UNITECH 2023 GABROVO
INTERNATIONAL SCIENTIFIC CONFERENCE
17-18 November 2023, GABROVO

IMPLEMENTATION OF 40 MW PHOTOVOLTAIC POWER PLANT BITOLA IN THE REPUBLIC OF NORTH MACEDONIA

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Abstract

From 2021 until today, RN Macedonia is facing a significant shortage of electricity for consumers. According to the energy balances, the import of electricity is increasing, while the domestic production of electricity is decreasing. The reason for this situation, which also contributed to the emergence of an energy crisis, is that the largest domestic electricity producer JSC ESM Macedonia produces smaller and smaller amounts of electricity. The largest producers of electrical energy, TPP Bitola and TPP Oslomej are 50-60 years old, the coal from the Suvodol and Oslomej mines is nearing its end and has a very low calorific value. According to the EU directives, it is necessary for thermal power plants, which represent the biggest polluters of electricity, to gradually shut down and to use renewable sources of electricity as much as possible. Each country, depending on its location, geographical location, as well as climatic conditions, should make significant use of its renewable energy resources. Macedonia is blessed with many sunny days, and the solar radiation ranges from 1 168 kWh/m^2 to 1 650 kWh/m^2, but unfortunately the use of the sun's energy is the least used.

In this working paper, the power for connecting a photovoltaic power plant PvPP Bitola with an installed power of 40 MW to the power grid will be considered. PvPP Bitola with 40 MW is located in the south-western region of RN Macedonia, where solar radiation is significantly high and amounts to 1 544,9 kWh/m^2. Several variants will be shown for choosing the equipment that would produce the largest amount of electricity.

The equipment with the lowest price, as well as its coverage in the selected location, is taken as the most favourable variant. For the selection of the location, land owned by JSC ESM Macedonia was taken, and thus there will be no additional costs for the land, and it is also close to the existing TS 400/100 kV/kV, so the total investment would cost less.

Keywords: Renewable energy sources, Photovoltaic power plants, Thermal power plants, energy transition.

INTRODUCTION

From 2021 until now, the Republic of North Macedonia has been facing significant energy problems. The annual domestic electricity production is in a huge decline and the needs of consumers cannot be reached. That is why the import of electricity is rising. Another reason for the reduced electricity production is the depletion of the coal from the Suvodol and Oslomej mines, as well as the extraction of coal with a very low calorific value.

Macedonia, as a member of the Energy Community, is obliged to apply the EU directives on captured energy, as well as the gradual replacement of conventional sources of electricity, coal, with renewable energy sources. These are the reasons, why it is necessary to gradually close thermal power plants and to substitute them with new sources of renewable energy. In this way, RN Macedonia moved from an energy crisis to an energy transition by implementing renewable energy sources.

Basic historical data of consumption, production and import of electricity in RN Macedonia

Figure 1 shows historical data from the shares of produced electricity expressed in

MW, according to different types of technologies in 2021. Figure 2 and 3 shows historical data consumption, production and import of electricity in GWh until 2021. It can be seen from the import graph that it is constantly increasing. [1]

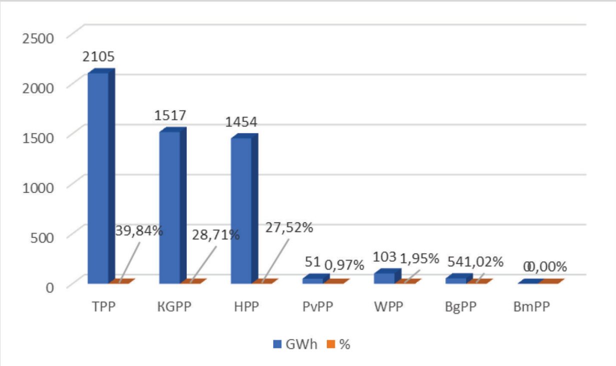


Fig. 1. Share of individual technologies in electricity production in 2021 (in %)

