

## DESIGN OF TRANSPORTABLE WIND TURBINE (HAWT) WITH SELF-ADJUSTING SYSTEM

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### Abstract

*In the paper authors presented an innovative design of the transportable horizontal axis wind turbine with a capacity of 3.5 kW, which can be use generally in hard field conditions. Simple, lightweight, and inexpensive design gives wide possibilities of its effective use. The self-adjusting system with the turbine protection against exceeding the speed limit ensures practically maintenance-free operation.*

*The self-adjusting system provides continuous setting of the wind turbine on the wind direction, and at the same time protects of the main rotor HAWT (Horizontal Axis Wind Turbine) against excessive speed in strong winds. This solution can replace the most commonly used solution like the directional rudder or the auxiliary wind motor, which usually requires using the generator rotor brake, because works without negative impact to the wind turbine (a low gyroscopic torque) and does not require additional electric power from outside. The use of ballast in exchange for the existing installation of the mast support structure to the foundation makes the project of the wind turbine proposed by the authors more transportable.*

*The design a wind turbine with low power, which can be easily assembled, leave to exploitation, disassembled and then transported to the new place of work without anchoring to the foundation which are permanently linked with a ground become the main goal of the work.*

**Keywords:** *transportable wind turbine, speed limit, self-adjusting system, environmental protection, energy generation from wind*

### 1. Introduction

The small, backyard wind turbines with horizontal axis of rotation, have the capacity of a few kilowatts (typically 3-5 kW) and are limited to storing energy in the batteries or as the power source such as the hot water tank, the under floor heating or the aeration compressor of the sewage treatment plants. Easy assembly and disassembly of the small wind turbines, as well as the possibility of maintenance-free operation of the generator set, allows to use them wherever required is to produce small amounts of the electricity, and in the hard to reach places with less favourable wind resources.

Keeping the angular velocity of the wind turbine main rotor and the active power at the certain level is achieved by the self-adjusting system of the wind turbine. Controlling of the low power wind turbine (the backyard wind turbine) can be done in three main ways, by setting the main rotor wind turbine on the wind direction (yaw control), by adjusting the tilt of the main rotor wind turbine (yaw regulation) – to reduce the active surface of the main rotor through deviation the rotor axis of wind direction or by changing the load (load control) – change of resistance, which is the load of generator, general used in systems with direct connecting to the energy grid [1, 2].

To obtain the currently available low power wind turbine, authors proposed the new design (Fig. 1), which allows the free work of the turbine's main rotor not depending on the location and the wind load.

The main goal was to design a wind turbine with low power, which can be easily assembled, disassembled and transported to the new place of work without anchoring to the foundation which are permanently linked with a ground.

