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The study of the characteristics of photovoltaic power stations and the identification of rational operating modes by changing the inclination and the spectral composition of the irradiation

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The study of the characteristics of photovoltaic power stations and the identification of rational operating modes by changing the inclination and the spectral composition of the irradiation

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Abstract. The global trends in the development of photovoltaic power stations (PPS) and their application are actively fighting for a place in the sun. On January 20, 2009, Vladimir Putin (at that time the chairman of the government) signed a decree approving the main directions of state policy in the development of renewable energy sources (RES) until 2024, and on May 13, 2019, by decree no. 216 “On the approval of the energy security of the Russian Federation” signed the Doctrine of the energy security of the Russian Federation. In this regard, the need to find the optimal operating modes of PPS has become acute, which is an environmentally friendly way to generate electricity. New designs and methods of using systems are being developed to study and determine the optimal operating modes of PPS. The work justified the design parameters and experimentally investigated the characteristics and operating modes of PPS, determined the effect of the spectral composition of radiation on the amount of generated energy. The study was conducted using graph-analytical processing of the results of practical PPS tests characteristics by simulating outlook surfaces using the biharmonic interpolation method in the Curve Fitting Toolbox application of the MATLAB program.

The scale of the use of renewable energy sources, which include solar energy, is increasing every year. Technologies for using renewable energy are steadily improving and becoming more competitive and attractive [1]. Engineering thought is evolving, and nowadays, scientists are developing new and improving existing power generation devices from PPS.

An assessment of the current state of the devices shows that researchers are solving the problems of mobility, reliability, ease of operation, transportation, repair, and performance of PPS with the possibility of their round-the-clock work in various climatically difficult and unfavorable operating conditions, in field conditions and mountainous areas.

The generation of electrical energy from the PPS for the estimated period is determined by the method described in studies [2, 3].

The results of theoretical calculations of electric power generation from one photovoltaic power module (PPM) and from PPS by months during the year, as well as the minimum required energy consumption of autonomous objects are presented in [4] and summarized in table 1.



Table 1. The results of theoretical calculations of the electric energy production by PPS in the city of Krasnoyarsk [3].

Month	Days	Number of sunshine hours	Number of peak sun hours		Amount of electricity produced by one module		Amount of electricity produced by PPS in a month
		$t_{ep,j}$, hr	$T_{sun,d,h}$ r	$T_{sun,m}$, hr	W_{day} , Wh	W_m , Wh	W , Wh
January	31	58	1.87	58	130.97	4060	40.60
February	28	90	3.21	90	225.00	6300	63.00
March	31	162	5.23	162	365.81	11340	113.40
April	30	202	6.73	202	471.33	14140	141.40
May	31	224	7.23	224	505.81	15680	156.80
June	30	278	9.27	278	648.67	19460	194.60
July	31	270	8.71	270	609.68	18900	189.00
August	31	217	7.00	217	490.00	15190	151.90
September	30	154	5.13	154	359.33	10780	107.80
October	31	96	3.10	96	216.77	6720	67.20
November	30	49	1.63	49	114.33	3430	34.30
December	31	33	1.06	33	74.52	2310	23.10
year	365	1833	5.02	1833	2881.12	128310	1283.1

To test the results of theoretical calculations, an experiment was conducted to study the characteristics of PPS [2], figure 1.

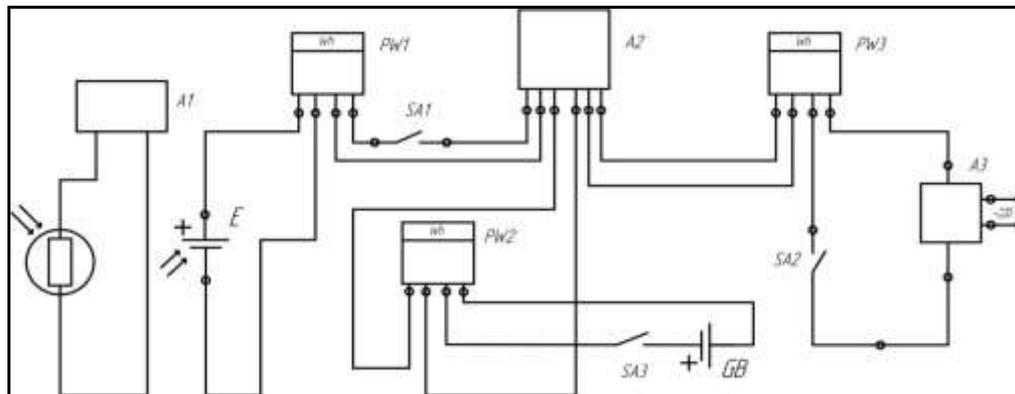


Figure 1. The circuit diagram of the experimental PPS: A1 - pyrometer; A2 - battery charge controller; A3 - inverter; E - solar module; GB - battery; PW1, PW2, PW3 – multi-meter; SA1, SA2 - switch.