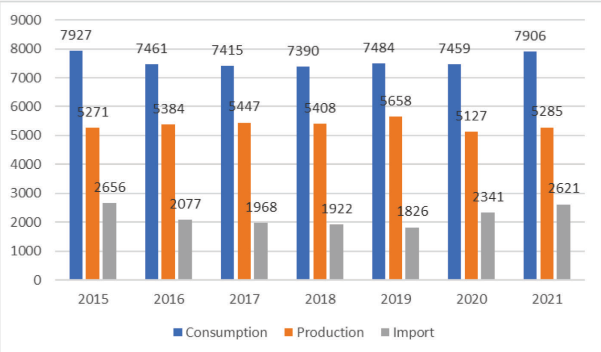


Fig. 2. Consumption, production, net import of electricity GWh, from 2015 to 2021

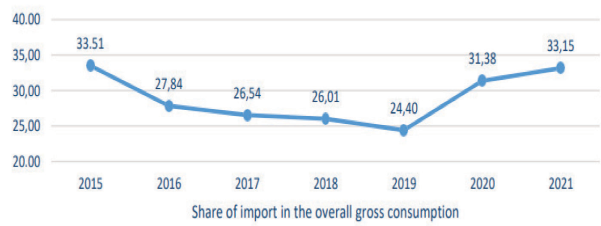


Fig. 3. Share import in the overall of the net import in electricity consumption in the period from 2015 to 2021 (in GWh and %)

Figure 4 shows historical data on the shares of produced electricity expressed in MW according to different types of technologies in 2022. [2]

Figure 5 and 6 shows the historical data of consumption, production and import of electricity in GWh until 2022 and it can be seen from the import graphic, that it is constantly increasing.

Macedonia is blessed with many sunny days, and the solar radiation ranges from 1 168 kWh/m^2 to 1 650 kWh/m^2, but unfortunately the use of the sun's energy is the least used. [3]

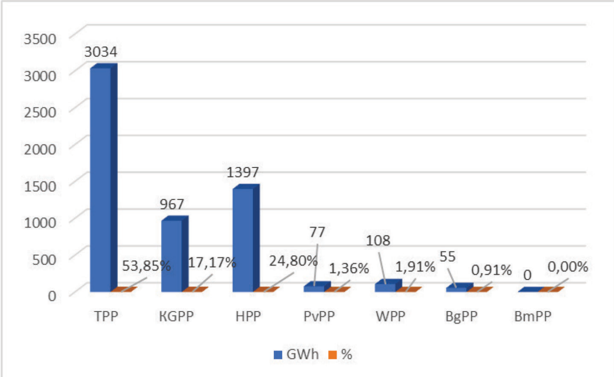


Fig. 4. Share of individual technologies in electricity production in 2022 (in %)

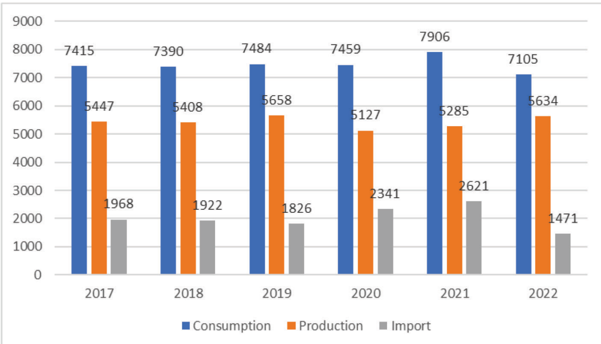


Fig. 5. Consumption, production, net import of electricity GWh, from 2017 to 2022

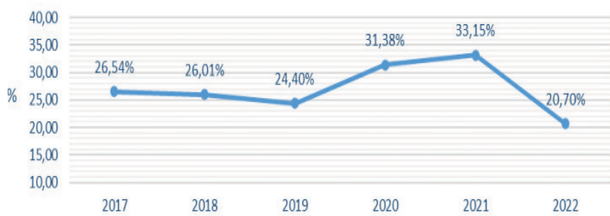


Fig. 6. Share import in the overall of the net import in electricity consumption in the period from 2017 to 2022 (in GWh and %)

The end of 2022 and 2023 are characterized by a large increase in the construction of photovoltaic power plants that are connected to the electricity distribution network, whose owners are private investors.

