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Possibilities Of Application Of A Photoelectric Current Source For Producing Hydrogen And Oxygen By Water Electrolysis

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ABSTRACT

This paper presents the results of theoretical and experimental studies on the possibility of using a solar photovoltaic current source (SPCS) to power an electrolysis plant designed to produce hydrogen and oxygen from water. For this purpose, SPCS is used with a maximum power of 700 W, with a solar radiation intensity (SRI) of 1000 W/m^2 and an ambient temperature of 20^{0}C. Various photoenergetic and temperature characteristics taken under field conditions in Baku are given.

Key words: photovoltaic converter, photovoltaic current source, solar panel, solar radiation, short circuit current, load current, no-load voltage, load voltage, maximum power, silicon photocells, ambient temperature

I. INTRODUCTION

Azerbaijan is one of the richest countries in the world in terms of alternative and renewable energy resources (RER). Therefore, it is a promising country for the use of renewable energy sources (RES). Thus, the real potential of RER in our country is 26,940 MW, of which 3,000 MW is wind energy, 23,040 MW is solar energy, 380 MW is bioenergy, and 520 MW is mountain river energy. Therefore, the use of this potential has always been in the spotlight, despite the fact that Azerbaijan is one of the countries producing oil and gas. Taking into account all the above, in 2004 our country adopted the “State Program for the use of RES in the Republic of Azerbaijan”. As a continuation of this work, by the Order of the President of the Republic of Azerbaijan Ilham Aliyev No. 1159, dated September 22, 2020, the State Agency for Renewable Energy Emissions under the Ministry of Energy of the Republic of Azerbaijan was established and its Charter was approved [1].

On January 9, 2020, in the Cabinet of the Ministry of the Republic of Azerbaijan between the Ministry of Energy of Azerbaijan and the "ACWA Power" Corporation of Saudi Arabia and "Masdar" of the United Arab Emirates, agreements were signed on the implementation of projects for the development of RES. According to these projects, ACWA Power Corporation is to build wind power plants (WPP) with a total capacity of 240 MW, and Masdar is to build a solar power plant (SPP) with a capacity of 230 MW [2]. Thus, until 2030, the design capacity of RES is envisaged, which will increase up to 30% in the overall energy balance of the republic. To achieve this goal, it is necessary to build new power plants for RES with a total capacity of 1500 MW. At the same time, it was envisaged to integrate, into the common electric grid, 440 MW of power in 2020-2022, 460 MW - in 2023-2025, and 600 MW - in 2026-2030, t .e. in three stages.

One of the leading scientific institutions in Azerbaijan, engaged in the development and application of RES, is the laboratory "Conversion of Renewable Energy" at the Institute of Radiation Problems of the Ministry of Science and Education (MSE) of the Republic of Azerbaijan. Since the 70s of the last century, the following research work has been carried out in this laboratory on the use of solar and wind energy: 1) H_2 + CH_4 + CO, by pyrolysis and gasification of various carbon-containing substances and organic wastes using parabolic concentrators [3-7]; 2) Hot water supply and heat supply, using flat and evacuated solar collectors, as well as their combined use with wind farms [8]; 3) Heat treatment and preparation of crude oil for transportation, using parabolic trough concentrators [9-10]; 4) Cathodic protection of oil and gas pipelines from electrochemical, electrical and bacteriological corrosion, using SES and WES, as well as their joint use [11-12]; 5) Heat supply of a greenhouse with the simultaneous use of two mini wind farms [13], etc. Patents of the Russian Federation, the Eurasian Patent Office and the Republic of Azerbaijan have been obtained for most of the power plants developed during the indicated periods.

As you know, the main disadvantage of using RES is the variability of solar radiation and wind speed, depending on the time of day and season, which in some cases is stochastic. So, if solar radiation in clear and cloudy conditions of the sky changes gradually, in a parabolic pattern, at noon, reaching its maximum, this cannot be said about the change in wind speed, since the wind speed changes stochastic almost all the time. And the stochastic course of changes in the intensity of solar radiation, as a rule, is observed only when the sky is semi-clear, characteristic in the spring and autumn seasons of the year. Therefore, when using RES as a current source for various purposes, as well as for powering various installations, including electrolysis, it is necessary to use stabilizing and accumulating systems. To stabilize the output parameters of SPP and WPP, electrochemical batteries (EB) are used, connected to each other, in parallel, in series or mixed, which simultaneously perform both the function of stabilization and accumulation. To accumulate the generated energy of solar and wind farms, in addition to EB, other types of storage systems are also used, among which the best is considered to be accumulation in the form of chemical energy of hydrogen. Therefore, of particular interest is the use of renewable energy to produce high-purity hydrogen and oxygen by water electrolysis. Such work was first started at the Institute of Physics of the Academy of Sciences of the Az.SSR, and then continued in the Sector of Radiation Research of the Academy of Sciences of the Az.SSR (the present Institute of Radiation Research of the MSE of the Azerbaijan Republic, which are still ongoing [14-17]. Below are detailed information about the SPCS, as well as graphical and tabular data obtained from its testing in the climatic conditions of Baku, which serves to power the electrolysis plant for producing high-purity hydrogen and oxygen from water [18] .

