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Inverter Losses Analysis Of 4.68 KW Rooftop Grid Connected Photovoltaic System In Tirana

Inverter losses analysis of a grid connected PV system

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Abstract — ***Performance, quality and reliability issues are important for all applications of photovoltaic technologies, including grid connected systems. The efficiency of PV grid connected systems depends not only on the efficiency of PV modules itself and solar radiation potential of the site but also on a number of other factors related to installation, temperature, connection, inverter sizing, load etc. Generally speaking, every individual case is a special case that needs specific study. This paper presents the results obtained from monitoring the first grid connected PV system in Albania. The system is composed by two sets of 12 panels of poly crystalline silicon modules connected in parallel; each with open circuit voltage 44.8V DC and nominal power is 190 Wp. The system is installed on the roof of the building of Institute of Geosciences, Energy, Water and Environment. The system was monitored for one year. Electrical energy generated was fed through a low voltage grid, 220 V, 50 Hz, to the consumer. The performance of PV system is influenced by insolation, air temperature, shading, inverter efficiency and sizing. In the present study we are focused more on inverter efficiency and sizing. Energy losses in the inverter used in our PV system depends in two factors main factors: input DC power and temperature of the air. Equations best describing relation between energy losses in inverter system and DC input power or temperature of the air are both power functions. We also proposed empirical formulae which consider influence of both factors as follows:***

$$Y=60.80X^{(-0.31)}-11.71Z^{(-0.81)}+0.59$$

Correlation coefficient is as high as R^2=0.92, F-factor 2825.7.

The proposed formulae can be of help when defining sizing of an inverter or calculating expected losses in inverter system.

Keywords—Solar energy, PV grid connected system, PV system efficiency, PV system performance.

I INTRODUCTION

Grid-connected photovoltaic systems are the main and most important technology for converting solar energy direct to electrical energy. Performance, quality and reliability issues are important for all applications of photovoltaic technologies, including grid connected systems. The efficiency of PV grid connected systems depends not only on the efficiency of PV modules itself and solar radiation potential of the site but also on a number of other factors related to installation, temperature, connection, inverter sizing, load etc. Distributed small PV systems installed in individual houses or on the top of the roof of buildings connected to the central grid is one of most promising applications. However, increasing rate of PV systems in the central grid, due to their inherent statistical and unpredictable characteristics, is followed with a number of stability and reliability problems, especially in area as high-density grid-connected PV systems. [1] Solution to these problems is strongly related, among others, to better knowledge performance indicators of individual systems. The energy produced by a grid-connected photovoltaic system depends on meteorological factors (irradiation, temperature, cloud coverage. etc), inverter characteristics and sizing, load and availability, etc. [2] In order to study how the aforementioned parameters influence the operation a roof top grid connected PV system, an experimental 4.68kWp grid-connected PV systems has been installed at the Polytechnic University of Tirana, on the roof of the building of Institute of Geosciences, Energy, Water and Environment. The PV system was monitored and analyzed for one year gathering information about working performance of components (PV array, grid connected inverter) and, also, in a more global perspective, system efficiency, electrical energy output, which helped to define some analytical relations helpful for predicting their future performance.

II SYSTEM DESCRIPTION

The PV system is composed by 24 polycrystalline silicon modules with total area of 29m², 12 modules connected in parallel with each other and both in series; each with open circuit voltage 44.8V DC and nominal power is 190Wp. The inverter used is a SG5K PV Grid-Connected Inverter: maximum power

4.68kWp, maximum PV voltage 780V DC and output voltage of 220V AC. Inverter converts 480V DC output of PV array to 220V AC voltages to connect to the grid supplying the building of the Institute. The modules were fixed on terrace of the building, with an inclination of 41° to the horizon and facing south. The terrace was approximately 5m from the ground. Meteorological parameters and input – output inverter data are recorded by the data acquisition system. In Table 1 are shown technical data SG5K PV Grid-Connected Inverter.