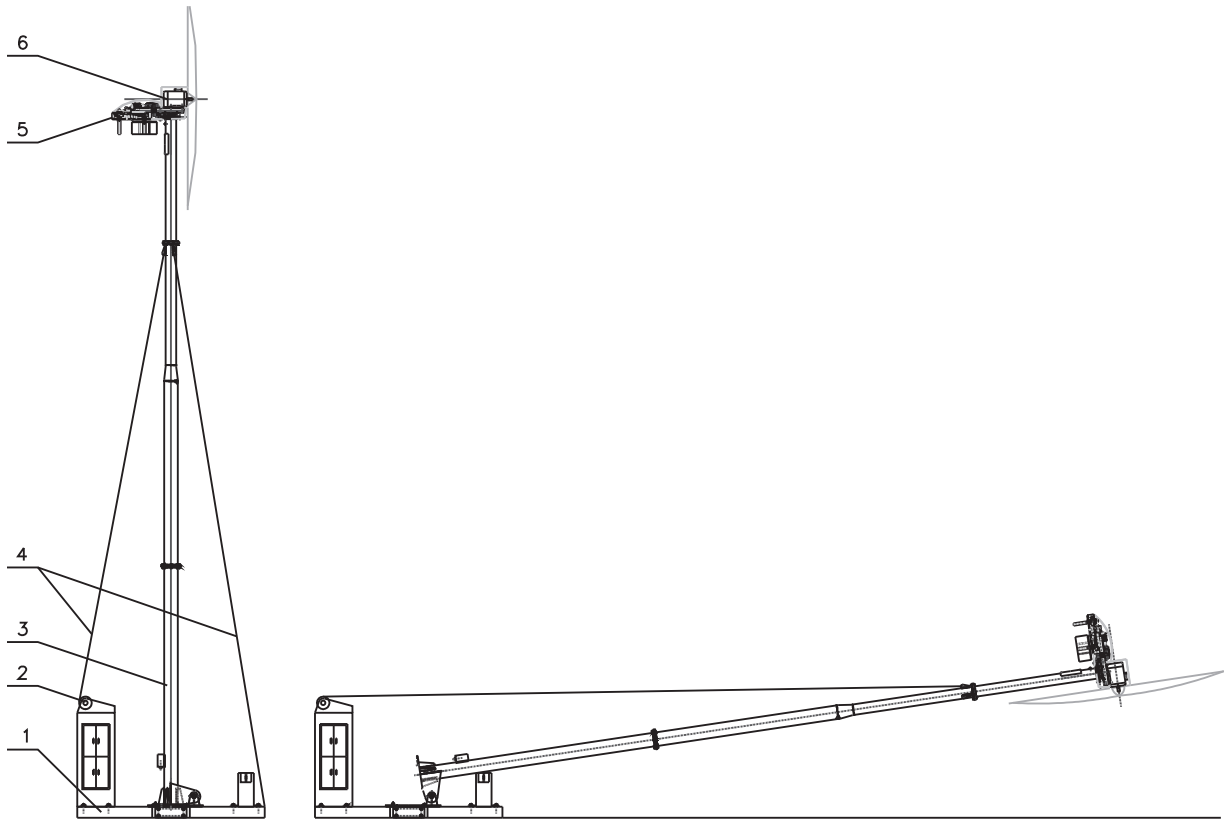


Fig. 1. Structure of the mobile turbine 3.5kW (HAWT) with self-adjusting system with the system of turbine protection against exceeding the speed limit: 1- Ballast, 2- Hoist, 3- supporting structure of the mast, 4- guy wires, 5- self-adjusting mechanism, 6- generator with main rotor

## 2. The assumption of the design of transportable wind turbine

The basic assumption of the design presented in the article, was the mobility of the wind turbine, in order to moving away from the anchoring to the previously prepared foundation the turbine mast, including with additional ballasts, which, depending on the height of the supporting structure (the turbine tower), are mounted with the guy wires. For less than thirteen meter structure, the ballast consisting of two symmetrical plates with a total weight of 8 tons, twisted together so as to form a flat surface, on which to mount the supporting structure of the wind turbine, was designed. The ballast is additionally equipped in the two auxiliary concrete blocks, necessary to put up the supporting structure. All elements are screwed together with form the concrete monolith plates. To ensure the stability of the wind turbine, the support structure was additionally connected with the ballast with three guy wires. Conditions of strength and stability to buckling have been checked according to [2].

The supporting structure of the mast consists of three tubular elements bolted together, to form a twelve meters turbine tower, to which is fastened the nacelle of wind turbine. In each of the elements is located an electric cable, which connect the individual mast sections together by electrical connectors. All elements of the wind turbine delivered at the installation place by the one means of transport equipped with the hydraulic crane. This solution allows quick and easy assembly of the wind turbine independent of the field conditions.

## 3. The direction and the correcting system of main rotor

Equally important feature of the designed wind turbine was practically maintenance-free operation of the generator set with the self-adjusting mechanism, which adjusts the turbine nacelle on the wind direction. Providing a constant angular speed of the main rotor and the active power, required