II. BASIC DESIGN AND PHOTOENERGETIC CHARACTERISTICS OF SPCS

The experimental SPCS consists of three solar panels (SP) connected in parallel to each other, which is mounted in the front part at the entrance of the Institute of Radiation Problems at the MSE of the Azerbaijan Republic. The maximum power of each joint venture is 250 W, and the total power of the SPCS is 750 W, with an SRI of 1000 W/m^2. Figure 1 shows the processes of mandling this SPCS on the facade at the entrance of the institute building.

To increase the service life and reliability of the SP of the experimental SPCS, transparent films of the EVA type are laid between the solar cells (SC) and protective glass coatings, which, at the same time, also reduces the degree of their degradation. High-quality films can last up to 30 years, while low-quality films will gradually turn yellow and after 3-5 years they will completely lose their qualities. In order to protect the joint venture from pollution, their back sides are covered with a film of the polyethylene terephthalate type (PET).

If the SP are located on the roof of the house, they are exposed to a lot of heat. This is especially observed when the roof is dark in color. The material of the roof of the house also significantly affects the temperature balance of the SP. In our case, SP are installed on a concrete facade located at the middle part of the institute building. At the same time, from both sides, without any obstacles on the surface of the SP, a wind flow enters, which cools them to the optimum operating temperature. Thus, under normal wind conditions, the maximum temperature of the SP is 25-30^{0}C, and under moderate wind conditions - 40-45^{0}C, which is considered optimal for the experimental SPCS. In addition, the SP on the facade are installed

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with an inclination, and their angle of inclination is equal to the angle of the northern latitude of the area, which for Baku is $40^0 24^I$.

Figure 1. General view of the SPCS, with a power of 750 W, mounted on the facade at the entrance of the Institute of Radiation Problems under the MSE of the Republic of Azerbaijan

It is determined that the solar cell (SC) converts only part of the solar radiation spectrum into electrical energy, and the rest in the form of thermal radiation propagates into the environment. It is this that leads to an increase in the temperature of the SC and the solar module (SM), which, in turn, leads to a decrease in work efficiency, efficiency. and output power of SPCS. Overheating of the surface of the SM leads to a sharp degradation of them. Due to thermal conductivity, thermal radiation and convection, heat exchange processes occur between the SC and the environment, and the established temperature balance determines the temperature of the SC [19-21].

In most cases, the actual test condition does not correspond to the standard STC (Standard Test Conditions) condition, which is carried out at a SRI value of 1000 W/m^2, a SM surface temperature of 25^{0}C, and sunlight on the SM surface in a perpendicular direction.

Therefore, taking into account the actual operating conditions, for the possibility of optimal power supply of any power plant (in our case, an electrolytic cell), it is of particular interest to preliminary determine the number of series and parallel connected, among themselves, SM and SP and a combination of their connection.

Experiments show that in addition to the ambient temperature, the operating mode of the SP is also significantly affected by the temperature power factor (TPF) and the type of device.

The dependence of the output power of the SC (photocell) P on temperature is described by the following equation:

$$P = P_0 \left(1 + \beta \times \Delta T\right), \qquad (1)$$

where: P_0 - SC power developed under standard temperature conditions (25^{0}C); β - temperature coefficient of power, %; ΔT - SC temperature difference from standard temperature, ^{0}C

Table 1 shows the energy parameters of a separate SP SPCS taken under standard test conditions. As can be seen from Table 1, the temperature coefficient for voltage has a negative sign and is relatively large than the temperature coefficient for current, which is -0.300 ± 0.024% ^{0}C. This is due to the fact that in

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each SP there are 72 SM connected, among themselves, in series. As for the current temperature coefficient, it has a positive sign and is 0.059 ± 0.007% ^{0}C.

The short circuit current of the SP is directly proportional and almost linearly dependent on the magnitude of the SRI. Deep and wide-range changes in its value occur under semi-cloudy sky conditions, which leads to a corresponding change in the output parameters of the SPCS, especially the load current and output power. And the voltage of the SPCS depends on the magnitude of the SRI in a logarithmic pattern.

As can be seen from Table 1, despite the fact that the efficiency SC account for over 17%, efficiency. The SP is 15.2%. This means that when switching from SC to SP, the overall efficiency decreases by [(17.0-15.2)/17.0]x100 = 10.6%. This is due to losses on the conductors, as well as ohmic losses occurring in the process of assembling the SP from SC. One hundred concerns power loss, it is mainly due to heat loss.

