Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 7, S. 14-19, 7, 2023

Araştırma Makalesi

IJANSER

https://as-proceeding.com/index.php/ijanser
ISSN: 2980-0811

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 7, pp. 14-19, 7, 2023

Research Article

Feasibility of a small on grid PV System in Albania

Irma Berdufi*, Driada Mitrushi [2] and Valbona Muda [3]

[1]*Department of Radiation Protection and Monitoring Network/Institute of Applied Nuclear Physics, University of Tirana, Albania*
[2]*Department of Engineering Physics, Faculty of Engineering Mathematics and Engineering Physics, Polytechnic University of Tirana, Albania*
[3]*Department of Engineering Physics, Faculty of Engineering Mathematics and Engineering Physics, Polytechnic University of Tirana, Albania*

(irmaberdufi@gmail.com) Email of the corresponding author

(Received: 29 July 2023, Accepted: 09 August 2023)

(1st International Conference on Modern and Advanced Research ICMAR 2023, July 29-31, 2023)

ATIF/REFERENCE: Berdufi, I., Mitrushi, D. & Muda, V. (2023). Feasibility of a small on grid PV System in Albania. *International Journal of Advanced Natural Sciences and Engineering Researches*, 7(7), 14-19.

***Abstract* –** The efficiency of the PV systems connected to the network depends not only on the efficiency of the PV module and the natural potential of solar radiation at the place of installation but also on several other factors related to the installation, temperature of the modules, nature and quality of the national or regional electrical network, inverter sizing, load, etc. The system in this study is installed on the roof of the Institute of Geosciences, Energy, Water, and Environment building. The system comprises two groups of 12 polycrystalline silicon panels connected in parallel. The designed power of the PV system is 4.56 kW. The PV panels are oriented towards the south, with an azimuth angle of 0° and an inclination to the horizon of 41°. The system is monitored for one year, from 2012 to 2013. Even though the PV system studied is of small size for the PV systems connected to the network, the results obtained and their interpretations enable us to determine an appropriate methodology for assessing the feasibility and designing of any similar PV system connected to the network. The used parameters during the evaluation, wherever possible, are defined in this study. In conclusion, considering all the calculated losses, the PV system's evaluated losses are 24.2%.

Keywords – PV Systems, PV System Efficiency, Grid Connected, Feasibility Determining Methodology, System Losses

I. INTRODUCTION

Occupational Photovoltaic systems connected to the network are actually the leading technology and the most important for converting solar energy into electricity. Performance, quality, and reliability issues are essential for all applications of photovoltaic technologies, including those connected to the network. The efficiency of the PV systems connected to the network depends not only on the efficiency of the PV modules themselves and solar radiation in the place where they are installed but also on several other factors related to the installation, temperature, network connections, the size of the inverter, load, etc. [1]. The distribution of small PV systems installed on the terraces of buildings connected to the central network is one of the most promising applications [2], [3], [4]. However, increasing the use of PV systems in the central electric network because of their inherent and unpredictable statistical characteristics is followed by several problems associated with stability and reliability, especially in areas with high-density PV systems related to the network [5]. The solution to these problems is strongly related, among others, to the best indicators of the performance of individual systems knowledge. To study how these parameters affect the operation of a PV system connected to the grid on the roof of a high building, an experimental 4.56 kWp PV system connected to the network is installed at the Polytechnic University of Tirana on the roof of the building of the Institute of Geosciences, Energy, Water, and Environment. The PV system is monitored and analyzed for one year gathering information about the performance of system (PV modules, inverter connected to the network) and also, from a more global perspective, the efficiency of the system, electricity produced, which will help to establish some analytical relationship tool to predict their performance in the future.

II. Materials and Method

In this study, we will try to pose concisely the guidelines and methodology to be followed during the installation of PVsystems for use in electrical energy generation and the way of their connection to the local and regional central network [6], [7]. As mentioned above, we will rely on experience, recommendations, and global standards as well as experience, however modest, we obtained during this first study in Albania.

