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Yield and Performance Study of a 1MWp Grid Connected Photovoltaic System in Bulgaria

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Abstract

In this study is suggested a statistical approach for evaluation of the solar radiation of a 1MWp grid connected photovoltaic system. The initial data is acquired with the help of specialized software and a measuring system. The statistical evaluations of the measured values ensure optimal design and high effectiveness of the energy systems, based on PV modules. With the help of modern technical tools is created a representative statistical database. Data for typical weather seasons was processed and analysed using specialized software for statistical estimations. As a result the numerical values of the parameters influencing the production of electricity were received. For greater clarity the results are visualized. The created models allow solving various problems associated with forecasting of electric loads. These results can also find application in the construction of smart grid systems.

Keywords: photovoltaic, solar radiation, generated electricity, statistical analysis.

1. Introduction

The potential of solar radiation on the territory of Bulgaria is considerable but there are significant differences in the intensity of solar radiation in different regions [1]. The yearly sum of the global solar irradiation varies between 1350 and 1750kWh/m^2. With an average duration of sunshine per year around 2150h [2] the yearly electricity production of an installed kWp with performance ratio of 0.75 varies from 1013 to 1313 kWh. These data are evidence that the country has the prerequisites for the construction of photovoltaic plants. In support of that, the Bulgarian government has adopted number regulations consistent with those of the European Union in the area, supporting the development and the usage of renewable energy sources (RES) [3, 4, 5].

These measures give a new boost to energy security in Europe and support the European strategy "20-20-20." The widespread use of renewables and the introduction of energy efficiency measures are among the priorities in our country's energy policy and correspond to the objectives in the new Energy policy for Europe [5, 6].

It is estimated that produced electricity from a photovoltaic system (PVS) depends on many factors such as levels of solar irradiation, part of the day, the temperature of the PV modules, shading from nearby sites and objects, the angle at which sunlight is falling on the photovoltaic panel, photovoltaic material, pollution of the surface of panels, used switch gear and more. Therefore when designing a photovoltaic plant is important to be able to foresee the impact of various factors on the energy produced [7, 8, 9, 10, 11].

The purpose of this paper is using electricity generation to assess the impact of key factors on electricity generated from an operational grid connected PVS.

2. Material and method

2.1. Description of the photovoltaic system

The work of three phase photovoltaic system have been studiedwith top power of 1,25MWp(Figure 1) [12]. It's made out of inverters / transformer module with two GT500E inverters. Photovoltaic modules have been connected in string to 18 array boxes. In which have been installed measuring modules. The generated DC energies converted to AC with the help of two powerful three phase Xantrex GT500 E 500 inverters.

The input of1is connected in parallel with 9 array boxes and inverter 2 is connected with the rest of the photovoltaic modules.

The outputs of the two inverters are connected to the primary coil in Y configuration of the power three phase transformer. The secondary coil is connected in "delta" configuration.This way the third harmonic is filtrated, generated by the impulse of the output of the inverters. [13]

