RESULTS OF CLIMATIC FIELD TESTS OF THE SOLAR BATTERY IN TOMSK

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The results of field tests of the MS-14-10 solar battery for the period from October of 1996 to October of 1997 are presented. The tests were conducted at the TOR-station for monitoring atmospheric parameters at Tomsk Institute of Atmospheric Optics. The influence of ambient temperature, pressure, and solar radiation upon the performance parameters of solar battery is discussed in the paper. We also have studied variations in the short circuit current depending on time during a day and season. The recommendations are given concerning the use of solar batteries.

INTRODUCTION

The possible global warming of the Earth's climate has recently become of a public concern. Many countries throughout the world are developing alternative power sources, which would not have a harmful effect upon the environment. Photovoltaic converters (solar elements), which directly convert the solar radiation into the electric power, are among such sources. Several versions of solar batteries have been developed in recent years at the Scientific Research Institute of Semiconductor Devices (Tomsk). To check the reliability of these batteries when used under different environmental conditions, climatic tests are needed.

The MS–14–10 solar battery has been tested under field conditions. This battery consists of 36 silicon solar elements connected in series. A solar element is the shallow *p*–*n*-junction (~1 μm) manufactured by the *p*-Si substrate diffusion method. The element's surface is textured and coated with the antireflection coating (SiO_2). The solar battery is designed to protect photovoltaic converters (PVCs) against harmful effects (moisture, dust, oxygen, etc.).

1. TEST CONDITIONS

The solar battery tested has been connected to a digital channel of the TOR-station for monitoring of atmospheric parameters.[1] The battery was deployed on roof of the station at an angle of 45° to the horizon. It was oriented toward the Sun position it takes at 02:00 p.m., local time. The 5-Ohm resistor was used as a load for the battery. The voltage across this load was the parameter under control. The electric current from the solar battery produced the voltage about 4 V at the 5-Ohm load, illumination of 1000 W/m^2, and the temperature of 25°C. The open-circuit voltage of the studied battery under the same conditions was 21 V. Thus, as follows from the volt-ampere characteristics (VAC) of the solar battery,[2] the measured current was close to the short circuit (SC) current accurate to 90%. The TOR-station provided for monitoring of 50 atmospheric parameters. The effects of ambient temperature, pressure, and solar radiation upon the performance characteristics of the solar battery have been analyzed. The SC current has been studied depending on the time of day and season.

2. RESULTS OF THE TESTS

The variation of solar power during the test period is shown in Fig. 1. The topology shown in Fig. 1 reflects the distribution of the solar power depending on the time of day (the ordinate) and a month (the abscissa). The grades of gray color reflect the level of the solar power, W/m^2, in accordance with the scale presented. The annual mean solar power as a function of time of day have been retrieved from Fig. 1 and is shown in Fig. 2 in comparison with the current through the load.

It is seen from Fig. 2 that the solar activity is maximum at 03:00 p.m. On average, over the period of one year (from November of 1996 to October of 1997), 4.5 kW·h of solar power per day fell on a sGuare meter of the ground near Tomsk. This value is 1.5 times higher than the average literature data.[3] One can also see from Fig. 2 that the favorable time for use of the solar battery is from 10:00 a.m. and until 06:00 p.m. L.T. for the Siberian region.