Table 2 shows the main design parameters, as well as some other passport data of the SP used on the SPCS. As you can see, the total area of the SP is 1.65 m^2. Therefore, efficiency it, determined taking into account the maximum power of the SP, with an SRI of 1000 W/m^2, is $\eta_{СП}$ = ([250/1650]x100) = 15.2% (see Table 1).

When powering any power plant from a SPCS, including an electrolyzer, such an operating mode should be selected so that the SP can operate at the point of maximum power of the current-voltage characteristic (CVC) or in the immediate vicinity of this point. This makes it possible to maximize the use of the developed capacity of the SPCS. Taking into account the above, in this case it is most expedient to use as a load a multi-cell filter-press electrolyzer with intermediate electrodes taken from separate bipolar electrodes. However, these issues are not considered in this article.

Table 1
Energy characteristics, one joint venture SPCS, maximum power
750 W defined under Standard Test Conditions (STC)

No in/or	Parameter name	Designation	Parameter value
1.	Maximum electrical power	$P_{\max}$	250 W
2.	Voltage at the point of maximum power CVC	$U_{\max.p}$	30,5 V
3.	Current at the point of maximum power CVC	$\dot{I}_{\max.p}$	8,25 A
4.	Short circuit curren	$\dot{I}_{sh.c}$	8,77 A
5.	Open circuit voltage	$U_{op.c}$	37,9 V
6.	Reverse saturation current	$\dot{I}_{rrv.sat}$	20 A
7.	Operating temperature range	$T_{op.temp}$	$-40 \le T_{раб} \le +80^0 C$
8.	Optimum operating temperature interval	$T_{opt.op.temp}$	$+43 \le T_{onm} \le +47^0 C$
9.	Temperature coefficient for current	K_i	0,059±0,007 %^{0}C
10.	Voltage temperature coefficient	K_U	- 0,300 ±0,024 %^{0}C
11.	Temperature coefficient for power	K_P	-0,342±0,04 %^{0}C
12.	Photocell efficiency	η_{SC}	Over 17 %
13.	Solar panel efficiency	η_{SP}	15,2 % ([250/1650]x100)

Figure 2 shows a constructive diagram for explaining the processes of assembling a SP

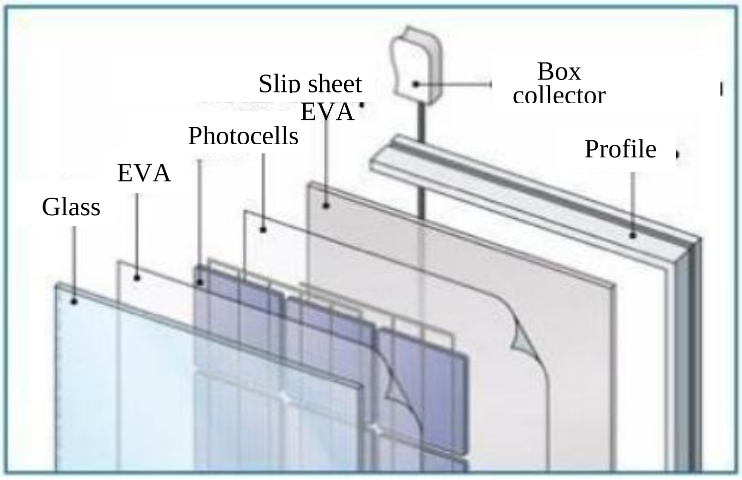

Figure 2. Structural diagram explaining the assembly processes of one SP SPCS

For the most accurate assessment of various types of energy loss, including thermal and electrical, below are the families of CVCs of individual SPs, taken at various values of ambient temperature and SRI, and analyzes of the results are carried out.

Table 2
Structural and some other characteristics of the joint venture with a capacity 250 W, from which SPCS is assembled

No in/or	Parameter name	Parameter designation and values
1.	Type of cells of photocells	6 “multi kristallik”; 3 bus bar
2.	Photocell configuration	60 (156x156)
3.	Profile view	Eloxal, aluminum, external profile
4.	Quantity of SC in one SP	72
5.	Overall dimensions of SP	1663x997x42 mm
6.	Total joint venture	19-20 kq
7.	Total area of the SP	1,65 m^2
8.	Type of glass and its parameters	3.2mm, flexible, with iron composition and high transparency
9.	Intermediate polymer protective pads	Glass-EVA-FV; Elements - slip sheet type EVA
10.	Spare parts in electric box	Spare diodes - 3 pcs; cable - 10 m-4 mm^2; convector-İP 665; dimensions – 110x115 mm
11.	Static surface load	2400 Pa
12.	Maximum surface load	5400 Pa
13.	Certificates	İEC 61215 and İEC 61730
14.	Package	Each SP has 21 SMs (it can also be different)

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III. MAIN PHOTOENERGY CHARACTERISTICS OF INDIVIDUAL SP AND SPCS

It has been determined that all energy characteristics, including the CVC of both the SP and the SPCS, taken in real operating conditions, are much different from the characteristics taken under standard STC conditions. The main external factors affecting the energy characteristics of the SP and SPCS are the nominal operating temperature of the SP, wind speeds, the degree of pollution of the surface of the SP and their degradation, etc., which should be taken into account when taking the main characteristics and establishing the optimal values of the output parameters of the SPCS.

