

To study the influence of snow cover on the power generated by photovoltaic modules

R V Meyta¹, F V Savrasov²

¹ Postgraduate student, Tomsk Polytechnic University, Tomsk, Russia

² Senior tutor, PhD, Tomsk Polytechnic University, Tomsk, Russia

E-mail: savrasov@tpu.ru

Abstract. The possibility of increasing the power generation of PV modules due to radiation reflected from the snow is investigated. An experiment has been held to determine the value of the current generated by PV-modules on account of the underlying snow surface. Also the experiment has been held to determine the influence of the PV-module's location due the snow surface on the performance of solar cells.

1. Introduction

The area of using micro-devices for different purposes is expanding rapidly. However, many electronic devices are not integral parts of a hardware system, but autonomous systems that operate without direct human intervention. Accordingly, there is the problem of providing a continuous and stable power supply of these devices. Currently becoming more common for energy autonomous systems to get power supply from renewable energy sources, among which the most promising (because of its availability) is a photovoltaic modules [1, 2].

Despite the popularity of this type of energy in other countries, in Russia it is still a very limited kind of distribution. At the same time, using of this in some Russian regions is highly advisable due to climatic features a number of subjects of the Russian Federation. This feature is associated with the periodic occurrence of snow cover, which, under certain conditions, can be a natural concentrator of the solar energy that can be used for photo-conversion (for comparison – in countries with hot climates concentrators are made artificially; this fact causes a significant increase of the photovoltaic installation's cost).

Snow cover – a layer of snow on the surface of the earth, formed as a result of snowfall and blizzards. Snow cover has a low density, increasing over time, especially in the spring. Reflectivity (albedo) of fresh snow up to 90% of the value of incident light flux depending on the angle of incidence (for comparison, the albedo of dark soil is about 10%). The reflectivity of the melting snow is not more than 40% [3]. Most parts of the Russian are covered by snow during 4-5 months in the year, and in the northern regions – 8-9 months. The average duration of snow cover in Tomsk, where research was provided, is more than 6 months. It appears mainly in the beginning of October, and begins to defrost in the middle of March.

Accordingly, using PV-converters in the places of possible snow occurrence, it seems interesting to measure the influence of snow cover to the performance of a single photovoltaic module, and as a result, the performance of the photovoltaic system. Studies devoted to the investigation of this effect were considered, particularly, in [4, 5]; in this cases, the results of these studies provide information over a long period, and for a set of combined photovoltaic modules (PV-power stations).



As is known, the energy generated by PV modules, depends on the intensity of solar radiation and the angle of the receiving surface's module orientation relatively to the sun. In turn, the efficiency of the module is simultaneously influenced by both the direct rays, and the light reflected from the underlying surface and diffused in the surrounding atmosphere [3].

In addition to transparency and clouds, a great influence on the diffused radiation has the nature of the underlying surface. As the reflectivity of the underlying surface is increasing, the flux of scattered radiation is greatly increasing too. In the presence of snow cover reflection of direct solar radiation increases, and its secondary scattering in the atmosphere leads to an increase of the diffused radiation.

2. Practical experiments

2.1. Basic study of the effects of radiation reflected from the snow

To determine the quality influence of the snow cover's reflectivity on the power value generated by the PV module, the special mechanical system of sun tracking IGS-1 was developed and used (figure 1). It allows to place on a special rod small-sized photovoltaic module as the sensing element. The measure element of the standard pyranometer M-80 used as standard model.



Figure 1. Experimental system for tracking the sun.

Mechanical system allows rotating module in a horizontal plane from 0° to 360° and vertical plane from 0° to 90° , with the possibility of placing the receiving surface of the PV converters in parallel down the underlying surface.

The experiment consisted of 2 parts. During the first, IGS-1 was set to open unshaded horizontal surface with a clean and uniform snow on the black cloth to remove the effects of reflected sunlight on the measuring module (figure 1). During the second, IGS-1 was located directly on the snow.

The measuring of generated current was provided February 8, 2013, from 10:00 to 16:00 (on the Tomsk time) with a digital multi-meter M-832P. The reception surface of the module was located at the angle to the underlying surface equal to the latitude of the area (about 56°), and was oriented to the south.

As the experimental unit, photovoltaic module FSM-2-6 (rated power – 2 W, open circuit voltage 6 V, short-circuit current 0.5 A, dimensions 230×145×4 mm) made of monocrystalline silicon, standard produced by JSC ‘NIIPP’, was selected.