Inverter	Specification
Grid Voltage Range	180V-260V
Grid Frequency Range	47-51.5/57-61.5Hz
Maximum efficiency	94.5%
Euro. Efficiency	93.6%
Weight	58.84kg

***Table 1:** Data sheet of SG5K PV Grid-Connected Inverter*

III ENERGY LOSSES IN PV SYSTEM

The behavior of a particular solar module will depend not only of the material and technology used,

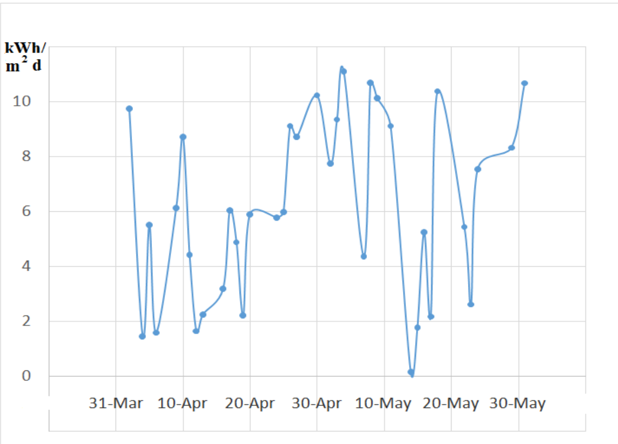

Fig. 1: The average daily solar density of energy in kWh/m^2/day generated by PV panel for period April - May 2012.

but also of the environmental work conditions like temperature, specific solar insolation, wind speed, air pollution, etc. These conditions have a direct influence in the in-situ behavior of the electrical parameters of modules manufactured with different technologies. Especially in the case of a PV system installed in a building situated within dense district of the city, as in our case, special attention was made to analyze and consider the influences coming from reflections and shades coming from surrounding buildings. The data were carefully inspected and were dismissed all of them that were altered by reflection or shading during morning hours and evening hours, respectively. The performance results of installed PV systems at the IGEWE had been monitored for several months during the year 2012 – 2013 to study operational characteristics of PV system and each component. Measurements of efficiency of PV system were made in half an hour basis. [3]

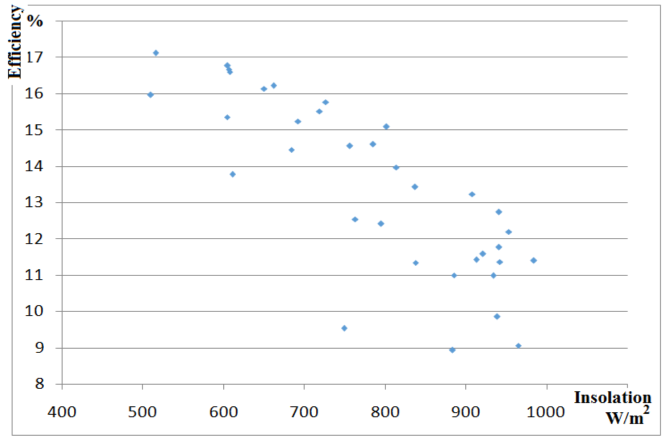

Fig. 2: Change of efficiency of PV module with solar insolation.

In Table 2 are shown more typical experimental results of solar insolation on 41 degree with horizon tilted surface of PV panel, average DC power generated by PV panel during half an hour period and loses of energy in inverter.

In figure 1 is shown a typical daily density of solar energy (kWh/m^2/day) falling on unit area of PV array during a specific period April- May 2012.[4] In Figure 2 is shown the variation of conversion efficiency of PV module with solar insolation for the same period of time. As shown in Figure 2, the conversion efficiency of PV array varies with insolation on tilted surface from around 10% for highest value of insolation (around 1000W/m^2) to around 17% for low insolation (around 500W/m^2) due to nonlinear I–V characteristics of PV array. Decrease of PV efficiency with increase of insolation is related more to influence increase of temperature of module due to absorbed increase of solar energy air temperature. [5, 6]

