Single case study photovoltaic panels within water heating system

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Abstract

The submitted article offers one of the possible options of a usage of photovoltaic panels for a domestic hot water preparation with an option to extra heating a heating system, and following recalculation of a produced electric energy amount in regards of a total return of the assembled system. An electric heating boiler combined with a heating option working on solid propellant was chosen for the experiment. The most frequently used combined electric storage tank was chosen as a classic option to heat domestic hot water.

Key words: photovoltaic panels, heating system

1 Introduction

Solar energy systems include photovoltaic (PV) materials and devices that convert sunlight into electric energy; PV cells are commonly called solar cells [1].

A large study in California completed by Lawrence Berkeley National Laboratory compared sales of homes with PV and without to determine what premium, if any, existed on homes sold with PV systems. Their results indicated that depending on whether the home was new construction, or existing, the price per watt premium varied between \$ 2.30 - \$ 2.60 /watt, and \$ 3.90 and \$ 6.40 /watt, respectively for homes with PV systems, as compared to comparable homes without PV.

Sample Comparison of Energy Savings Value to better understand some factors that affect energy savings, and therefore value to the consumer, an example follows comparing identical 5 kW PV systems—one in Colorado and one in Louisiana. This example illustrates the difference in energy savings as a function of production potential, utility electricity rates, and typical electricity consumption patterns. The example uses average conditions and is only intended as an illustration, not a real-world scenario. According to US Energy (2011) the typical Colorado household uses around 711 kWh of electricity per month that is approximately 8532 kWh/year.

Information Administration (EIA) data.¹⁶ Using the typical PV system size of 5 kW, a PV

system in Denver will produce approximately 7.594 kilowatt-hours (kWh) in the first year, 17 offsetting approximately 89 % of the household usage. Using average electricity rates in Denver of 11.1 cents/kWh, the price typically paid by the homeowner is around \$ 947/year, and the value of electricity produced by the PV system is approximately \$843 in the first year ($11.1 \text{ cents/kWh} \times 7.594 \text{ kWh}$), effectively reducing the amount paid by the homeowner from \$ 947 to \$ 104 in the first year, an 89 % reduction [2].

A photovoltaic system by itself and its behaviour should be introduced at the beginning. The article will follow the characteristics of the system's equipment. Subsequently, we will evaluate amount of produced electric energy used on a production of domestic hot water and amount of produced electric energy used for additional heating-up the heating system, also with calculation of payback from designed solution for heating [3].

The photovoltaic is a technical section, which concerns with a process of a direct transformation of light into the electric energy. The term is derived from a word photo (light) and volt (electric current unit). The transformation process runs in a photovoltaic cell. The photovoltaics were discovered by Alexander Edmond Becquerel in 1839. The photovoltaic cells for energy production in cosmic programs were used for the first time in 1958. Since then, it becomes inseparable part of the cosmic program. The article will not analyse a transformation process more deeply [4].

The basis of the photovoltaic (PV) systems is the photovoltaic (PV) cells merged into the photovoltaic (PV) panels. The most popular photovoltaic panels are made from silicium. The different ways of silicium treatment can create monocrystalline, polycrystalline and amorphous (non crystalline) photovoltaic cells. The monocrystalline cell is black octagon and the polycrystalline cell is a blue square.

The monocrystalline cells are more efficient than polycrystalline, however, the usage of an area in the polycrystalline cells is not so perfect according to its shape, so both types has similar performance in the conclusion.

The polycrystalline cells effectivity is 12-14 %. The monocrystalline cells effectivity is 12-16 %. Price and durability are the same. The photovoltaic panels are capable to produce an electric energy without a direct sunlight based on diffuse equipment, which is dominant in the Slovakia.

2 2. Designed system

The designed system is with a direct connection. This system was chosen due to its quick payback, what was the initiative though of a system design.

- Used system elements: Photovoltaic (PV) panels Kyoto 275 kWp – 16 pieces
- MPPT regulators DC/AC designed for PV system – 2 pieces
- Combined boiler Mora k 120 L 2 x 1000 W or 2 x 1800 W
- Storage tank Regulus 200 L
- Electric heating spirals 2 x 2000 W

Existing heating system that combined electric boiler and heating by a solid propellant. It is necessary to mention, that the photovoltaic system was installed into the existing fully functional system of domestic water heating. It was ensured by an electric energy from the network in a summer and the heat exchanger connected to the heating system in a winter.

The combined boiler was used MORA K 120 L by reason of having dry spirals installed in

the flange with changeable input power 2 x 1000 W or 2 x 1800 W /LD TOPTEL/. The combination of the spirals settings 2 x 1000W was used during connection to the network 230 V/ ~50 Hz, combination 2 x1800 W was used during connection of the MPPT / MPPT Stands for Maximum Power Point Tracking is a technique for tracking and regulate the output energy from the solar panel to the battery. The MPPT detects the solar panel output voltage and current in real-time and continuously track the maximum power ($P=U \cdot I$), regulates the output voltage correspondingly so that the system can always charge the battery with the maximum power./ regulators DC/AC determined for medium solar PV system in a number of 2 pieces. They are connected to the photovoltaic panels in number of 8 pieces with a performance 275 Wp by piece on every regulator, what gives together approximately 4.4 kWp (Figure 1).

