SOLAR POWER PLANT „STUDENTSKI RESTORAN VARAŽDIN"

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POVZETEK

Članek opisuje glavne elemente sončne elektrarne, zgrajene na strehi študentsko restavracijo v Varaždinu, predvsem uporabljenih omrežnih pretvorniki. Poleg tega je pokazan način povezave fotonapetostnih modulov s pretvorniki in instalacijo uporabnika. Na koncu tega članka je pregled proizvodnje električne energije v prvih petih mesecih delovanja.

ABSTRACT

This article describes the main elements of solar power plant built on the roof of the student restaurant in Varaždin, the used grid inverters in particular. Moreover, the way of connecting the photovoltaic cells on grid converters and user's installation is presented. At the end of this paper, there is a review of electrical energy production during the first five months of operation.

1. INTRODUCTION

During 2014, solar power plant with 68 kW was designed and built on the roof of the newly built student restaurant in Varaždin. The power plant consists of 274 photovoltaic modules, 270Wp each, i.e. total output of 73.98 kWp, four inverters, 17 kW each, i.e. a total output of 68kW and steel construction with aluminum subconstruction for modules mounting. The plant will be connected to the main distribution cabinet inside the facility. All the produced energy will be used for its own consumption, and any surplus will be sent in the network. Expected mean production per kilowatt of installed capacity for a fixed system is about 1150 kWh per year.

2. INVERTERS ON THE SOLAR POWER PLANT „STUDENTSKI RESTORAN VARAŽDIN"

Inverters that are used for PV systems can be divided according to topology into [6]:

- • inverters with low frequency transformer (LF)
- • inverters with high frequency transformer (HF)
- • inverters without transformers (transformerless (TL) inverter).

The first group of inverters in the output circuit includes a low frequency transformer (Figure 1), which transforms the output voltage into the electricity network voltage.

Alongside the transformation of voltage, the transformer realizes galvanic isolation between the PV generator and power networks. The main advantages of the inverter with a low frequency transformer are as follows: galvanic isolation between the input voltage of the photovoltaic generator and the output voltage which is connected to the electricity network; the ability to design systems with extra-low voltage PV generator; distribution and reliability. The disadvantages are as follows: large volume and weight of low-frequency transformers and losses due to transformation (magnetic and ohmic losses). The efficiency of such inverters is about 96%.