Solar radiation Gβ (W/m²)	Average power DC (W)	Losses in inverter %	Solar radiation Gβ (W/m²)	Average power DC (W)	Losses in inverter %	Solar radiation Gβ (W/m²)	Average power DC (W)	Losses in inverter %
801.51	3267.6	5.07	527	1385.74	6.83	938.88	2499.85	5.30
984.25	3080.38	2.27	411.07	677.45	7.69	933.67	2769.79	4.59
942.16	2892.65	1.38	61.14	82.56	17.37	884.88	2628.19	5.43
134.54	258.21	9.81	34.13	22.65	17.35	748.89	1926.42	6.45
342.44	842.84	7.63	964.72	2860.13	4.00	519.49	2222.23	3.97
637.99	1956.08	5.97	920.64	2880.14	5.60	610.57	2689.66	5.32
534.01	1549.29	6.73	649.98	2834.08	4.17	704.42	2699.02	3.33
125.39	218.31	11.28	762.67	2585.23	4.98	779.59	2821.65	3.58
161.67	356.86	9.45	661.52	2897.39	4.91	12.56	2.42	41.74
530.47	1148.93	7.17	726.57	3096	5.99	12.57	7.71	37.09
572.5	1425.54	6.76	785.08	3096	5.99	129.03	587.95	7.70
766.77	814.62	7.59	837.65	2566.51	5.19	191.63	585.84	7.31
599.71	1113.32	6.76	883.61	2131.36	5.12	147.09	459.22	8.86
184.61	352.22	8.89	909.1	1456.5	6.89	221.02	741.58	7.24
145.32	307.73	9.87	510	2200.81	3.69	285.88	731.36	7.91
272.37	725.78	7.31	607.4	2723.37	6.70	496.57	1112.33	7.12
259.78	652.35	7.49	604.18	2506.11	5.26	563.2	1774.39	5.84
231.37	601.22	13.42	683.83	2670.61	5.17	111.56	531.84	8.41
107.05	296.92	9.99	837.15	3035.61	5.93	182.07	573.28	8.08
95.06	238.39	11.78	722.37	2588.81	4.03	824.48	2012.02	4.88
296	254.83	10.36	777.15	2941.71	6.49	737.12	1755.95	6.51
345.75	591.37	8.42	864.37	3173.39	5.91	47.35	121.76	14.94
170.5	448.71	9.20	907.45	3244.04	4.87	748.69	1815.76	6.52
370.5	2520.29	4.50	940.89	3239.31	5.75	124.12	674.87	7.60
301.9	3042.89	5.15	952.76	3138.51	5.67	221.29	912.94	7.38
807.74	1748.07	6.39	940.84	2992.59	4.52	167.52	438.36	8.33
585.24	1121.96	7.00	912.75	2815.91	5.08	192.15	843.93	7.36
133.4	476.66	7.73	170.82	422.12	8.95	238.11	912.54	7.60
199.97	610.84	7.65	154.77	537.08	7.86	444.4	2236.32	5.14
303.8	902.04	7.08	580.02	1766.21	5.29	888.23	3287.07	6.26
420.67	1500.54	6.85	452.01	1549.68	6.37	433.87	1592.97	5.94
610.78	2272.21	4.26	606.56	2731.1	5.60	782.53	1240.28	6.74
794.94	2665.72	5.34	718.41	3010.25	5.72	681.66	1381.5	6.36
197.58	505.52	8.47	1006.25	1395.24	6.61	511.84	1381.5	6.36
181.2	405.8	9.41	934.56	850.24	7.26	692.05	2849.68	6.27
480.1	1196.96	7.06	515.73	2384.32	4.51	756.22	2973.07	4.84
524.45	2299.56	4.33	604.66	2740.26	4.87	813.51	3071.66	6.54
62.04	318.41	8.58	93.63	328.21	8.93	165.42	407.22	8.67

Table 2: *Typical experimental results of solar insolation **Gβ** on 41 degree with horizon tilted surface of PV panel, average DC power generated by PV panel during half an hour period and loses of energy in inverter.*

Another important source of losses of energy in PV system connected to the grid is system converting DC voltage supplied by PV panel to AC voltage suitable for

