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Small wind-driven power plant operating experience

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Abstract. This paper addresses the operating experience of a small wind-driven power plant at Saint Petersburg Mining University. The paper describes the wind power generator operation, the deficiencies, revealed during the exploitation, as well as provides the recommendations for the plant improvement.

1. Introduction

According to the World Wind Energy Association (WWEA) as of 2017, the installed capacity of wind-driven power plants is 539.3 GW [1]. According to recent data in the field of small wind-power engineering, presented by WWEA, in 2015 the number of wind-driven power plants (WDPP) in the world reached 990 thousand (a unit capacity of a plant is less than 100 kW) [2].

In Russia, the potential owners of small WDPP are the inhabitants of sparsely populated areas that are beyond the reach of the centralized power supply system, as well as separate facilities of the mineral resources sector, located on the northern sea shelf and in the remote north-eastern regions of the country [3, 4].

Currently, there are favorable conditions to develop wind-power engineering in Russia: there are enough regulatory and legal framework and technical rules and regulations [5]. Nevertheless, at the present time, the operating experience of low-power WDPP is insufficient and problems arising during its operation are not disclosed in a proper manner [6–8].

In 2012, the Saint-Petersburg Mining University acquired an electro-technical complex based on a small WDPP Briz of domestic manufacture by CJSC Wind Power Production Company (St. Petersburg). The power complex is designed for conducting scientific research [9–11], assessing the performance and the residual life of such systems [12, 13], as well as for providing outdoor illumination autonomous power supply within the territory of the training and experimental base Neftianik, which serves for educational purposes (figure 1).

During the operation of the wind-powered complex, a few deficiencies and observations have been revealed that affect the ease of operation and maintenance of the complex, safety, and reliability of power supply to consumers.

In this article, the authors have analyzed the ways to solve and eliminate the revealed deficiencies and formulated recommendations to improve this energy complex based on the WDPP Briz, which are given below.



