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STUDY OF THE ENERGY POTENTIAL OF RENEWABLE ENERGY SOURCES IN THE REGION OF GABROVO FOR USE IN HYBRID WIND-PHOTOVOLTAIC STAND-ALONE SYSTEM

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Summary: This paper presents the measurements conducted for two periods (winter and summer) in the region of Gabrovo, Bulgaria for solar radiation and wind conditions using the digital measuring equipment. The aim is to evaluate and predict the possible production of electricity from already installed low power hybrid system. The conclusion is that a combination of a wind generator and a photovoltaic system in the hybrid system for independent power supply has a good economic effect and allows fuller use of energy from renewable sources.

Keywords: renewable energy, hybrid system, energy production.

1. INTRODUCTION

The European energy industry focused on the energy production from wind, kept pace with the growth of the global market. Currently, there is a push for the development of wind energy and solar energy in Europe. The European Union remains the world leader in electricity produced by means of wind and sun, with 60% global market share [1,4,5]. Hybrid systems that combine the use of energy from wind and sun, and making better use of the potential of renewable energy sources can be used as stand-alone sources of power, as well as grid-connected ones.

Wind-solar hybrid systems combine the advantages of wind turbines and photovoltaics (solar panels). These systems successfully combine both types of energies: wind and solar. In summer, when the wind is weak, the dominant source is photovoltaics and in winter, when sunlight is limited, the leading source is wind turbines. Due to the different intensity of wind and solar energy during the day and the year, hybrid systems are more suitable for producing the required electricity [1,6].

In the Republic of Bulgaria, as a full EU member, this is also enshrined in particular development of this part of the energy sector. In relation to that, except implementation and building of wind power, photovoltaic and hybrid systems studies are necessary in order to study and possibly optimize their work [1]. The paper deals with the study of the wind and solar energy potential in the region of Gabrovo for use in low power stand-alone hybrid system. The results can be extended to the systems with greater power.

2. STUDY APPROACH

In the town of, Gabrovo, for the period from January to July 2015, near Building №1 of Technical University – Gabrovo, measurements of characteristics of wind and solar radiation were done. An outline of the measurement system is shown in Figure 1. In Figure 2 satellite image of Building №1 of Technical University - Gabrovo with the location of the measuring apparatus is presented, and in Figure 3 – the picture of the measuring mast.

For the measurements Nomad 2 Data Logger by Second Wind was used – Figure 4. Nomad 2 Data Logger by Second Wind is the new, breakthrough data logger for wind resource assessment. It connects up to 12 anemometers and 8 vane or analog sensors with no hardware modifications. It communicates remotely via cellular, internet, and dial–up. It connects sensors easily with large, color–coded terminals and stores the data on Compact Flash cards. There is no need to mount various components into a shelter box with this integrated design.

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Data Logger Features:

• 12 digital inputs (for anemometers);

• 8 analog inputs (for wind vanes, temperature sensors, etc.);

• Recording data at 1 Hz;

• Intervals scanning and recording: 1, 10, 60 minutes;

• Mean, standard deviation, maximum, minimum, total, test values;

• 4x20 alphanumeric display LCD or VFD;

• Operating temperature from -40 ° to + 85 ° C;

• Built-in protection against lightning.

SOLAR RADIATION SENSOR (PYRANOMETER)

The sensor measures the density of the solar flux (in watts per square meter, W/m^2). It is designed for continuous outdoor use, including the building of field weather stations. The measured data are reported and recorded by a data logger. The standard measurement depends on horizontal mounting, which is controlled by the built-in sensor level.

