PV effectiveness under natural conditions

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Abstract. Based on previous studies, the main factors which influence photovoltaic module under natural conditions were determined, In terms of hardware factors created the monitoring system prototype of photovoltaic module electrical parameters. Next, the system was upgraded and expanded by taking into account the meteorological data. The operating system results were available on the internet and presented in the article. The data analysed the efficiency of photovoltaic modules in Tomsk based on operating results of the monitoring system prototype. Finally, a conclusion was made about application efficiency of photovoltaic modules.

1. Introduction

The main factor limiting the widespread use of solar energy in practice is the cost of energy systems based on of alternative energy systems. Modern development of solar techniques can be used photovoltaic modules (PV) at latitudes previously considered unsuitable for this type of renewable energy.

The factors which may impact the work of PV were analyzed in previous papers [1, 2]. All factors affecting PV systems in natural conditions can be divided into two groups:

- Hardware factors which depend on the construction of the PV module and solar elements, and the technology of their implementation, specific arrangement of PV modules on buildings and structures (architectural factors), and PV module distribution and degradation characteristics (short-circuit current, performance coefficient and temperature coefficient of idling).
- Climatic factors which depend on different climatic parameters affecting the output energy characteristics of solar batteries (solar radiation, air temperature, humidity, wind speed, and aerosol concentration).

To determine of the PV effectiveness in Tomsk was a system of control of the solar module with the influence of climatic parameters. Main characteristic, which describe the PV work under natural conditions and during the operation, is the current-voltage characteristic.

To study the influence of factors on operating photovoltaic module and determine its effectiveness developed the electronic load, which allows measuring the current-voltage characteristics of PV.

The characteristics of PV are determined based on the measured current-voltage characteristic: performance coefficient, short circuit current and open circuit voltage.

2. The measuring of current-voltage characteristic with electron load

Figure1 shows a diagram of current-voltage characteristic measuring via electron load. The main element of a current-voltage characteristic measurement is electronic load. Electronic load changes its resistance under the influence of the signal from the DAC. The voltage of electron load is determined by the ADC. The operating principle of the electronic load is based on the change in resistance of the field effect transistor gate [2].

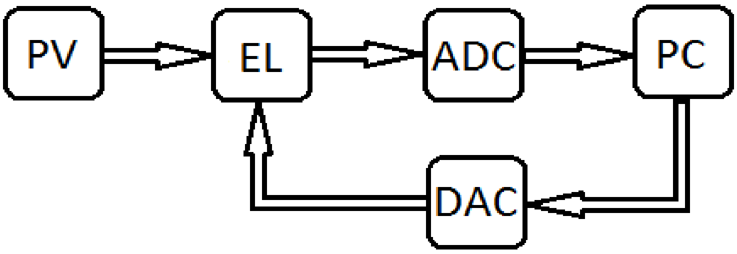

Figure 1. Scheme of measuring with electron load, PV – photovoltaic module, El – electron load, ADC – analog-digital converter, DAC – digital-analog converter, PC – personal computer.

The similar scheme implementation is not possible to measure current-voltage characteristic in low light. The number of points in the current-voltage characteristics of solar radiation at 200 W/m^2 is 2-3 points.

3. The modification measuring of current-voltage

In order to be able to measure the current-voltage characteristic in low light, has been modified the measuring scheme of current-voltage characteristic on the basis of a multi-valued measure of resistance. Multi-valued measure of resistance is controlled the computer and microcontroller (Figure 2). The number of dimensions is reaches 30, thus increasing the accuracy of measurement. [2]

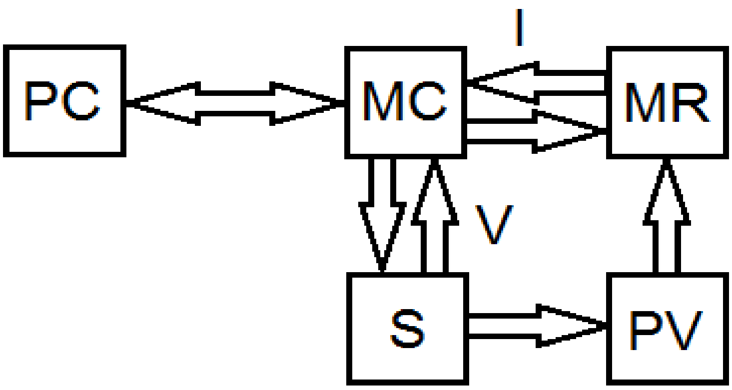

Figure 2. Modification scheme of measuring with electron load, PC – personal computer, MC – microcontroller, MR – multi-valued measure of resistance, S – switch, PV – photovoltaic module.