The venue of the experiment was chosen flat area close to the riverside Tom. Over the entire period of observation the sun was not eclipsed by clouds and near buildings and trees. The average ambient temperature during the period of observation was -18 °C.

During the measurements, it was observed that the PV module’s voltage varies slightly depending on the sunlight. The results of measuring the current produced by the modules shown in figure 2.

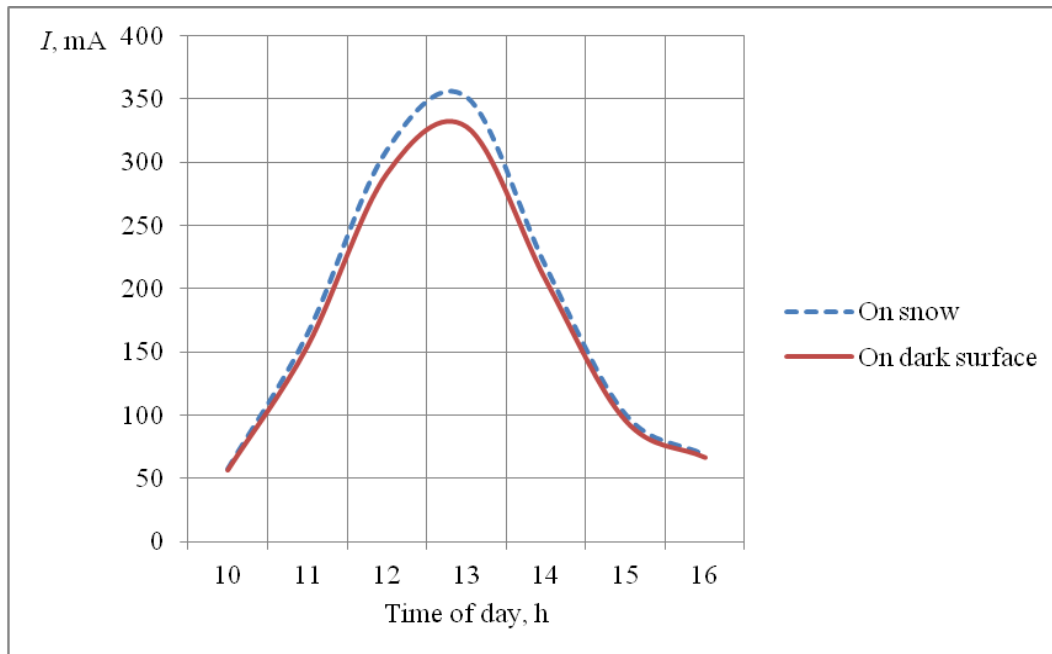


Figure 2. The measurement results of IGS-1 current depending on the type of the underlying surface.

From these data it follows that photovoltaic module, disposed directly onto the snow, produces more energy than onto black cloth (to 7.3%). It should be noted the fact that at different illumination of photovoltaic module depending on the time of day (and, therefore, the position of the sun in the sky), there is a difference in the generated current values. Thus, the lighting the module disposed at angle in which the reflected insolation has less effect on PV modules, there is a decrease in the effectiveness of the current generation.

Total (all day) value of the current generated by the arrangement of photovoltaic module on the snow, exceeds the value of the module generated on a black canvas is greater than 6%. Accordingly, it is assumed that with the presence of stable snow cover with high albedo in a shorter duration of daylight of the year (for example, in December and January), the resulting value will be less, and in the longer (March) – more.

Thus, the experiment shows that the reflected radiation from the snow affects the current produced by the PV converter in the direction of its increase. Therefore, it makes sense to install PV modules, which are an integral part of the power supply devices, in the places with a high albedo (for example, on the roof, painted in bright colors, the roof of galvanized iron, etc.), or on the surface where snow cover is located within significant part of the year.

2.2. Determination of the current's quantify generated due to the different reflective surfaces

In order to identify the potential value of the amount of current generated by radiation reflected from the snow, the corresponding experiment was also provided. During this experiment, the solar module

located in a plane parallel to the sun rays (PV converter's surface was pointing down), towards the sun, with a 2 sides the construction was protected with plywood plates, painted black, to minimize the impact of peripheral reflected and diffused solar radiation, as well as to remove the effects of direct radiation (figure 3). Generated current was measured for various types of underlying surface (snow or a fragment of black cloth, I_S and I_C , respectively).