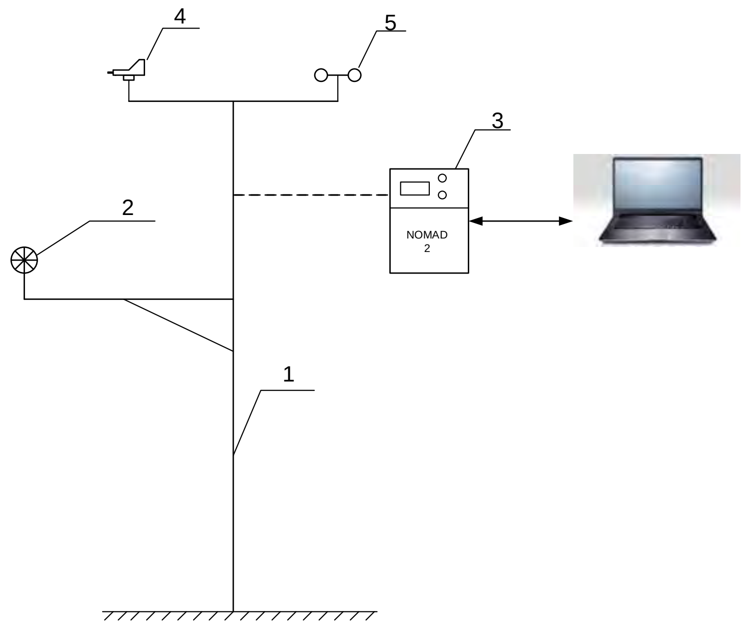


Figure 1. Scheme of equipment for measuring wind parameters
1 - measuring mast; 2 – pyranometer; 3 – data logger NOMAD 2; 4 – anemometer; 5- wind vane

It includes: 9V alkaline batteries, cable terminals, serial cable, NOMAD Desktop ™ software and a 32MB Compact Flash card. Built-in protection against lightning is demonstrated in the field work and does not require additional connections. Large colored terminals help easier and faster connection, even when using gloves. Built-in serial output allows the use of the software NOMAD Desktop on the site. The front panel of NOMAD2 is easy to use (the menu system provides all the necessary information) and can also reprogram the logger in seconds to load the new configuration from the Compact Flash card. The built-in relay provides power, including heating for no-frost sensors. Measurement accuracy is 0.02% for impulse and 0.2% for analog sensors.

The second Wind C3 anemometer represents the calibrated anemometer. It is manufactured by improved material in order to increase durability and reliability. The new improved version of the popular three-A pan design used for decades in the evaluation of wind resource is produced in accordance with applicable industry standards. The rotor of model C3 is produced by resistant polycarbonate for superior durability and reliability. The base of the sensor C3 is also made of durable polycarbonate, which provides greater resistance to damage during mounting.

The vane, which includes the contact potentiometer, accurately detects the angle of rotation and allows the blade to pin down wind direction when connected with appropriate measuring equipment, in this case the logger. The potentiometer has the lowest possible torque consistent with long life and reliability, while the small interruption around the „North“ is filled with insulating material to ensure smooth operation of the full 360°. The construction is of anodised aluminum alloy and stainless steel parts that are exposed outdoors. In combination with a hard plastic (upper) bearing and precision ball bearings, the result is a sensor suitable for continuous exposure to weather conditions, with long periods of service. This vane has to be oriented to the north during installation and fixed in this position during operation.

Figure 2. Satellite image of Building №1 of Technical University - Gabrovo
1 – wind generator and PV modules; 2 – sensors for temperature, atmospheric pressure and humidity
3 – wind sensors and pyranometer

The pressure sensor features:

• 600 to 1100 mbar pressure range;
• 1.25 mbar precision;
• Low power consumption.

The temperature sensor of Second Wind Inc. is designed specifically to work with logger NOMAD2. It includes a thermistor of type 10K in aluminum shield, and is preliminary wired with the cable for sensors, 3.5 m long. The resistance of the thermistor varies with temperature, following the known but non-linear curve. Logger Nomad2 measures resistance of the sensor, and uses a table of more than 4096 values to determine the current temperature.

The temperature sensor features:

• Without active electronic components;
• High level of reliability and stability, calibration is not necessary;
• Accuracy to ± 0.2 ° C between 0 ° to 50 °C;
• -40 ° to + 105 °C temperature range.

