Journal of Engineering and Applied Sciences 12 (Special Issue 1): 5761-5766, 2017
ISSN: 1816-949X

Determination of Basic Operating Parameters of Solar Photovoltaic Modules for Farms

[1]Rashit Omarov, [1]Seitkazy Keshuov, [1]Dauren Omar, [2]Murat Kunelbayev and [1]Sabit Amirseit
[1]LLP "Kazakh Scientific Research Institute of Mechanization and Electrification of Agriculture", 312 Rayimbek Avenue, 050005 Almaty, Republic of Kazakhstan
[2]Faculty of Physical-Mathematical, Kazakh State Women's Teacher Training University, Almaty, Republic of Kazakhstan

Abstract: Solar Photovoltaic Modules (SPM) are popular in agriculture. For a lot of small farms, the main source of electrical energy is electric generators driven by Internal Combustion Engines (ICE), since installation of electrical networks is economically unprofitable. In these conditions, SPM are economically and environmentally promising, since it does not require the consumption of fuels and lubricants does not harm the environment. Determination of the main SPM operating parameters in 2 modes is considered in this research. In the cases when the panels oriented towards the sun (tracking mode) and in a stationary state with orientation to the south (without tracking mode). The dependences of current, voltage and power on time and density of solar radiation were measured. Accordingly, the voltage and current of Transportable Photovoltaic Unit (TPU), the charging current and the voltage of the batteries, the voltage at the output of the inverter, the temperature and humidity of the outside air and the electrical energy consumption by the electric receivers were recorded. The study of the TPU operation showed that the mode of orientation to the sun increases the daytime power generation by 25, ..., 33% in comparison with the fixed installation of Solar Panels (SP). The analysis showed the discrepancy between SP passport data and the experimental results. The decrease in electricity generation was 14% compared to the expected estimates.

Key words: Sun, solar photovoltaic modules, solar panel, inverter, battery, solar radiation

INTRODUCTION

Solar cells in the production of electricity from renewable energy sources is now developing rapidly and soon will be increased overall use. For example, small solar cells used in watches, calculators, small toys, radios and portable TVs. While large objects are combined into modules and are used to supply the power system (Klugmann-Radziemska, 2010).

A solar cell is an electrical device that converts light energy into electricity using the photoelectric effect. The main material used for the production of solar cells is silicon.

The design and manufacture of silicon solar battery: Large blocks of molten silicon carefully cooled and solidified is made from cast ingots of polycrystalline silicon square. Polycrystalline silicon is less costly than single crystal and are less effective (Wolanczyk, 2011; Lipinski, 2010). Solar battery consists of the following elements (Rodacki and Kandyba, 2000; Dobrzanski and Szindler, 2012; Markvart and Castaner, 2003).

Silicon wafer (mono or polycrystalline) with a p-n junctions on the surface. Front and back contact; front contact must have the correct shape to make the most of the incident radiation. Antireflection layer-cover the front surface. There are three major types of solar cells. Single crystal formed on a silicon crystal with a homogeneous structure. The basis for the formation of cells that are suitable silicon-sized blocks.

They are cut into plates whose thickness is about 0.3 mm. Photovoltaic cells achieve the highest levels of performance and life (Wolanczyk, 2011; Rodacki and Kandyba, 2000).

Polycrystalline are comprised of many small grains of silicon. These solar cells are less efficient than single crystal. The production process is simpler and have lower rates (Wolanczyk, 2011; Rodacki and Kandyba, 2000).

Amorphous (thin film) produced by incorporating multiple layers of silicon on the surface of another material such as glass. In these solar batteries, we can not distinguish individual cells. Amorphous solar cells are

Corresponding Author: Rashit Omarov, LLP "Kazakh Scientific Research Institute of Mechanization and Electrification of Agriculture", 312 Rayimbek Avenue, 050005 Almaty, Republic of Kazakhstan

generally used in small devices such as calculators and watches (Wolanczyk, 2011; Rodacki and Kandyba, 2000; Brendel, 2003). As the metal contacts are made, the solar cells are interconnected by flat wires or metal ribbons and assembled into modules or solar panels (Dobrzanski and Szindler, 2012; Wurfel, 2009; Dobrzanski and Musztyfaga, 2011).

If the lower flow resistance of the current, the output current is a multiple of the current cell panel and associated with parallel connections of elements and modules. Similarly, the output voltage of the module depends on the amount series-connected cells and modules. Photovoltaic solar cell generates electricity only when it is illuminated, electricity is not stored.

