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Management the efficiency of a photovoltaic installation

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Abstract
A photovoltaic installation is a technical system consisting of several elements that determine the correct operation of the entire system. One of the most important elements of this system are photovoltaic panels consisting of photovoltaic cells. The highest efficiency of the photovoltaic system is achieved when the power generated by photovoltaic panels is the highest. The aim of the work is to investigate the influence of temperature and solar radiation intensity on the operation of a photovoltaic installation. Research shows that temperature and solar radiation intensity affect the power of a photovoltaic installation, so these parameters should be controlled in order obtaining the highest electricity.

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1. Introduction

The demand for primary energy is growing as the world's population grows. It is believed that the sharp increase in energy occurred after 1950, which was associated with the rapid economic and demographic development of the world. There are currently approximately 8 billion people in the world, and as a result, the demand for energy has increased rapidly. However, it should be noted that the demand for energy varies depending on the region of the world; the most industrialized countries consume more energy than developing countries. At the same time, there was a change in the demand structure; in the second half of the 20th century, hard coal had the largest sharp in energy production, and now crude oil is the leader. It is assumed that if we continue to draw energy from non-renewable energy sources, oil and natural gas resources will be exhausted at the very beginning. (Luque et al., 2003)

The situation in Poland reflects the situation in the world - the demand for energy is increasing every year and natural resources are decreasing. Undoubtedly, hard coal and lignite have the greatest importance in the energy balance. The share of crude oil and natural gas is negligible. It is believed that the country's fuel structure must change and this is slowly happening through appropriate management of the energy market structure. This structure must primarily have the largest possible share of renewable energy. This is due to the need to meet the requirements regarding the emission of carbon dioxide IV, which is the most important product of fuel combustion in thermal power plants (Idzikowski et al., 2022; .Mroziński et al., 2016)

Installations that convert energy (radiation, wind, water) into electricity are clean energy sources. They contribute to the reduction of emissions of sulfur oxides, nitrogen oxides, dust and carbon dioxide IV.. The prosumer system of photovoltaic installations has developed in Poland very well. It involves the installation of photovoltaic installations by residents and then selling the excess energy through the distribution network. However, the efficiency of photovoltaic installations depends on many factors. The following work focuses on comparing the production of electricity in a home photovoltaic installation and determining the impact of temperature and solar radiation intensity on the efficiency of photovoltaic installations. For this purpose, a program was used that allows controlling the operation of the photovoltaic installation (Idzikowski et al., 2021; Leda et al., 2023).

Research by other authors has shown that the temperature of photovoltaic panels is an important parameter affecting the efficiency of photovoltaic installations. However, the research mainly highlights this problem without indicating how users of photovoltaic installations can cope with reduced efficiency of photovoltaic installations as a result of panel temperatures rising above STC standards. This is an important issue because both in Poland and in Europe it is noticed that the average air temperature is increasing every year. Therefore, it is justified to address this topic in the above research.

2. Literature review

The main task of a photovoltaic installation is convert solar energy into electricity. This is possible thanks to the photovoltaic effect. The photovoltaic effect consists in the ejection of electrons by photons from the valence band to the conduction level, causing holes to be created in the place of the electron ejected from the lattice. In a p-n semiconductor junction, there is an internal electric field, causing a constant electric potential. This potential is responsible for creating an electric field. Which separates the generated media. Then opposite charges are created - positive on the p side and negative on the n side. By connecting them with an external wire, an electric current flows, which can power the connected load. It should be remembered that for photogeneration to take place, the cell must be made of semiconductors with different types of conductivity (Wrzesiński, 2017a).

Photovoltaic installations consist primarily of photovoltaic panels, an inverter, AC and DC cables and protection devices. The listed elements of the photovoltaic installation can be treated as a certain technical system (F). From which the following relations can be derived: input - model state, input - output and state - output. The quantities defining the input, state and output are functions that depend on time t. These variables are divided into the following sets:

a) Input variables: $x_1(t)$, $x_2(t)$, ..., $x_n(t)$ - which determine the system forces that ensure its functioning,
b) Constant variables: $c_1(t)$, $c_2(t)$,…., $c_n(t)$ – which allow to describe the states of the system and its properties,
c) Output variables: $y_1(t)$, $y_2(t)$, ..., $y_n(t)$ - which describe the symptoms of the system at the output,
d) Disturbances $z_1(t)$, $z_2(t)$, ..., $z_n(t)$ - which include known and unknown factors, e.g. system ambient conditions, humidity, temperature, atmosphere, measurement errors, etc.