In Building №1 of Technical University - Gabrovo the Scientific Laboratory №1300 on renewable energy is equipped. The place of installation of sensors is on the roof of Building №1 of Technical University - Gabrovo and cables of wind turbines and sensors to measure the wind characteristics are joined in the lab, as there are other systems, components and devices of the stand that are supplied with the low voltage wiring.

A joint research with partners from the EU and Bulgaria has been envisaged, with which Technical University - Gabrovo has a long-term cooperation in the field of renewable energy. The laboratory provides training to „Bachelor“ and „Master“ students in certain subjects included in the curricula of courses „Electrical Power Engineering“, „Hydraulic and Pneumatic Equipment" and „Industrial Engineering“. Additionally, training and research of undergraduate, graduate and doctoral students is delivered by the Department of „Electrical Power Engineering“, „Energy Technology“ and others from the Technical University - Gabrovo.

Figure 3. Measuring mast

Figure 4. General view of NOMAD2

Wind-solar hybrid stand-alone system includes: wind generator *1* mounted on high mast, which converts kinetic energy of wind flow into electricity. Photovoltaic modules 3 are connected in series and/or parallel. The orientation and tilt of the photovoltaic modules are the two main parameters. It is important to avoid shadowing by the surrounding objects. Wind and solar controllers *3* manage charging the batteries, the performance of wind turbines and photovoltaic modules. Rechargeable batteries 5 - one or more, are connected so as to provide the necessary voltage and capacity of the system. The optimum of their capacity must match the usable and generating power. Inverter 6 converts DC power made by photovoltaic and wind generator to the battery in AC 230V 50Hz - voltage necessary for most appliances.

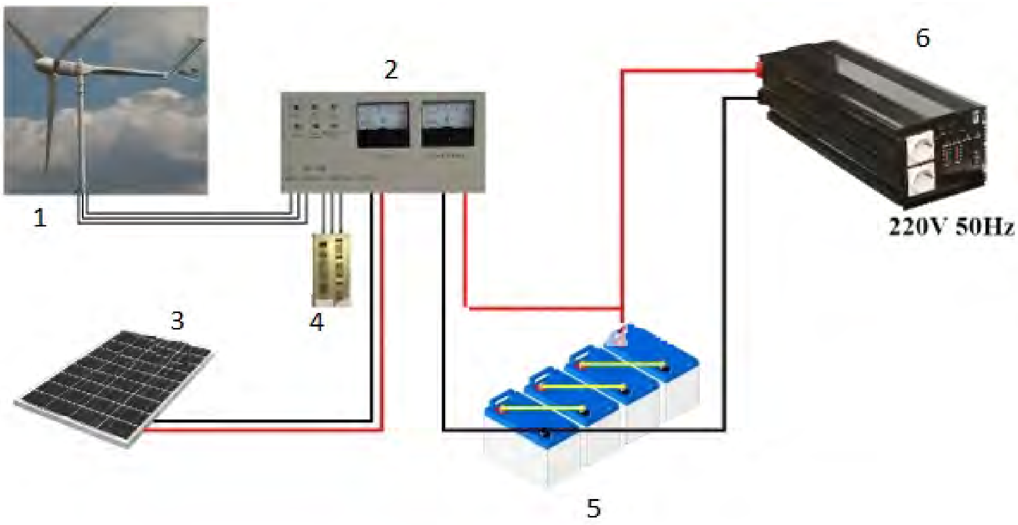


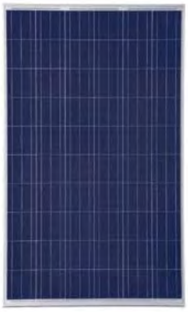
Figure 5. Components of hybrid system.
1 – Wind generator; 2 – Controller; 3 – PV module; 4 – Load Resistance; 5 – Accumulator; 6 – Inverter