The current-voltage characteristics of the cell are shown the output current PV generator, depending on the voltage at the set temperature and lighting (Klugmann-Radziemska, 2010; Moller, 2006). Short circuit current (ISC) the output current of the photoelectric. Generative at a given temperature and irradiance, PMPP-Point MPP (Maximum Power Point) is (Klugmann-Radziemska, 2010; Rodacki and Kandyba, 2000; Dobrzanski and Musztyfaga, 2011). The output voltage is heavily dependent on the temperature of solar cells: increase results in a lower operating temperature and efficiency of (Klugmann-Radziemska, 2010).

The developed mathematical model of a helio heating installation from a biogas plant allows us to calculate the thermal regimes, optimize the parameters of the solar collector and the circulating water flow in the solar circuit. As calculations have shown, when one ton of water is heated, the saving of electric energy is from 35-50 kWh and the annual saving is 3000, ..., 4500 kWh. The developed mathematical model of a photo of an electrical installation allows one to determine the capacity of a PV battery, depending on the number of operating cycles of the process equipment and the recharging time in each cycle. An analysis of the shown calculations of the photovoltaic system shows that, depending on the number of charge cycles, the capacity of the battery pack asymptotically approaches the limiting value (Keshuov *et al*., 2017).

MATERIALS AND METHODS

The laboratory testing program provides the following:

- Study of the current, voltage and power dependency on time and the density of solar radiation
- Control of environmental parameters; temperature and humidity of the outside air

Studies are conducted according to single-factor method; the experiments are performed 3 times each. During the study, the following parameters are recorded: the voltage and the current of the SPM, the charging current and the voltage on the batteries, the voltage at the output of the inverter, the temperature and humidity of the outside air (from +5 to +35°C), the electric power consumption of the switched load electric receivers.

In the experimental studies the following instruments were used: solar radiation meter SM-206, ammeter and a DC voltmeter, UT206 multimeter, electric meter "Saiman", infrared thermometer CENTER-350 and Meteorological meter MES-202. The measurement of solar radiation was carried out with a portable SM-206 instrument with an error of ±5% (measuring range 0.1, ..., 399.9 W/m^2), temperature was measured with infrared thermometer CENTER-350 with an error of ±2% (measuring range -20 to +5000°C). The air humidity and temperature was measured by psychrometer MV-4M with an error of ±4% and meteorological meter MES-202, maximum permissible values of the absolute error of the pressure measurement is not more than ±0.3 kPa in the temperature range from 0-60°C. Overall dimensions were measured with a metal tape with an error of ±0.5 mm (measuring range 0-10 m with division value of 1 mm) and metal ruler (1 m) with an error of ±1 mm. Devices and equipment connection diagram during the laboratory-field tests shown on Fig. 1.

The general view of SPM installed at the "Toyshan Madeniet" farm in Almaty region is shown in Fig. 2. The main elements of the control unit are shown in Fig. 3.

SPM prototype consists of 10 solar panels 1 which placed on a rectangular metal bearing frame 2 in two rows with the control unit (Fig. 2). Bearing frame 2 is mounted on the main frame 3 with the possibility of adjusting the zenithal inclination angle. Main frame 3 has isosceles triangle view on the tops of which there are wheels 4 with which main frame 3 rests on the platform. Main frame 3 is mounted for rotation around a fixed vertical anchor axis.

The control unit of SPM consists of charge controller M2460 60A, 12/24/V, battery from 6 gel battery Ritar 12-200, 12 V, 200 Ah, inverter PSW-3000 with a capacity of 3 kW, 24/220 V (Fig. 3). The daily electricity consumption by electrical appliances of the farmhouse is shown in Table 1.

RESULTS AND DISCUSSION

Experimental investigation: The results of the dependency study of SP electric power hourly output on cloudiness are shown in Fig. 4.