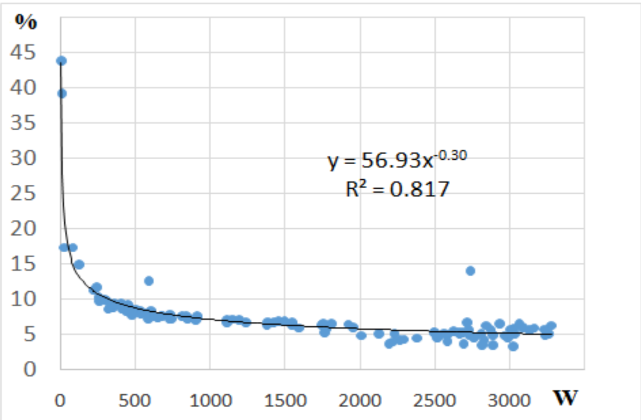

Fig. 3: Losses of energy in during inverting DC input energy to AC output energy supplied to the grid.

the grid, it is, inverter and connecting wires. These losses result to be neither constant nor linearly dependent to the charge. Therefore, to correctly asses the efficiency of a PV system connected to the grid a detailed investigation of losses of energy in inverting system was necessary. In Figure 3 are shown losses of energy in during inverting DC input energy to AC output energy supplied to the grid. The measured data are best approximated with a power function of the form:

$$Y=56.93X^{-0.30}$$

Where: Y stands for losses in inverter and in percent of input DC power and X stands for DC input power in watt. Correlation coefficient is $R^2=0.817$. Fast increase of losses for DC power supply under 500W is an indicator of importance of optimal sizing of inverter with power of PV panel.

However sizing of inverter is not the only factor influencing the losses in inverter even it remains the principal one. Air or inverter temperature is another factor. In Figure 4 is shown the change of losses in inverter system with temperature of the air. The data again are best approximated with a power function, even the correlation coefficient is as low as R^2=0.216. In this case the power function is:

$$Y=73.49Z^{-0.81}$$

Where: Y again stands for losses in inverter and in percent of input DC power and Z stands for temperature of the air in degree centigrade. To take in account influence of both factors on energy losses in inverter system we developed empirical formulae as following:

$$Y=60.80X^{(-0.31)})-11.71Z^{(-0.81)}+0.59$$

Correlation coefficient is as high as R^2=0.92, F-factor is 2825.7.

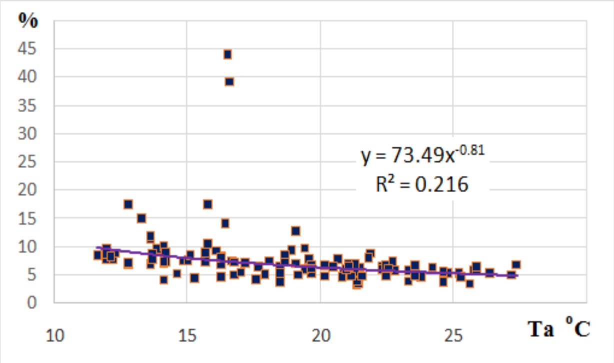

Fig. 4: Dependence of power losses in inverter from temperature of surrounding air.

The proposed formulae can be of help when defining sizing of an inverter or calculating expected losses in inverter system.

IV Conclusion

In our study we presented and analyzed first results coming from monitoring of the first grid connected PV system in Albania, an array composed by two sets of 12 panels of poly crystalline silicon modules connected in parallel, each with open circuit voltage 44.8V DC and installed power is 190Wp, installed on the roof of IGEWE. The system was monitored for one year. Electrical energy generated was fed through a low voltage grid, 220V, 50Hz, to the consumer. Monthly, daily and annual performance parameters of the PV system are evaluated which include: energy generated, system efficiency, inverter efficiency and array efficiency. In the present study we are focused more on inverter efficiency and sizing. Energy losses in the inverter used in our PV system depends in two factors main factors: input DC power and temperature of the air. Equations best describing relation between energy losses in inverter system and DC input power or temperature of the air are both power functions. We also proposed empirical formulae which consider influence of both factors as follows:

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