Figure 6. General view of wind generator

Table 1. Wind generator 500W

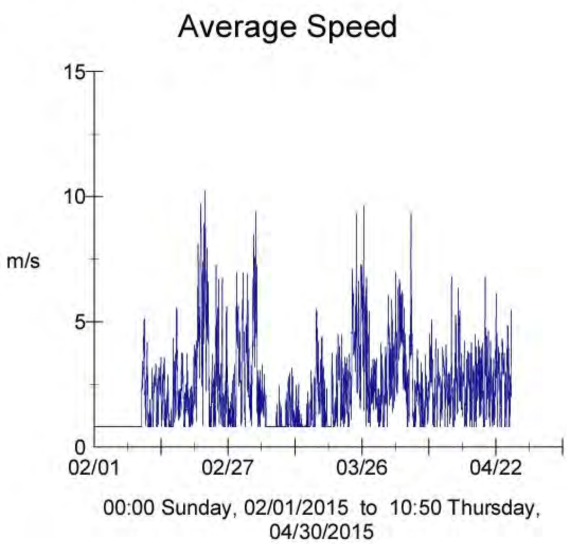
Rated power	500 W
Number of blades	3
Maximal power	730 W
Voltage	24 VDC; 230 VAC
Initial wind speed for generation starting	2,5 m/s
Maximal operated wind speed	50 m/s
Screw diameter	2,5 m
Mast height	6 m
Rated rotational frequency	450 min^{-1}
Generator weight	46 kg
Total weight of the system (incl. mast)	90 kg
Operating temperature	-40 -:- +60° C
Recommended batteries	12V 150-200Ah - 2 pieces

Table 2. Main technical data of the PV module Jinko-solar

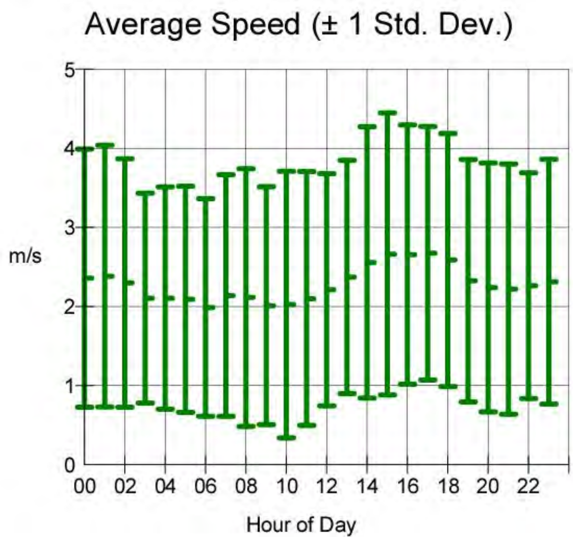
	• Power: 240 Wp • Connectors: MC4 • Maximum current Impp: 8.01A • Suitable for 24 VDC systems • Type of cells: polycrystalline • Dimensions: 1650 * 992 * 45mm; Weight: 19.0 kg

3. STUDY RESULTS

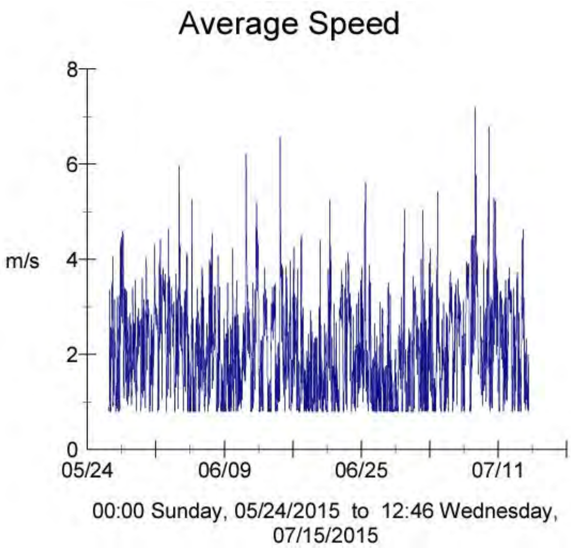
Measurements of parameters of the wind and the sun are made for two periods - from 02 January 2015 to 30 April 2105 winter, and summer – 24 May 2015 - 15.07.2015.