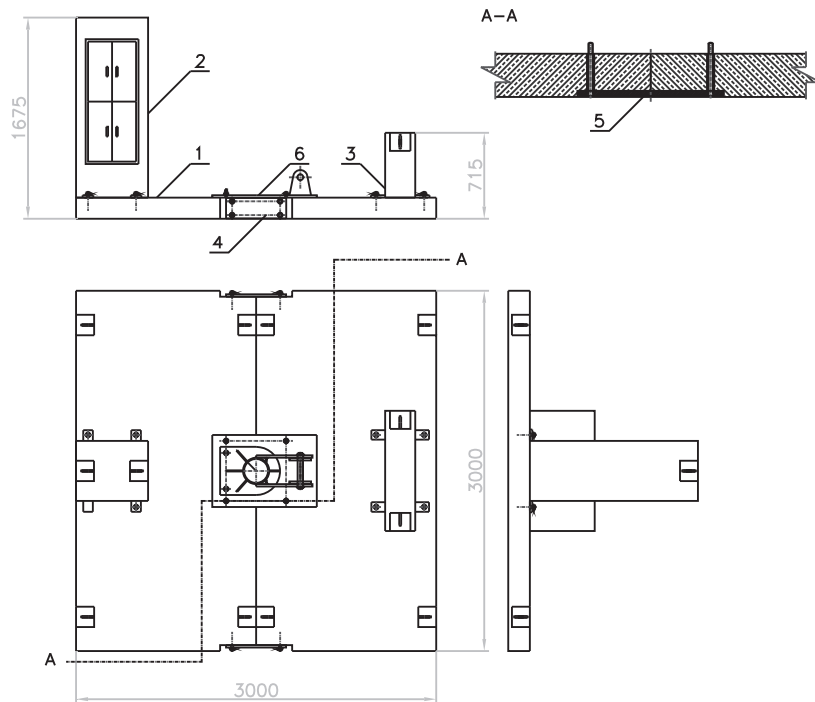


Fig. 2. Ballast: 1 – Road plate, 2 – Ballast – the control box, 3 – Prop of the supporting structure, 4 – Buckle to connecting plates, 5 – Anchor of the supporting structure, 6 – Foot of the supporting structure

to design, was the self-adjusting system on the wind direction [3-5], which also protects against exceeding the rotor speed limit, and thus destruction of the turbine. Currently used for small wind turbines solutions, which allow on setting the turbine in wind direction like yaw control - the rudder directional or without auxiliary wind motor, in this case was replaced the two-blades carousel rotor (Fig. 3) [5, 6].

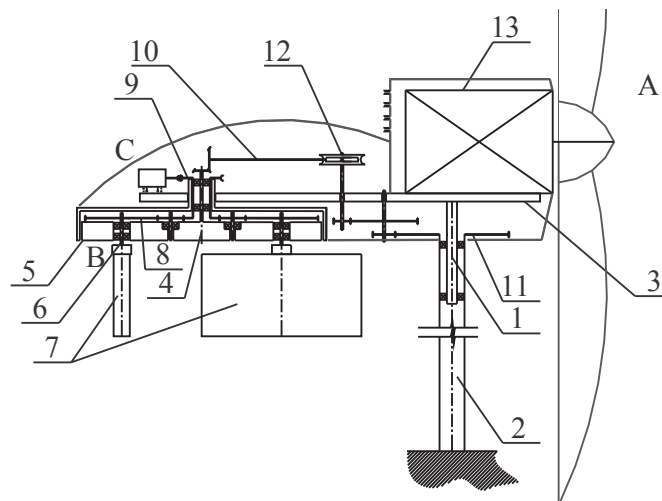


Fig. 3. Kinematic scheme of the turbine with the self-adjusting system; A – main rotor, B – rotor of self-adjusting turbine, C – electromagnetic actuator, 1 – shaft of the nacelle mounted with bearings, 2 – supporting structure, 3 – jib, 4 – axis of the adjusting rotor, 5 – supporting beam, 6 – axis of the blade, 7 – blade of the adjusting rotor, 8 – transmission gears, 9 – self-locking worm gear, 10 – cone-drive gear, 11 – gear wheel mounted on the supporting structure, 12 – self-locking worm gear, 13 – generator of the main rotor

The introduction of such a solution, as the self-adjusting system, allows changing the setting of the main wind turbine rotor to the wind direction (Fig. 4) in the manner set without negative impact to the turbine, with a low gyroscopic torque.

