Impact of the type, orientation, and temperature of solar panels on observed efficiency in Latvian climate conditions

D Heincis[1,2], J Telicko[1] and A Jakovics[1]

[1] University of Latvia, Institute of Numerical Modelling, Jelgavas 3, Riga, Latvia
[2] E-mail: daniels.heincis@lu.lv

Abstract. As solar panel technologies become more and more popular and are increasingly used in nearly zero-energy building solutions, one must make sure that the panels are able to achieve performance indicators similar to those determined by manufacturers under standard testing in real-world conditions. To determine the efficiency of poly- and monocrystalline panels, depending on their spatial orientation and other parameters, a set of test panels was installed in Riga, Latvia in 2018 for long-term monitoring of their power output. This article summarizes the results for the first two years. In the autumn of the second year of monitoring, temperature sensors were installed on the solar panels to study the effects of temperature on panel's efficiency. The data show that the panel's spatial positioning is a crucial element affecting the amount of energy produced, although the type of panels and climate conditions are also important.

1. Introduction

Between 2005 and 2017, the share of renewable energy sources in electricity generation in the European Union increased from approximately 15% to almost 31%. This increase was mainly caused by more extensive usage of wind and solar photovoltaic (PV) energy [1]. Installing solar panel systems is an affordable, straightforward process, which has contributed to the popularity of PV technologies.

The effectiveness of PV panels is known to vary significantly depending on panel technology, solar radiation intensity, orientation, and temperature – the aim of this study has been to analyse the real-world efficiency of solar panels depending on these factors in Latvian climate. This article compares two types of solar panels – monocrystalline (MC) and polycrystalline (PC) – with various orientations.

Efficiency is expected to be significantly affected by the specific nature of Latvia's climate – temperatures exceed 30 °C in summer, high cloudiness throughout the year, and low temperatures in winter (down to –20 °C) with the added impact of snow.

2. Installation

A system of 5 PC and 5 MC solar panels was installed in 2018 at the Botanical Garden of the University of Latvia (see table 1). In the table below, efficiency coefficients are given per the standard test conditions (STC): 25°C ambient temperature, 1000 W/m^2 solar radiation intensity. The panels were arranged in five different spatial orientations, which can be further classified into 2 groups:

- southward orientations with a 13°, 40° or 90° angle to the horizon (S13, S40, S90);
- orientations with a 13° angle to the horizon towards the south (S13), west (W13) and eastern (E13) directions.

The selected orientations are typical for Latvian climate conditions. The panels were mounted on building rooftops to avoid environmental shading, with system installation described in [2]. In 2020, temperature sensors were installed on the panels to assess the impact of temperature on efficiency.

Table 1. Specifications for PC and MC solar panels.

Panel type	Model	Surface area, m^2	Efficiency, %	Maximal power, W	Temp. coeff. of P_{max}, %/°C
Polycrystalline	JAP60-275/4BB	1.64	16	200	-0.410
Monocrystalline	LG365Q1C-A5	1.72	20	275	-0.30

3. Results and discussion

Data on the power generated by solar panels were analysed, including the relationship with angle to horizon, total received solar radiation on a horizontal surface, and the temperature of the panels. There are orientations for solar panels which have a steady performance throughout the year and orientations that are effective only for part of the year. For instance, in winter, when the sun is located low above the horizon, higher efficiency than compared to the rest of the year observed in the panel oriented vertically relative to the ground and facing the south (S90). As shown in figure 1, the efficiency of this panel is comparable to that of other panels during the September-April period only. The S40 panel produces the most energy during the year (see figure 2); however, in the middle of summer, it can produce less energy than panels with 13° orientation. Comparing the data from 2019 and 2020, the overall trends remain unchanged. MC S40 panels on average generate 15.4% more energy than any MC 13° orientated and PC S40 on average generate 12.9% more energy than any PC 13°. On average, PC panels produce 20 – 30% less energy per year than MC panels with the same spatial orientation.

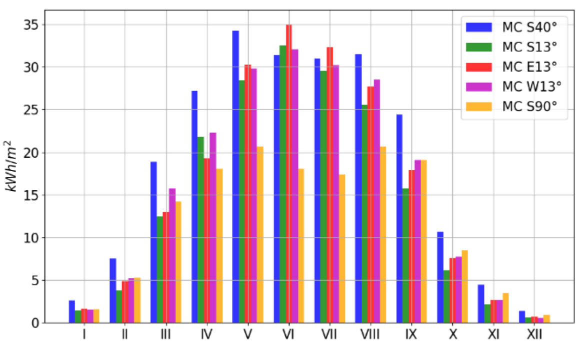

Figure 1. Energy produced by monocrystal panels in 2020, shown by month.

