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DEVELOPMENT AND CALCULATION OF PARAMETERS OF THE LABORATORY LAYOUT OF THE MOBILE PHOTOVOLTAIC STATION

Abstract. The paper describes the development of a laboratory model of a mobile photovoltaic station, as well as calculations of the parameters of the photovoltaic station. To date, obtaining energy from renewable sources is becoming a priority task for all countries in the world. Consequently, the relevance of the work is obvious: the development of a working model of a photovoltaic station based on the developed laboratory model will allow delivering cheap electricity to remote areas of our country during field works and agriculture. And also when carrying out seasonal and regular road repairs, where fuel generators are often used. Solar power stations are able to successfully replace fuel generators, despite the high price of silicon polycrystalline solar cells. When we use fuel generators, there is a constant fuel consumption for bringing the plant into operation, which has a number of drawbacks, from the production of greenhouse gases, noise and short service life due to motile working parts. The novelty of the work is the development of a transported power plant with a power of 3 kW, in contrast to existing stationary solar power plants of high power and low-power portable installations. The paper presents a three-dimensional model of a solar power plant and a description of structural blocks. Also in the methods of connecting solar cells and output characteristics in combined ways of connecting solar panels work are shown.

Key words. Solar cells, mobile power plants, accumulator, inverter, controller.

1. INTRODUCTION

Central Asia, including the Republic of Kazakhstan, is a region with high potential for the use of solar energy in the production of electricity. To date, the structure of the country's primary fuel and energy resources is dominated by oil and gas. The share of renewable energy sources in the Republic exceeds one percent. These indicators are negligibly small compared to those of more developed countries, using the energy of alternative sources [1-3]. Today the role of alternative energy in the world is very important. This is proved by modern discoveries and achievements of science on the way to obtaining clean ecological energy.

Advances in the field of direct conversion of solar energy into electric in terrestrial conditions on the basis of semiconductor crystals are largely determined by the creation of cheap and technological methods for obtaining highly efficient solar cells [4-6]. Therefore, there is a constant search for new physical, technical, technological ways, the study of which should contribute to the successful promotion of the creation of efficient semiconductor photoconverters. The use of systems of direct conversion of solar radiation into electrical energy throughout the world is based almost on 90% on silicon photoconverters (FP). Their efficiency is reached in laboratory conditions up to 25% -26%, industrial output provides ~ 20% on monocrystals, and 16% -18% on polycrystals [7]. However, the practical use of such attractive energy sources has its own, and very significant, difficulties associated with uncontrollability and low density of energy flows. This, in turn, generates a high cost of used energy. In this regard, renewable energy sources are still used mainly in autonomous power systems of low power, although there are successful projects for their use in grid electricity as backup and unloading power plants.

Today many countries in Europe and Asia are actively using solar power plants on a city scale [8-10]. Such large power plants, along with wind power stations, are able to compete in the near future with traditional thermal power plants. However, in practice, situations often arise where an energy source is needed in the field conditions. For example: in remote areas when workers are carrying out construction, repair work, in agriculture with seminomadic cattle breeding, tourist walks. In such cases, it is advisable to use low-power mobile solar power plants.

2. THE CONCEPT OF SOLAR POWER PLANTS

2.1. Solar power plants

The sun is a source of renewable energy that can be converted into electrical energy directly or using steam turbines, where the thermal energy of the Sun goes to expand the gas, which drives steam turbines, converting mechanical energy into electrical energy. Obviously, for mobile power plants it is advisable to use direct energy conversion using photovoltaic converters. However, to date, the efficiency of solar cells made of polycrystalline silicon does not exceed 18%. To meet the electricity needs of settlements, the area of the power plant should be several tens of square meters. The problem of location, optimization of power and area is a priority in the design of solar power plants. Another disadvantage of solar power plants is the lack of generation of electricity at night, while most of the energy consumed falls precisely on the evening time of the day. Therefore, it is necessary to consider ways of accumulating electricity for its further use.

Thus, we obtain the following universal units for any solar power plant: solar cells (1), voltage converters (controller) for stable battery charging (2), rechargeable batteries (3), voltage converter (inverter) for stable operation of the consumer (4) and the consumer itself (Figure 1).