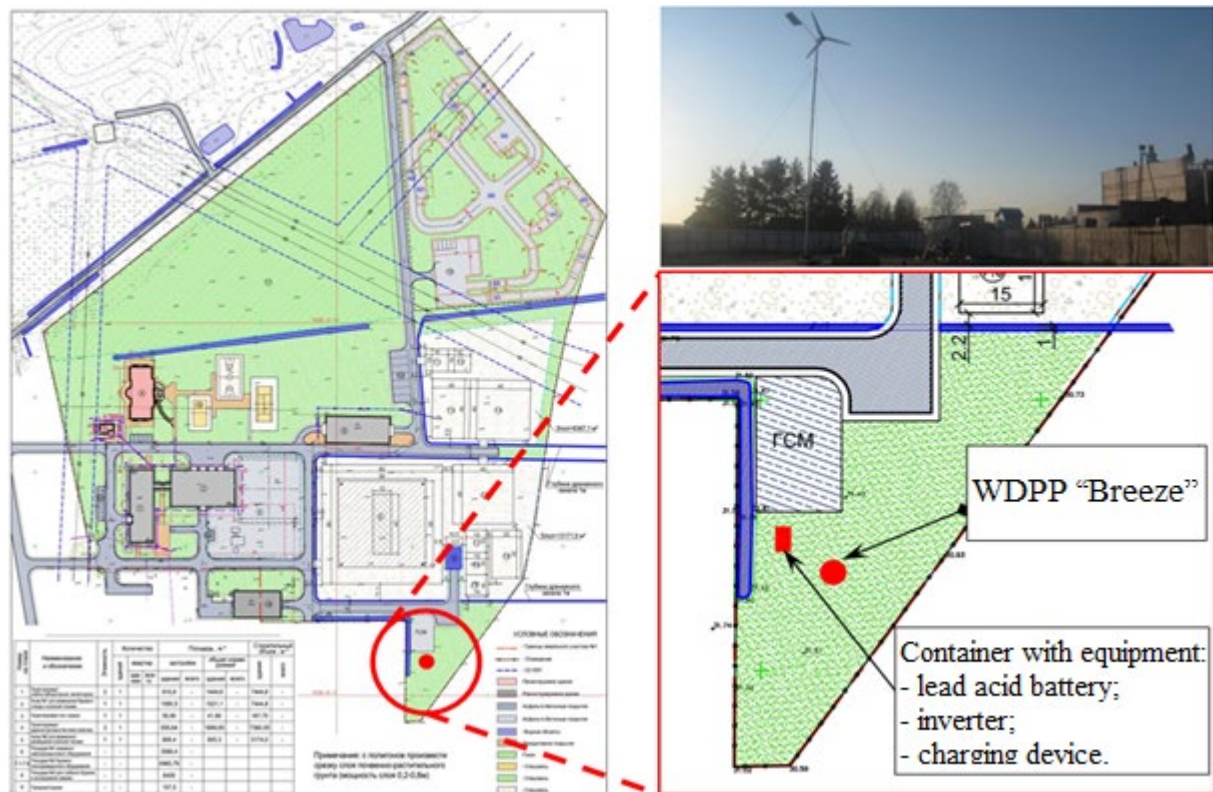


Figure 1. The WDPP installation site within the territory of the training and experimental base

2. Description of WDPP

The main elements of the electro-generating complex (Figure 2): the WDPP Briz: sealed lead-acid rechargeable batteries (SB); inverter; charging device.

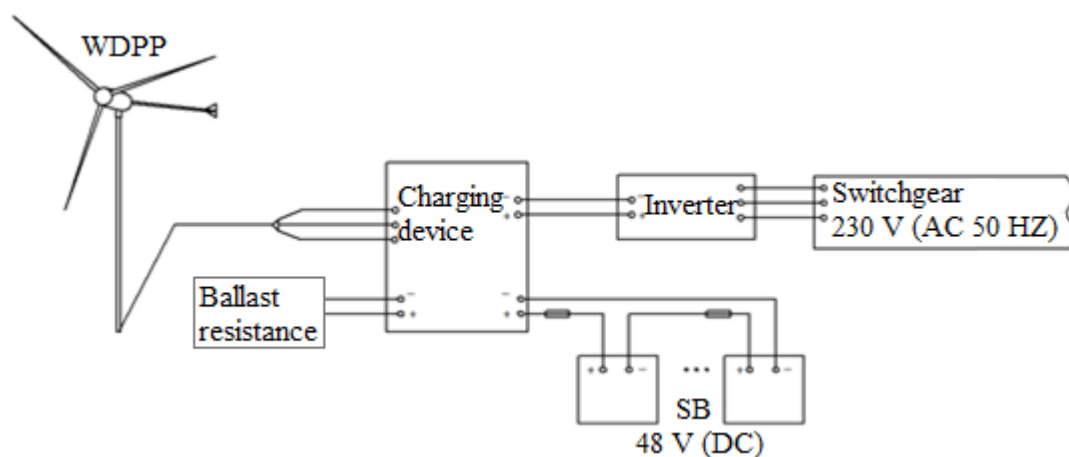


Figure 2. The scheme of the electro-generating complex with the WDPP

The WDPP Briz consists of a wind wheel with three blades of fiberglass, which is attached directly to the generator shaft. The generator is mounted on a supporting and turning assembly, which has an extended tail swiveling vane, to orient the wind-powered generator with the wind. The supporting and turning assembly hosts a current collector to transfer energy from the generator to the cable line, the

assembly itself is attached to an assembled tubular mast, which is held in a vertical position via two levels of stretching wires.

Basic technical specifications of the power-generating complex under consideration:

- nominal rating power: 4 kW;
- cut-in-wind speed: $3 \text{ m}\cdot\text{s}^{-1}$;
- nominal (rated) wind speed: $12 \text{ m}\cdot\text{s}^{-1}$;
- cut-out-wind speed: $45 \text{ m}\cdot\text{s}^{-1}$;
- rotor diameter (spread of blades): 5 m;
- number of blades: 3 pcs.;
- mast type: steel pipe with tension cables;
- operating temperature: from -40°C to $+50^{\circ}\text{C}$;
- orientation to the wind: swiveling vane;
- method of power control: taking the wind wheel away from the wind;
- generator: synchronous three-phase energized by constant magnets;
- nominal speed of the wind wheel: 400 rpm;
- foundation blocks (L x W x D): $0.8 \times 0.8 \times 1.8 \text{ m}$, 5 pcs.;
- wind-driven power plant's operational lifetime: 20 years;
- DC link voltage: 48 V;
- storage battery (SB): lead acid, 12 V, 200 Ah, 4 pcs.;
- parameters of the inverter: $U_{\text{input}} = 40\text{--}60 \text{ V (DC)}$; $U_{\text{output}} = 230 \text{ V (AC 50 Hz)}$; 6 kW;
- ballast resistance power: 6 kW.

3. Analysis of WDPP

The authors have analyzed the ways to solve and eliminate the revealed deficiencies (Figure 3) and formulated recommendations to improve this energy complex based on the WDPP Briz, which are given below.

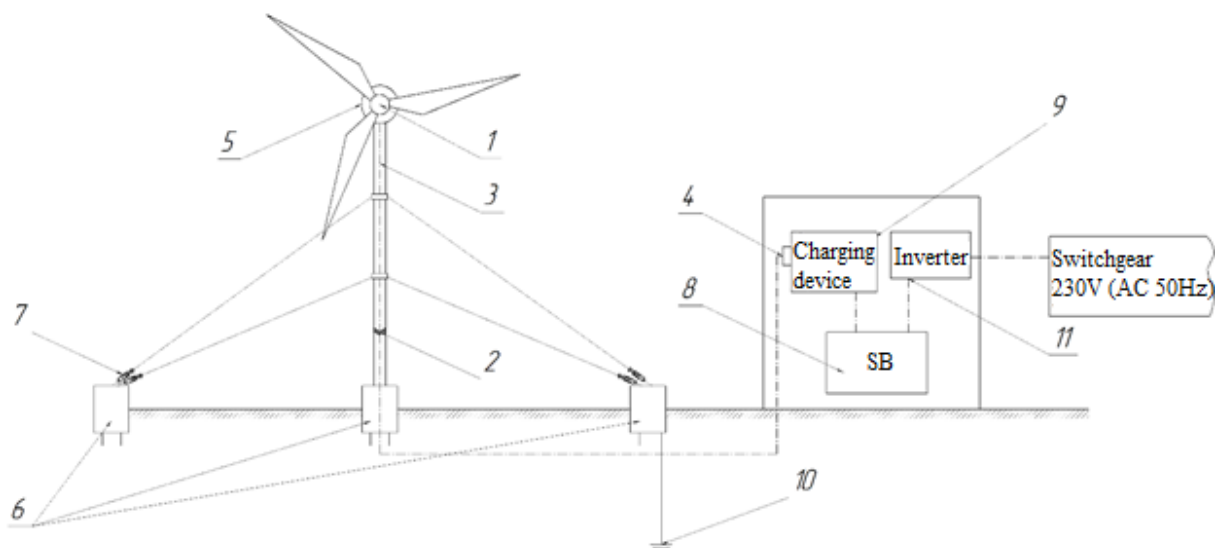


Figure 3. The scheme of the energy complex with the WDPP Briz with an indication of the revealed deficiencies' numbers

Observation No. 1: The attaching point of the blades to the wind wheel hub and the generator shaft.

Existing implementation (a complete set), manufacturer's solution: Open threaded connection of elements on the wind wheel hub.

Proposed implementation (a complete set), the authors' solution: Equip the wind wheel hub with a protective aerodynamic housing.

Brief comment: Under the effect of precipitation the open threaded joints get rusty. The protective housing will reduce the impact of precipitation, decrease the aerodynamic factor of wind flotation along the WDPP body, and also increase the aesthetic appeal of the complex.

Observation No. 2: Wind wheel emergency brake.

Existing: None.

Proposed: Place on the mast (at a height of 1.8 m from the ground level) a cutoff switch (short-circuit of the WDPP generator windings), which serves as the wind wheel emergency electric brake.

Brief comment: According to national standard GOST R 51991–2002, a wind-power unit must have a manually actuated brake. Brake control must be available to the operator, standing at the ground level.