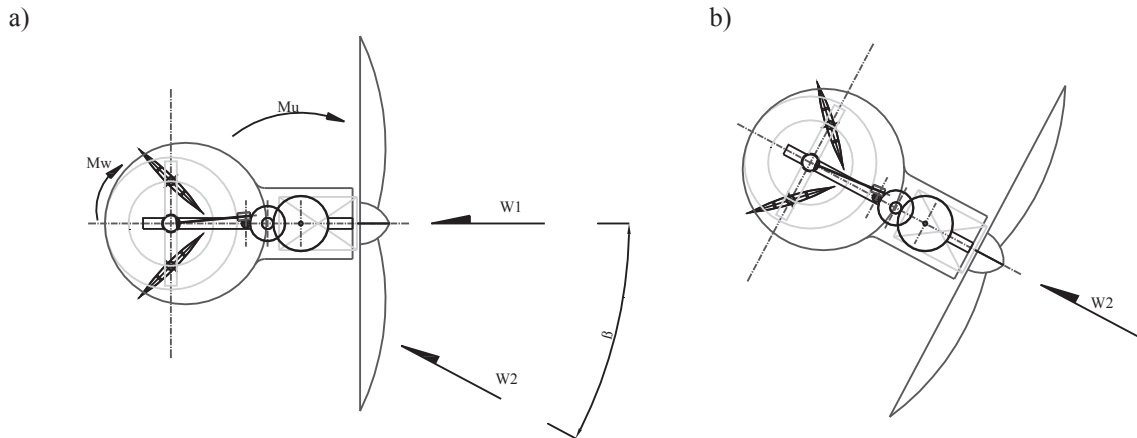


Fig. 4. Method of operation of self-adjusting system (neutral position of the lobe of self-adjusting mechanism): a) change of the wind direction from  $W1$  on  $W2$ , b) new position for the new direction of the wind  $W2$ ;  $Mw$  – torque on the rotor of the self-adjusting mechanism,  $Mu$  – torque on the nacelle of the turbine;  $Mu=k \cdot Mw$ ,  $k$  – constant

The presented solution is characterized by high precision of the adjusting for the wind direction, even at low wind speeds, and in the directional variable gusts exhibits anti-oscillation properties. Does not cause of the design vibration, which significantly promotes the self-locking gear.

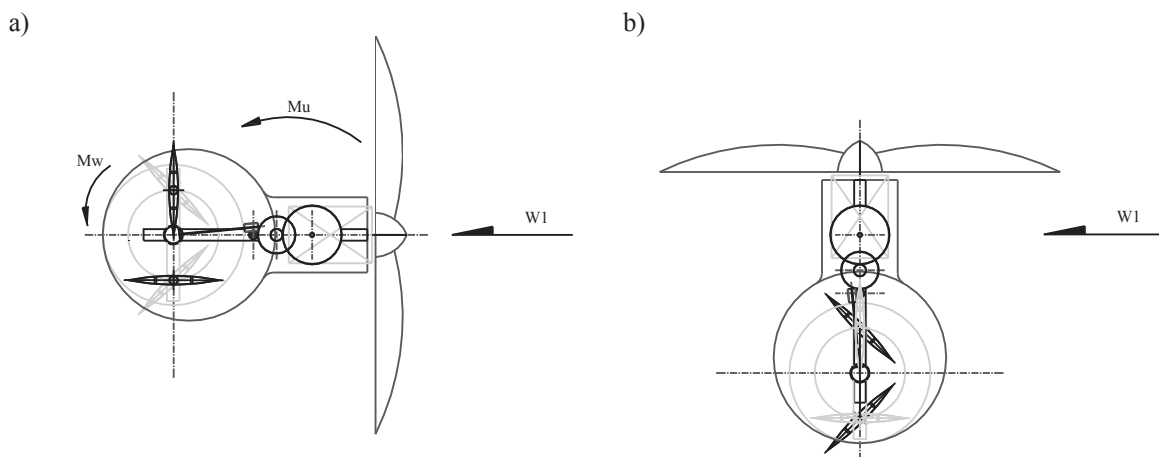


Fig. 5. The operating principle of the correcting system (active position of the label of self-adjusting mechanism): a) position of the turbine, where the rotor speed exceeding speed limit and the self-adjusting system is change of the position of the lobes and starting work, b) position, where the self-adjusting system protects against exceeding the rotor speed limit