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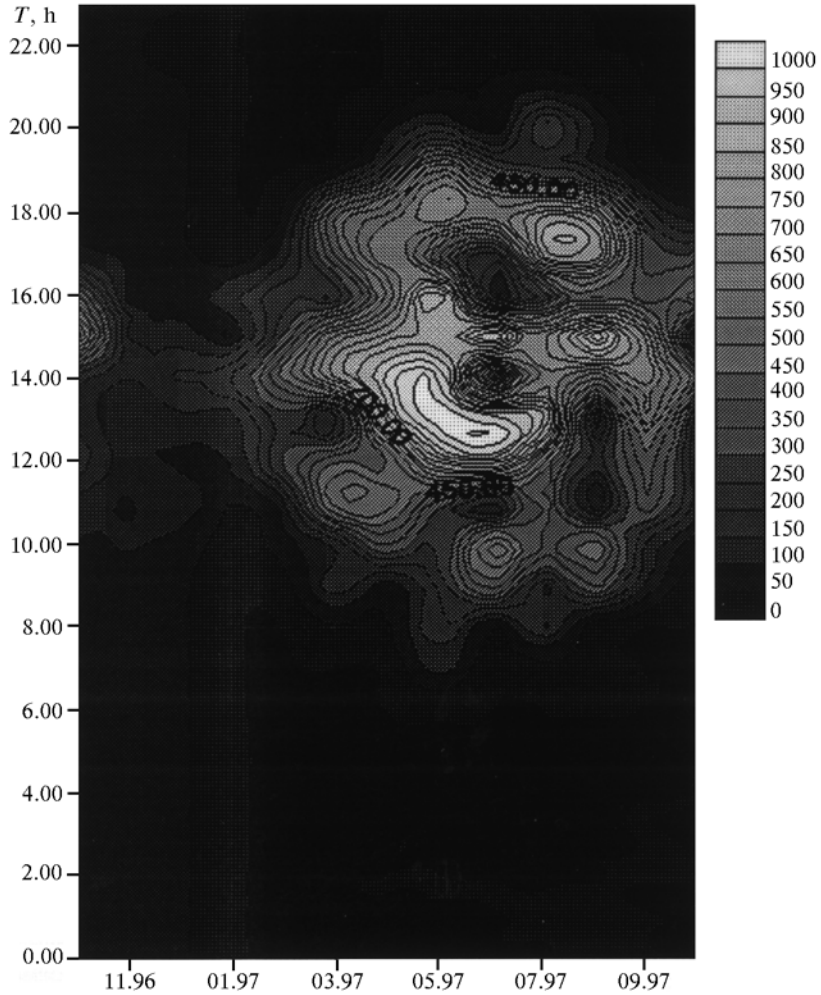

FIG. 1. Solar power distribution depending on the time of day and month.

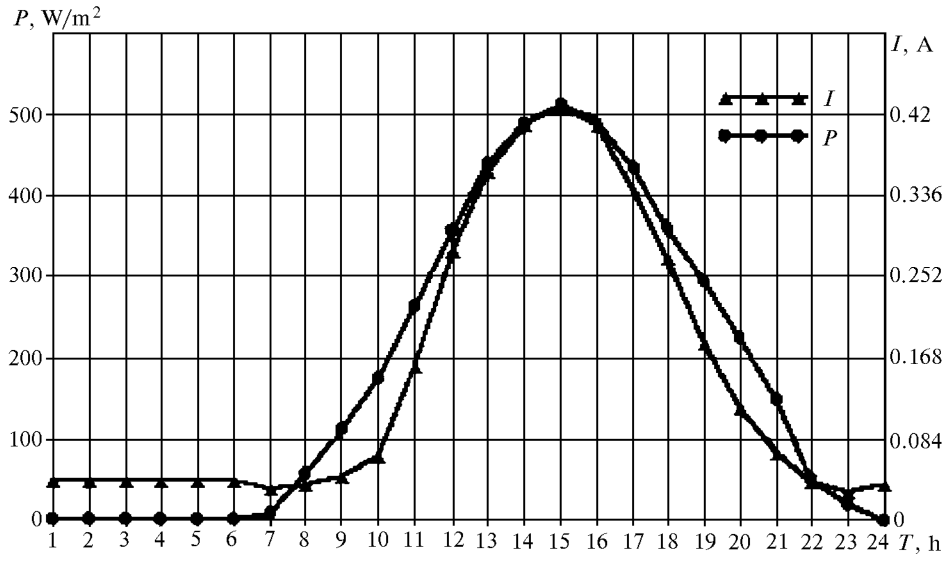

FIG. 2. Annual mean dependence of the short circuit current and the power of incident solar radiation on time during a day.

It should be noted that the solar power recorded with a pyranometer in evening and morning measurements is somewhat higher than the value given by the solar battery (see Fig. 2). This can be explained by the fact that the solar battery is set stationary, and it has worse directional pattern than the pyranometer. In particular, the directional pattern of the solar battery is such that the current through the load at a fixed position of the solar battery changes by no more than 5–10% as the Sun changes its position by 40°. Thus, application of a system for solar battery orientation toward the Sun would allow an increase in the solar power yield by 10–20% during a day and even up to 30% in May, June, and July.

The monthly distribution of the solar radiation power shown in Fig. 1 is presented separately in Fig. 3. The months for efficient operation of the solar battery can be found from this distribution. Such months are in the period from March to September. In other months, the efficiency of the solar battery drops by a factor of four to five as compared to the summer months because of atmospheric attenuation of solar radiation.