The above system can be written as the equation:

$F(x_1(t), x_2(t), …, x_n(t), c_1(t), c_2(t),…., c_n(t), y_1(t), y_2(t), …, y_n(t), z_1(t), z_2(t), …, z_2(t), t) = 0$

The correct operation of the photovoltaic system is influenced by the appropriate design of the system and its proper management. Proper design is understood as the appropriate selection of the installation power to meet the demand for electricity, the selection of appropriate parameters of photovoltaic panels for the inverter, the appropriate arrangement of photovoltaic panels on the roof, taking into account possible shading, the selection of the appropriate diameter of direct and alternating current cables, the selection of appropriate safeguards to protect the photovoltaic installation, and electrical installations of the facility against overvoltages (Mertens, 2019; Skibiński et al., 2021).

Some variables affecting the efficiency of photovoltaic installations cannot be influenced because they result from the design of individual components and interference. The main losses in photovoltaic installations include losses resulting from variability of sunlight throughout the year, variability of the angle of incidence of sunlight, thermal losses on DC cables, inverter losses, losses on elements connecting photovoltaic panels with solar cables, and, above all, the construction of photovoltaic panels (Mertens, 2019; Skibiński et al., 2021).

Photovoltaic panels are structures usually consisting of glass, EVA polymer foil, TEDLAR foil, aluminum frame, connectors and junction box, and above all, silicon cells whose task is to convert solar energy into electricity (Boyd, 2012; Markvart et al., 2005).

A p-n type photovoltaic cell consists of an anti-reflective layer located on the cell surface, a front electrode, an emitter layer usually up to 2 µm thick, a p-type layer up to 300 µm thick and a rear electrode, i.e. a smooth metallic layer. The mentioned layers play important roles in the functioning of the solar cell. The front electrode collects electrons from the cell surface. It is made in such a way as to enable the discharge of loads as much as possible. They appear in the form of thin paths on the cell surface. To reduce recombination, anti-reflective layers are used on the front surface of the cell. Their task is to reduce the reflection of light in the wavelength range responsible for photoconversion. Most often, this material is SiO_2 because it is compatible with the silicon structure. However, its refractive value is not quite ideal. Therefore, to improve its optical properties, the SiO_2 layer is etched with KOH and NaOH bases, which enable greater absorption of sunlight. The thickness of the emitter layer depends on the penetration of the high energy light wave. This layer is to ensure the efficient movement of electrons to the front electrode, so it must have low resistance and a low recombination speed. The absorber layer is intended to ensure easy absorption of photons at a level that guarantees high efficiency of the photovoltaic cell. The rear electrode, made of a metallic layer or a grid over the entire surface, is designed to detect holes and ensure the reflection of photons penetrating the cell back into its structure (Boyd, 2012; Markvart et al., 2005; Paranthaman et al., 2002; Pawłowska et al., 2014).

As already mentioned, silicon (Si) having a regular or quasi-regular crystal lattice is mainly used to build photovoltaic cells. It has an energy gap E_g of 1,12 eV. To produce the photovoltaic effect, phosphorus or boron is introduced into the silicon crystal. Adding phosphorus creates n-type silicon. Phosphorus has five valence electrons, so an extra electron appears, creating a cell called a donor. The additional electron is energetically weak and therefore moves freely in the crystal volume. If silicon is doped with boron, p-type silicon will be formed. Note that boron has three valence electrons, so one electron will be missing, such a cell is called an acceptor. An n-type semiconductor has electronic conduction, and a p-type conductor has hole conduction. When light radiation has a higher energy than the band gap E_g, electron-hole pairs are created, which are separated by the electric field of the junction. This relationship is derived below (Wrzesiński, 2017).