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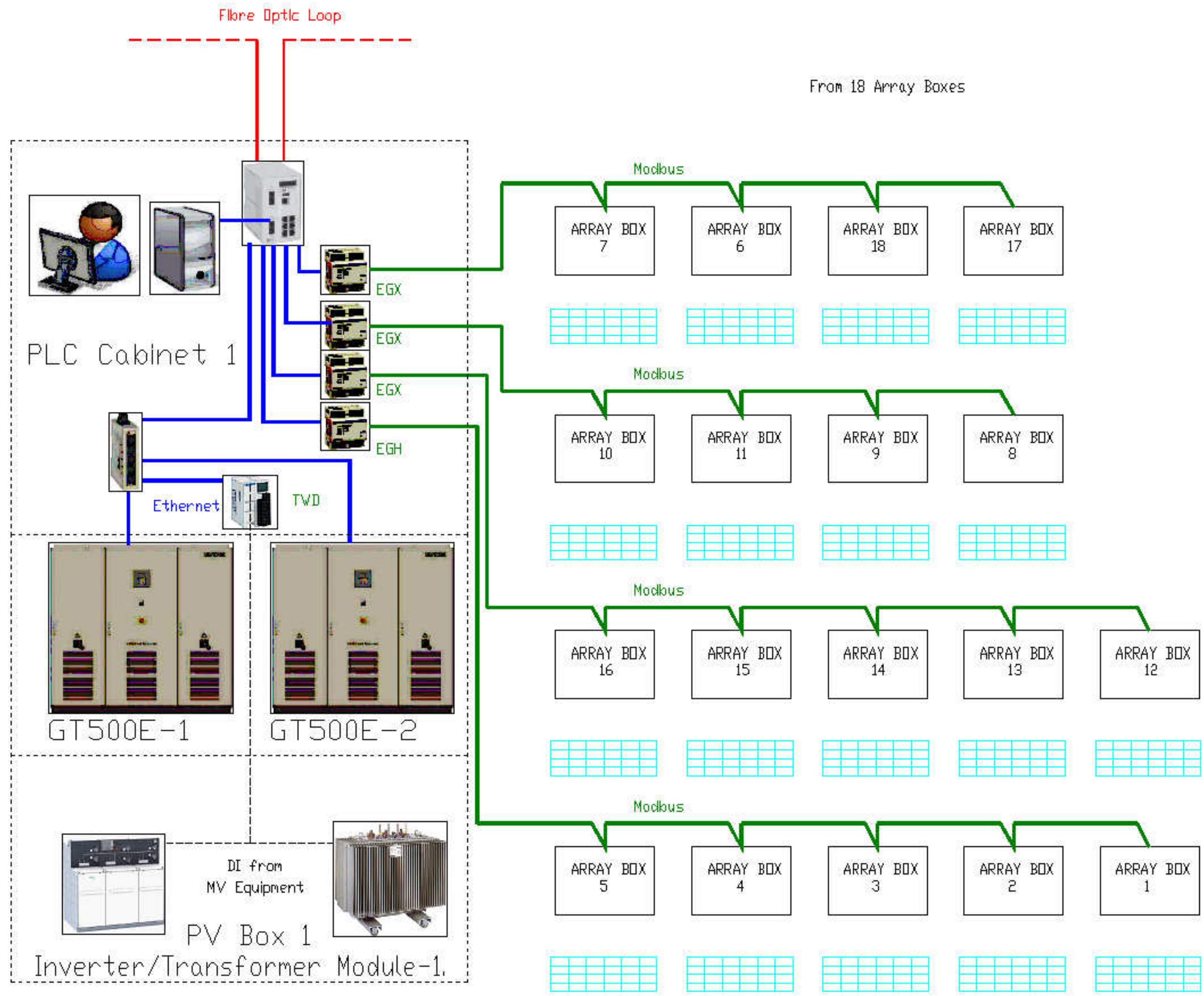

Fig. 1. Architecture of photovoltaic system.

Architecture of Figure 2gives us an idea about the installation and the area that the photovoltaic needs so it could be constructed.

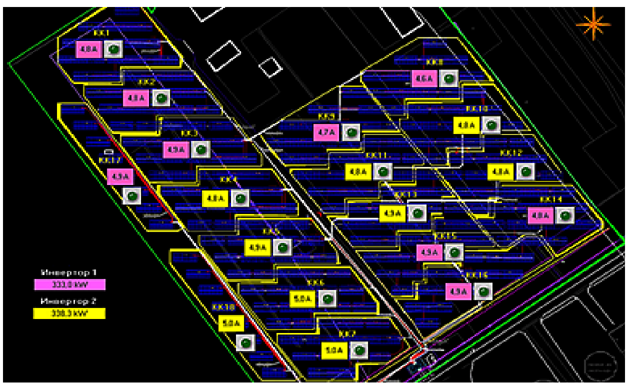

Fig. 2. Location of PV modules.

Photovoltaic system consists of 2232 photovoltaic modules type GES-P280, placed in area4062,24m^2.

2.2. Methodologyand equipment

The measurements are recorded in different points. In the collector boxes are placed different modules type Carlo Gavazzi [14]:

- VMU-S module for measuring the current and the voltage in every string;
- VMU-P temperature measuring module;
- Module for solar radiation measuring with mounted plane sensor –1 in every 2 inverter stations;
- VMU-M module for communication between different devices RS485.