When removing the CVC family of the SP, its optimal mode is considered to be such a mode in which the following conditions are provided [18]:

- SRİ value - 800 W/m^2;
- radiation spectrum - AM 1.5;
- ambient temperature - 20^{0}C;
- wind speed - above 1.0 m/s.

Since the SPCS we use consists of three SP connected to each other in series, its open-circuit voltage remains unchanged, and the short-circuit current is three times higher in comparison with the SP. This makes it more suitable to use SPCS to power an electrolyser that requires a large load current.

If we use the data from Table 1, then we can determine that under standard conditions the SPCS has the following output parameters: maximum electrical power - 750 W (excluding possible losses); short circuit current - 26.3 A; open circuit voltage - 37.9 V; current at the point of maximum power of the CVC at SRİ 1000 W/m^2 (load current) - 24.75 A; the voltage at the point of maximum power of the CVC is 30.5 V. However, all these parameters, depending on the change in the value of the SRİ, are subject to change, and this, in turn, affects the useful power obtained at the point of maximum power of the CVC of the SPCS.

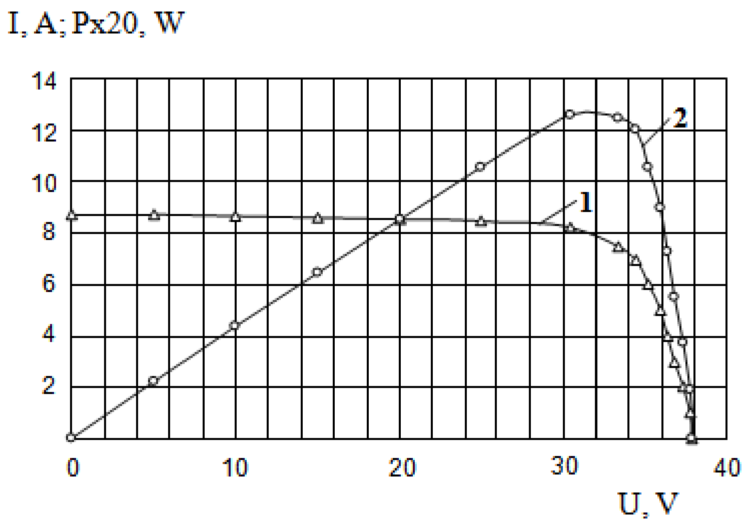

Figure 3. CVC (curve 1) and CVC (curve 2) of a separate SP SFIT taken under standard conditions

Figure 3 shows the CVCs and the volt-watt characteristic (VWC) of a separate SP SPCS (curves 1 and 2, respectively), taken under standard conditions. Moreover, VWC is called the maximum power curve of the SP. The point of maximum power on the CVC of the SP is indicated by the letter **x**, in which the values of the load current and voltage are, respectively, 8.25 A and 30.5 V.

Table 3 shows the actual values of current and voltage at the point of maximum VWC of one SP SPCS, as well as the maximum power of the SP for various values of the SRI.

As can be seen from Table 3, the maximum power of the SP is 251.6 W, with a load current of 8.25 A and a voltage at the optimum load of 30.5 V. In the CVC section, up to the point of maximum power **x**, the output

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power of the SP increases linearly (with a constant slope angle), and after this point (at a voltage of more than 30.5 V), its value decreases sharply, which is due to a similar decrease in the load current on the right part of the CVC of the SP and the inconsistency of the SP with the real value of the load of the external circuit. In the areas before and after the point of maximum power **x** CVC, the operation of the SP is not rational, which is associated with heat loss, leading to heating of the SC and SM SPCS.

Table 3
The values of current and voltage at the point of maximum the CVC power of one SP SPCS, as well as the maximum SP power for different values of SRI

SRI, W/m^2	$U_{\max.p}$, V	$\dot{I}_{\max.p}$, A	$P_{\max}$, W
1000	30,5	8,25	251,6
800	30,5	6,56	200,1
600	30,5	4,93	150,1
400	30,4	3,27	99,4
200	29,9	1,61	48,1

Similar characteristics were also taken for a separate SP at SRI 800 and 200 W/m^2, and families of CVCs were constructed based on the data obtained from the measurement. Figure 4 and Figure 5 show the CVCs of one SP SPCS, taken at the indicated values of the SRI, respectively.