The following factors influence the electrical energy supplying the local electrical grid:

The average daily solar radiation energy falling on PV panel's area;

Technological tolerances of PV modules;

Effects of temperature on the efficiency of PV modules;

The effects of pollution;

The energy losses in the system;

The inverter efficiency;

The following formula calculates the average yearly energy yield supplied to the grid [6], [7]:

$$E_{sys.} = P_{array\_STC.} \times f_{tem.} \times f_{man.} \times f_{dirt} \times H_{tilt} \times \eta_{pv} \times \eta_{PV-inv.} \times \eta_{inv.} \times \eta_{inv.-sub.} \quad (1)$$

Where:

E_{sys}. - average yearly energy output of the PV array, in wathours,

P_{array_STC} - rated output power of the array under standard test condition in watts,

f_{temp} - temperature de - rating factor, dimensionless,

$f_{man.}$ - de - rating factor for manufacturing tolerance, dimensionless,

f_{dirt} - de - rating factor for dirt, dimensionless,

H_{tilt} - yearly irradiation value (kWh/m^2) for the selected site (allowing for tilt, orientation and shading),

η_{PV} - efficiency of the solar modules

η_{PV_inv} - efficiency of the subsystem (cable) between the PV array and inverter,

η_{inv} - efficiency of the inverter dimensionless,

η_{inv_sub} - efficiency of the subsystem (cable) between the inverter and the switchboard.

To obtain the expected energy supplied by the PV system, we are presenting, in summary, its parameters and characteristics to be applied to this procedure. The designed power of the PV system is 4.56 kW. The PV panels are oriented towards the south, with an azimuth angle of 0° and an inclination to the horizon of 41°. The most accurate predictions of the angle of inclination, at which the maximum annual energy is obtained for the installation region of the PV system, as you will see below, give for a perspective a smaller value for an annual angle of the solar panel, 33.5°. Still, at the time of installation, it was unknown to us. In the paper published in the Bulletin of technical sciences, this angle for the region of Tirana is 31 degrees [8].

III. Results

A. *The AC electrical energy yield of PV system*

For Table 1 summarizes the primary indicators used to estimate the expected energy supplied by the PV system. When it was possible, the determination of the indicators was based on concrete experimental data realized by us or other authors. In the inability to provide experimental data, indicators provided by best practices in the field have been used.

Table 1. The main indicators used to estimate the expected energy supply by PV system

Indicators Values	**Values**
Projected power	4.56 kWp
Projected used time	20 years
Tilt angle by horizon	41°
Azimuth angle	0°
Average daily potential of solar energy on a horizontal surface	3.9 kWh/m^2
Average daily potential of solar energy on a tilt surface 41° with horizon	5.19 kWh/m^2
Losses by percentage of aerosols	9.1%
Losses by dust deposition	5.0%
Losses in inverter	7.1%
Losses in DC current	3.0%
Evaluation of total system losses	24.2%

The only source of energy for a PV system is solar radiation. The potential of solar energy in a particular region is the most critical parameter that affects the feasibility of a project to use solar energy to produce electricity. Usually, the energy potential of solar energy is generally defined for a horizontal surface. The orientation of the PV panels' surface affects the energy potential's magnitude. For the location region of the PV system that we studied, the annual energy potential of solar radiation on the horizontal surface is 1442.13kWh/m^2, the maximum potential is reached for the angle of inclination of the panel with the horizon of 33.5 degrees, and its value is 5.19 kW/m^2 per day. Its annual maximum is 1894.35 kWh/m^2. This value is reached for the orientation of the PV panel towards the south, i.e., for the zero azimuth angles. If the slope changes from the angle of the maximum value, the energy potential decreases at 0.08 % W per degree. Figure 1 shows the variation of solar energy on a sloping surface for the PV system installation in Tirana from the inclination angle to the horizon for zero-degree azimuth angles.

The presented curve can be approximated by the equation $y = -0.0005x^2 + 0.0335x + 4.5671$, which gets the maximum value for an angle of 33.5 degrees. However, the change in the slope of the curve around the maximum is prolonged, a fact that proves the slight influence of deviations from the angle of inclination for which the maximum of the incident energy is reached on the obtained energy.

