

HYBRID GENERATION OF EXISTING WIND POWER PLANTS WITH ADDITIONAL INSTALLATION OF PHOTOVOLTAIC POWER PLANTS

Dragan Mrković^{1,3}, Perica Perić², Božidar Marić¹

Abstract: The paper describes the possibility of hybrid electricity generation in already existing wind power plants (WPP) by additional installation of photovoltaic power plants (PVPP) on individual wind turbines (WT). Wind turbines have the lowest generation of electricity in the summer months, while PVPPs have the opposite, the highest generation in those months. Connecting the PVPP to the existing WT (hybrid electricity generation) brings a more even generation and a greater degree of use of the infrastructure of the existing wind farms (HV/MV transformer station, medium voltage cable distribution...). This way the variation of generation in relation to the average annual generation is reduced, which reduces the problems of balancing electricity.

Keywords: Wind turbine, wind power plant, photovoltaic power plant, hybrid generation of electricity

INTRODUCTION

Hybrid systems of renewable electricity sources have been written about in the literature for many years [1] - [5]. Due to the unmanageability of the generation of WPPs and PVPPs, the best option is the combination of their generation with pumping or accumulation hydropower plants. There are also solutions for the combination of WPP, PVPP and accumulation units.

This paper indicates the possibility of hybrid generation by additional installation of PVPPs on already existing WPPs, while using the already existing wind farm infrastructure. In this manner, the utilization of the installed equipment and the efficiency of the power plant itself are increased and the variation of generation compared to the average annual generation is reduced.

The construction of WPPs and PVPPs in Bosnia and Herzegovina has become increasingly intensive in recent years. Three WPPs are operational (WPP "Mesihovina" - 50.6 MW, WPP "Jelovača" - 36 MW and WPP "Podveležje" - 48 MW) at the moment. WPP with a total capacity of 2181 MW and PVPP with a total capacity of 2144 MW are under construction or in the process of obtaining permits for connection to the B&H transmission network [6]. The construction of hydro and thermal power plants is at the standstill at the same time. This reduces the possible acceptance power from unmanageable energy sources into the electric power system of B&H, which is currently limited by the State Electricity Regulatory Commission (DERK) to 840 MW for WPPs and 825 MW for PVPPs [6]. That is why even small

advances in reducing the unmanageability of WPP and PVPP generation are welcome. This paper is a modest contribution in that direction. The proposed hybrid generation achieves smaller deviations from the average annual generation of independent WPP or PVPP. The estimation of the planned annual generation is becoming more accurate, which reduces balancing problems. This paper indicates the objective possibility of adding PVPP to the existing WPP "Mesihovina" - 50.6 MW and achieving efficient and economical hybrid generation of electricity in this manner. According to the same logic, this kind of solution is applicable in areas that have similar resources of wind and solar energy. This kind of hybrid generation at the energy source itself has many advantages in terms of a more rational energy flow in the transmission and consumption system. In addition, the hybrid generation of WPP and PVPP is better adapted to the needs of electricity consumption in the 24-hour mode of operation. Namely, the generation of WPP and PVPP is combined in the daytime period of the day when the consumption is at the highest level. During the night, when consumption decreases, only WPP does the generation.

The average wind speed at the location and the average generation of one turbine, on which it is planned to additionally install one PVPP with a power of 1.85 MW, are presented in the first part of the paper, based on the data obtained on the four-year generation of WPP "Mesihovina" by JP EP HZ HB [7]. The average annual generation of PVPP was obtained using the software package "HelioScope" [8]. A graph of the possible hybrid generation of one WT and PVPP is shown.

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In the second part of the paper, the possibility of connecting PVPP and WPP was analysed, and possible solutions for management and control of hybrid generation were proposed.

The advantages and results of this type of hybrid generation are listed in the last part of the paper.