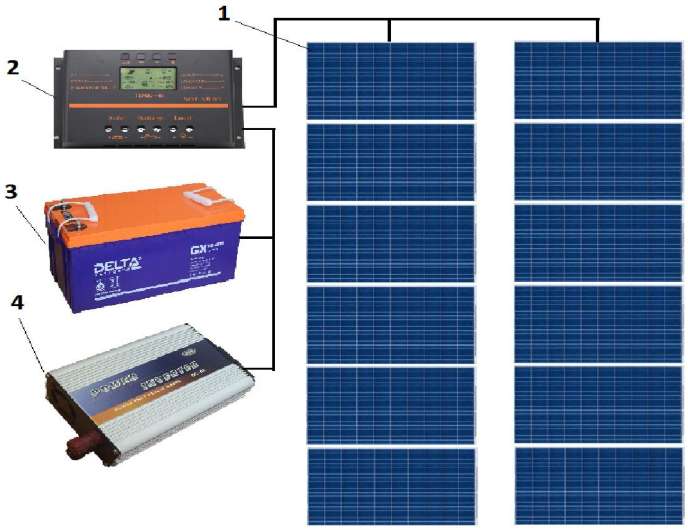

Figure 1- Block-diagram of solar power plant

As for mobile power plants, the requirements put forward for them besides the optimum area and output power, and the accumulation of energy, are mobility and ease of operation.

2.2. Structure of mobile power plant

Modern mobile power plants can be classified according to the output power, design and method of the sweep, as well as by electricity consumers. Low-power portable solar power plants with a small capacity of batteries serve to charge mobile devices, such as tablets, telephones and laptops. Solar power plants of higher power are designed for more powerful consumers, for example, construction tools or household appliances.

Figure 2 - General view of a three-dimensional model of a mobile power plant

Figure 2 shows a three-dimensional model of a mobile power plant. The solar panels are located on a four-wheel basis. The mechanism of uniaxial orientation to the Sun is provided. In the lower part are located batteries, battery charge controller and inverter.

The most important devices in the structure of mobile power plants are inverters and battery charge controllers. Inverters serve to convert DC to AC, which is necessary in the field, if we want, for example, to boil water with an electric kettle. Battery charge controllers serve to stabilize voltage and current when charging batteries to increase their service life.

3. RESULTS AND DISCUSSIONS

The power of solar power plants directly depends on solar panels. For calculation, solar batteries with a nominal power of 250 W were chosen. Short-circuit current I_{sc} = 7.9 A, idling voltage U_i = 40 V, current at maximum power I_{mp} = 7 A, voltage at maximum power U_{mp} = 32.5 V (Figure 3).

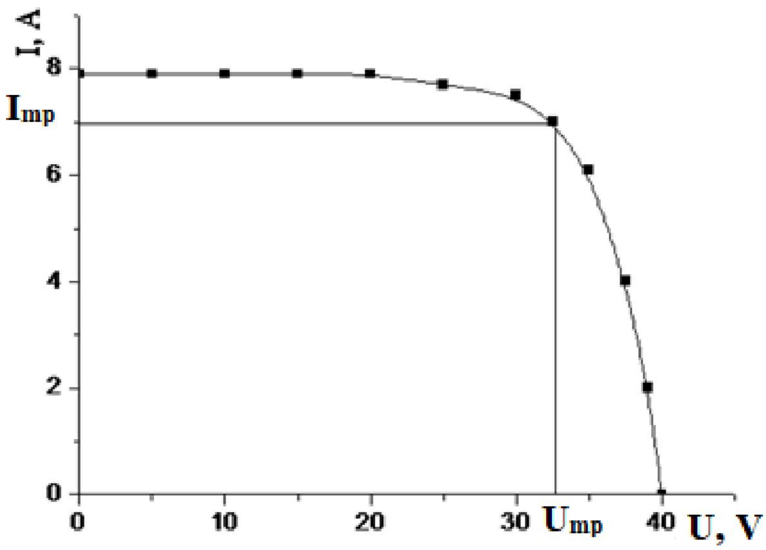

Figure 3 - Volt-ampere characteristic of a solar battery

For the construction of the current-voltage characteristic of a solar cell, there is a well-known formula:

$$I_{SE} = I_{PC} - I_0\left(e^{\frac{qU_{SE}}{kT}} - 1\right) \quad (1)$$

where I_{SE} is the output current of the solar cell, I_{PC} is the photocurrent, which, with an open circuit, is equal to the short-circuit current, I_0 is the saturation current of the solar cell, q is the electron charge, U_{SE} is the output voltage of the solar cell, which, with an open circuit, is equal to the idling voltage U_i , k is the Boltzmann constant, and T is the absolute temperature in Kelvin. If the solar cell consists of identical solar cells, the equation of the current-voltage characteristic will look like (1), only with high voltage and high current, and will look like (2):

$$I_{СЭ} = MI_{PC} - MI_0\left(e^{\frac{qU_{PC}}{kTN}} - 1\right) \quad (2)$$

where M is the number of elements connected in parallel, N is the number of elements connected in series. In our case, the number of elements connected in series is 60. At the same time, the voltage of each solar cell is ~ 0.5 V, and the current is about 7.5 A.

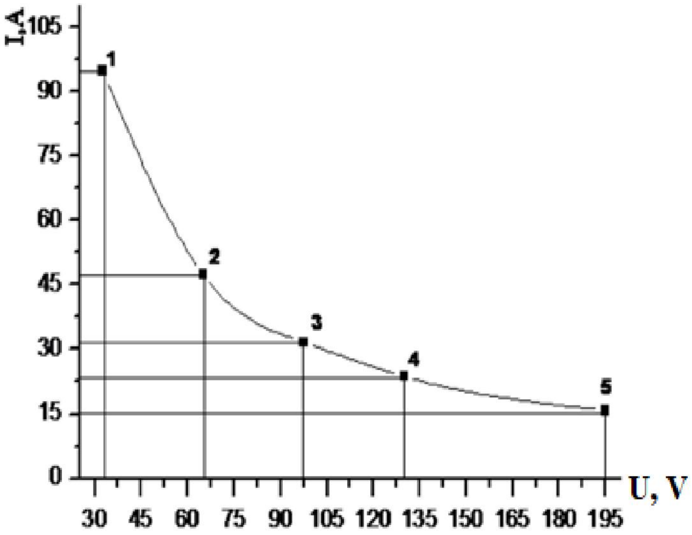

Figure 4 - The ratio of voltages and currents for different ways of connecting solar panels

When designing a power plant, the question arises of how to connect solar panels. For the calculation, 12 identical solar cells with a power of 250 W were taken. Figure 4 is a graph showing the relationship between voltages and currents for different ways of connecting the batteries. Point 1 corresponds to the highest current intensity and the lowest voltage of 94.8 and 32.5, respectively, when all twelve solar panels are connected in parallel. Another extreme point with coordinates 15.8 A and 195 V is point 5, corresponding to the connection of all panels in series. Point 2 corresponds to a connection in which solar cells are connected in pairs in series, and the resulting 6 pairs are connected in parallel. The current is 47.4 A, the voltage reaches 65 V. At point 3, three batteries are connected in series, and the blocks formed are connected in parallel. Voltage rises to a value of 97.5 V, while current continues to decrease falling to a value of 31.6 A. Accordingly, at 4 point, four batteries are connected in series, and the resulting blocks are connected in parallel. Here the current is 23.7 A, and the voltage is 130 V. The power plant capacity is ~ 3 kW.

To date, helium accumulators are becoming increasingly popular. In our case, we chose a battery with a nominal voltage of 12 V, a capacity of 200 Ah, the internal resistance of which is 3.6 mOhm, the number of charge-discharge cycles is 1200 units. The minimum and maximum charge currents are 20 and 40 A, respectively. The connection of the batteries depends on what the customer is trying to achieve. At high loads, the current output should be maximum, but most often such devices are connected for a short period of time; on the contrary, low-power consumers such as light bulbs or refrigerators have low consumption, but they should increase the capacity of the battery pack by connecting the batteries in parallel.

4. CONCLUSION

Solar energy is gaining an increasing consumer market. In addition, the use of solar panels as portable power sources is becoming more and more popular. To use electricity for domestic and other purposes in remote areas or in emergency situations, portable power supplies are needed. Until recently, this market was dominated by portable fuel generators. However, their short service life, constant fuel costs, noise and waste products are becoming less attractive to consumers. In this regard, mobile solar power stations are able to completely displace gasoline and diesel generators from the market. Our work is devoted to the development of a mobile power station and the results obtained during the work can be used in future when designing various portable autonomous systems.