Mostly, these photovoltaic power plants are built on the roofs of the buildings, where the installed power of the free-standing photovoltaic power plants is the largest. The greatest interest has appeared in the eastern and south-eastern regions of RN Macedonia. As a consequence of the enormous installation in some cities, a problem with over voltages in the electricity distribution network is already appearing.

In order to increase the production of electricity from photovoltaic power plants, in this scientific paper it is shown, the construction of a new photovoltaic power plant PvPP Bitola with an installed capacity of 40 MW near TPP Bitola is foreseen. On the other hand, 15 minutes far away from PvPP Bitola, a new PvPP MEJ, with a power of 50 MW, was built 10-11 months ago, which is a private and Turkish investment.

EXPOSITION

This scientific paper foresees the construction of a new photovoltaic power plant PvPP Bitola with an installed capacity of 40 MW. The newly planned PvPP Bitola with 40 MW is planned to be built by the largest electricity producer in the RN Macedonia, public company JSC ESM Macedonia. The considerations are to increase the domestic production of JSC ESM Macedonia, whose annual production is in constant decline.

The location of the PvPP Bitola is planned to be in the immediate vicinity of the thermal power plant TPP Bitola, which has an installed capacity of 666 MW, on KP 221/1 cadastral territory of Dobromiri in the municipality of Bitola.

Forty percent of the cadastral plot, there is free undeveloped area, i.e. an area of 400 000 m^2, of which 400 000 m^2 will be used for the construction of PvPP Bitola with an installed capacity of 40,01 MW. For the production of electricity, it is exposed to high solar radiation with an average annual energy density of solar radiation of 1 544,9 kWh/m^2. [4]

***Fig.** 7. Planned location for PvPP Bitola*

Figure 7 shows the location of PvPP Bitola with 40 MW. The location was chosen in such a way that the land belongs to the category of agricultural barren land, the sixth category of construction, and it is a state land. [5]

During the preparation of this working paper, calculations and simulations were made with the help of the PVsyst software, as well as several variants in order to choose the most favourable one. The best type of upholstery available on the market in the RN Macedonia it was chosen, which has good technical characteristics, will be chosen. That is, by choosing the most favourable photovoltaic panels and inverters, the largest amount of electricity will be produced, while taking into account the maximum utilization of the free space of the cadastral plot.

Figure 8 shows the solar radiation for the selected location. [6]

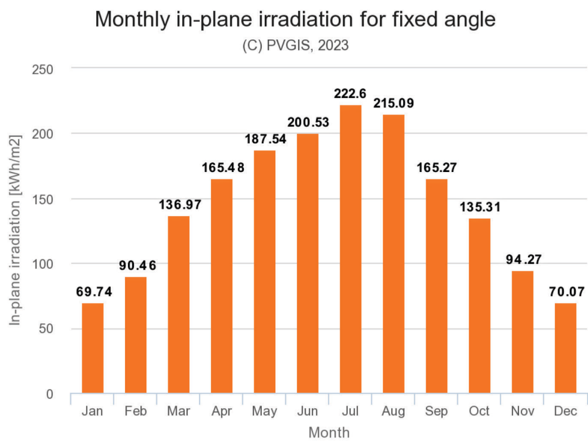


***Fig. 8.** Solar monthly radiation on the territory of PvPP Bitola*

Figure 9 shows the expected annual electricity production for the selected location.