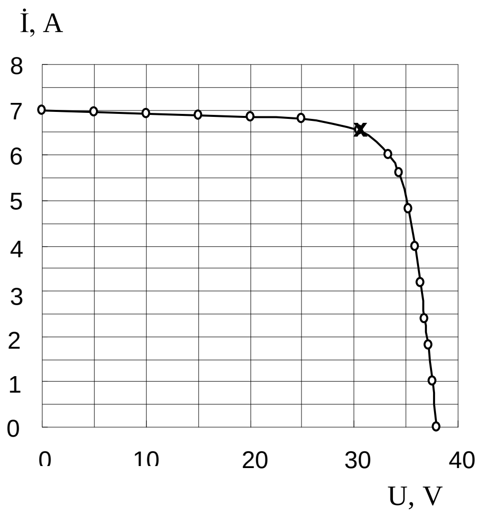

Figure 4. CVC of one SPCS panel, taken at an SRI value of 800 W/m^2

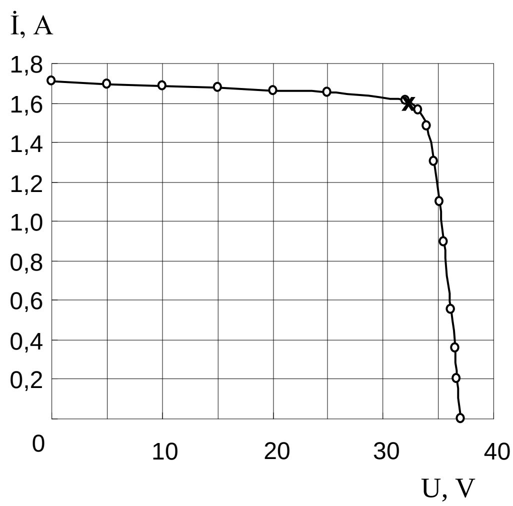

Figure 5. CVC of one SPCS panel, taken at an SRI value of 200 W/m^2

From a comparison of Figures 3, 4 and 5, it can be seen that changes in the SRI value have little effect on the output voltage of the SP, and the load current sharply depends on the SRI, since the voltage from the SRI depends exponentially, and the load current - linearly.

This is more clearly seen from the graphical dependencies, the voltage at the optimal load and the load current of the SP from the SRI, shown, respectively, in Figures 6 and 7.

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The weak dependence of the voltage on the SRI at first glance gives reason to understand that the use of this current source to power the electrolysis plant is quite reasonable. However, since in the electrolysis process the yield of hydrogen and oxygen is affected more strongly by the load current than by the voltage, therefore, at low SRI values, the electrolyzer operates in the nonlinear section of the CVC of the SPCS, which does not give the release of end products (hydrogen and oxygen) and leads to a sharp an increase in the value of the gas filling coefficient in the internal cavity of the electrolyzer, which, in turn, leads to an increase in both the voltage of water decomposition per cell of the electrolyzer and the total amount of electricity consumed to obtain 1 m^2 H_2 and 0.5 m^3 O_2.

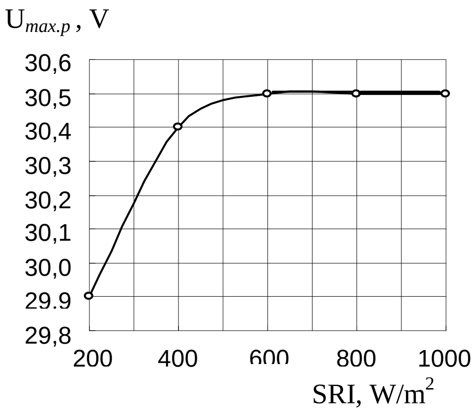

Figure 6. Graphical dependence of the voltage on the load of the joint venture from the SRI

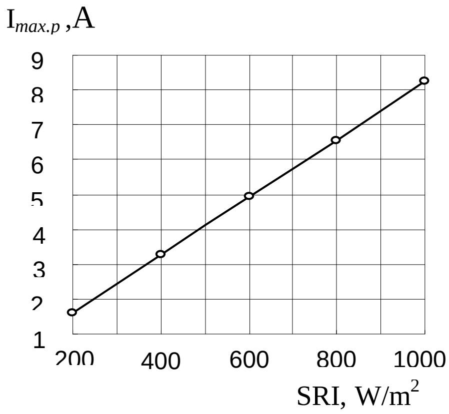

Figure 7. Graphical dependence of the SP load current on the SRI

Thus, at SRI values below 300 W/m^2, the work efficiency and efficiency electrolyzer drops sharply.

Figure 8 shows a graphical dependence of the output power of one SPCS panel on the SRI. As you can see, this graph is linear.