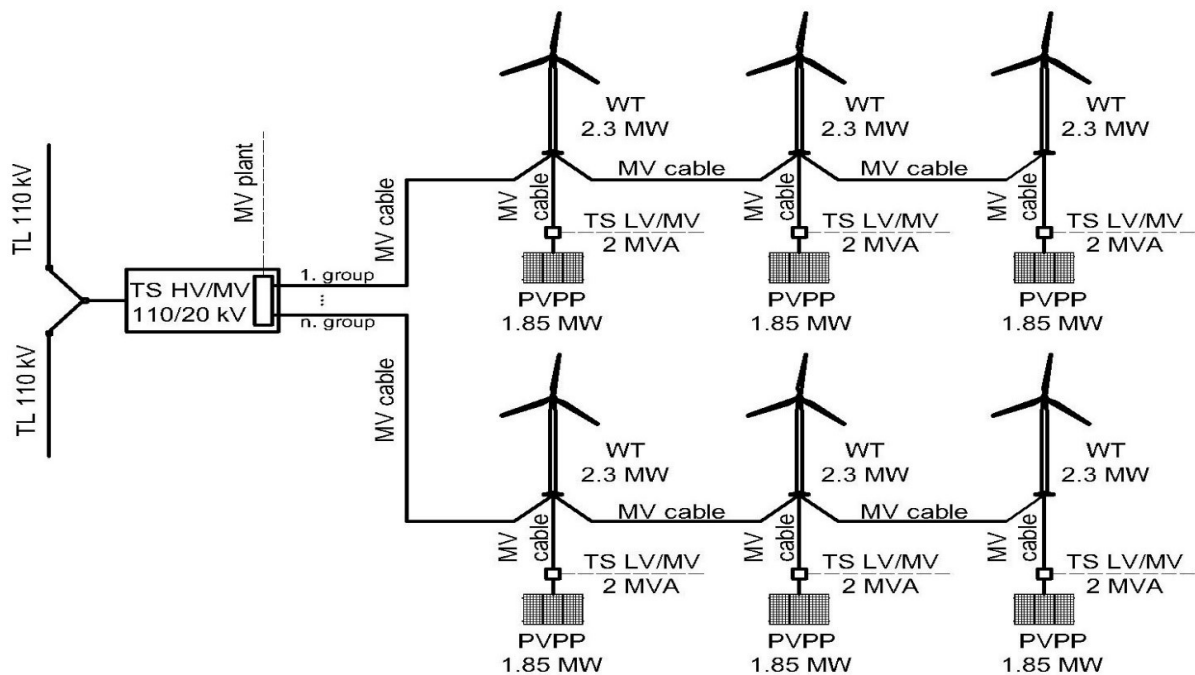


Figure 1: Principal scheme of hybrid generation of WT and PVPP

1. ANALYSIS OF THE POSSIBILITY OF HYBRID ELECTRICITY GENERATION

Figure 1 shows the principal scheme of a possible hybrid generation of electricity by a combination of already existing WT (WPP “Mesihovina”) and subsequently added and connected PVPP.

The utilization of wind power plants built in Herzegovina is around 37% of their nominal installed power, which enables the extension of photovoltaic power plants and connection to wind turbines using already built installations, especially since the efficiency of PVPP is only about 20%. In this manner, hybrid electricity generation is achieved by combining two sources of renewable energy, wind and solar, which are compatible for several reasons that are explained in this paper.

The paper analyses the generation of the existing wind power plant “Mesihovina” with a capacity of 50.6 MW (22 WT x 2.3 MW) in the period from March 2018 to September 2022 [7]. An annual diagram of the generation of one average wind turbine with a power of 2.3 MW was obtained, depending on the wind speed in that period (Table I, Figure 2).

That four-year average diagram is much more realistic than the one-year turbine generation diagram. Figure 3 shows the average four-year diagram of wind speed, which equals to 6.41 m/s.

The diagram (Figure 2) shows that the generation of wind turbines is the lowest in the period from May to October. The wind speed is also lower than the average speed marked in orange in Figure 3 at that time.

