CALCULATION OF ENERGY EFFICIENCY OF PHOTOCELL OF THE SOLAR STATION

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Annotatsiya. *Quyosh elektr stansiyalarining energiya effektivligi nazariy asoslarga tayangan holda hisoblab chiqilgan. Alohida olingan kunlik beriladigan yukning o'zgarishini hisobga olish va shu bilan kerakli batareya quvvatini aniqlash imkonini beradigan quyosh elektr stantsiyalari va uning elementlarining quvvatini va samaradorligini hisoblash usuli ishlab chiqilgan.*

Kalit so'zlar: *elektr stansiyasi. Energiya, quvvat, samaradorlik,quyosh elementlari.*

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Аннотация. *Разработана методика расчета мощности и коэффициента полезного действия солнечных электростанций и ее элементов, позволяющая учитывать изменение нагрузки в течение суток и тем самым точно определять требуемую емкость аккумуляторной батареи.*

Ключевые слова: *солнечный модуль, солнечная электростанция, автономная солнечная электростанция, импульсный преобразователь постоянного напряжения, автономный инвертор напряжения.*

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Abstract. *A methodology has been developed for calculating the power and efficiency of solar power plants and its elements, allowing to take into account the change in load during the day and thereby accurately determine the required battery capacity.*

Key words: *solar module, solar power plant, autonomous solar power plant, pulsed converter, autonomous voltage inverter.*

INTRODUCTION

Solar power refers to renewable energy sources and has almost unlimited potential for use in terms of resources spent. It is one of the environmentally friendly sources of energy that does not pollute the environment. Today, the solar industry is experiencing rapid growth, around the world actively exploring the possibility of increasing the efficiency of solar cells. In this case, the urgent task is the problem of increasing the efficiency (efficiency) of the solar battery. It is known that the efficiency of solar cells depends on the material used in them. More than 95% of solar panels operate on silicon semiconductors, which provide an efficiency of 15–25% [1]. For example, the efficiency of solar panels based on perovskite is 12% [2], and for thin films based on cadmium telluride, the efficiency reaches 22% [3]. Important factors that determine the efficiency are the level of insolation in the installation region, the azimuth and the angle of inclination of the solar panels [3].

It is well known that a solar photovoltaic station (hereinafter - FES) is designed to provide electric power to household and other devices and is a power plant belonging to the class of renewable energy sources. The principle of operation of the FES is based on the direct conversion of solar radiation into electrical energy with a constant voltage, its accumulation and conversion into electrical energy of alternating voltage 220 V with a frequency of 50 Hz for use by consumers.

Solar panels

The power of the solar radiation flux per square meter, excluding losses in the atmosphere, is about 1350 watts. At the same time, the specific power of solar radiation in very cloudy weather even during the day can be less than 100 W / m². Using the most common solar panels, you can convert this energy into electricity with an efficiency of 9-24%. In this case, the battery price will be about 1-3 dollars per watt of rated power. In the industrial generation of electricity using photocells, the price per kWh will be $ 0.25. It is expected that by 2020 the cost will drop to $ 0.15. It is reported that solar cells with an efficiency of 44% have been received in individual laboratories in the world. In 2007, information appeared about the invention by Russian scientists (Dubna) of elements with an efficiency of 54%, but these highly efficient panels cannot be massively used because of their high cost, many scientists are working on this problem.

RESULTS AND DISCUSSIONS

When using photocells, the question often arises of the energy efficiency of converting electrical energy. As we know, in practice two main modes of using photocells are applied - continuous and periodic. The calculation of the energy efficiency of solar cells for these modes is carried out according to different methods. So, to evaluate the effectiveness in continuous mode, the efficiency indicator is used. In periodic mode, the efficiency indicator does not reflect the picture of energy consumption [2].

In continuous operation, the photocell is constantly working on load. The power of this load may vary over time. Let us evaluate the effect of the efficiency of photocells on the duration of their work. Then for the load power and duration of work we have the following formulas

$$P = \eta \cdot P_i.$$

$$T = \eta \cdot \frac{E}{P}.$$

where P is the load power; P_i power consumption from the battery; E is the available energy of the accumulator; T - the duration of the load; η is an indicator of efficiency. It can be seen that the duration of the load is proportional to the efficiency. So, if in the ideal case when η = 100% the battery life is 10 hours, then with a real value of 80% efficiency, the battery life decreases by 20% and will be 8 hours. In order to evaluate the efficiency of the photocell, we need to know the efficiency indicator at an arbitrary load power [1]. Now consider the proposed linear energy model of the solar cell. This model is a simplification of the real processes occurring in the photocell; accordingly, the efficiency indicator obtained using the model has a certain error. The model can be displayed in the form of an electrical circuit shown in Fig. 1. The essence of the circuit is that there is a load from the source of electrical energy displayed by the resistance R_n. The R_s and R_p present in the resistance circuit simulate energy losses. P_p models the no-load losses, and P_s models the losses due to the introduced series resistance. A typical graph of this dependence is shown in Fig. 1.