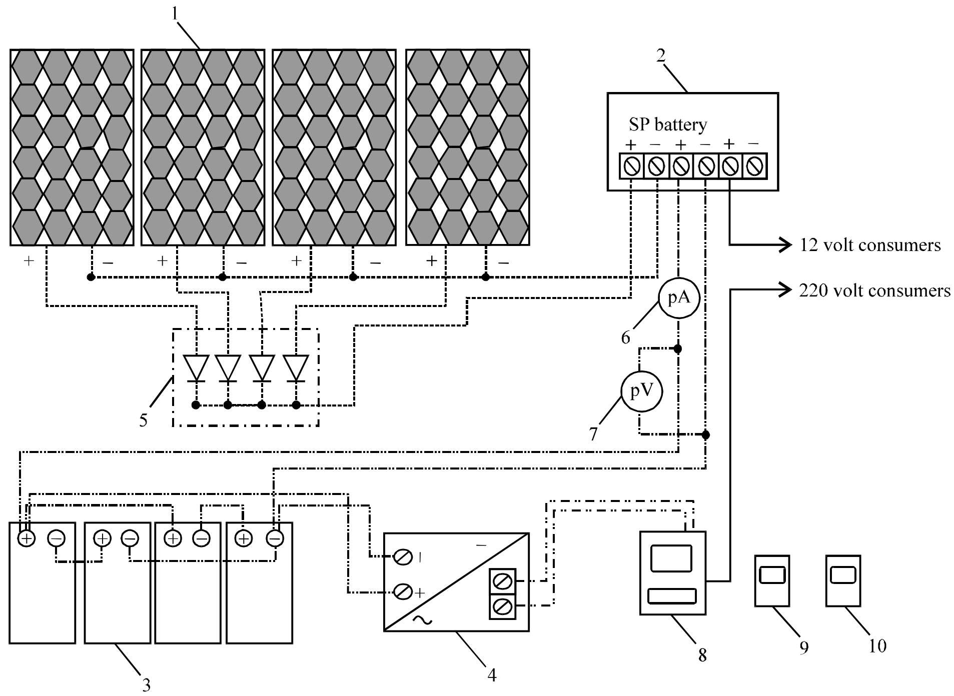

Fig. 1: Devices and equipment connection diagram: 1) SPM; 2) controller; 3) battery; 4) inverter; 5) diodes; 6) direct current ammeter; 7) direct current voltmeter; 8) electricle meter; 9) solar radiation meter and 10) meteorological meter

Fig. 2: The general view of SPM prototype during laboratory tests: 1) SP; 2) bearing frame; 3) main frame and 4) wheels

The data analysis of SP electric power hourly output dependency shows (Fig. 4) that:

- With a clear sky (total solar radiation per day is 8747 W·h/m^2), the generation of electricity is 1350 W·h
- At an average cloudiness (total solar radiation per day is 5295 W·h/m^2), the generation of electricity is 705 W·h
- With a strong cloudiness (total solar radiation for the day is 1920 W·h/m^2), the generation of electricity is 316 W·h

Analysis of the test results showed inconsistency in the passport data of solar panels manufactured in China with a nominal power of 200 W and experimental data: peak output 160 W, average output per day 102 W with solar radiation intensity of 887.5, ..., 1178.2 W/m^2. This

Table 1: The daily electricity consumption by electrical appliances of the farmhouse

Electrical appliances	Quantity	Total capacity P_{cap} (kW)	Usage per day (h)	Electricity consumption (kW·h/d)
Computer Viseo 223DX	1	0.200	4	0.80
Refrigerator Indesit	1	0.168	12	2.02
TV Harper	1	0.080	4	0.32
Iron BOSCH sensixx B1	1	2.100	0.25	0.50
Electric kettle Polaris	1	1.350	0.5	0.67
Microwave oven Akel	1	1.500	0.5	0.75
Washing machine Samsung WF 8590	1	0.800	1	0.80
Energy-saving LED lamp	5	0.005	6	0.15
Submersible pump Maxima WQD-1,1	1	1.100	2	2.20
Electric crusher "Lan4"	1	0.160	4	0.64
Total capacity of electrical appliances, P_{cap}	-	7.5	-	-
Total				8.85

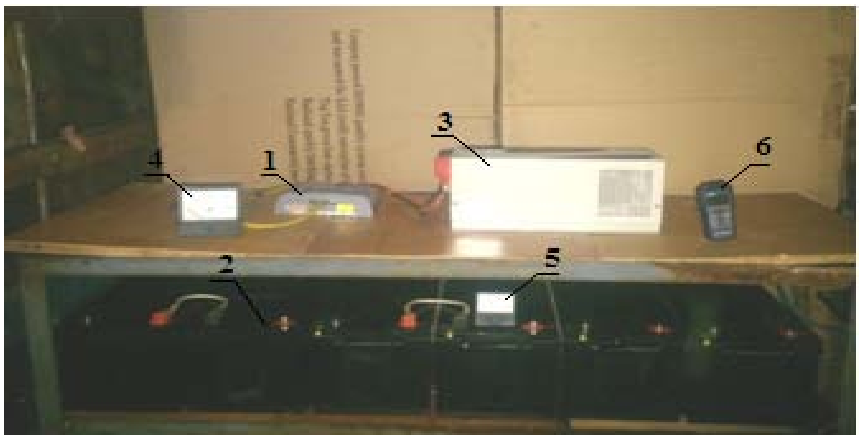

Fig. 3: Basic elements of the control unit: 1) charge controller; 2) battery; 3) inverter; 4) direct current ammeter; 5) direct current voltmeter and 6) solar charge meter