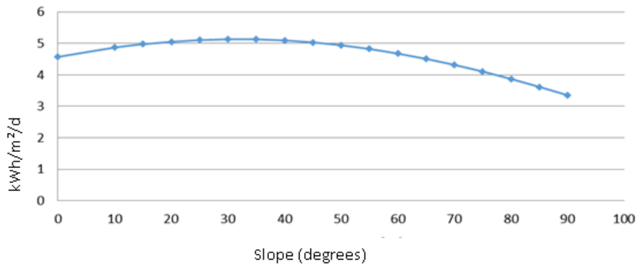

Fig. 1. Dependence of solar energy from PV system tilt angle with the horizon

B. *Decline production of PV modules*

A photovoltaic system is characterized by a series of losses caused by factors closely related to the technology and operation of the system as well as by environmental or installation factors. In general, the main losses typologies in a photovoltaic system can be classified as follows:

a. Production decline due to production technology. Allowed limits.

b. Production decline due to pollution.

c. Production decline due to the temperature of PV panels.

1) Production technology

The deviations of energy generated in standard temperature conditions, 25°C, fluctuate within level 5%. In recent years, the allowed value of deviation has reached 3%. It is understood that the developer of such a project should consider this deviation. In our case, assuming a 5% deviation, in the "worst case," the corrected output of a 190W module will be about 180.5W (0.95x190W).

2) Pollution

Pollution can affect the productivity of a PV system in two ways: on the one hand, the increase in the concentration of aerosols in the atmosphere is associated with the reduction of solar energy arriving at the PV panels, and on the other hand, it intensifies the deposition of dust on the surface of the panels, causing absorption addition of this energy. The energy loss due to the increase in the concentration of aerosols in the atmosphere on days without rain increases gradually with the increase of days after the last rain according to [9]:

$$\frac{E_1 - E_N}{E_1} = 0.201\ln(N) - 0.453 \qquad (2)$$

Considering an average interval between rainy days from 15 days, a period for which the concentration of aerosols in Tirana remains almost unchanged (see figure 2) can determine the loss of productivity of the PV module due to the concentration of aerosols in the atmosphere at about 9.1% [9]. The reduction in module productivity can be reduced due to the superimposition of impurities on the surface of the module. If one is unsure, the reduction in production can be about 5% of the calculated value after correction for production technology. The total losses due to pollution in the region under consideration can be estimated at around 14.1%. Therefore, the corrected power value of 180.5W will be further reduced to 155.05W (0.859 x 180.5W).

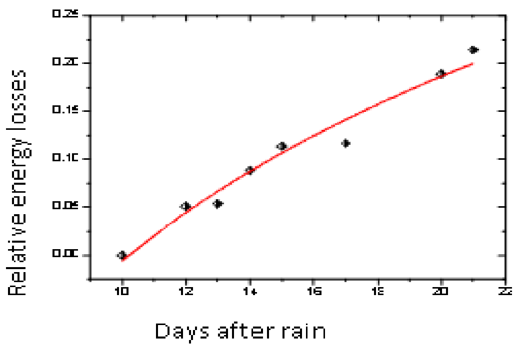

Fig. 2. Relative energy attenuation corrected for relative humidity and wind speed. FIM&IF station

3) *DC energy output of PV panels*

The current value of the direct power output of solar panels = corrected output power x number of modules x intensity of radiation corrected for tilt and azimuth angle.

For our experimental system, the daily hours of the average annual peak are 5.1, and the number of PV panels is 24. The PV system's daily average continuous energy output will be 16132.32 Wh (131.8W x 24 x 5.1h). The continuous output power will further decrease due to the voltage drop in the connecting cables to the inverter. Losses in the PV module connector cables are 3%. Consequently, the powerful energy that will supply the inverter will be 15648.35 Wh (16132.32Wh x 0.97)

4) *Inverter efficiency*

The selection of the inverter will depend on the system's power output. For example, the PV system we studied uses a single inverter for both series of panels connected in parallel.