Table I: Average generation of WT in the period from 2018 to 2022 [7]

Month	Average wind speed [m/s]	Average generation of WT [MWh]
January	7.57	833
February	7.55	735
March	7.63	858
April	6.48	626
May	6.03	565
June	5.47	451
July	5.51	494
August	5.05	402
September	5.34	433
October	6.01	566
November	6.55	643
December	7.73	805
Average	6.41	618

Unlike wind turbines, photovoltaic power plants have the highest generation precisely in those months. This is the reason why a 1.85 MW photovoltaic power plant was chosen as one of the possible options for combination with a 2.3 MW wind turbine. The program package “Helioscope”, which contains in its database

all the meteorological and geographical data necessary for determining the annual generation of photovoltaic power plants, obtained a diagram of the average annual generation for the photovoltaic power plant in question with a power of 1.85 MW in the area of the wind power plant “Mesihovina” (Table II, Figure 4) [8].



Figure 2: Average monthly generation of WT (2.3 MW) [7]



Figure 3: Average wind speed in the period from 2018 to 2022 [7]

Table II shows the average monthly generation of a PVPP with an installed capacity of 1.85 MW.

Table II: Generation of a 1.85 MW PVPP [8]

Month	Generation PVPP 1.85 MW [MWh]
January	152
February	161
March	224
April	261
May	311
June	320
July	356
August	335
September	278
October	220
November	155
December	128
Average	242
Total	2901

Hybrid generation of the existing 2.3 MW wind turbine in combination with a 1.85 MW photovoltaic power plant (Table III, Figure 5) would result in increased generation that would improve the generation diagram, which has less variation compared to the diagram of the wind turbine itself (Figure 2).

Table III: Hybrid generation of WT + PVPP

Month	Generation of WT [MWh]	Generation of PVPP [MWh]	WT + PVPP [MWh]
January	833	152	985
February	735	161	896
March	858	224	1082
April	626	261	887
May	565	311	876
June	451	320	771
July	494	356	850
August	402	335	737
September	433	278	711
October	566	220	786
November	643	155	798
December	805	128	933
Total	7411	2901	10312

In Figure 4 and Figure 5, the generation of the wind turbine (2.3 MW) is shown in blue and the generation of the photovoltaic power plant (1.85 MW) in orange colour. Figure 4 and Figure 5 shows that the hybrid generation of these two renewable energy sources is equal to the average monthly

and annual generation in relation to the wind power plants or photovoltaic power plants themselves, and thus reduces the problems of balancing electricity in the system electricity in the power system and better utilization of the installed equipment of the wind power plant.