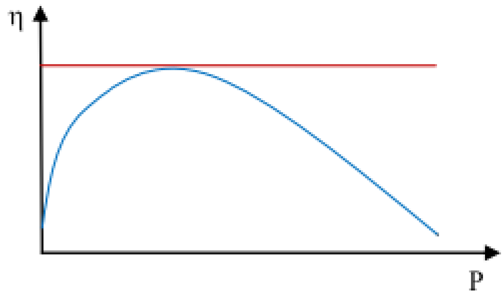

Fig. 1. The dependence of the efficiency on the power

Let us consider the operation of the photocell in the field of large and small powers in more detail. To simplify the calculations, we consider these cases as separate modes.

1. The area of low power

In the low power region, the effect of losses in the series resistance R_s is negligible. The main losses are associated with the parallel resistance R_p. Accordingly, for this case, we can simplify the model by eliminating the resistance R_s. We calculate the efficiency of the photocell for this case

$$\eta = \frac{P}{P_i} = \frac{P}{P + P_p}$$

where P_p is the power loss in resistance R_p. Thus, if we take the efficiency threshold of 80%, then substituting it into the formula, we obtain the power value P_{min} at which such an efficiency is achieved

$$\frac{P_{min}}{P_{min} + P_p} = 0.8\%.$$

2. The area of great power

In the high power range, the power loss P_p becomes insignificant compared to the output, therefore, this type of loss can be ignored and R_p can be excluded from the circuit. Then, only the resistance Rs remains as the source of losses. Similar calculations show that in this case for the load efficiency we have the following expression

$$\eta = \frac{P}{P_i} = \frac{P}{P + P_s} = \frac{R_n}{R_n + R_s}.$$

The total load power

$$P=\frac{E^2}{R_s}\eta(1-\eta).$$

where P_s is the power loss in resistance R_s. The last expression describes a parabola rotated 90^o in the coordinate system. As in the previous case with the simulation results, the graph has two branches, that is, the values of η correspond to one Po value. The upper branch of the graph that interests us is decreasing, that is, the efficiency decreases with increasing output power. Similarly to previous calculations, you can substitute the threshold efficiency to obtain the power value Pmax, at which the efficiency is 80%

$$P=0.16\cdot\frac{E^2}{R_s}.$$

However, often there is no need to perform mathematical calculations to determine the range of effective operation of the solar cell in the field of high power, because the solar cell in this situation is quite effective. In many cases, the efficiency of the photocell is determined by the rated power. And it is not capable of working for a long time at a power of more than the rated photocell, therefore the indicated efficiency at the rated power will be minimal, especially in the field of high power. Therefore, if the specified efficiency is greater than the threshold, then the photocell is obviously effective. Based on the analysis for these two boundary modes, an analytical graph of the dependence of the efficiency on the output power is constructed, shown in Fig. 2.

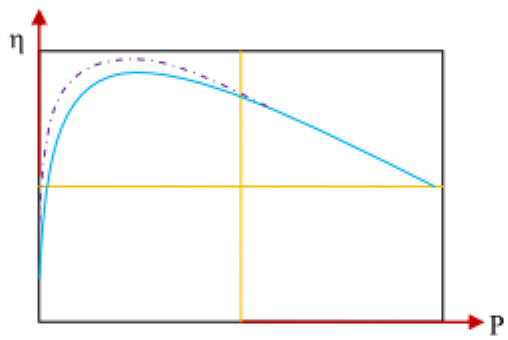

Fig. 2. The dependence of the efficiency on the output power

The solid line in the graph shows the upper branch of the dependence of the efficiency on the output power for the model shown in Fig. 2. The dashed lines show simplified dependences for regions of low and high power. It can be noted that just in these areas the dashed and solid lines converge, that is, simplified models accurately reflect the original one.

CONCLUSION

Based on the results obtained, it can be noted that the photocell is able to work effectively in a certain range of output power, limited both from below and above. And usually from above the range of output power is limited not by the drop in efficiency below the threshold, but by the value of the rated power. Therefore, in the future, as the P_{max}, you can use the rated power of the photocell P_n. This power range is an important characteristic of the photocell and shows how much power the load can be connected to remain in the area of efficient photocell operation.

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