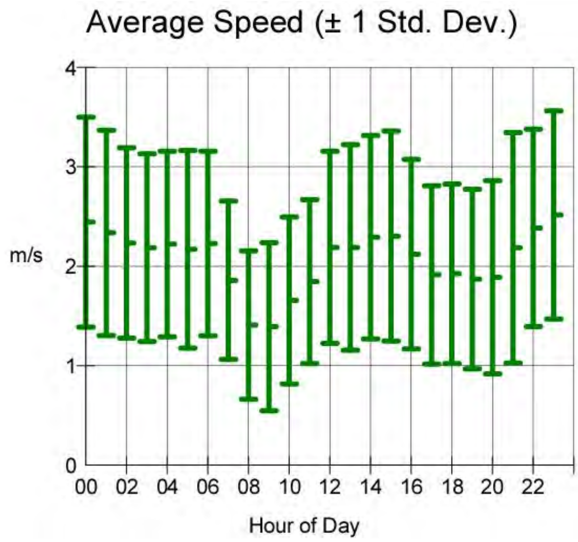
a



b

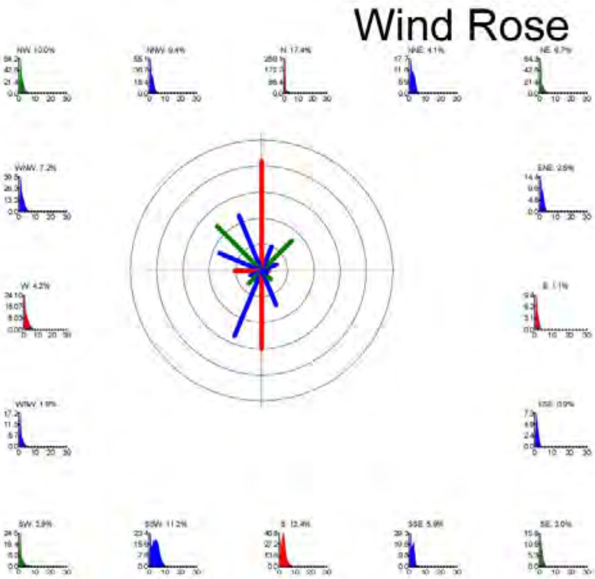


c

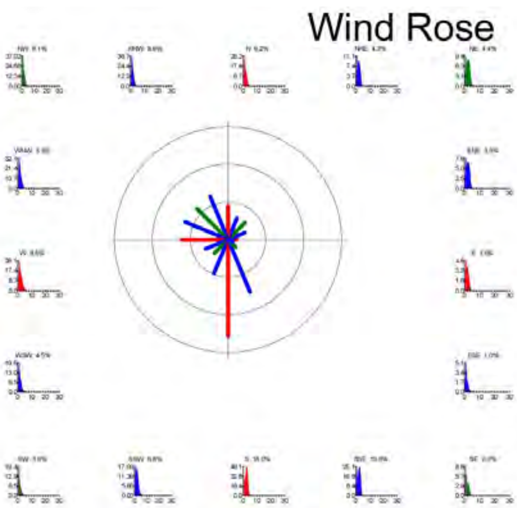


d

Figure 7. Data on wind speed for the winter - a, b and summer season - c, d



a



B

Figure 8. Wind rose for the winter - a, and summer - b

Expected Energy Report: 06948

Site: My Nomad2's
Reference: Reference Turbine: 500 W
Wind Speed: C1 - NRG IceFreeII (m/s) @10f 1 min. Average
Time Range: 01/02/2015 00:00 To 30/04/2015 10:50
Total Hrs: 2122.8
Data Hrs: 2008.7
Percent: 94.6 %