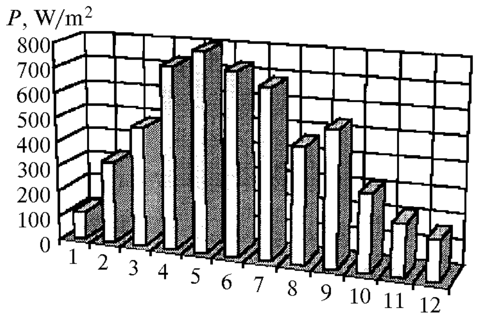

*FIG. 3. Monthly distribution of the solar radiation power at the maximum solar activity (*02:00 p.m. L.T.*).*

Knowing the SC current and typical VAC for the given battery, we can estimate its efficiency (Fig. 4). The calculated efficiency of 13% is in a close agreement with the efficiency measured under laboratory conditions ($P_{sol.rad}$ = 1000 W/m^2, T = 25°C).

To find the temperature dependence of the current, let us divide the data into groups by the solar radiation power: 100–200, 200–300...900–1000 W/m^2. Figure 5 shows the temperature dependence of the current. It should be noted that at low levels of irradiance (100–200 W/m^2) the slope of the curve is positive, while at higher levels it is negative. At the irradiance of 100–200 W/m^2 the current flowing through the load is the SC current. As known, the SC current has the temperature dependence of $2\cdot10^{-5}$ A/(deg·cm^2) (Ref. 4). With further increase in the irradiance, the working point shifts along VAC toward the open-circuit voltage having negative temperature coefficient –2.4 mV/deg (Ref. 4).

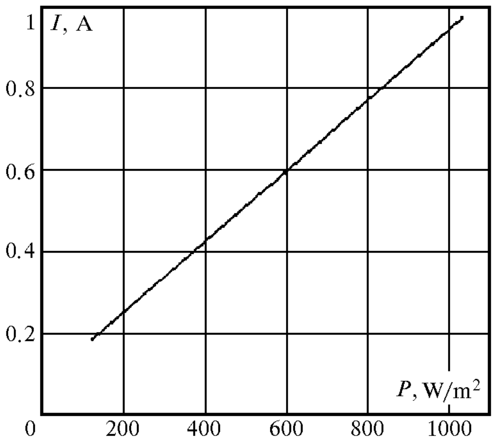

FIG. 4. Dependence of the SC current on the solar radiation intensity.

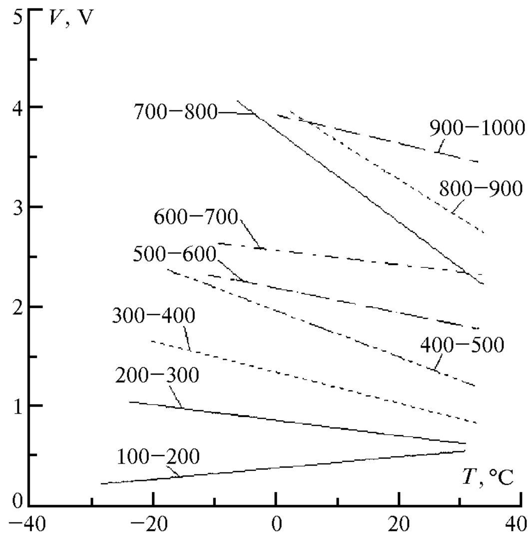

FIG. 5. Temperature dependence of the potential drop across the load resistor for the solar battery at different levels of irradiance.

During the test, we did not observe degradation of the SC current of the solar battery. The pressure dependence of the current was not observed as well.

3. CONCLUSIONS

The results obtained allow us to conclude the following:

1. The period of efficient operation of solar battery is from 10:00 a.m. and until 06:00 p.m. L.T. for the Siberian region and from March to September as regards the monthly behavior.

2. To increase the efficiency of the solar battery, it should be completed with the system for orientation toward the Sun.

3. In winter, the decrease in the power coming from battery to the load is partially compensated for by the increase in the open-circuit voltage.

4. During the year (November 1, 1996, to October 31, 1997) the solar battery has received ~150 (kW·h)/m^2 of solar power.

Based on the analysis of meteorological conditions in Tomsk made and on the established correlation between the solar activity and the output power of the solar battery, it is possible to predict the battery performance in other regions using the data on their meteorological conditions.

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