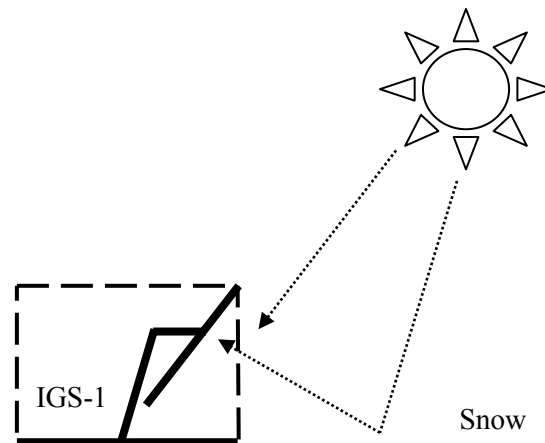


Figure 3. Experiment to determine the magnitude of the current generated due to the reflected radiation.

Also simultaneously current I_H measured; it produced by module located on the horizontal top surface (PV module's surface was pointing up – for a given location the exposure of reflected from the underlying surface radiation does not occur to the converters). There were measured two current's values: I_{H1} – for the case when the surface of the module was not covered with snow, and I_{H2} – for the case when the surface of the module was artificially caused snow layer thickness of 2 cm. The latter value was measured to determine the possibility of developing electricity by PV unit in the event of its bloom of snow cover (for example, in the case of snowfall or snowstorm).

For this experiment the photovoltaic module FSM-2-6 also was used. Readings were taken with a multi-meter M-832P. The experiment had been occurred for 3 days, at one and the same time (13:00). Selection of observation's dates was made in such a way as to make measurements at various cloudiness and atmospheric aerosol component saturation (low clouds, haze or fog, heavy cloudiness). The measurement results are presented in table 1.

Table 1. Determination of the amount of current generated due to the reflected radiation

Date of measurements	Air temperature (°C)	Cloudiness	I_{H1} (mA)	I_{H2} (mA)	I_S (mA)	I_C (mA)
07.03.13	-10	overcast	124	75	35	15
12.03.13	-8	clear	311	272	199	52
13.03.13	-5	haze	146	97	56	23

From the results for a horizontal-oriented module it allows that in times when the value of the direct solar radiation is small (foggy or cloudy day), the generated current's value less by 2-2.5 times than in the cloudless sky. The difference between produced values depending on the saturation of the atmosphere aerosols and clouds are not so significant (18% of the difference between the haze and strong cloudiness); that fact indicates a minor influence of the diffused radiation's nature on the silicon type, which the converters made of.

It also shows that only due the reflected from the surface radiation, PV panels are able to generate current; the difference depending on the intensity of insolation can be substantial (64% of the value of the current generated by the direct solar radiation, in clear weather, and 28-38% – in cloudy weather and fog, respectively). Depending on the degree of radiation's reflection, the current value also changes: when the reflected radiation is formed by a straight line, the presence of snow increases the value of 3.83 times in comparison with a dark surface; when the reflected radiation is formed by diffused, there is an increase of 2.3-2.4 times. The difference between the currents produced by the various types of surface in the case of a diffused light is 53-60%, depending on the nature of the diffuse solar radiation. It should be noted that, according to [6], the albedo of the snow surface in the overcast exceeds albedo in clear weather about 3-5%.

The presence of a thin snow layer on the surface of monocrystalline solar cells does not lead to a intensive decline in their performance. According to experiments, in clear weather performance module is 87% of the cases, when the surface is clean. In the presence in the air aerosols and cloudiness this value is 66 and 60%, respectively. These values are close enough to correspond to the results described in [7].

3. Conclusion

Summarizing the results, the following conclusions may be done:

- snow cover increases current generated from monocrystalline silicon PV modules up to 7.3%; in case of using automatic solar guidance systems (trackers), this value probably will be larger;
- the radiation reflected from the snow cover and its impact on the performance of the PV module is largely dependent on the presence of clouds and aerosols in the atmosphere; simultaneously, the difference in the production of current in cases of haze and strong cloudiness is not huge;
- the presence of a shallow snow layer on the solar cell's surface can reduce performance by 13% on a clear day, and 40% – in cloudy.

4. Acknowledgments

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