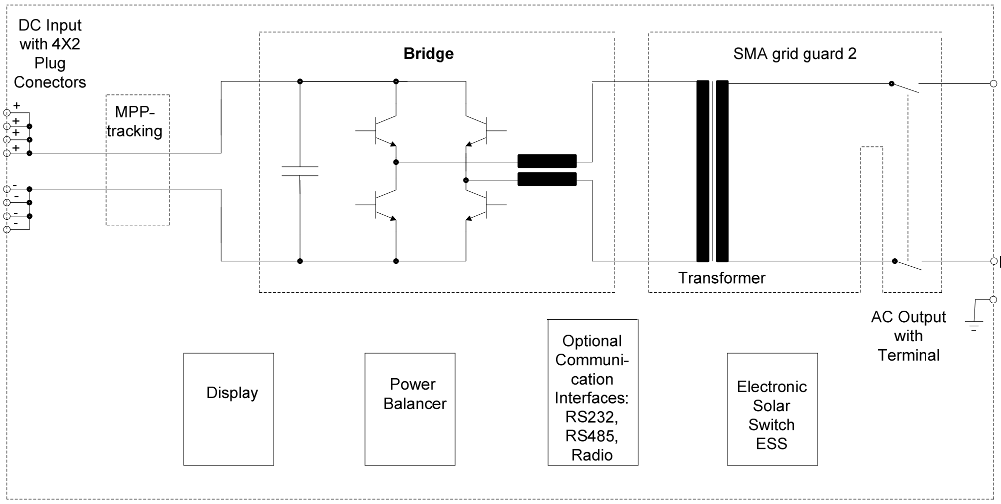

Fig. 1: Schematic diagram of the inverter with low-frequency transformer

In the second group of inverters there are inverters with high-frequency transformer (Figure 2). This construction consists of a bridge by which the DC voltage of the photovoltaic generator is converted into AC voltage of high frequency. The output voltage from the bridge is connected to the primary side of the high-frequency transformer. Rectifier on the secondary side of the high-frequency transformer rectifies voltage which is again converted into alternating current with frequency of 50 Hz by another bridge. Benefits of inverters with high-frequency transformer in relation to the inverters with LF transformer are low weight and volume of high-frequency transformer, while the disadvantages are complex electronics, lower reliability, and lower efficiency, typically 94.5%.

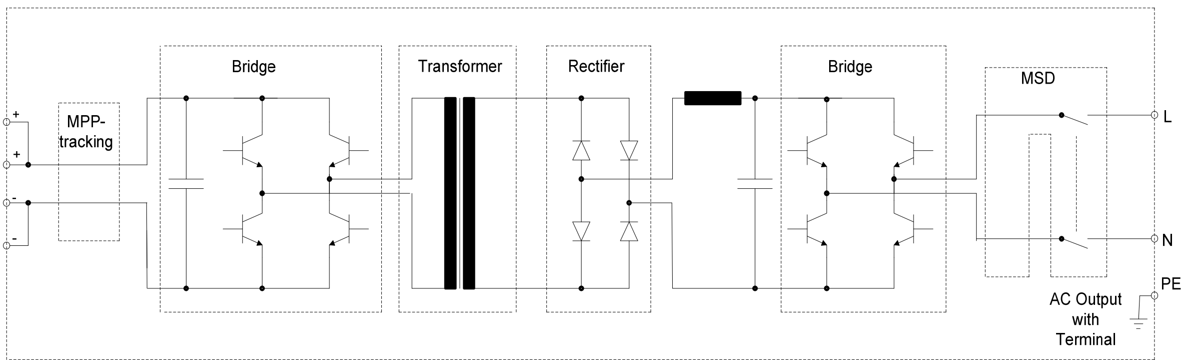

Fig. 2: Schematic diagram of the inverter with high-frequency transformer

Alongside the inverters with transformer with galvanic isolation PV generator and the power network, there is a topology of inverters without transformer, i.e. without galvanic isolation (Figure 3).