The protection of the rotor from strong gusts of wind is done by positioning mechanism rotor lobes of the self-adjusting system - the correcting system (Fig. 5). This system can be powered by for example the stepper motor, the electromagnetic actuator, the drive screw or the linear guide, and requires no additional power supply. At the time when the rotor speed exceed the speed limit and the terminal voltage of the generator is equal 230 V, the electromagnetic actuator starts work and then the correcting system of the blade changes the lobes position from the neutral position (Fig. 4) an the active position (Fig. 5). The design solution of the self-adjusting and the correcting system in detail in the patent application were discussed [6].

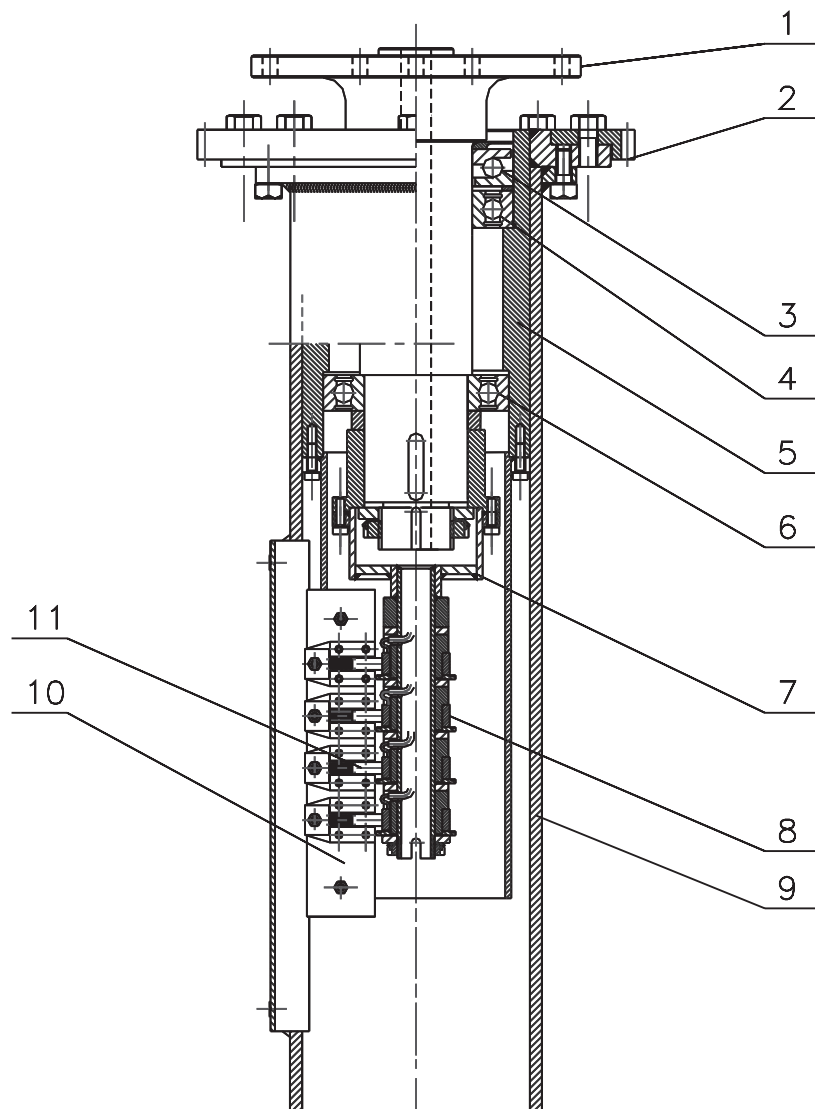
#### 4. Generator, main turbine rotor and system of output electric power

For converting mechanical energy into electrical energy, the generator made by BOBRME Komel was proposed. It is the three-phase synchronous generator AC voltage activated by the

permanent magnet. The power of the generator 3.5 kW, voltage 400 V and weighing 68 kg. The rotational speed 375 rpm and the frequency of 50 Hz. The efficiency of the generator at 84.3%. Cooling the generator is realized by means of a fan mounted on the shaft on the rear of the generator [7]. On the shaft on the front of generator is mounted the main rotor turbine.