At startup program signal is sent to a microcontroller that provides a control signal to the switch, which connect the load. The load is a multi-valued measure of resistance from 1 Ohm to 8 Ohm that allows to measure current-voltage characteristic with high accuracy and to determine the operating point.

The time period between measurements of current-voltage characteristic of the PV modules is one of the parameters of the program. During its automatic operation the electron load resistance gradual changes from 0.1 Ohm with the simultaneous current and voltage control. Measuring stops at the moment when the PV module current approaches zero. After this the electron load is switched off and open circuit voltage is measured. Afterwards the system is in the waiting mode.

The computer contains specific software which controls the electron loading, receives and stores measurement results. The program has created in LabVIEW. The window of the program is shown in Figure 3.

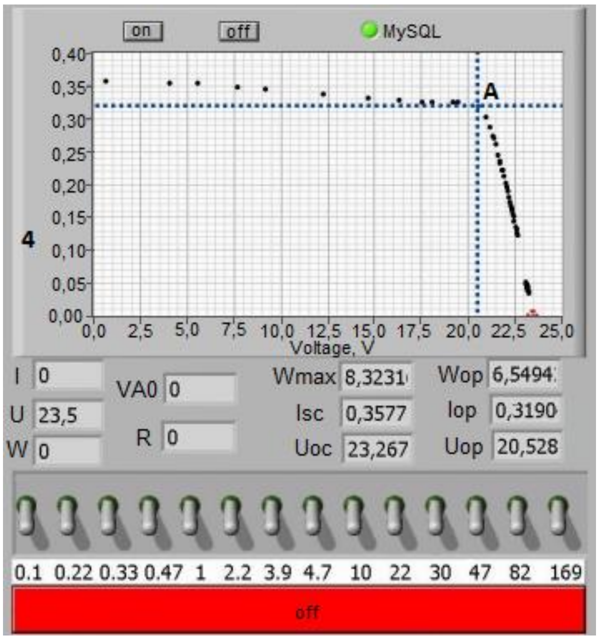

Figure 3. The window of the software.

In the lower left corner of the program window represented 14 switches that allow measurement by hand, that gives the chance most accurately evaluate the performance of PV [2].

To implement a full research combined current-voltage characteristic measuring station with climatic parameters sensors.

4. Station of on-line monitoring

The control system of PV allows to measure the current-voltage characteristic of PV, determine its parameters and to measure the main parameters of climate (temperature, pressure and humidity, the amount of incoming solar radiation), the surface temperature of the PV. This enables to determine the efficiency of the PV under different weather conditions.

Described station is set on the roof of the Institute of Atmospheric Optics in Tomsk and is connected to the PV (25 W), that is installed at an angle of 54˚ to the horizon to the south. [2, 3]

Measurements of current-voltage characteristics and climatic parameters are carried out once with an interval of time; recorded voltage characteristic photovoltaic module, the temperature, the air temperature, the operating point is calculated. As a result, one cycle for each parameter is collected one-dimensional array, which consists of 30 elements. Next the array is averaged. The result is stored in the data file. Moreover, the measurement results, where the short circuit current less than 0.1 A are not retained [3].

4.1. Database

As a result of the tests was collected database consisting of 20 000 entries. The following table shows structure of the database.

Table 1. Database structure

Field	Measurement units	Description
Date time	DD.MM.YYYY hh:mm:ss.	Date and time
Open-circuit voltage	V	Open-circuit voltage
Operating voltage	V	operating Voltage
Short-circuit current	A	Short-circuit current
Operating current	A	Operating current
Temperature	˚C	Air temperature
Humidity	%	Humidity
Total solar radiation	W/m2	The total solar radiation
Wind speed	m/s	Wind speed
A	Grad	Azimuth of the sun
H	grad	Declination of the sun
Pressure	mm Hg	Air pressure

4.2. On-line resource

The measurement data are automatically recorded and are shown on the site *lop.iao.ru* in January 2011 (Figure 4 and 5).