Observation No. 3: Power cable.

Existing: The rubber-insulated cable is used.

Proposed: Use the PVC-insulated cable.

Brief comment: The rubber-insulated cable service life, according to the technical specifications for manufacturing is 4 years, which does not comply with the equipment service life — 20 years. The service life of the PVC-insulated cable is at least 25 years.

Observation No. 4: Plug connector, for connecting a charge regulator, in the power supply line, coming from the WDPP.

Existing: Power plug connector 2P + PE, 32 A is installed.

Proposed: Replace the plug connector with the closed terminal connection.

Brief comment: The presence of a plug connector in the power supply line reduces the safety of the WDPP operation. Disconnection of this connector will result in the WDPP operation under the idle mode with a subsequent uncontrolled speeding-up of the wind wheel.

Observation No. 5: Open current-carrying parts, on a supporting and turning arrangement of the WDPP generator.

Existing: Open terminal blocks are installed for connecting wires, coming from the generator to the slip rings inside the tilting device.

Proposed: Install terminal blocks in closed junction boxes IP67.

Brief comment: Under the effect of precipitation, open terminal connections are oxidized, get rusty, which contributes to an increase in transient resistance at the connection point.

Observation No. 6: Grounding device.

Existing: Reinforced concrete foundation blocks are installed separately of each other, complicating their use as natural grounding electrodes.

Proposed: Connect the reinforcement of separate reinforced concrete foundation blocks with a steel strip of 40x4 mm under the ground in a trench at a depth of at least 0.7 m.

Brief comment: As a result, it will allow equalizing the potentials of the electric plant; performing the potentials grading (to reduce step voltage) in case of thunderstorm damage to the WDPP; in case of autonomous power supply it will allow using the existing grounding loop for other equipment (inverter).

Observation No. 7: Restraining wire ropes tension control.

Existing: A “ring-hook” lanyard M16 is used, the range of adjustment is about 140 mm.

Proposed: Use an M24 “male-male” lanyard, the range of adjustment is about 300 mm.

Brief comment: the range of adjustment of the used lanyards is not enough to compensate for the natural extension of wire ropes while in operation, especially in summer-time.

Observation No. 8: Lead-acid rechargeable batteries installation site (as a condition).

Existing: Lead-acid rechargeable batteries are placed on open shelves in a container without heating.

Proposed: Place lead-acid rechargeable batteries in a separate closed cabinet (housing) with an electric heating element installed therein (25–50 W), to maintain a positive temperature and a fan that provides the required number of air changes.

Brief comment: When using lead-acid rechargeable batteries, in order to prolong lead-acid rechargeable battery lifetime, it is necessary to prevent them from operation at negative ambient temperatures.

Observation No. 9: Lead-acid rechargeable batteries charging control method.

Existing: Electromechanical relay is used, without redundancy and emergency shutdown.

Proposed: Use a solid-state relay with an emergency shutdown of the WDPP [14, 15].

Brief comment: This relay connects/disconnects the ballast resistance to control the process of lead-acid rechargeable batteries charging from the WDPP. The electromechanical relay has a low threshold frequency of switching.

Observation No. 10: The grounding of lead-acid rechargeable batteries.

Existing: The manual does not contain information on the necessity to ensure the grounding of lead-acid rechargeable batteries.

Proposed: Ensure the correct operation of the inverter; it is necessary to provide the grounding of the battery.

Brief comment: This requirement is present in the manual for the inverter, which is not provided to the customer of the WDPP.

Observation No. 11: Protection of autonomous inverter against overvoltage at the input.

Existing: None.

Proposed: Use a voltage control relay at the input of the inverter.

Brief comment: In case of failure of lead-acid rechargeable batteries charge control relay (see Observation No. 9), overcharge of lead-acid rechargeable batteries may occur and the voltage at the inverter input will exceed the permissible value, which may cause the inverter breakage.

4. Conclusions

The above observations are not critical but can complicate the process of the energy complex operation and should be taken into account when purchasing and mantling the WDPP. The updated list of observations is submitted to the manufacturer.

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Acknowledgments

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