The next stage of processing the results was carried out by constructing models of curves and surfaces using regression, interpolation and smoothing [5, 6, 7].

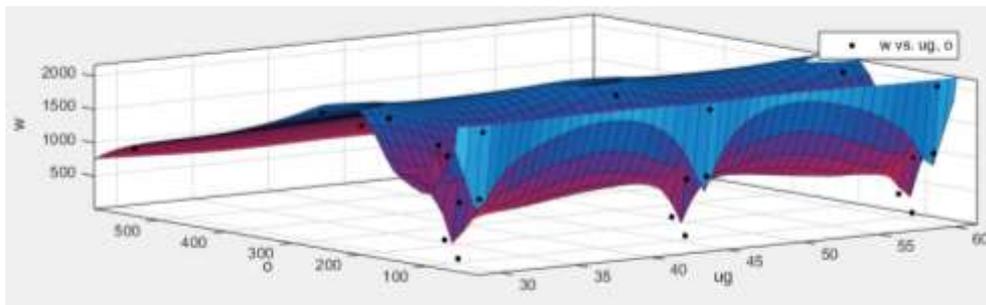


Figure 2. The results of the processed practical tests data. The dependence of power on the irradiance and the inclination of PPS.

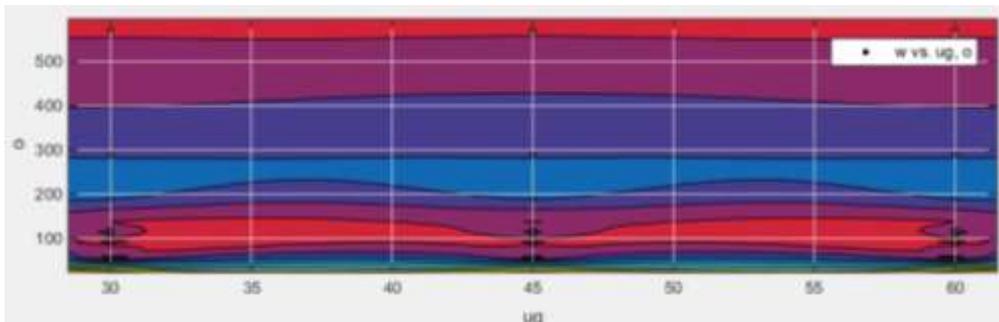


Figure 3. Transformation of a three-dimensional plane into an outline picture of the dependence of power on irradiance and the inclination of the PPS.

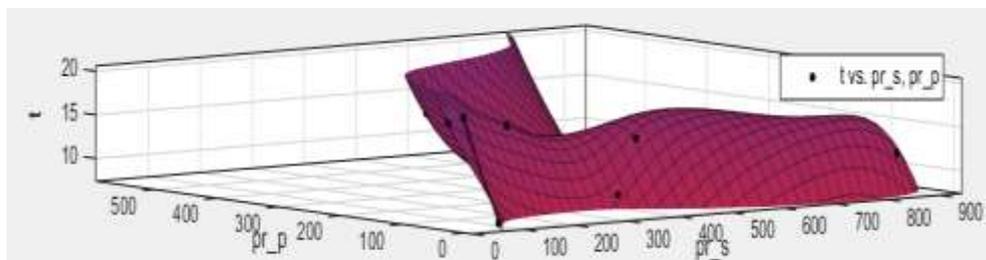


Figure 4. The maximum increase in power, independent of the weather.