Wind (m/s)	Hours	Power (kW)	Energy (kWh)
0.0	0.0	0	0.0
0.5	0.0	0	0.0
1.0	699.1	0	0.0
1.5	221.4	0	0.0
2.0	235.1	0.015	3.5
2.5	223.2	0.03	6.7
3.0	188.7	0.05	9.4
3.5	132.1	0.064	8.5
4.0	88.2	0.075	6.6
4.5	62.0	0.1	6.2
5.0	44.3	0.125	5.5
5.5	32.7	0.15	4.9
6.0	26.6	0.2	5.3
6.5	18.4	0.275	5.1
7.0	12.1	0.32	3.9
7.5	9.2	0.45	4.1
8.0	5.8	0.47	2.7
8.5	3.7	0.5	1.9
9.0	2.8	0.52	1.5
9.5	2.0	0.522	1.0
10.0	0.8	0.525	0.4
10.5	0.5	0.522	0.3
11.0	0.2	0.52	0.1
11.5	0.0	0.5	0.0
12.0	0.0	0.495	0.0
12.5	0.0	0	0.0
13.0	0.0	0	0.0
13.5	0.0	0	0.0
14.0	0.0	0	0.0
14.5	0.0	0	0.0
15.0	0.0	0	0.0
Total	2008.7		77.6

a

Site: My Nomad2's
Reference: Reference Turbine: 500 W
Wind Speed: C1 - NRG IceFreeII (m/s) @10f 1 min. Average
Time Range: 24/05/2015 00:00 To 15/07/2015 12:50
Total Hrs: 1260.8
Data Hrs: 1190.6
Percent: 94.4 %

Notes: xc

Wind (m/s)	Hours	Power (kW)	Energy (kWh)
0.0	0.0	0	0.0
0.5	0.0	0	0.0
1.0	314.8	0	0.0
1.5	186.4	0.01	1.9
2.0	195.1	0.015	2.9
2.5	192.4	0.02	3.8
3.0	154.1	0.025	3.9
3.5	84.5	0.03	2.5
4.0	35.9	0.045	1.6
4.5	15.5	0.05	0.8
5.0	6.4	0.055	0.4
5.5	2.8	0.06	0.2
6.0	1.4	0.065	0.1
6.5	0.7	0.095	0.1
7.0	0.3	0.115	0.0
7.5	0.2	0.155	0.0
8.0	0.1	0.18	0.0
8.5	0.0	0.22	0.0
9.0	0.1	0.26	0.0
9.5	0.0	0.3	0.0
10.0	0.0	0.345	0.0
10.5	0.0	0.39	0.0
11.0	0.0	0.43	0.0
11.5	0.0	0.46	0.0
12.0	0.0	0.49	0.0
12.5	0.0	0.52	0.0
13.0	0.0	0.55	0.0
13.5	0.0	0.55	0.0
14.0	0.0	0.55	0.0
14.5	0.0	0.54	0.0
15.0	0.0	0.52	0.0
Total	1190.6		18.2

b

Figure 9. Electrical energy produced from wind generator: winter - a, and summer - b