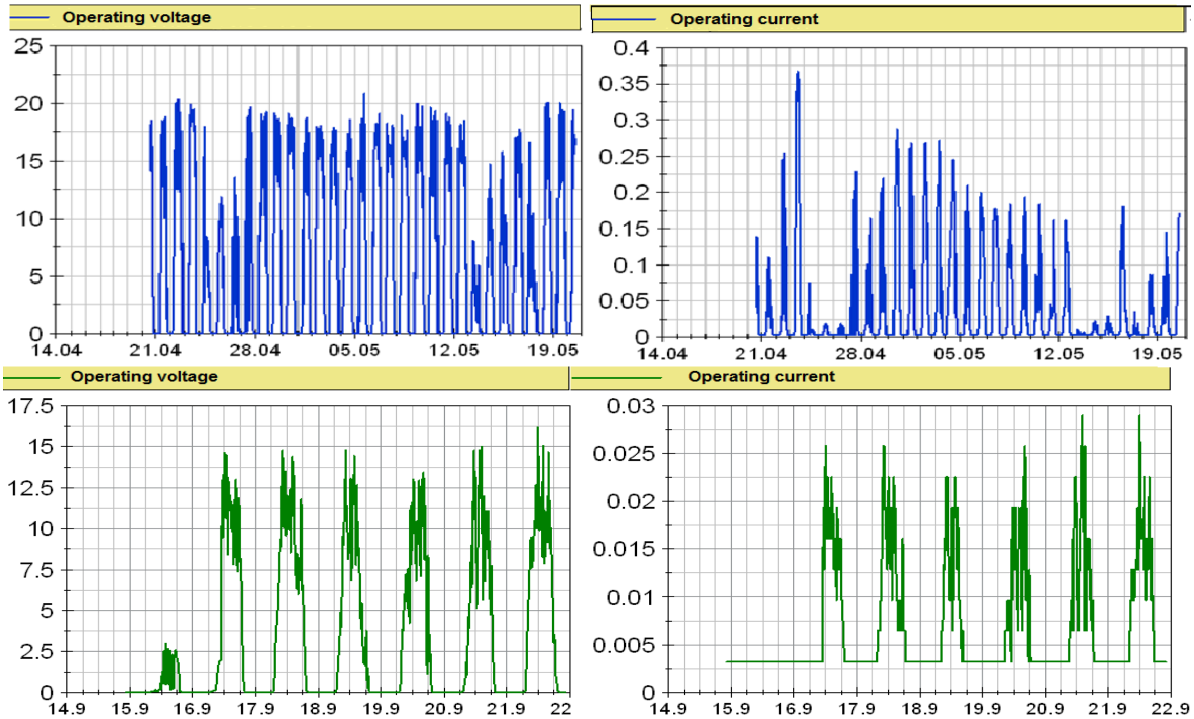

Figure 4. On-line measures.

"Solar Eye" shows incoming solar radiation throughout the year by month and hours. According to this schedule is possible to tell about the duration of sunshine during the day.

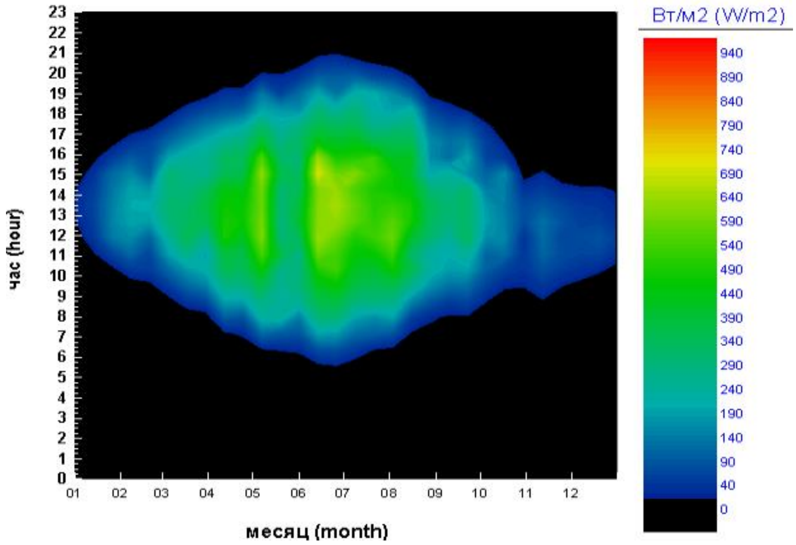

Figure 5. "Solar Eye" in 2014.

5. Effectiveness of PV module

Based on previous data, we calculated the efficiency of the solar module during the year [2]. Efficiency was calculated as the ratio of the PV module average power generated during the day to coming in for a day of solar radiation on the surface of the PV module [5]. The results are shown in Figure 6.