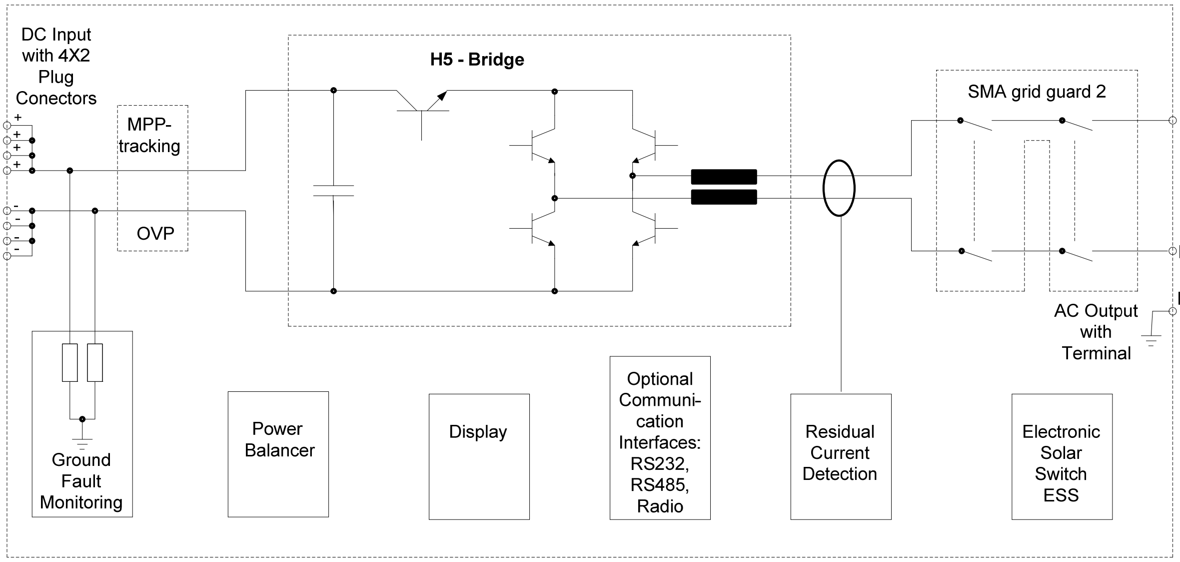

Fig. 3: Schematic diagram of the inverter without transformer

This construction uses the so-called H5 topology that is distinguished from the usual topology with four semiconductor switches by an additional switch. The reason for the addition of this switch is that current flows even in a short time when the current does not flow through the bridge. This current flows in the reverse direction, towards to the input capacitor. To prevent the transfer of energy in that direction a new overlap concept with 5 switches is developed. Losses caused by the current flow to the capacitor are thereby substantially reduced to around 2%. Because photovoltaic field and the electricity network are not mutually isolated, it is necessary to include additional protection. The problem caused by the absence of the transformer is injection of direct current. For this reason, the amount of that current at the inverter output is measured and if it is greater than the allowed amount, the inverter signalizes failure.

Benefits of inverters without transformer are high efficiency, which rises up to 98%, and a low weight; the major disadvantage is that there is no galvanic isolation of inputs and outputs.

For this power station four inverters SUNNY TRIPOWER 17000TL manufactured by SMA have been selected. They are placed on the outside wall inside the building, above the auxiliary entrance for staff (Figure 4). The electrical characteristics on the output of the photovoltaic field fully correspond to the electrical properties on the input of inverter in the whole temperature range of power plant operation.

Fig. 4: Inverters SMA Sunny Tripower 17000TL placed on the outside wall

Sunny Tripower 17000TL is transformerless inverter with a nominal power of 17 kW and maximum efficiency of 98.20%. Inverter has a built-in advanced security subsystems protection of isolated operation, overcurrent and overvoltage protection for photovoltaic field, and wireless communications and overvoltage protection for module strings. At this power plant four inverters with total output power of 68 kW are used.

Technical specifications of the built-in inverters are [2]:

Maximum DC power at cosϕ=1	17410 W
Maximum DC voltage	1000 V DC
MPP voltage range	400 -800 / 600V
AC nominal power at 230V, 50 Hz	17 000 kW
Nominal AC voltage	230 / 400V
Nominal AC grid frequency	50 Hz
Maximum output current AC	24.6 A
Maximum short-circuit current AC	50 A

3. OTHER ELEMENTS OF THE SOLAR POWER PLANT

For this power plant, the project required monocrystalline photovoltaic modules and standard monocrystalline PV modules with dimensions 1650x990x40 mm have been purchased.

Table I: Characteristics of selected photovoltaic modules

Type of solar cells	Monocrystalline
Number of cells	72
Rated output power (P_{nom})	270W
Open circuit voltage (U_{oc})	38,60 V
Short-circuit current	9,43A
Nominal voltage	35,70V
Nominal current	7,61A

Photovoltaic modules are mounted on a steel construction with aluminum subframe assembly module (Figure 5) and are connected to each other serially. From 17 to a maximum of 19 serially connected modules can make one string. This string has a maximum gross power 5.12 kWp. At one inverter of 17 kW, three strings are connected to input A and one to the input B, divided into groups according to the plans in the project documentation:

- inverter 1: 4 strings x 17 modules
- inverter 2: 4 strings x 17 modules
- inverter 2: 3 strings x 17 modules + 1 string x 18 module
- inverter 2: 3 strings x 17 modules + 1 string x 18 module.