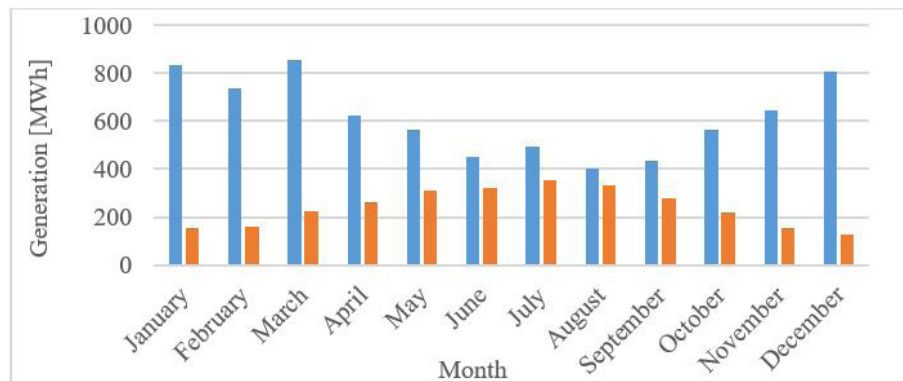


Figure 4: Generation of WT and PVPP during the year

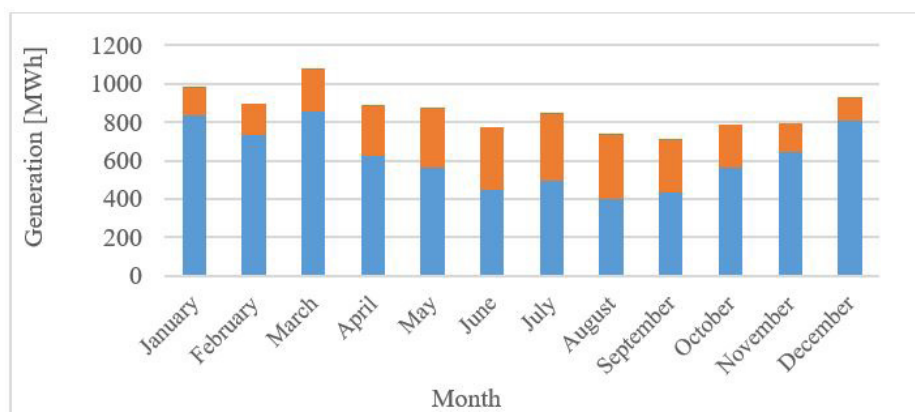


Figure 5: Expected hybrid generation of WT and PVPP

2. POSSIBILITY OF CONNECTING PVPP TO WT

The 2.3 MW wind turbine has a diagram of the power provided by the wind turbine generator depending on the wind speed (Figure 6) [9]. Taking into account that the average wind speed at the location of the wind farm in the four-year period is 6.41 m/s (Table I), it is clear that the wind turbine works on average with only 37.4% of its nominal power during the year. This enables the connection of a photovoltaic power plant with a power of 1.85 MW (utility about 20%) to a wind turbine with a power of 2.3 MW.

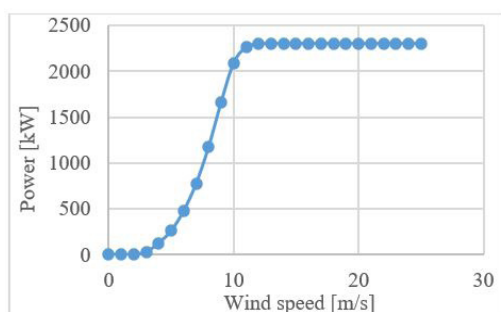


Figure 6: Characteristics of power of WT 2.3 MW [9]

Figure 7 shows the average monthly engaged power of the wind turbine + photovoltaic power plant (blue columns) compared to the installed power of the wind turbine itself, for which all the electrical installation and the power substation were designed (orange line – 2.3 MW).

The Figure 7 shows that there is a reserve in the installed power WT + PVPP during the year. This shows that one photovoltaic power plant with a power of 1.85 MW can be added to each of the 22 wind turbines, by connecting the photovoltaic power plant with a medium voltage cable to the medium voltage block of the wind turbine.

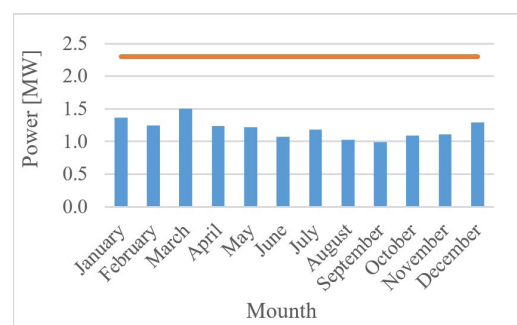


Figure 7: Average engaged power of WT+PVPP

Table IV shows the data of the average monthly and annual engaged power of the wind turbine and photovoltaic power plant individually and combined.

Table IV: Engaged power by month

Month	WT power [MW]	PVPP power [MW]	WT+PVPP [MW]
January	1.16	0.21	1.37
February	1.02	0.22	1.24
March	1.19	0.31	1.50
April	0.87	0.36	1.23
May	0.78	0.43	1.21
June	0.63	0.44	1.07
July	0.68	0.49	1.17
August	0.56	0.46	1.02
September	0.60	0.39	0.99
October	0.79	0.31	1.10
November	0.89	0.22	1.11
December	1.12	0.18	1.30
Average	0.86	0.36	1.19

In doing so, the already built infrastructure of the wind park is used, that is:

- medium voltage wind farm cable distribution,
- power substation MV/HV 20/110 kV,
- connecting power line to a 110 kV network transmission power line.