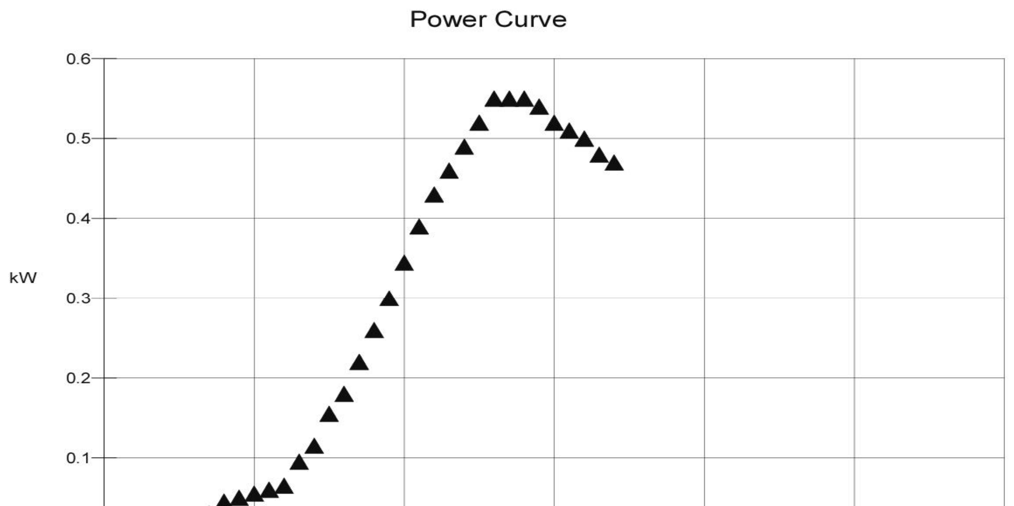
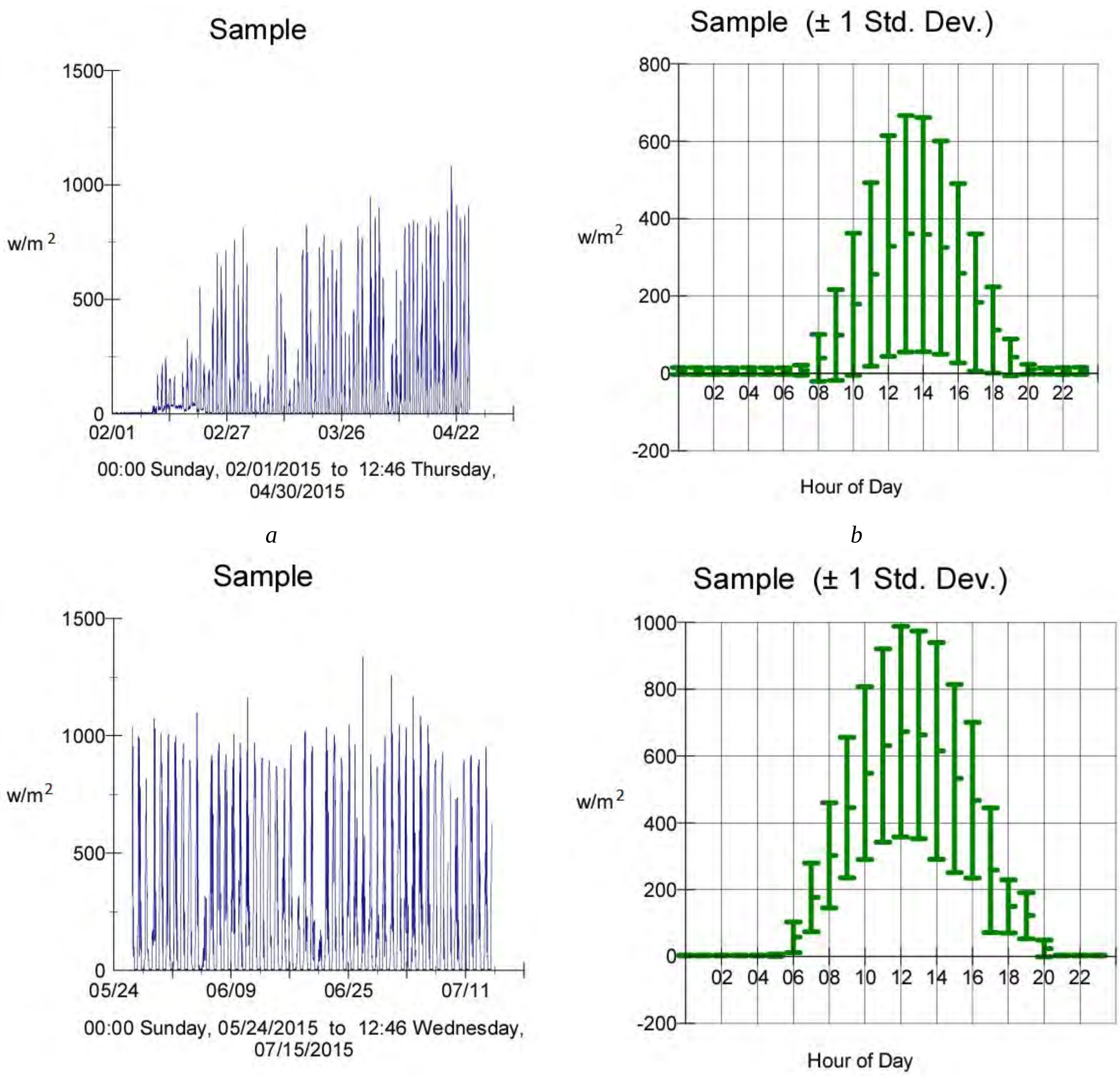