A moving photon particle has total energy equal to the kinetic energy E_k and rest energy m_0c^2, therefore (Bauer, 2002; Gunnarsson et al., 2005; Szaynok et al., 2000; Wrzesiński, 2017a, Wrzesiński, 2017b):

$$E = E_k + m_0c^2 \quad (1)$$

The total energy E of a photon moving with speed v is equal to:

$$E = mc^2 \quad (2)$$

Where: $m = \gamma m_0$

$$m = \gamma m_0 \quad (3)$$

Where γ:

$$\gamma = \left(1 - \left(\frac{v}{c}\right)^2\right)^{-\frac{1}{2}} \quad (4)$$

The momentum of a body with mass m:

$$p = mv = m_0\gamma v \quad (5)$$

The relationship between total energy and momentum can be written:

$$E^2 - p^2c^2 = m_0^2\gamma^2c^4 - m_0^2\gamma^2v^2c^2$$
$$= m_o^2c^4(\gamma^2 - \gamma^2c^{-2}v^2)$$
$$= m_o^2c^4\left(\left(\left(1-\left(\frac{v}{c}\right)^2\right)^{-\frac{1}{2}}\right)^2 - \left(\left(1-\left(\frac{v}{c}\right)^2\right)^{-\frac{1}{2}}\right)^2\left(\frac{1}{c}\right)^2 v^2\right)$$
$$= m_o^2c^4\left(\left(1-\left(\frac{v}{c}\right)^2\right)^{-1} - \left(1-\left(\frac{v}{c}\right)^2\right)^{-1}\left(\frac{v}{c}\right)^2\right) \quad (6)$$
$$= m_o^2c^4\left(\left(1-\left(\frac{v}{c}\right)^2\right)^{-1}\left(1 - \left(\frac{v}{c}\right)^2\right)\right) = m_o^2c^4$$

Therefore:

$$E^2 = p^2c^2 + m_0^2c^4 \quad (7)$$

Remember that a photon has no mass, so the mass is:

$$m_0 = 0 \quad (8)$$

That is:

$$E^2 = p^2c^2 \quad (9)$$

Hence:

$$E = pc \quad (10)$$

According to Planck's postulate, the energy of a photon is equal to:

$$E = h\nu \quad (11)$$

If it put the relationship into the equation 10:

$$p = \frac{h\nu}{c} \quad (12)$$

Taking into account:

$$\nu = \frac{c}{\lambda} \quad (13)$$

So the momentum of a photon has the value:

$$p = \frac{h}{\lambda} \quad (14)$$

Accordingly, in order for the energy of the photon hitting the cell surface to be greater than the energy gap of the semiconductor E_g.

$$E_g < h\nu \quad (15)$$

$$E_g < \frac{hc}{\lambda} \quad (16)$$

Where: E_g – width of the energy gap of the semiconductor, h – Planck's constant, ν = c/λ

As a result of the above relationships, quantum efficiency is an important parameter describing photovoltaic cells. Cells react differently to illumination with different wavelengths. This is because cells are made of different materials with different properties. Quantum efficiency was derived due to the determination of the cell's sensitivity to solar radiation, which has a different range of wavelengths. Quantum efficiency is defined as the ratio of the short-circuit current density obtained from the cell for a specific wavelength to the product of the elementary charge and the density of incident photons of the same wavelength absorbed by the cell. Therefore Quantum yield determines the number of carrier pairs generated by the striking photon. In cells, the quantum efficiency is a function that depends on the wavelength and parameters of the semiconductor material, and is in the range [0,1]. Quantum efficiency is often given as a percentage or as a nonnominal value (Skibiński et al., 2021).

The quantum efficiency is different from 0 for photons with energy greater than the energy gap of crystalline silicon 1,12 eV. If the photon energy is lower than this gap, generation does not occur. For short wavelengths, quantum efficiency is reduced due to recombinations on the front surface of the cell. If the recombination speed is higher, the lower the quantum yield value. For waves absorbed by the back of the cell, i.e. waves in the red range, the quantum efficiency is decreasing due to the lower absorption coefficient for long wavelengths and the short diffusion path. The level of quantum efficiency for a real cell is reduced compared to an ideal cell, which is the result of light reflection and shortening the diffusion path by reducing the resistivity of the photovoltaic cell base (Skibiński et al., 2021).