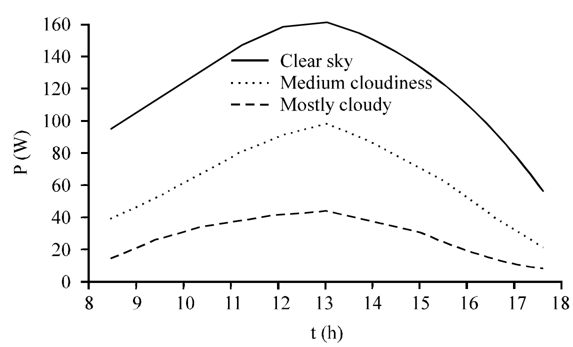

Fig. 4: The dependency study of SP electric power hourly output on cloudiness (August, total capacity of SP 200 W)

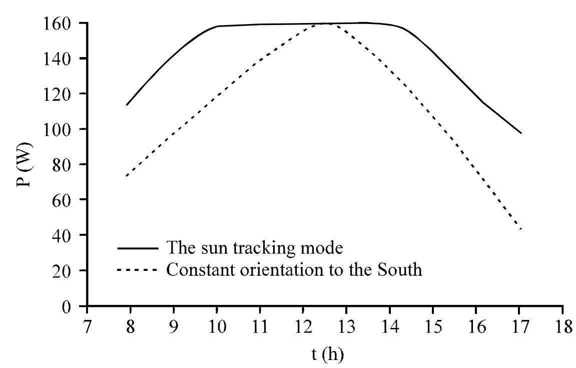

Fig. 5: Change of SP power during the day in the sun tracking mode at an average cloudiness (September)

leads to 14% reduction in the output of electricity by the SP. As can be seen, the selected SP does not satisfy the conditions for power output, hence, it is necessary to increase the total capacity of the solar panels to compensate for the identified factors.

The study of 200 WSP work with an area of 1.4 m^2 in the sun oriented mode showed that in this case the daily power output increases by 25, ..., 33% from 1235-1580 W·h (in September) as compared to stationary mode of solar panels with orientation to the South (Fig. 5).

The daily schedule of electricity output during the daylight hours when performing laboratory tests of the TPU prototype with orientation to the South is shown in Fig. 6.

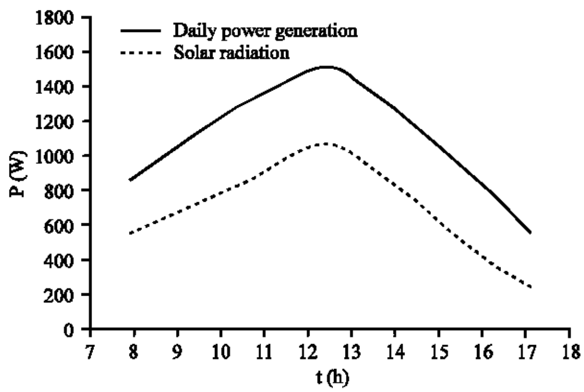

Fig. 6: The daily schedule of SPM electricity output with the capacity of 2 kW during the daylight hours with a clear sky (September-October, total solar radiation per unit area in a day is 8.98 kW·h/m^2)

Table 2: Summary test parameters

Name of parameter (UM)	Parameter values
Operational characteristics of SP:	
Peak output (W)	175
No-load voltage (V)	38, …, 44
Load voltage (V)	24, …, 26.4
Load current (A)	5.2, …, 6.2
Operational characteristics of battery:	
Capcity (A·h)	170.5, …, 188.5
Charging rate (A)	6.2, …, 11.5
Voltage (V)	12
Charging time (h)	7, …, 9
Operational characteristics of inverter:	
Input voltage (V)	24, …, 26.4
Output voltage (V)	220, …, 230
Input load current (A)	44.8
Output load current (A)	5.45
Operational characteristics of TPU prototype:	
Total capacity of SP (W)	2000
Total battery capacity (A·h)	1200
Nominal rating power of inverter (kW)	3.0
Generated electricity per day (kW·h)	17.5
Charging and discharging modes of battery under load (h):	
700 (W)	13.7
1000 (W)	9.6
1500 (W)	6.4
2000 (W)	4.8
Total capacity of electrical appliances (kW)	7.5
Daily power consumption of the consumer (kW·h)	6.0, …, 8.85

Table 3: Characteristics of the test conditions (August-October)

Name of parameters (UM)	Parameter values
Characteristics of climatic conditions	
Outside temperature (°C)	23, …, 34
Relative humidity of outside air (%)	72, …, 90
Intensity of solar radiation (W/m^2)	180, …, 1195

According to the graph in Fig. 6, the total solar radiation per day received by SP with a total area of 14 m^2 is 125.7 kWh and the average electricity output of TPU per day is 17.5 kWh. Summary parameters of laboratory-field tests are given in Table 2 and the characteristics of the test conditions in Table 3.