Fig. 5: Solar panels mounted on the roof of the student restaurant in Varaždin

The power plant is over its own distributor and control electricity meter connected to the main distribution in facility (Figure 6). All the energy produced will be used for its own consumption, and any surplus will be submitted to the network.

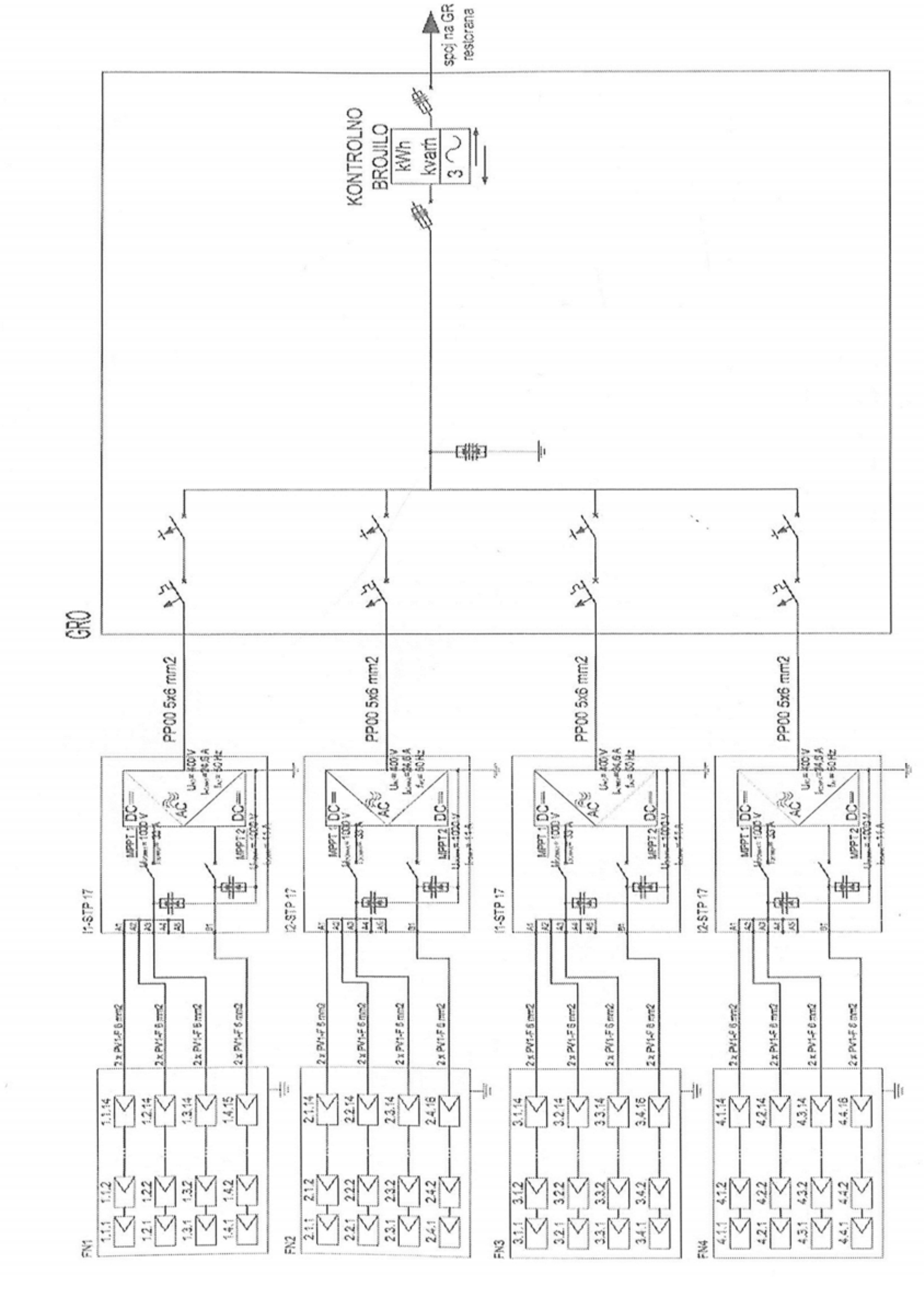

Fig. 6: Single pole wiring diagram of the strings to the inverters and the hub [3]