The material from which the photovoltaic cell is made influences the maximum parameters of the photovoltaic cell, i.e. open circuit voltage V_{OC} and short-circuit current I_{ph}, as well as the photoconversion efficiency. In particular, the energy gap of the material. The energy gap should not be excessively increased because it will result in a decrease in the photocurrent density in the photovoltaic cell. Significantly reducing the energy gap reduces the open circuit voltage V_{OC}. As established, sunlight has a certain light wave distribution determined by the AM (Air Mass) coefficient. Thanks to this, a certain optimal width of the energy gap was determined due to the achieved efficiency of the cell. The optimal energy gap for semiconductors is approximately 1,45 eV. Analyzing the properties of various semiconductors, it can be concluded that the value of the energy gap is different (Wang et al., 2022).

Manufacturers are trying to effectively increase the efficiency of photovoltaic cells by using semiconductor heterojunctions. Such a joint is created by combining two different materials with different energy gaps. Thanks to this structure, photons from different wave ranges, i.e. different energies, can be captured. A conductor with a wider energy gap, i.e. the emitter, is the top layer of the cell. The emitter absorbs high-energy photons, which do not penetrate deep into the material due to the high absorption coefficient. Low-energy photons penetrate deeper areas of the cell, i.e. the second semiconductor (Chapin et al., 1954, Rekioua et al., 2012; Twidell et al., 2015).

Another possibility of achieving high efficiency is to build the cell with several heterojunctions, which allows the use of a wider spectrum of light. However, the use of this possibility is difficult due to the need to maintain appropriate optical transmittance, enable diffusion through many areas of the connector and high production costs (Markvart, 2005; Rekioua 2012).

3. Photovoltaic cell as a clockwise heat engine

A photovoltaic cell can be treated as a clockwise circulation heat engine because heat flows from a hot supply source, which is the Sun, to a receiving source, which is the surroundings, i.e. the atmosphere. The transformation of energy into electricity always involves some loss of energy, i.e. energy losses. In a photovoltaic cell, this loss is manifested by a voltage drop determined by the Carnot coefficient (Carnot loss). As a result of the inequality of absorption angles, Boltzmann loss can be distinguished (Bauer, 2002; Metens, 2019;Wrzesiński 2017a).

Thanks to thermodynamics, it is possible to estimate the efficiency of the energy conversion process. By taking into account the rate of energy flow and entropy, the performance limits of a photovoltaic cell can be determined. If the cell is treated as a heat engine of the Carnot cycle, the Carnot limit can be determined for such a photovoltaic cell.

Figure 1 shows the operating model of the solar converter. The solar cell is in contact with a high-temperature Z_s source T_s (the sun) and a lower-temperature Z_s source T_o, which represents the surroundings. Q_s is the energy of solar radiation falling on the cell, Q_w is the amount of energy flowing from the cell. During the flow of energy between the supplying source (Sun) and the receiving source, work W is performed in the form of electrical energy (Bauer 2002; Mertens 2018; Wrzesiński 2017b).

The way of achieved results – experiment, the case study. This information should be understandable for Reader (after completion the knowledge) that he could repeat research on his own.

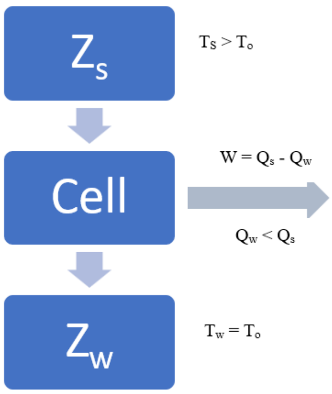

Fig. 1. The operating model of the solar converter

Based on the definition of entropy, the efficiency of the Carnot cycle can be derived by performing the following steps (Bauer 2002; Mertens 2018; Wrzesiński 2017b):

$$dS = \frac{dQ}{T} \tag{17}$$

Deriving from the Q equation, we get:

$$dQ = TdS \tag{18}$$

Then after integrating this relationship:

$$Q_{s-w} = \int_{s}^{w} TdS = T_s\,(S_w - S_s) \tag{19}$$

Useful heat converted into work is:

$$Q_u = (T_s - T_w)(S_w - S_s) \tag{20}$$

That is, the efficiency of the Carnot cycle:

$$\eta = \frac{Q_u}{Q_{s-w}} = \frac{T_s - T_w}{T_s} \tag{21}$$

This relationship shows that the conversion efficiency is a function of temperature. The efficiency of the Carnot cycle is the greater the lower the temperature T_w at a specific temperature T_s. In order to obtain the highest efficiency η, the temperature T_s had to be the highest and the temperature T_w the lowest. Unfortunately, economic and technical conditions in the construction of photovoltaic cells stand in the way. Therefore, the efficiency of the Carnot cycle is always less than 1. Because $\eta = 1$ is for $T_w = 0$ and $T_s = \infty$. However, for $\eta = 0$, the cell temperature must be equal to the sun's temperature, then the system is in thermal equilibrium and there is no energy exchange (Bauer 2002; Mertens 2018; Wrzesiński 2017b).

Substituting the average temperature of the Sun's photosphere of 6000 K and the temperature of the photovoltaic cell at approximately 300 K into equation 20, the efficiency of the Carnot cycle will be 95%. According to the Landsberg limit, this limit should be reduced to 93.3%, because the energy generated in the photovoltaic cell does not return to the Sun (Skibiński et al., 2021).

4. Object of research and purpose of research

The object of the research is a photovoltaic installation with a capacity of 6.68 kWp. The installation consists of photovoltaic panels from LONGI SOLAR with the parameters shown in table 1 and a photovoltaic inverter with a power of 6.6 kW. The PV installation is mounted on the roof facing south at an angle of 26°. As of February 2021, it has produced 17.72 MWh of electricity. Thanks to this production, it was possible to reduce carbon dioxide emissions at the level of approximately 10.5 tons. The task of a photovoltaic installation is to convert solar energy into electricity and use this energy for home purposes. The investment in a photovoltaic installation was aimed at reducing the costs of purchasing electricity from the operator and limiting the impact of the house on the environment. According to Poland's policy, people investing in renewable energy sources contribute to the reduction of air pollutant emissions by reducing the primary energy level of a given house.

According to the literature analysis, the conversion of solar energy into electricity is associated with certain energy losses due to thermodynamic processes taking place in photovoltaic cells. Temperature and sunlight are important factors for the proper operation of photovoltaic cells. Karthikeyan et al. in their artical are written that the efficients of PV panels decreases about 0.4-0.5% as the temperature increase about 1°C.

Table 1. Parameters of the LONGI SOLAR 445 Wp photovoltaic panel

Electrical and Mechanical Characteristic		
	STC	NOCT
Maximum Power (P_{max}, W_P)	445.00	332.30
Open Circuit Voltage (V_{oc}, V)	49.10	46.00
Short Circuit Current (I_{sc}, A)	11.53	9.33
Voltage at Maximum Power (V_{mpp}, V)	41.30	38.50
Current at Maximum Power (I_{mpp}, A)	10.78	8.64
Module Efficiency (%)	20.70	
Operational Temperature	40°C- 85°C	
Nominal Operating Cell Temperature	45°C ± 2°C	
Front Side Maximum Static Loading (Pa)	5400	
Rear Side Maximum Static Loading (Pa)	2400	
Temperature Coefficient of P_{max}	-0.35%/C	
Temperature Coefficient of V_{oc}	-0.27%/C	
Temperature Coefficient of I_{sc}	+0.048%/C	
Hailstone test	25 mm Hailstone at the speed of 23 m/s	

Their artical writed that the temperature of solar panels is function of verious external environment factors, as the wind speed, ambient temperature and solar irradiantion. Tyagi and Kumar are written that in the result of upsurge of temperature of PV panels is following increase speed of recombination electron-hole pairs. That is caused higher proportion charge carries do not participate with generation of current. When the temperature of solar panels exceeds above standard temperature the efficiency of the PV module rise down. Also Li et al. in artical are written that the temperature play the important role in shaping the efficiency solar panels.

Therefore, the aim of the work was to investigate the influence of temperature and solar radiation intensity on the operation of the photovoltaic installation. An attempt was made to determine the strength of the relationship between temperature and radiation intensity on selected parameters of a photovoltaic cell.

An application enabling monitoring of a photovoltaic installation was used to carry out the research. This application allows you to control the power, voltage, current and temperature of the photovoltaic installation. After entering the data of the designed PV installation, it is possible to continuously monitor the PV installation and react if there is a problem with the PV installation. After collecting data from the application, a statistical analysis of the relationship between temperature and solar radiation intensity on the PV installation was performed.