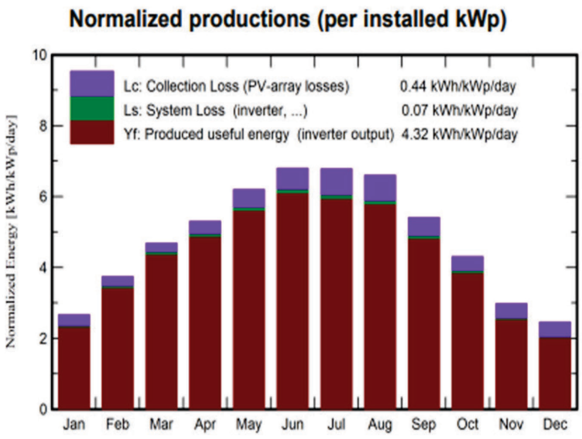


Fig. 9. *The annual electricity production for the selected location.*

Figure 10 shows the distribution of photovoltaic panels and transformer stations at the selected location.

According to the calculations by PVsyst software, the following characteristic values were obtained:

- Solar radiation of 1 771,18 kWh/m^2,
- Specific production 1 544 kWh/kWp/year;
- Expected annual electricity production of 62 942 978 kWh or 62 943 MWh;
- Installation angle of PV panels: 25^0 ;
- Azimuth of installation of PV panels: -12^0.

Fig. 10. *Location, position and placement of panels and TS for PvPP Bitola*

Total number of 73 216 PV modules with monocrystalline bifacial technology manufacturer type JETION type JT545SSh(B) with panel dimensions 2 279 x 1 134 x 30 mm and peak power per module of 545 Wp, are planned to be installed at this location.

On the other hand, 176 Huawei SUN2000 -185 KTL – H1 inverters are also planned in this project. Each inverter has 16 strings with 26 modules connected in series. The total number of strings are 2 816 strings.

15 transformer stations were also selected to be in this project, with a voltage transformation of 10(20) / 0,8 kV. The Power is 2 500 kVA. One TS 110/10(20) kVA transformer station is also planned.

The installed power of PvPP Bitola will be with amount of 39,10 kWp, i.e. 40 MW. [7]

Figure 11 shows the placement of the photovoltaic panels in relation to the sun and the azimuth angle. Figure 12 shows the mutual shading of the photovoltaic panels during the day, due to the rising of the sun. The blue numbers show the shading of a small part of certain panels.

Calculations and simulations have also been made with other types of equipment, ie panels, in order to make the most suitable and economical installation, which will produce the greatest amount of electricity. Calculations were also made with non-bifacial silicon panels, i.e. single layer JETION type JT545SSh with the same number of panels and the same type of Huawei SUN2000 -185 KTL – H1 inverters.

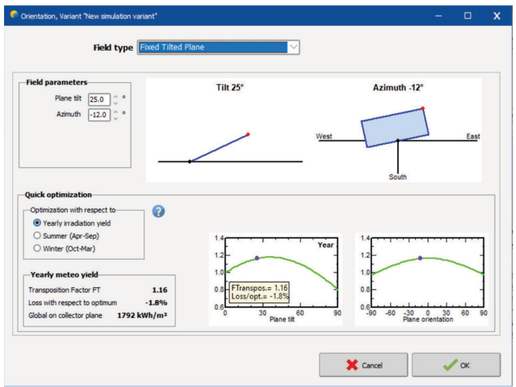
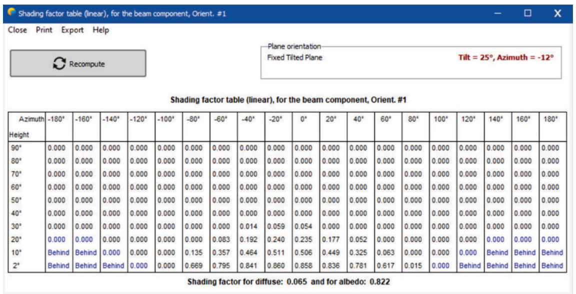