The inverters on the market today are classified according to maximum continuous power at the input, that is, the corresponding power at its peak, the maximum continuous current, and the maximum alternating power at the output it can supply to the grid [10].

Many inverters have a range of operating values. If the voltage is outside this band, the inverter does not work, or the output power may be significantly reduced. In cases where the maximum input voltage of the inverter is specified, and the panel's output voltage is above the specified maximum value, the inverter may be damaged. When the temperature is maximum, the Maximum Voltage Point (V_{max}) of the panel must never fall below the minimum value of the working voltage of the inverter. It is recommended that the maximum effective temperature of the cells is taken to be 70°C.

The selected module has a maximum working voltage of 400V and a temperature coefficient of the maximum voltage Vmax -1.77V/°C for an effective cell temperature of 70°C, so 45° above the standard temperature of 25°C. Therefore, the maximum Vmax will be reduced by 45°C x 1.77 V/°C = 79.7V.

The maximum voltage Vmp at the temperature of 70°C will be 400V - 79.7V = 320.35V. This is the practical value of the minimum input voltage of the inverter. However, in cities, where PV panels are mostly placed on the roofs of houses, shading during part of the day cannot always be avoided. Therefore, care must be taken when selecting modules connected in series with which shading can reduce the maximum value of the voltage at high temperatures, bringing it below the minimum allowed value of the inverter's operation. On the coldest days of the year, the open circuit voltage of the panel must never be greater than the maximum allowed value of the input voltage of the inverter, in our case, 400V. As a result, the lowest value of the daily temperature must be used for the maximum value of the input voltage of the inverter.

Further, the energy supplied by the inverter will be reduced due to the losses in the inverter while transforming the direct voltage supplied by the PV panels into alternating voltage with the parameters of the central grid. The average energy losses in the inverter of the system under study are estimated at 7.1% [11]. As a result, the alternating current energy that will supply the inverter will be 14537.3 Wh (15648.35Wh x 0.929).

Losses will further reduce the output alternating current of the inverter in the alternating current cables connecting the inverter to the grid. Losses in connecting cables are usually around 3%. As a result, the alternating current energy that will supply the network will be 14101.2 Wh (14537.3Wh x 0.97).

C. *Annual energy obtained from the PV system*

The average daily alternative energy supplied to the network is 14.101 kWh/d. Therefore, in a typical year with 365 days, the maximum possible energy will be 365 day x 14.101 kWh/day = 5147 kWh/year.

Two indicators are usually used to evaluate the efficiency of the system: the energy density SY and the performance ratio PR [6, 12].

The specific energy yield is expressed in kWh per kWp, and it is calculated as follows:

$$SY = \frac{E_{sys}}{P_{proj}} \quad (\mathbf{3})$$

The Performance ratio PR is used as an indicator to evaluate the quality of the system. The performance ratio provides a normalized basis to compare PV systems of different types and sizes. It is a reflection of system losses [12].

$$PR = \frac{E_{sys}}{E_{ideal}} \quad (4)$$

Where: E_{sys} is the actual yearly energy yield from the system, $E_{ideal}= P_{array\_STC}\, x H_{titl}$ is the ideal energy output of the array, H_{tilt} is the yearly average daily irradiation, in kWh/m^2 for the specified tilt angle, P_{array_STC} is the rated output power of the array under standard test conditions, in watts.

The alternative energy supplied to the network by the system E_{sys} is 5147 kWh/year, while the system was designed with a power of 4560Wp. As a result, the obtained energy density SY is 1.13 kWh per kWp (5147kWh/4560Wp).

The annual average radiant energy for the annual average daily incident solar energy, in kWh/m^2 for the given slope angle, 5.19kWh/m^2/day, will be 1894.35 kWh/m^2 (5.19kWh/m^2/day x 365day). The total annual time with a standard solar radiation intensity of 1000 W/m^2 that would provide the same energy for each square meter will be 1894.35h. The estimated power of the system under standard conditions is 4560Wp. The system's ideal energy produced during a year will be 8638.24kWh (4.56kW x 1894.35h). The actual alternative energy supplied by the system during one year was 5147 kWh/year. Hence the performance ratio PR will be 0.6 (5147kWh/year /8488.44kWh/year).