5. Results and discussion

The analysis was carried out for the selected operating day of the photovoltaic installation, which was July 8, 2023. That day, the installation looked flawless, the ambient temperature was 29 degrees Celsius and it was a sunny day. The PV installation produced 40,22 kWh that day. Figure2 presents the power of the PV installation in individual hours.

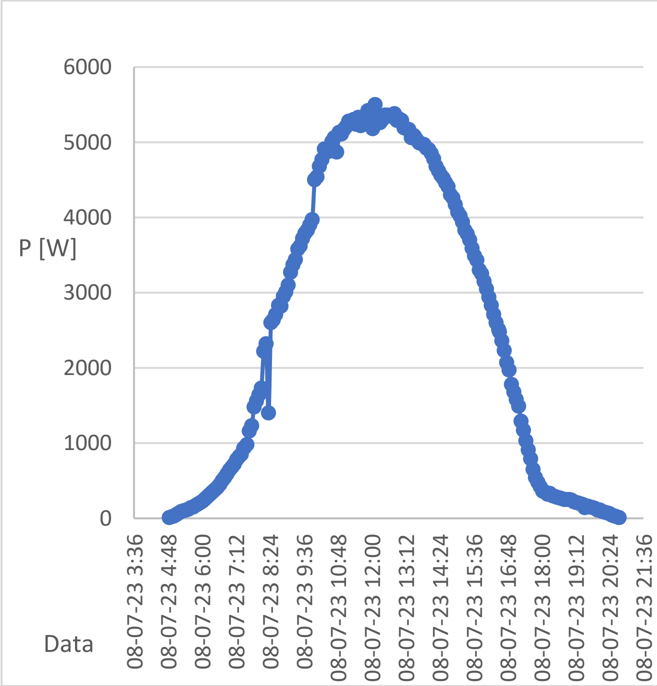

Fig. 2. Power chart of the tested installation on July 8, 2023

Below is the value of solar radiation intensity on July 8, 2023 for the town of Turzynek (Kujawsko-Pomorskie Voivodeship), where the photovoltaic installation is installed.

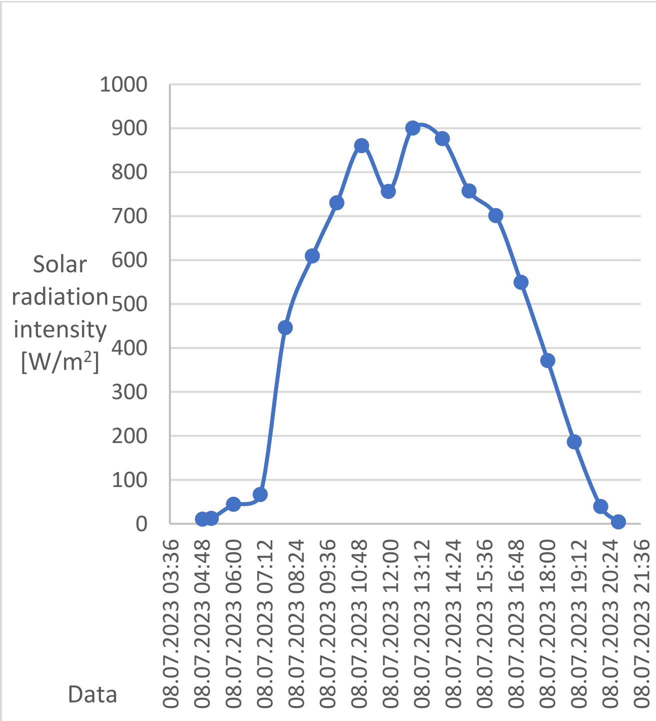

Fig. 3. Radiation intensity chart on July 8, 2023

The figures 2 and 3 show that the highest power of the PV installation was at the moment of the highest solar radiation intensity. Figure 4 shows the temperature value of the photovoltaic module during individual operating hours. Comparing figures1, 2 and 3, it can be concluded that the highest temperature of the photovoltaic module was between 12-3 p.m., i.e. during the hours of the highest power of the PV installation and the highest level of solar radiation intensity.