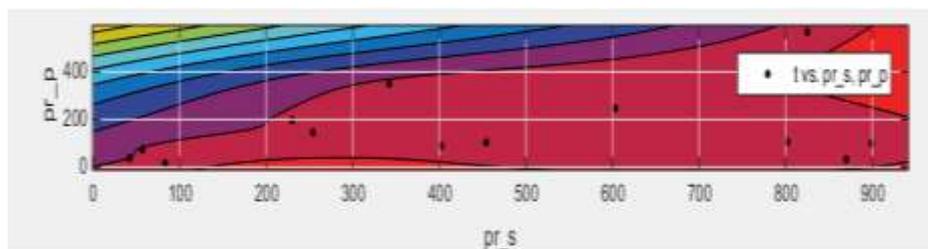


Figure 5. Transformation of a three-dimensional plane into an outline picture of the maximum power growth no matter the weather.

According to the results of power increase in cloudy and sunny weather, it can be concluded that the operating mode of PPS depends largely on the spectral composition of the light irradiating the PPM, since sunlight in cloudy weather, passing through clouds, changes its spectral composition due to absorption and scattering of the shortwave part of the radiation spectrum.

To conduct an experiment to identify the dependence of the generated power of PPS on the wavelength of the light irradiating PPM, the block diagram of the experimental plant is presented, figure 6.

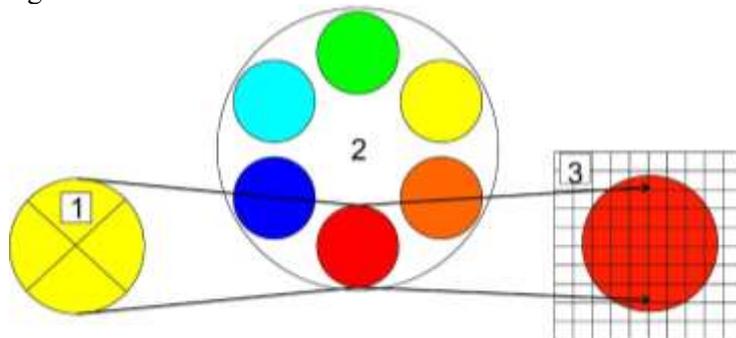


Figure 6. The block diagram of the experimental plant: 1) Light source; 2) Set of concentrating filters; 3) Photovoltaic module.

Table 2. The results of the experiment to identify the dependence of the generated power PPS on the wavelength of the light irradiating PPM.

Color / wavelength, Nm	Red 625-740	Orange 590-625	Yellow 565-590	Green 500-565	Indigo 440-485	Violet 380-440
Illumination, lux	90	100	97	96	44	13
Capacity, W	3.85	4.03	3.75	3.88	3.90	3.55

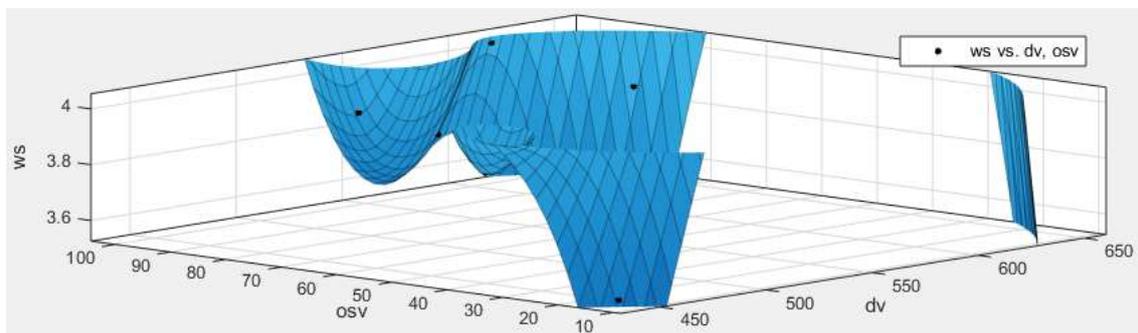


Figure 7. Graph-analytical processing of the experiment.

Due to the small amount of data with different dimensions, the three-dimensional plane is not closed, but an increase in the power value with increasing wavelength is observed. For a more detailed study of changes in power received from the PPM, an outline projection of the plane should be constructed.