Fig. 11. *Placement of Photovoltaic panels*



Shading factor table (linear), for the beam component, Orient. #1

Azimuth / Height	-180°	-160°	-140°	-120°	-100°	-80°	-60°	-40°	-20°	0°	20°	40°	60°	80°	100°	120°	140°	160°	180°
90°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.014	0.059	0.054	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20°	0.000	0.000	0.000	0.000	0.000	0.000	0.083	0.192	0.240	0.235	0.177	0.052	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10°	Behind	Behind	0.000	0.000	0.000	0.135	0.357	0.464	0.511	0.506	0.449	0.325	0.063	0.000	0.000	0.000	Behind	Behind	Behind
2°	Behind	Behind	Behind	0.000	0.000	0.669	0.795	0.841	0.860	0.858	0.836	0.781	0.617	0.015	0.000	Behind	Behind	Behind	Behind

Shading factor for diffuse: 0.065 and for albedo: 0.822

Fig. 12. Shading of photovoltaic panels

A second variant of calculations were made with non-bifacial silicon modules from the same manufacturer, with the same power JT545SSh, the placement angle as well as the azimuth were the same, i.e. 25^0 and -12^0. 73 216 panels are planned. The power according to panels is 39,90 MW. 176 inverters of the SUN2000-185KTL-H1 type are planned, the total power according to the inverters is 30,80 MW. 2 816 strings with 26 modules connected in series are foreseen. In this case, less produced electricity was obtained on an annual basis, 60 706 125 kWh/year or 60 706 MWh/year, 62 942 978 kWh/year or 62 943 MWh/year.

From this calculation it can be concluded that with the same number of panels but not bifacial with the same number of inverters, the produced electricity is lower by 2 236 853 kWh/year or 2 237 MWh/year.

The capacity of the photovoltaic power plant is identical to that of PvPP Bitola with 39,90 MW.

A third variant of calculations was made with cadmium modules FS-6480A-C April 2021, with a power of 480 Wp. The placement angle and the azimuth are the same ie 25^0 and -12^0. 83 340 panels are planned. The power according to panels is 40 MW. 160 inverters of type GW25K-HT with power according to inverters 250 kW, total power according to inverters amounts to 40 MW are foreseen.

16 668 strings with 5 modules connected in series are foreseen. In this case, less produced electricity was obtained on an annual basis, 61 394 499 kWh/year or 61 394 MWh/year compared to the bifacial panels of the first variant 62 942 978 kWh/year or 62 943 MWh/year. In this calculation it can be concluded that the number of panels has significantly increased compared to bifacial by 10 124, also the number of inverters has decreased by 16, the produced electricity is lower then 1 548 479 kWh/year or 1 548 MWh/year.

The capacity of the photovoltaic power plant has been significantly increased as compared to the first variant with the bifacial modules of PvPP Bitola to 39,90 MW.

From the previously explained situation, it can be concluded that this third variant is the most unfavourable because the photovoltaic power plant with this type of equipment occupies a significantly larger area, the number of panels is significantly higher, the produced electricity is significantly reduced. The investment is the largest, which means that this variant is the most economically unprofitable.

The most favourable variant for the construction of PvPP Bitola is the first variant with the choice of silicon bifacial panels.

CONCLUSIONS

From the present study, it can be concluded that there should not be a transition for the construction of photovoltaic power plants only in the distribution network, but also in the power transmission network. With the planning of the construction of PvPP Bitola with an installed capacity of 40 MW, the electricity produced by the largest producer AD ESM Macedonia will increase, as well as the domestic electricity production by 62 943 MWh/year.

It may be little to begin with, but it would still encourage foreign and powerful investors to invest in renewable energy sources, such as the investor of PvPP Oslomej with an installed capacity of 50 MW. In that way, the import dependence of the RN Macedonia would decrease. Considering that the RN Macedonia is a country with many sunny days and high solar radiation, other photovoltaic power plants should be built in the future.

However, we should not focus only on the construction of photovoltaic power plants, but also on wind power plants.

Also, if the Chebren hydropower plant with an installed capacity of 333 MW is built, diversity would be obtained from the use of renewable energy sources. In that way, different weather conditions would be used and renewable energy sources would be used in the most rational way, which would also save the largest amount of electricity.

The diversity of renewable sources of electricity will enable easier management and balancing in the electricity system. System services of the power transmission system would also be provided accordingly.

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