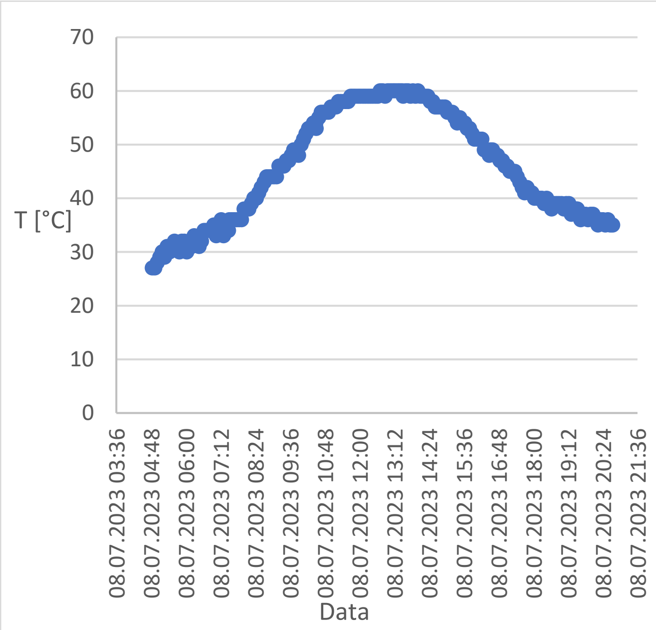

Fig. 4. Photovoltaic module temperature graph

Using statistical methods, Correlation of the influence of temperature and solar radiation intensity on the power of the photovoltaic installation were calculated.

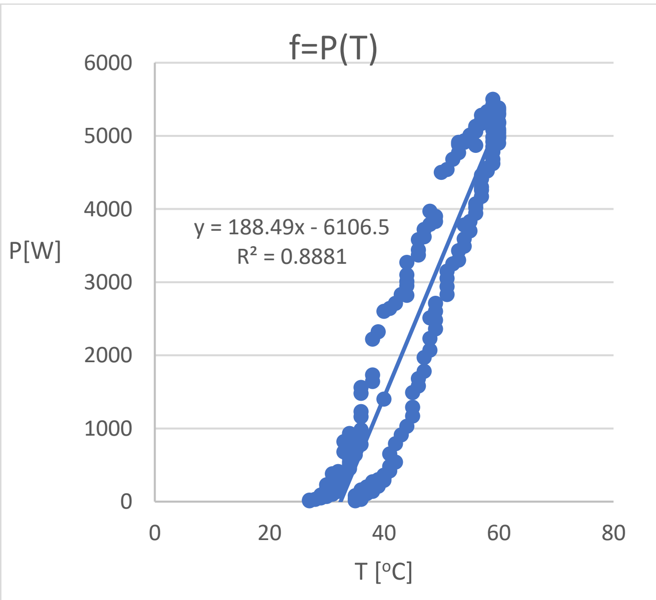

Fig. 5. Graph of the power and temperature function of the PV module

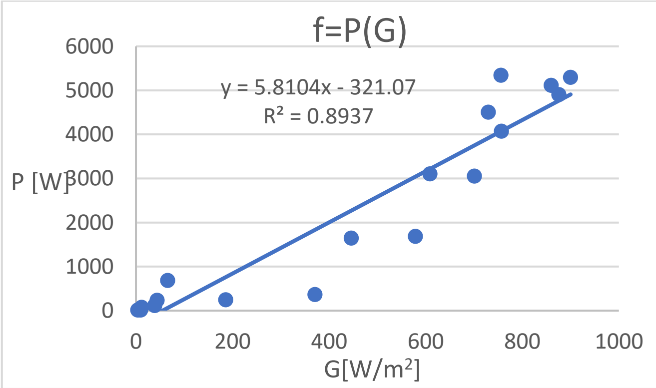

Fig. 6. Graph of the power and radiation intensity of the PV module

As can be seen in Figures 4 and 5, the correlation between the influence of radiation intensity and temperature on the power of a photovoltaic installation is positive, i.e. it increases with the increase in solar radiation intensity and power temperature.