Figure 10. Power curve of the wind generator from hybrid system



a *b*

c *d*

Figure 11. Solar radiation data for winter - a, b and summer season - c, d

Based on the measured data and entered power curve using software NOMAD 2, we can determine the average monthly production of electricity from the wind generator. For winter electricity produced in one month it is 25.87 kWh/month. For the summer period it is 11.38 kWh/month.

Determining the average monthly production of electricity from the generator [1,2,3]:

$$\text{average monthly production} = \frac{\text{energy generated}}{\text{number of months}} \quad (1)$$

Determination of the average daily production of electricity generated by the generator [1,2,3]:

$$\text{average daily production} = \frac{\text{average generated energy for a month}}{\text{number of days}} \quad (2)$$

The amount of electricity produced by photovoltaic modules is determined by global formula [1]:

$$E = A \cdot r \cdot H \cdot PR, \quad (3)$$

where:

E = Energy (kWh)
A = Total solar panel area (m^2)
r = solar panel yield (%)
H = Annual average irradiation on tilted panels (shadings not included) (kWh/m^2y)
PR = Performance ratio, coefficient for losses (range between 0.9 and 0.5, default value = 0.75)

For specific calculations, software from www.photovoltaic-software.com has been used.

For winter electricity produced in one month is 7.33 kWh/month. For the summer period respectively it is 15.66 kWh/month.

4. CONCLUSION

On the basis of performed measurements, it can be seen that the average wind speed in the area of Building №1 of Technical University − Gabrovo is about 2,5 m/s. At this monthly rate it is not appropriate to place large aggregates a large rate of acceleration, but is suitable for small aggregates of the order of 10 kW at a low rate of acceleration. Measurements were done for three months. This period is not sufficient for a final evaluation of wind-energy potential in the region: to be fully assessed it requires at least two years of study.

The analysis of the results of measurements and calculations shows that the amount of energy produced in winter by wind turbines 25.87 kWh/month is much greater than that produced by photovoltaic modules − 7.33 kWh/month. For the summer months, these data are 11.38 kWh/month and 15.66 kWh/month, respectively, as the greater the value of the energy produced by photovoltaic.

The combination of wind generator and photovoltaic system in hybrid system for independent power supply has a good economic effect and allows full use of energy from renewable sources.

The potential of renewable energy in the area of the town of Gabrovo enables its use in hybrid systems with small unit capacity, while its application is for smaller residential or industrial installations. In different seasons − winter and summer maximum recovery potential of energy through the combination of wind and photovoltaic modules is achieved.

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ПРОУЧАВАЊЕ ЕНЕРГЕТСКОГ ПОТЕНЦИЈАЛА ОБНОВЉИВИХ ИЗВОРА ЕНЕРГИЈЕ ЗА КОРИШЋЕЊЕ ВЈЕТАР-ФОТОНАПОНСКОГ САМОСТАЛНОГ СИСТЕМА У ГАБРОВУ

Сажетак: У раду су дати резултати мјерења интензитета сунчевог зрачења и брзине вјетра у току зиме и љета у Габрову (Бугарској). Циљ рада је био процјена и предвиђање могућности производње електричне енергије помоћу инсталираног хибридног система мале снаге. У раду је закључено да комбиновани хибридни вјетар-фотонапонски систем за независно добијање електричне енергије има добре економске ефекте и да омогућава боље коришћење обновљивих извора енергије.

Кључне ријечи: обновљива енергија, хибридни систем, производња енергије.