In every inverter station there are two collectors for acquisition the data of the array boxes; form inverters GT500E; for the status of the electrical furnishing; for any emergency situations and etc. exploitation indicators.

The server of the photovoltaic system collects and processes the data received from inverter stations, manages the archives, shows information to the operator through different interfaces-screens, references, WEB access and others, sends notifications and messages about the condition of the system.

In the preliminary studies it was found that the greatest impact on productivity of a PVS have the solar radiation (G) and the temperature of the panels[2, 15]. This temperature in turn depends mainly on the ambient temperature (T) and wind speed.

In this context, it is necessary to identify appropriately the statistical indicators needed to make the necessary analysis.

For this purpose the coefficients of the shape K_S and the loadK_L, can be used:

$$K_S = \frac{E_{MS}}{\bar{E}}; \qquad K_L = \frac{\bar{E}}{E_{max}}, \qquad (1)$$

where

$E_{MS} = \sqrt{\frac{E_1^2\Delta T_1 + E_2^2\Delta T_2 + \cdots E_n^2\Delta T_n}{\sum_1^n \Delta T_i}}$ is the mean square of the electricity energy;

$\sum_1^n \Delta T_i$- the duration of the time interval;

$\bar{E}$- the mean value;

E_{max}- the maximum observed value.

The annual coefficient of the shape K_S is 1 if the electricity energy is constant through the period observed, i.e. it characterizes the irregularity of the process. For its better physical research corresponding monthly coefficients are suggested.

3. Results and discussion

The variables described above were measured to calculate the energy production of the photovoltaic system.

Figure 3 shows data about the surface of the modulesTemp1 and the surrounding temperatureTemp2.

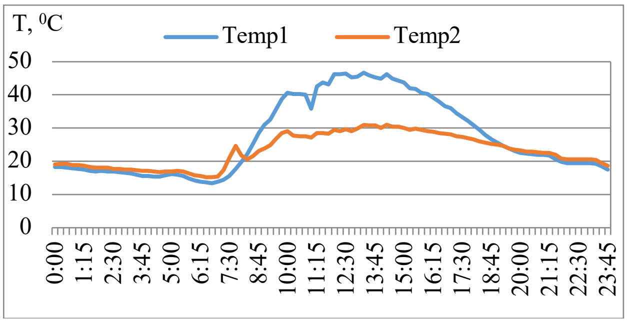

Fig. 3. The dependence between temperature of the surface of the modules Temp1and the surrounding temperature Temp2.

Figure4 shows the amendment of the generated current from the photovoltaics' strings.

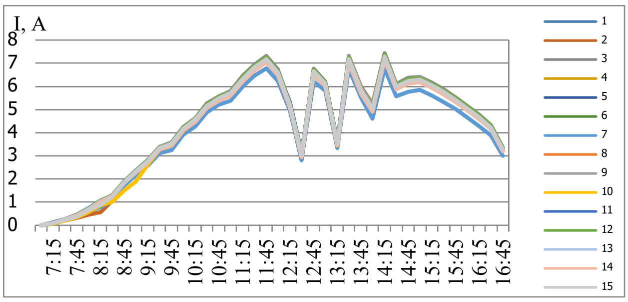

Fig. 4. Characteristic levels of the current form the photovoltaic' strings in array boxes 1.

We are viewing the amplitudes with huge widen of current in the periods where there are shadows overshadowing the photovoltaic module. This is prerequisite for the inverters idle running and generating higher harmonics[16, 17].

Figure 5 shows the characteristics of the different value of the current for 9 consecutive days.

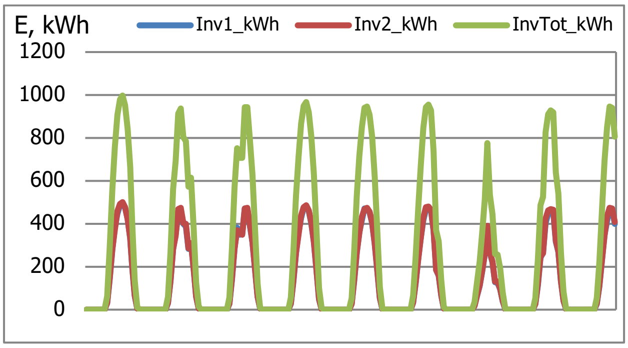

Fig. 5. Dynamics of the electrical energy generated from PVS

The value of the energy produced from the two inverters is pretty much the same(their diagrams are the same),it reaches up to 480 kWh. The total electrical energy has maximal value of 997kWh.