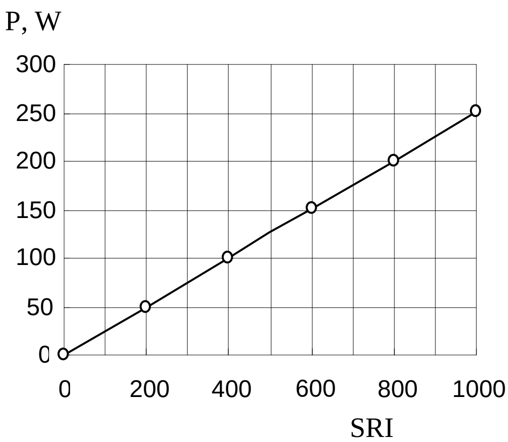

Figure 8. Graphical dependence of the output power of one SP SPCS on the SRI

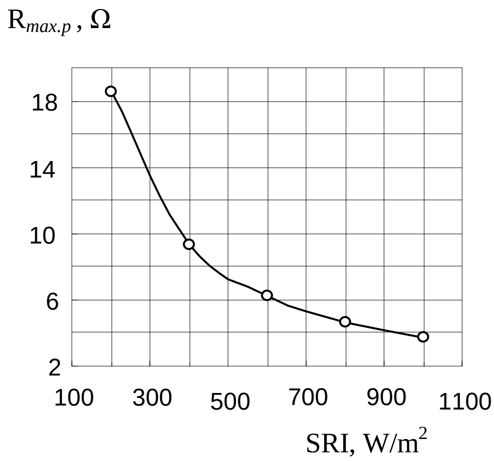

Figure 9. Graphical dependency optimal resistance load SP SPCS from SRI

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When powering any power plant from SPCS, including an electrolytic cell with non-linear current-voltage characteristics, it is of particular importance to ensure the optimal variant of matching the electrolytic cell with SPCS, at an arbitrary value of SRI. Taking this into account, for the experimental SPCS, the dependences of the optimal load resistance on the SRI were taken and the corresponding graphs were plotted. Figure 9 shows the graphical dependence of the optimal load resistance of one SPCS panel on the SRI. As can be seen, there is a non-linear relationship between the optimal load resistance and the SRI for the SP. At the same time, the most dramatic change in the optimal load resistance is observed at small values of the SRI, which is explained with a similar dependence of the SP voltage on the SRI, which is shown in Figure 6.

Since it is planned to power a multi-cell filter-press electrolyzer from an SPCS operating at high values of the load current, in addition to individual SPs, the CVC characteristics of the SPCS itself, consisting of three SPs connected in parallel, were also taken. Figure 10 shows the CVC of the SPCS, taken under the climatic conditions of Baku, with an SRI of 900 W/ m^2.

As you can see, when powering a filter-press type electrolyzer from SPCS, it should be ensured that it operates in the immediate vicinity of the point of maximum power **x** CVC SPCS, in which the power developed by them is used to the maximum. To ensure the specified mode, the number of cells of the electrolyzer should be: n = $U_{max.p}$ / U_{cell} = 30.5/(2.25÷2.45) = 12÷13 pieces. Here: Ucell is the voltage on one cell of the electrolyzer. For a high intensity of the electrolysis process, the load current and its density on the electro-des must be greater. In industrial electrolyzers of the filter-press type, the current density is up to 10,000 A/m^2. Since the maximum value of the load current of the SPCS is 24.75 A, in our case, in order to achieve a current density on the electrodes up to 1000 A/m^2, the areas of the electrodes and cells should be 247.5 cm^2. Therefore, if we use from the circle area equation S $= \pi D_{эл}^{2/} / 4$, then the diameters of the electrodes, as well as the cells, with a round configuration, are $D_{эл} = \sqrt{(247{,}5 \cdot 4)/3{,}14} = 17{,}8$ cm. Similarly, if the electrolyzer is operated at a current density of 750 A/m^2, the electrode and cell areas should be 24,75/0,075=330 cm^2, and the diameters of the electrodes and electrolytic cells $D_{эл} = \sqrt{420{,}4}$ = 20,5 cm, which, in this case, is considered the optimal design dimensions for the electrodes and cells of the experimental electrolyzer [22].

