Fier the highest value 1496kWh. Capacity factor from simulations varies from 14.9% to 17.0% for Kukës and Fier respectively.

The simulations from PvPlanner tool are performed for small size of installed photovoltaics in Albania. For medium size and large scale of installed PV power plants another method that affect other factors influencing in energy losses should be discussed.

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