Fig. 1: photovoltaic panels

3. Measurement of the consumption of an electric energy taken from the network

I did not measure the real consumption of an electric energy from the network. I keep up to the information from manufacturer, who officially indicate 7.64 kWh with input power 2 x 1000 W and temperature up to 65 °C from initial entry temperature of water 15 °C (Figure 1). This information is sufficient for a functionality demonstration and a payback of the whole system. It is possible to measure the real consumption of an electric energy with given type of the boiler and boundary conditions in a case of deeper examination (Table 1).

It is required to mention the spirals connection to the boiler 2 x 1000 W was changed to 2 x 1800 W to use the most input power from the photovoltaic panels in the shortest time. We watched it as an advantage during winter, when there is a less sunlight.

3.1 Display of the system connection:

The domestic hot water heating system is solved by 16 pieces of the photovoltaic panels FV Kyoto 275 kWp, which are connected by 8 pieces in a series with 2 pieces of regulators MPPT SOLARECO. The panels are directly connected into to the regulators, where a switch

is designed by a capillary thermometer in a case of overheating the combined boiler. An excessive energy after overheating of the combined boiler goes straight to the heating system via resisting heating spirals assembled to the storage tank connected to the existing heating system. The excessive energy after overheating the combined boiler will be discussed some other time. The combined boiler is directly connected to the MPPT SOLARECO regulators with classic 16A plug box, although there is a change against the classical electric energy network. The dry spirals with a performance 2×1000 W were changed for the heating device for contact heating LD-TOPTEL, cartridge heater with caliber 12.5 mm, $L = 400$ mm, and outlet length $L_v = 250$ mm, $U = 230$ V and performance 1800 W for one piece [8].

Table 1: Technical parameters of energy consumption

TYPE	K 120 L
Volume (l)	120
Pressure (MPa)	0.6
Weight / filled with water (kg)	62/66
Anticorrosive protection	Enamel / Mg anode
Input power (W)	2×1000
Voltage	230 V ~
Protection class	I.
Protection level	IP25
Time to heat water to 65 °C (h)	3.82
Energy consumption to temperature 65 °C (kW)	7.64
Quantity of water with 40 °C (l)	228
Heat loss (kWh / 24 h)	1.77

3.2 Measurement methodology

The basis of my research is the question: “Will the given photovoltaic system fulfil needs of a domestic hot water with correct operation and without any feeling of missing comfort due to lack of hot water, or any necessary physical switching to a classical electric network?” The measurement was designed for reading the values based on a boiler’s water temperature, which was set on a maximum operational temperature. The reading was always at 5 pm. The measurement of the really produced electric energy was made similarly; however, we will not represent it in this article. [9].

3.3 Payback of domestic water heating:

It is necessary to bring up that particular photovoltaic system would also run with a half number of panels and one regulator MPPT SOLARECO a half price of photovoltaic panels with accessories. However, my thought was to design a heating system, which will still work during winter months – December, January. It could not be done with a system of 8 pieces of panels and only one regulator MPPT SOLARECO. The measurement implemented in 2016, 2017 and 2018 is presented in the Figure 2. Input requirements and total initial costs are specified in Table 2.

Fig. 2: Designed system [10].

Table 2: Input costs

Photovoltaic panels	140 € x 16	2 240 €
Connection accessories + cables		387€
regulator MPPT SOLARECO	2	300€
Cartridge heater	2	105€
Assembly material on the roof		274€
Total costs		3285€

Real consumption of an electric energy reported by a manufacturer multiplied by ratio 1.5, because of need of hot water was mostly more than 1 heat up of the combined boiler in a day $7.64 \text{ kW/h} \times 1.5 = 11.46 \text{ kW/h} \times 365 \text{ day} = 4182 \text{ kW/h}$.

Table 3: Calculation of a total electricity price

Distributive area	Product	Amount of energy import [kW/h]
East Slovakia	DD2*	1T/VT - 4 182.00
Invoicing items [€]	Yearly	Monthly
Payment for electricity	186.68	15.56
Fixed monthly payment – keeper	7.80	0.65
Fixed payment for distribution (breaker, emergency capacity)	50.83	4.24
Variable payment for distribution	105.80	8.82
Loss	25.05	2.09
System services	28.82	2.40
System operation	109.57	9.13
Nuclear fund	13.42	1.12
DPH	105.60	8.80
Total	633.59 [€]	52.80 [€]

* DD2 - Single-band rate for consumption points with higher electricity consumption

The payback of the whole system after total calculation of all costs is 5.18 year. However, with half number of the panels and only one regulator is payback 2.59 year.

4 Conclusion

The photovoltaic system for a hot water heating was design with a thought to speed up money payback from initial capital. The time of 5.18 year might look long, yet, we did not focus on an excessive energy after overheating the combined boiler. This energy could be used to heat water in a heating system, though this topic will be discussed in some other article.

4.1.1 References

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