4. OPERATION OF THE POWER PLANT CONNECTED TO THE GRID

The potential of utilization of solar power plants in Croatia is between 970-1380 kWh per m^2 of solar collectors mounted under the optimum annual angle. With help of Fig. 7, the power of solar energy for the area of interest in Croatia can be approximately determined.

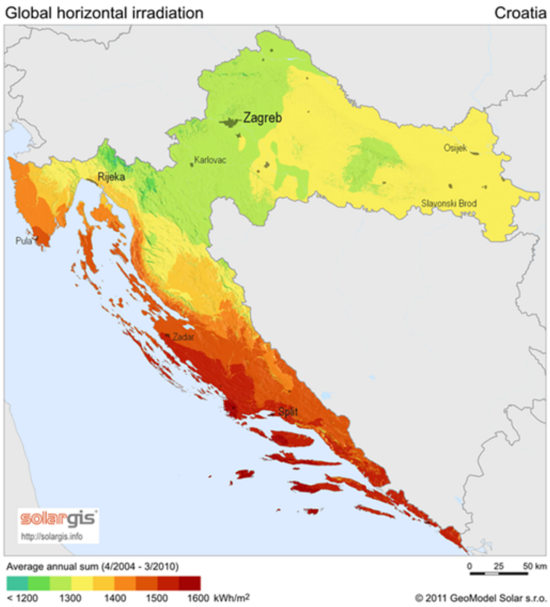

Fig. 7: Solar radiation on Croatian territory [4]

Since commissioning of the plant (trial operation during October 2014) to 31/12/2014, the value of realized total production (via all four inverters) is 1988.70 kWh. The beginning of the year was quite sunny, and during this period (from 01/01/2015 – 14/01/2015) the total production realized is (via all four inverters) 1051,28 kWh.

Fig. 8: Display of production 02/27/2015 at 12:15 – exchanger 1-4

In Figure 8, all four inverter screens are visible, recorded on 02/27/2015 at 12:15. It is visible that the total production (shown in Table II) at the inverters 3 and 4 is greater than at the inverters 1 and 2 because they have one PV module more.

Table II: Production of each inverter on SP "Studentski restoran Varaždin"

Label	Total production up to 27/02/2015
Inverter 1	1700,8 kWh
Inverter 2	1784,2 kWh
Inverter 3	1827,4 kWh
Inverter 4	1863,4 kWh

5. CONCLUSION

From the results shown in this article, it is evident that the solar radiation even in the area of Varaždin is sufficient for significant production of electricity using solar power plants. Construction of this plant was funded by the European Fund for renewable sources, and it was estimated that the power plant could cover up to 80% of energy required to operate the restaurant. Considering that the SP "Student restaurant Varaždin" has been operating only for five months in the period autumn - winter, and a total of 7172.8 kWh of electricity is produced, higher production is expected in the spring and summer months, which results in the justifiability and profitability of this investment.

6. REFERENCES:

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[2] SMA Solar Technology AG, PV – Wechselrichter SUNNY TRIPOWER 8000TL/10000TL/12000TL/17000TL Installatonsanleitung STP8-17TL-IA-de-3.1

[3] Glavni-izvedbeni projekt elektrpinstalacija sunčana elektrana za vlastitu potrošnju br. 17/2013, MBT Inženjering d.o.o. Macinec

[4] http://hr.wikipedia.org/wiki/Insolacija#mediaviewer/File:SolarGIS-Solar-map-Croatia-en.png, 28.02.2015.

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