By continuous measurement of current power WT + PVPP and appropriate automation, the total current generation power is ensured, which will not be higher than the designed installed power of 2.3 MW. This would be achieved by regulating the power of the PVPP by switching individual inverters or the entire PVPP, off-on, in the automatic operating mode. The time periods in which this automation will operate will be short and rare during the year, in the daytime mode of operation, only in periods when the wind reaches a speed of 13 m/s or higher, i.e., VT power of 2.3 MW.

For a better use of PVPP energy, it is possible in these periods, instead of turning it off, to set the PVPP switch to charge energy into the accumulator batteries and later in periods of reduction of the engaged power to send that accumulated energy to the network (Figure 8) [10]. The DC/AC inverter is automatically switched off during these periods and the PV modules, connected to the PV+ and PV- terminals, charge the accumulator batteries via the DC/DC regulator. The automation in the set mode enables reactivation of the inverter and discharge of the accumulator batteries through it, which is, sending energy to the network.

There is a possibility that by determining the capacity of the batteries, the balancing of the energy delivered to the network can be achieved in cooperation with the Independent System Operator in Bosnia and Herzegovina (ISO BiH/NOS BiH).

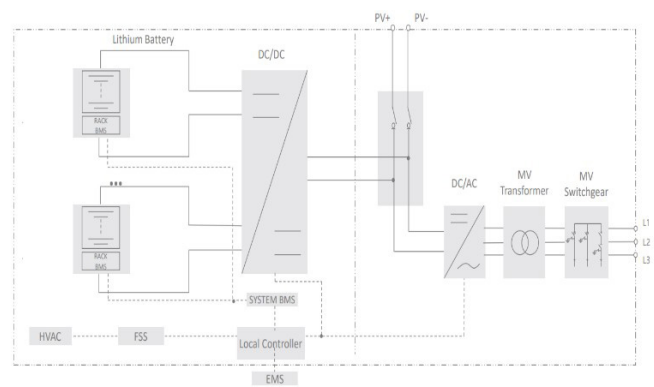


Figure 8. Principle scheme of PVPP energy utilization by charging the accumulator [10]

3. CONCLUSION

The advantages of the described possibility of hybrid electricity generation are:

- Smaller generation deviation compared to the average monthly and annual generation. This reduces the problem of balancing the produced electricity in the entire power system.
- Better adaptation of the daily generation diagram to the needs of electricity consumption during 24 hours.
- A greater degree of use of the existing electrical infrastructure of wind farms (medium voltage cable distribution, MV/HV transformer station, connecting transmission line of the main transformer station to the high voltage network).
- Reducing the costs of connecting the photovoltaic power plant to the power system. The local power substation of PVPP (LV/MV) is connected with the MV cable to the MV block of the wind turbine, which represents much lower costs compared to the usual costs and problems of connecting the PVPP to the power grid.
- As a rule, the terrains in the areas where wind farms are built are not interesting for agriculture and are far from urban settlements.
- Access roads built for wind farms provide access for the construction and servicing of photovoltaic power plants near the wind turbines to which they are connected.
- Hybrid generation of wind turbines and photovoltaic power plants uses renewable energy sources and contributes to lower emissions of CO₂ into the atmosphere compared to classic electricity generation using fossil fuels.

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BIOGRAPHY

Dragan Mrković was born in 1947 in Nevesinje. He received a MSc degree at Faculty of Electrical Engineering, University of Ljubljana, majoring in Power Engineering, in 1971. Working experience in process industry (11 years), electrical installation works (9 years), installation of complete facilities (20 years). Employed in Energocontrol-ing d.o.o. Mostar as chief designer and supervision engineer for power plants, especially Renewables.

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