For the study are used the average daily values of input variables and for the output value – the total electricity output for the day. The experimental data were processed by means of the computer program STATISTICA.

The determination of the value coefficient K_S and $K_L$is based onaverage value by months (seeFigure 6 and Figure 7).

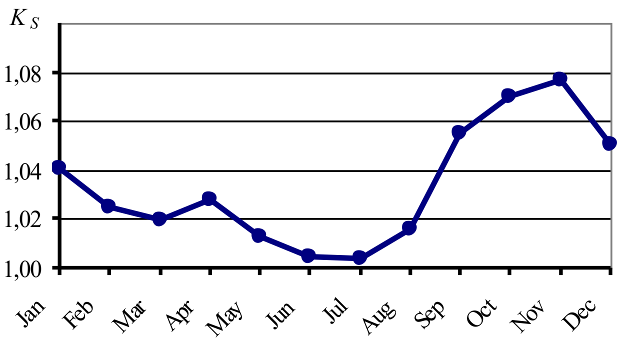

Fig. 6. Dynamics of $K_S$through different months.

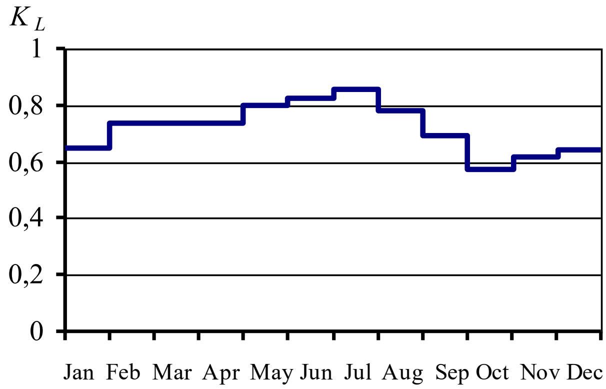

Fig. 7. Dynamics of K_L through different months.

The closer *Ks* is to 1 the deviation in the sun radiation levels is smaller in the average year value. The smallest deviationshave been seen during the summer seasons and the biggest deviations are during the winter seasons. The explanation is the high levels of sun radiation during the summer seasons.

Thecoefficientofload K_L gives us access to different technical-economic tasks during the design of the PV system. This coefficient suggests the maximal monthly value of E(t) by calculating. By means of this calculation method of the coefficient we can get data of how much is mathematical expectation given value (E) is getting closer to its maximal. The value of K_L is changing between 0 and 1.The bigger K_L is (the closer to 1) the bigger is the possibility to achieve maximal power.

With the help ofK_L we can determinate maximal duration of usage T_{max} in days by specific length of time by the formula:

$$T_{max} = K_L N, \quad (2)$$

where N is the duration of the period (in days).

In Table 1 the values of T_{max} for different monthsare presented.

Table 1. Value of$K_L$for different months.

Month	Jan	Feb	Mar	Apr	May	Jun
K_L	0.65	0.74	0.74	0.74	0.80	0.82
N, days	31	28	31	30	31	30
T_{max}, *days*	20.1	20.6	22.8	22.2	24.7	24.6
Month	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
K_L	0.86	0.78	0.69	0.57	0.61	0.64
N, days	31	31	30	31	30	31
T_{max}, *days*	26.6	24.2	20.7	17.8	18.4	19.9

The biggest duration in usage, we achieve of photovoltaic usage in May, June, July and August For example: Trough July photovoltaic system can be used for the period of 26.6 days.

The yearly coefficient of load$K_L$for the observed period is 0,72.For 365 days for a year the max usage of the photovoltaic T_{max} = 262,8 days.

6. Conclusions

The study of the high power photovoltaic system shows that the main influence on the generated electrical energy is caused by the levels of the sun radiation and the temperature of the photovoltaic modules.

The maximal usage of photovoltaic system by months has been determinated.The biggest duration of usage is in July 26.6 days and for a year is 262.8 days.

These data can be used in the design of installations using solar energy.

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