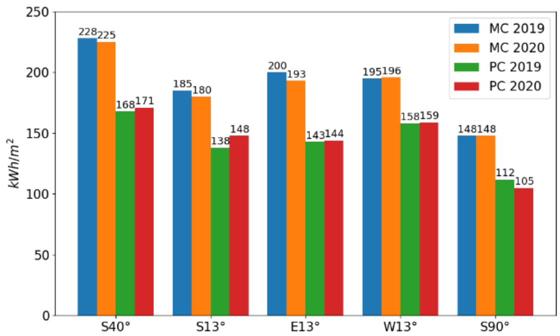

Figure 2. Total energy produced by varied-oriented panels during 2019 and 2020.

The technical specifications of the PC panels indicate that they lose 0.41% of their maximum power per degree above 25 °C.

$$P = P_{max} \cdot (1 - \Delta t \cdot 0.0041) \quad (1)$$

Accordingly, the PC panels will lose 6.15% of their maximum power upon heating up to 40 °C. For the MC panels, this value is 0.30%/°C. The observations do show that, when PC panels heat up, their efficiency is reduced slightly (see figure 3).

On a perfectly sunny August day, the surface temperature of the panel exceeds 50 °C (see figure 4). Figure 4 below shows that, in the middle of the day, the output power of the panel does not increase as quickly as the intensity of solar radiation does. This can be explained by the fact that the panel reaches its maximum power at the time, which should be 7.5% lower compared to standard test conditions at 25 °C. Observations show that when PC panels heat up, their actual efficiency (energy produced per unit of solar energy per m^2 of horizontal surface area [$(W_pW_s^{-1})m^{-1}$]) decreases slightly. MC panels, in turn, heat up less, and their efficiency reduction is less pronounced.

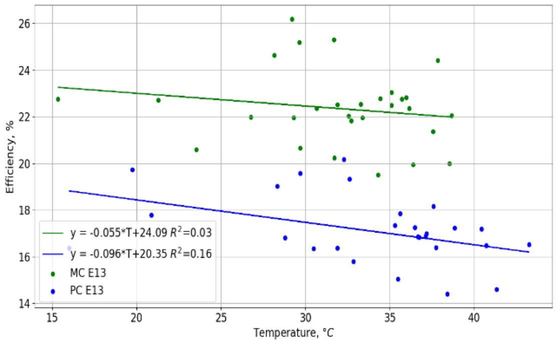

Figure 3. Actual efficiency of E13-oriented panels with respect to the maximum temperature of the panels surface, in September 2020.

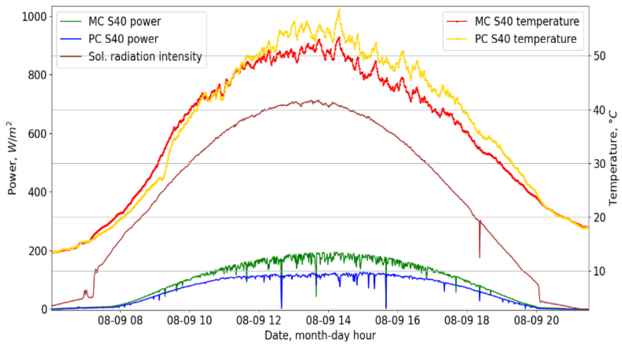

Figure 4. S40 panels' surface temperatures, solar radiation intensity on a horizontal surface and the panels' power output on a sunny August day.

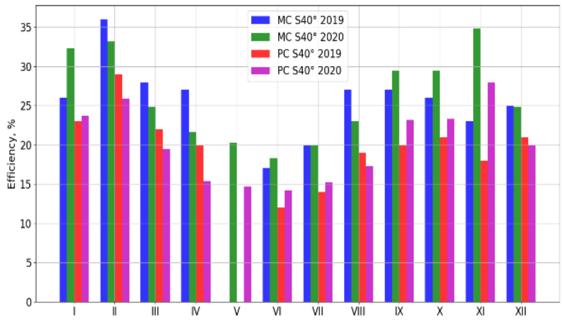

Figure 5. Actual efficiency of S40-oriented panels by month in 2019 and 2020.

Comparison of the data for the 2 observation years shows that S40 panels tend to exhibit a decrease in observed efficiency during the summer (see figure 5). This may be associated with heating up, but more observations are needed. Figure 5 does not display data for May 2019, as no data were available at the time. In winter, the efficiency of the panels is also affected by snowfall, as panels with a small angle to the horizon tend to become fully covered in snow (as was the case in January 2021). The average actual efficiency of the S40 MC panel in the Latvian climate is 22.5% and PC efficiency is 17%.

4. Conclusions

After the second observation year, it can be concluded that the actual efficiency values in the Latvian climate are slightly higher than the standardised ones (20% for MC, 16% for PC). The tendency for panel efficiency to decrease (especially for PC panels) with rising temperature was observed, although a quantitative assessment of the impact of temperature will require further monitoring data.

Acknowledgements

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References

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