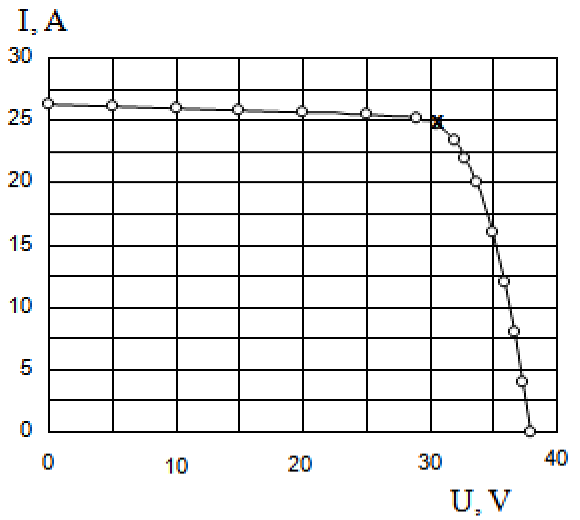

Figure 10. CVC SPCS taken at SRI value 900 W/m^2

It should be taken into account that in real operating conditions, the developed power of SPCS is 30-40% less than under standard conditions, which should be taken into account

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when designing electrolysis plants powered by SPCS. Therefore, in the next stage of the experiments, the graphic dependences of the output power of a separate SP SPCS on voltage were taken at different ambient temperatures, which are shown in Figure 11.

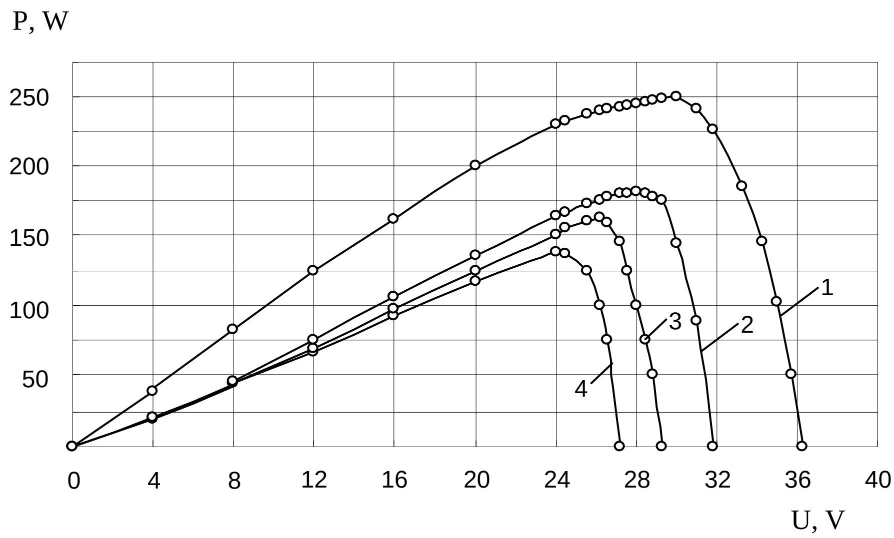

Figure 11. Graphical dependences of the output power of a separate SP SFIT on voltage, for different ambient temperatures:

curves 1, 2, 3 and 4, respectively for temperature: 25^0C (standard temperature), 35^0C, 45^0C and 55^0C

In addition, a graph of the dependence of the output power of the SP SPCS on the ambient temperature was also taken, shown in Figure 12. As can be seen from figures 11 and 12, as the ambient temperature rises, both voltages and power of the SP are significantly reduced.

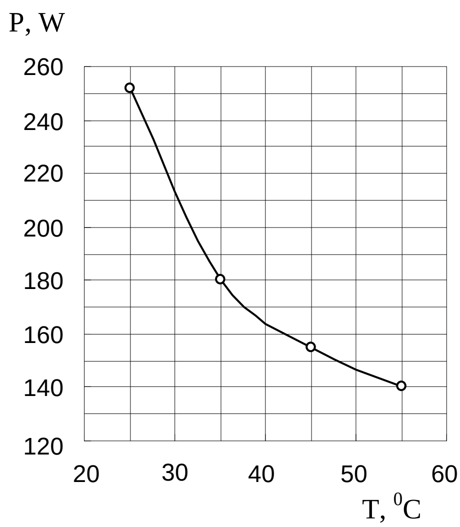

Figure 12. Dependence of the output capacity of one joint venture SFIT on temperature environment

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With an increase in ambient temperature from 25^{0}C to 55^{0}C, the power of the SP is 40-50%, the short circuit current is 30%, and the voltage at the external load (the voltage at the point of maximum power **x** CVC of the SP) decreases by 15.6%, which affects negatively on the optimal mode of operation of the cell powered by SPCS. And when using electrochemical batteries operating in a buffer mode, together with SPCS, there is a violation of the charging and discharging processes of the EB, which ultimately leads to incomplete use of the energy developed by SPCS. Therefore, all these points should be taken into account in the assembly of SMs based on SC, SPs, based on SMs and SPCS - based on SPs. It is necessary to accurately select the number of parallel and series-connected SCs in SM and SMs in SPCS. In this aspect, if the electrolyzer is powered directly from the SPCS, without the use of EB, then the greater the short-circuit current, the better, since this is what gives the most rational use of the developed power of the SPCS on the load (in this case, on the electrolyzer). Therefore, when assembling SPCS, on the basis of individual joint ventures, it is necessary to make it so that the number of panels connected in parallel was greater, which was taken into account in this case. Otherwise, at low SRI values, especially in the morning and evening hours of the day, the electrolyzer operates in the initial, non-linear section of its current-voltage characteristic, at low values of current density at its electrodes. At the same time, due to the small overall dimensions, the resulting gas bubbles, both hydrogen and oxygen, will not be able to leave the electrodes and leave the cell space. As a result, inside the electrolyzer, in the electrolyte, the gas-filling coefficient increases, leading to a sharp decrease in its conductivity, due to which both the water decomposition voltage and the amount of energy consumption to obtain a single volume of the target product (1 m^3 H_2 and 0.5 m^3 O_2), which is undesirable. To eliminate this shortcoming, we have developed some methods that will be considered in further work.