The above results indicate that temperature and solar radiation intensity affect the power of the photovoltaic installation. When it comes to the intensity of solar radiation, its importance is most important in relation to the efficiency of the photovoltaic module. Bouger's law states that the intensity of solar radiation decreases exponentially as the thickness of the material medium increases. Based on Bouger's law, the absorption coefficient can be derived, which depends on the wavelength λ. The absorption coefficient for photons with lower wavelengths is higher, therefore they are more easily absorbed by semiconductor materials. However, the length of their wavelengths causes the absorption depth to decrease as the thickness of the emitter increases (Hmamou et al., 2021; Luque et al., 2003 Skibiński et al., 2021).

A photovoltaic cell has a certain spectral sensitivity, which varies depending on the material used to construct the photovoltaic cell. If the photons reaching the photovoltaic cell have wavelengths outside the spectral sensitivity range, photovoltaic conversion will not occur because the energy is too low. And for photons with energy higher than the spectral sensitivity, part of the energy will be used for photocurrent, and part of it will be converted into heat and will contribute to reducing the efficiency of the photovoltaic module (Mertens, 2019; Luque et al., 2003; Skibiński et al., 2021; Wrzesiński, 2017b).

As known, sunlight reaching the Earth carries all possible wavelengths, so it is worth using only wavelengths above ultraviolet and shorter than infrared in photovoltaic cells to ensure the highest level of energy conversion. The level of shading of photovoltaic modules, air pollution and cloud cover is also important to generation of electricity because the distribution of the solar spectrum itself is unchanged, but the value of photon energy decreases due to the absorption of this energy by, among others, dust and gases (Skibiński et al., 2021; Szaynok et al., 2000).

Another important factor is temperature, it affects the electrical parameters of the PV module. Excessive heating of PV modules reduces the efficiency of PV modules. The temperature increases by absorption of radiation with energy higher than the spectral sensitivity, recombinations of hole-electron pairs outside the junction and as a result of heat release in accordance with the Joule-Lenz law. An increase in temperature causes the material properties of semiconductors to change. Therefore, manufacturers of photovoltaic cells distinguish the temperature coefficient, which determines the change in the electrical parameters of the cell with an increase in temperature higher than that specified in STC conditions, i.e. 25 °C (Mertens, 2019; Luque 2003; Skibiński et al., 2021; Szaynok et al., 2000)

All this means that actions should be traken to protect the photovoltaic module against high temperatures and radiation above the spectral sensitivity range. Methods to reduce the temperature include introducing standards for mounting photovoltaic panels on the roof, so that the space between the photovoltaic panel and the roof allows for free flow of air (wind), which will cool the surface of the photovoltaic panel. Karthikeyan et all in their artical writed that the high temperature of PV panels is caused the high thermal resistance between the PV panels and its surroundings, what is a consequence of low wind speed. Another possibility is the cooperation of a photovoltaic panel with a solar collector. Constructions that combine photovoltaic cells and a solar collector have appeared on the market. These activities will help to reduce the impact of temperature on the efficiency of the photovoltaic installation (Sheik et al., 2022).

6. Summary and conclusion

When operating machines/technical facilities, efforts are made to ensure that they have the highest possible efficiency and effectiveness throughout the entire operation phase. Activities aimed at controlling the suitability and reliability of technical facilities are part of the field of operation management. Due to the fact that photovoltaic cells are becoming more and more popular, the operation of photovoltaic cells should be managed in such a way that they have the highest possible efficiency. The worth is undertaking activities such as washing photovoltaic cells, checking cable connections and monitoring the operation of photovoltaic cells to ensure proper operation of photovoltaic cells. The basic characteristic of a photovoltaic cell is the current-voltage characteristic, which changes due to the appropriate selection of semiconductor materials and the operation of parameters such as solar radiation intensity, wind speed, angle of incidence of solar rays and many other factors taken into account in the publication. Therefore, when managing operation and monitoring the operation of photovoltaic cells, one should primarily control the current-voltage characteristics. If an irregularity is detected, the cause of the distortion of the current-voltage curve must be found. The paper discusses the influence of temperature and solar radiation intensity on the efficiency of a photovoltaic installation. It was indicated that these are important parameters determining the efficiency of the photovoltaic installation and it was proposed how to reduce the surface temperature of the panels. In further research, it would be worth determining whether the proposed actions can effectively reduce the temperature of the panels while increasing the efficiency of the photovoltaic installation.

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