The analysis of the test results shows that the prototype of TPU with a power of 2 kW and the total batteries capacity of 1200 Ah provides the farm with electric energy of 6.0, ..., 8.85 kWh for a day with the installed capacity of 7.5 kW for electric appliances (Table 1). The discharge time of the battery varies from 13.7-4.8 h when the average electric load of the consumer changes from 700-2000 W.

The total solar radiation per day, received by TPU with a total area of 14 m^2 is 125.7 kWh, the average amount of electricity produced by TPU per day is 17.5 kWh.

The prototype of TPU with a power of 2 kW and the total batteries capacity of 1200 Ah provides the farm with electric energy of 6.0, ..., 8.85 kWh each day with the installed capacity of 7.5 kW for electric appliances. The study of the TPU operation showed that the mode of orientation to the sun increases the daytime power generation by 25, ..., 33%.

CONCLUSION

Solar Photovoltaic Modules (SPM) are popular in agriculture. For a lot of small farms, the main source of electrical energy is electric generators driven by internal combustion engines, since installation of electrical networks is economically unprofitable. In these conditions, SPM are economically and environmentally promising, since it does not require the consumption of fuels and lubricants does not harm the environment. Determination of the main SPM operating parameters in 2 modes is considered in this research. In the cases when the panels oriented towards the sun (tracking mode) and in a stationary state with orientation to the south (without tracking mode). The dependences of current, voltage and power on time and density of solar radiation were measured. Accordingly, the voltage and current of Transportable Photovoltaic Unit (TPU), the charging current and the voltage on the batteries, the voltage at the output of the inverter, the temperature and humidity of the outside air and the electrical energy consumption by the electric receivers were recorded. The study of the TPU operation showed that the mode of orientation to the sun increases the daytime power generation by 25, ..., 33% in comparison with the fixed installation of Solar Panels (SP). The analysis showed the discrepancy between SP passport data and the experimental results. The decrease in electricity generation was 14% compared to the expected estimates.

REFERENCES

Brendel, R., 2003. Thin-Film Crystalline Silicon Solar Cells, Physics and Technology. Wiley-VCH, Weinheim, Germany, ISBN:978-3527-403769, Pages: 291.

Dobrzanski, L.A. and M. Musztyfaga, 2011. Effect of the front electrode metallisation process on electrical parameters of a silicon solar cell. J. Achiev. Mater. Manuf. Eng., 48: 115-144.

Dobrzanski, L.A. and M. Szindler, 2012. Sol-gel and ALD antireflection coatings for silicon solar cells. Electron. Constructions Technol. Appl., 53: 125-127.

Keshuov, S., R. Omarov, A. Tokmoldayev, D. Omar and M. Kunelbayev *et al*., 2017. Hybrid system for using renewable sources of energy for local consumer in agriculture. J. Eng. Appl. Sci., 12: 1296-1306.

Klugmann-Radziemska, E., 2010. Photovoltaic, in Theory and Practice. BTC Korporacja, Legionowo, Poland.

Lipinski, M., 2010. Silicon nitride for photovoltaic application. Arch. Mater. Sci. Eng., 46: 69-87.

Markvart, T. and L. Castaner, 2003. Practical Handbook of Photovoltaics: Fundamentals and Applications. 1st Edn., Elsevier, Oxford, ISBN: 1856173909.

Moller, H.J., 2006. Photovoltaics-current status and perspectives. Environ. Prot. Eng., 32: 127-134.

Rodacki, T. and A. Kandyba, 2000. Energy Conversion in Solar Power, Wydaw. Silesian University of Technology, Gliwice, Poland,.

Wolanczyk, F., 2011. How to use the Power of Gifts the Solar Collectors and Photovoltaic Cells. KaBe s.c. Wydawnictwo i Handel Ksiazkami, Krosno, Poland,.

Wurfel, P., 2009. Physics of Solar Cells: From Basic Principles to Advanced Concepts. Wiley-VCH, Weinheim, Germany, ISBN:978-3-527-40857-3, Pages: 243.