IV. DISCUSSION

Although the PV system in this study is of small size for a grid-connected PV system, a suitable methodology was defined for the design of any similar grid-connected PV system. The PV system was monitored for a short period of time, one year and we calculated parameters were possible such as losses by percentage of aerosols, losses by dust deposition, losses in DC current and losses in inverter. We would obtained more realistic results if the PV system would be monitored and analyzed for a longer time horizon, for example 10 years but this wasn’t possible.

V. CONCLUSION

Although the PV system in this study is of small size for a grid-connected PV system, a suitable methodology was defined for the design of any similar grid-connected PV system, where given the steps that must be followed, the necessary parameters that must be known or estimated and the regional specifics of the installation site.

The methodology foresees the verification of the situation in the country, the necessary technical-economic documentation, the energy obtained, the impacts of the solar energy potential, the geometry of the installation, meteorological conditions, the features of the technology used, shading or reflections, losses from atmospheric pollution, losses in inverter and its dimensions, etc.

The parameters used during the evaluations, wherever possible, were defined in this study. In other cases, parameters determined by other researchers of the same study group were used or standardized parameters based on the best international experience.

In conclusion, considering all the calculated losses, the PV system's evaluated losses are 24.2%.

ACKNOWLEDGMENT

I am grateful to all of those with whom I have had the pleasure to work during this paper.

REFERENCES

[1] B. Van der Zwaan, et al. “Prospects for PV: a learning curve analysis”. Solar Energy (2003).

[2] A. Zahedi. “Solar photovoltaic (PV) energy; latest developments in the building integrated and hybrid PV systems”. Renew Energy (2006).

[3] J. D. Mondol, et al. “Optimal sizing of array and inverter for grid-connected photovoltaic systems”. Solar Energy (2006).

[4] B. Burger, et al. “Inverter sizing of grid-connected photovoltaic systems in the light of local solar resource distribution characteristics and temperature”. Solar Energy (2006).

[5] J. D. Mondol, et al. “Optimising the economic viability of grid-connected photovoltaic systems”. Applied Energy, Volume 86, Issues 7–8, July–August 2009, Pages 985-999. https://doi.org/10.1016/j.apenergy.2008.10.001

[6] Grid-Connected-PV-Systems-Design-Guidelines, guideline funded through the Sustainable Energy Industry Development Project (SEIDP). file:///C:/Users/perdorues/Desktop/Article%20Feasibility/Grid-Connected-PV-Systems-Design-Guidelines-v4-250719.pdf.

[7] Grid Connected Power Systems, System Design Guidelines. “Introduction on technical guidelines for utilities integrating PV into their grid”. https://www.irena.org/media/Files/IRENA/Agency/Events/2013/Nov/8_1/3_design_grid_connect_systems.pdf?la=en&hash=40354A1C1B081C1AA40B0BD2AF7E347010DBDFB5

[8] M. Sanxhaku, et. al. "Evaluation of solar radiation and solarization on vertical faces of buildings", Meteorological and Hydrological studies,. Tirana, Academy of Sciences of Albania, Hydrometeorological Institute, 1984.

[9] U. Buzra, et. al. “An Assessment of Impact of Anthropogenic Aerosols in Atmosphere of Tirana on Solar Insolation. Part II: Modification of solar energy potential” AIP Conf. Proc. 1722, 2016. https://doi.org/10.1063/1.4944274

[10] "IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) Systems". IEEE STD 929, 2000.

[11] I. Bërdufi, et. al. “Inverter Losses Analysis of 4.56kW Rooftop Grid Connected Photovoltaic System in Tirana”. Issue 5, Germany: Journal of Multidisciplinary Engineering Science and Technology (JMEST), May – 2016, Vol. ISSN: 2458-9403. Vol. 3. http://www.jmest.org/wp-content/uploads/JMESTN42351584.pdf

[12] “Performance ratio Quality factor for the PV plant”, Technical Information. https://files.sma.de/downloads/Perfratio-TI-en-11.pdf