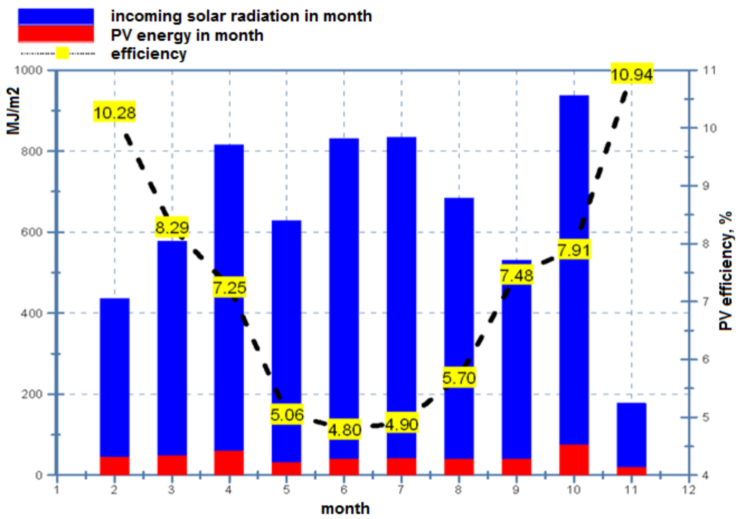

Figure 6. Effectiveness of PV module.

Figure 6 shows that the effectiveness of PV module varies greatly in different months. The maximum value is achieved in the winter months; this is due to a high proportion of reflected light from the snow in the winter, as well as due to the low angle of declination of the sun, and light falls on the solar module throughout the day. In the summer months the efficiency a PV module is significantly reduced due to the fact that the sun in the morning and evening is the surface of a PV module due to high seasonal angle.

On average the efficiency is about 6%, which is about half the maximum possible efficiency for a used the PV module (η_{PV} = 13.8%, the efficiency is a parameter specified by the manufacturer in the passport on the basis of laboratory tests PV module). Efficiency can be increased by using more modern modules, tracking or combined systems.

The calculated values of PV power during the year compared with the results obtained on the basis of a fifteen-year analysis of the PV in Siberia (Figure 7) [2, 3].

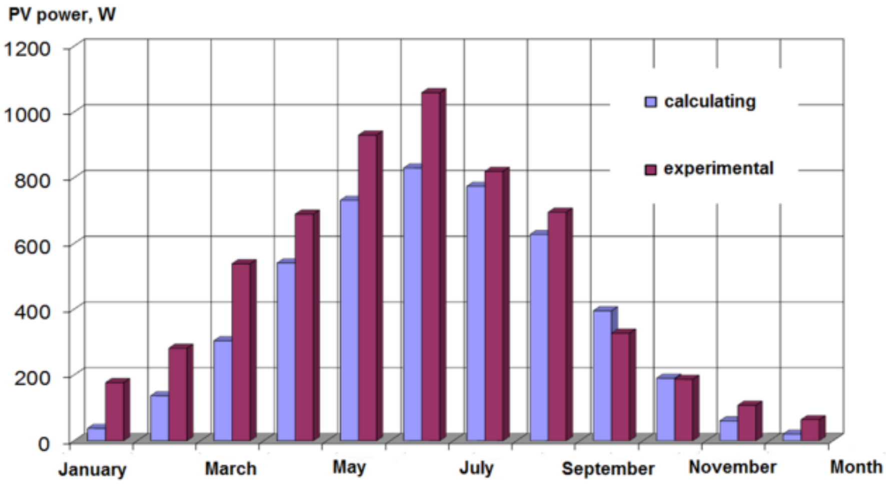

Figure 7. The PV power for a year.

As seen in Figure 7 changes the power dynamics of the PV during the year is the same. The experimental values are higher than the theoretical, which is due to the fact that the average annual solar radiation in the year under review was above average. Also influenced by the background and scattered radiation. In the winter months is a big difference due to the presence of the reflected light from the snow, which is also not taken into account in the calculations.

6. Conclusion

- The online-monitoring system of PV module operating has been designed (http://lop.iao.ru/activity/?id=sb). The system consists of a PV module, personal or portable computer and electron load. The computer contains specific software which controls the electron loading, receives and stores measurement results.
- The efficiency of the PV in Tomsk has been determined, that allows draw a conclusion on the effectiveness of solar systems on the territory of Tomsk and Siberia.

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References

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