IV. CONCLUSIONS

1. It has been revealed that for a continuous and reliable supply of consumers from SPCS, it is necessary to accumulate the energy developed by them under good weather conditions, and to use this energy in unfavorable weather conditions, as well as during the November hours of the day. As the most promising way of accumulation, it is proposed to accumulate the energy of SPCS in the form of the chemical energy of hydrogen and oxygen, obtained by the method of water electrolysis.
2. To power the electrolysis plant, an SPCS with a maximum power of 750 W (with an SRI of 1000 W/m^2) was developed and created, consisting of three SP connected in parallel. It has been determined that under light cloudiness, the energy efficiency of the SP decreases to 60-80%, in comparison with clear weather conditions, and when the sky is cloudy, these indicators decrease to the level of 20-30% of the maximum. When using a single-layer protective shell and the incoming sunlight in a perpendicular direction, there is a loss of energy by 9%, under identical lighting conditions and using a two-layer shell - by 16%, with a single-layer shell and setting the surface of the joint venture at an angle, relative to the influx of sunlight - by 36 %, which is characterized by reflection and scattering of sunlight from the surface of glass coatings.
3. It is determined that the values of voltage and current, at the point of maximum power I–V characteristics of the joint venture, are, respectively, 30.5 V and 8.25 A, the open circuit voltage and short circuit current, respectively, 37.9 and 8.77 A, the reverse current saturation - 20 A, operating temperature range - from 40^{0}C to + 80^{0}C, optimal operating temperature + (43 ÷ 47) ^{0}C, temperature coefficients for current and voltage, respectively - 0.059 ± 0.007% ^{0}C, and - 0.300 ± 0.024% ^{0}C, temperature power factor - 0.342±0.04% ^{0}C, efficiency individual SM - 17%, and efficiency SP - 15.2%.
4. In the experimental SPCS, the surfaces of the SP under good wind conditions are heated up to 25-30^{0}C, and under non-wind conditions, up to 40-45^{0}C, which does not exceed the optimal temperature regime for these SP.
5. It has been established that in the first year of operation, the degradation coefficient of solar cells in the joint venture is 2.67%, and in subsequent years this indicator decreases by 3.5-4.0 times. To increase the service life of the SP of the experimental SPCS, in the front side of them, between the SCs and the protective glass shell, a transparent film of the EVA type was used, which also leads to a significant decrease

in the degradation coefficient of the SC. High-quality film can serve up to 30 years.

6. The ways of maximum use of the developed energy of the SPCS are analyzed and the corresponding CVC and WVC are constructed. At the same time, for the standard condition, both the CVC characteristics and the WVC characteristics of the SPCS are constructed, and for the SRI values of 800 W/m^2 and 200 W/m^2, only the CVC characteristics are constructed. From these CVC characteristics, it is determined that for the standard condition, the values of short circuit current, open circuit voltage, as well as current, voltage and power, at the point of maximum power **x** CVC characteristics are, respectively, 8.77 A, 37.9 V, 8.25 A, 30.5 V and 251.6 W. And for SRI 800 W/m^2 and 200 W/m^2, these parameters are, respectively, 6.97 A, 37.9 V, 6.56 A, 30.5 V, 200.8 W (for SRI 800 W/m^2) and 1.71 A, 37.0 V, 1.61 A, 32 V, 51.5 W (for SRI 200 W/m^2).

7. For the maximum value of SRI, in the climatic conditions of Baku 900 W/m^2, the CVC of the SPCS were taken and it was determined that, in this case, the values of the short circuit current, open circuit voltage, current and voltage at the point of maximum power **x** CVC of the SPCS, as well as its maximum output power is 26.3A, 37.9V, 24.6A, 30.5V and 750W respectively. For one SP SPCS, a graphical dependence of its maximum output power on the ambient temperature was also plotted. It was found that depending on the increase in ambient temperature, the output power of the joint venture decreases exponentially.

8. It was determined that when the ambient temperature rises from 25^{0}C to 55^{0}C, the output power of the SP decreases by 40-50%, and the open circuit voltage is ~ 30%, which should be taken into account when using SPCS to power the electrolyzer.

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