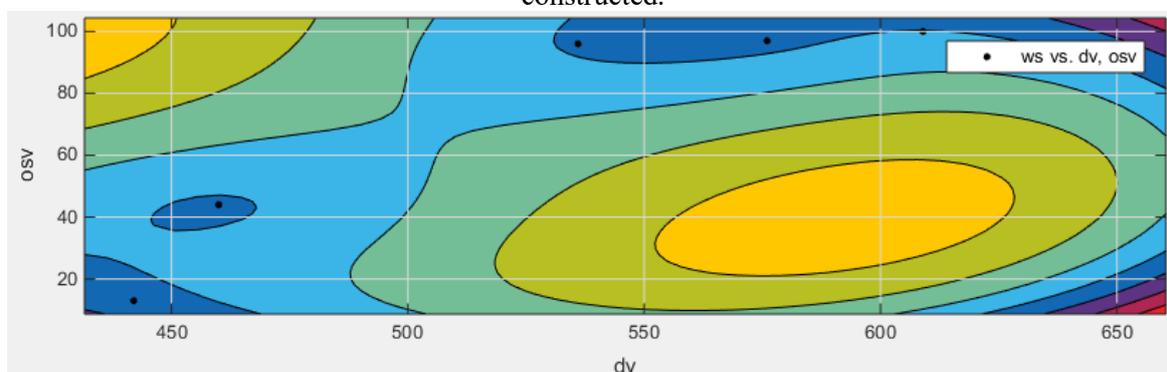


Figure 8. Outline projection of the plane of power change received by PPM from irradiation with different spectral composition.

Calculations of practical tests of photovoltaic power plants by determining the dependence of the power generated on irradiance and the inclination of the solar panel showed that the total solar radiation on a relatively overcast day was 2064 Wh/m². The conversion rate of solar energy into electrical energy was 4.9%. The voltage generated by the solar photovoltaic module (and therefore energy), depending on its spatial location, can be reduced by 70%.

The graph-analytical processing of the results of a full-scale experiment to determine the dependence of the generated power on irradiance and the inclination of the solar panel revealed the following dependencies of PPS operating modes:

- for the optimal PPS operating mode for power generation, it is necessary to irradiate the PPM with 300–400 Wm² and 400–550 Wm², no matter the inclination, there is the maximum power output by irradiating the PPM with 300–400 Wm² and the inclination 30°–40° and 55°–60°.

The graph-analytical processing of the results of a full-scale experiment to estimate energy growth on a sunny and cloudy day showed that the operating mode of the PPS depends largely on the spectral composition of the light irradiating the PPM.

The graph-analytical processing of the results of a full-scale experiment to determine the operating mode of the PPS with a change in the spectral composition of the radiation showed that the power generated is the highest when the PPM is irradiated with wavelengths in the range 520–625 nm. Consequently, for rational PPS operation it is not necessary to have clear sunny weather and a high PPM irradiation, it is enough to install a green, yellow or orange light filter in front of the PPM, and even in cloudy weather PPS will work with a high rate of power generated.

References

- [1] Pritomskiy A D, Mikheeva N B and Bastron A V 2015 Economic aspects of the solar hot water system (SSGW) for heat supply of personal household plot (LPH). *Innovative trends in the development of Russian science VII Int. Scient. and Pract. Conf. of Young Scientists* (Krasnoyarsk) 155-7
- [2] Dubov V A, Chebodaev A V Evaluation of the efficiency of the PPS use for autonomous power supply to the peasant-farmers holds *Newsletter of the Irkutsk State Agrarian University* 89-94
- [3] Bastron A V, Chebodaev A V, Ursegov V N, Debrin A S, Smelova S A and Andrykhov S K 2016 Photovoltaic power station to power a self-contained device for the extraction of bee venom. *Innovation in agriculture The All-Russian Scient.-Res. Inst. For Electrification of Agriculture* (Moscow) 199-204
- [4] Chebodaev A V, Bastron A V, Ursegov V N, Debrin A S and Smelova S A 2016 The use of solar photovoltaic power stations for autonomous power supply systems of peasant-farmers holds *Energy and Resource Saving - XXI Century the XIV Int. Scient. and Pract. Internet Conference* (Oryol)
- [5] Debrin A S, Bastron A V, Semyonov A F and Sutugina K A Graph-analytical processing of the results of a full-scale experiment to determine the dependence of the generated power on the irradiance and tilt angle of the photoelectric module *State registration of computer programs No. 2019610369*
- [6] Debrin A S, Bastron A V, Semyonov A F and Sutugina K A Graph-analytical processing of the results of a full-scale experiment to determine the dependence of the generated power on the irradiance and tilt angle of the photoelectric module *State registration of computer programs No. 2019610980*
- [7] Semyonov A F 2011 Simulation of energy-saving modes of growing vegetables in the greenhouse *Krasnoyarsk State Agrarian University* (Krasnoyarsk)