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МОБИЛЬДІ ФОТОЭЛЕКТРЛІК СТАНЦИЯНЫҢ ЗЕРТХАНАЛЫҚ ҮЛГІСІН ДАЙЫНДАУ ЖӘНЕ ПАРАМЕТРЛЕРІН ЕСЕПТЕУ

Аннотация. Бұл жұмыста мобильді фотоэлектрлік станцияның зертханалық үлгісін дайындау туралы жазылған, сонымен қатар фотоэлектрлік станция арқылы өңделетін параметрлердің есептеулері көрсетілген. Қазіргі кезде қалпына келтірілетін қорек көзінен энергия алу әлемнің барлық елдері үшін басым мәселе болып бара жатыр. Жұмыстың өзектілігі: дайындалатын зертханалық үлгінің негізіндегі фотоэлектрлік станцияның жұмыстық моделін жасау, біздің еліміздің шалғай орналасқан жерлерінде өрістік жұмыстар мен ауылшаруашылығын жүргізген кезде арзан электр энергиясын алуға мүмкіндік береді. Сонымен қатар маусымдық және кезекті жол жөндеу жұмыстарын жүргізген кезде жанармайлы генераторлар жиі қолданылады. Кремнийлі поликристаллдық күн батареяларының жоғары бағасына қарамастан, күн электростанциялары жанармайлы генераторлардың орнын ауыстыруға қабілетті. Жанармайлы генераторларды қолданған кезде оны жұмыстық қалпына келтіру үшін үнемі көп мөлшерде жанармай жұмсалады, ол жылыжайлық газдардың шығуы, шуыл және жұмыстың жылжымалы бөліктері үшін үнемі эксплуатация әсерінен жұмыс істеу мерзімінің аздығы секілді кемшіліктерге ие болады. Жұмыстың жаңалылығы жоғары қуатты стационарлы күн электростанциялары мен аз қуатты қондарғылардан бөлек 3кВт қуаты бар тасымалданатын электростанция дайындауға негізделген. Бұл жұмыста күн электростанциясының үш өлшемді моделі мен құрылымдық блоктардың сипаттамасы көрсетілген. Сонымен қатар жұмыста күн батереяларын қосу әдістері мен күн батереяларын қосудың біріктірілген әдісі кезіндегі шығыс сипаттамалары көрсетілген.

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РАЗРАБОТКА И РАСЧЕТ ПАРАМЕТРОВ ЛАБОРАТОРНОГО МАКЕТА МОБИЛЬНОЙ ФОТОЭЛЕКТРИЧЕСКОЙ СТАНЦИИ

Аннотация. В работе описана разработка лабораторного макета мобильной фотоэлектрической станции, а так же показаны расчеты параметров разрабатываемой фотоэлектрической станции. На сегодняшний день получение энергии из возобновляемых источников становится приоритетной задачей всех стран мира. Следовательно, актуальность работы очевидна: разработка рабочей модели фотоэлектрической станции на основе разрабатываемого лабораторного макета позволит доставлять дешевую электроэнергию в отдаленные участки нашей страны при проведении полевых работ и ведении сельского хозяйства. А так же при проведении сезонных и очередных дорожных ремонтных работ, где часто используются топливные генераторы. Солнечные электростанции способны успешно заменить топливные генераторы, несмотря на высокую цену кремниевых поликристаллических солнечных батарей. При использовании топливных генераторов происходит постоянный расход горючего для приведения установки в действие, имеющей ряд недостатков, начиная с производства парниковых газов, шум и малый срок службы при постоянной эксплуатации из-за подвижных рабочих частей. Новизна работы заключается разработке транспортируемой электростанции мощностью от 3 кВт, в отличие от существующих стационарных солнечных электростанций высокой мощности и маломощных портативных установок. В работе представлена трехмерная модель солнечной электростанции и описание структурных блоков. Так же в работе показаны способы соединения солнечных батарей и выходные характеристики при комбинированных способах соединения солнечных панелей.

Ключевые слова. Солнечные батареи, мобильные электрические станции, аккумулятор, инвертор, контроллер.

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