To the drive of the generator the three-blade rotor made by SWIND with a diameter of 3.5 m was proposed [8]. The blades of the rotor are made of composite materials. The maximum rotor speed is 380 rpm, the maximum power at the maximum rotor speed 380 rpm is 4 kW and the maximum wind speed while the work of the turbine is equal 16 m/s. The weight of the rotor is equal 30 kg.

The electric power from the generator to the electrical switchboard is passed by the system of output electric power (Fig. 6).



*Fig. 6. System of output electric power: 1– shaft of the nacelle, 2 – gearwheel, 3–angular contact ball bearing, 4–deep groove ball bearings, 5– sleeve of the nacelle, 6– deep groove ball bearings, 7–supporting structure of the system of output electric power, 8– ring of bronze, 9–last section of the supporting structure of the mast, 10– textolite plate, 11– carbon brushes*

Electrical cable from the generator into axially made hole in the shaft of the nacelle was inserted (Fig. 5). The shaft is mounted onto three bearings, in the fixed sleeve of the nacelle, which is rigidly connected with the supporting structure of the mast. The angular contact ball bearing and

the two deep groove ball bearings with non-contact seals were proposed. At the end of the nacelle shaft, the system of output electric power was attached. This is a tube with the rings made of bronze, on which are slipping the carbon brushes. The brushes are attached to the textolite plate, which is mounted to the sleeve of the nacelle. The whole creates the turntable of the nacelle, which can be easily mounted on top of the mast. Any maintenance work of the system output power can be carried out through the revising door on the supporting structure of the mast.

## 5. Conclusion and outlook for further work

This paper presents the design of the low power wind turbine, which simple and compact construction reduces the cost of production and operation, and also allows for quick and easy assembly/disassembly independent of the field conditions. The use of ballast in exchange for the existing installation of the support structure of the mast to the foundation proposed by the authors makes the wind turbine more mobile. The use of the self-adjusting system to the wind direction, with the correcting system, which protects against exceeding the rotor speed limit, allows maintaining a constant angular speed of the main rotor and the active power. The changing of the setting of the main wind turbine rotor to the wind direction is running without negative impact to the turbine, with a low gyroscopic torque. Used in the self-adjusting system to wind direction the self-locking gear does not allow the nacelle to oscillations during sudden changes of direction the wind stream. The self-adjusting system with the turbine protection against exceeding the speed limit does not require additional electric power from outside.

The presented design of the transportable wind turbine is removals connected to the ground, thus is not subject to the building law and not require a building consent. The proposed design can be also developed as a design of certain type of modules, for which depending on the needs and conditions (selecting an appropriate power of the generator) can be select a suitable design of the support structure of the mast and ballast for setting up our own wind turbine.

## References

- [1] Augustyn, M., *The study of aerodynamic forces on the turbine blades with use aerodynamic balance*, Monograph, Published by Cracow University of Technology, 2012 [in Polish].
- [2] Flaga, A., *Modelling of aerodynamically and mechanical characteristic of different type of wind rotors*, Environmental Effects on Buildings and People: Actions, Influences, Discomfort, eds.: A. Flaga, T. Lipecki, Polish Associations for Wind Engineering, Cracow 2012 [in Polish].
- [3] Ryś, J., *Homing head unit of wind turbine with respect to wind direction*, Inventive design, No. P-298964, 1993 [in Polish].
- [4] Hau, E., *Wind turbines: Fundamentals, Technologies, Application, Economics*, Springer Verlag, Berlin 2000.
- [5] Ryś, J., Augustyn, M., *Experimental studies of a two-coherent cross-section blade of wind rotor with vertical axis - motion and a propelling torque of wind turbine*, Technical Journal Mechanika, Published by Cracow University of Technology, 6-M/2012, Is. 11, pp. 93-115, 2012 [in Polish].
- [6] Ryś, J., Augustyn, M., *The guidance system of horizontal axis wind turbine (HAWT) onto wind direction with the collateral of exceeding of speed limit*, The patent application under, P.400514, 2012 [in Polish].
- [7] KOMEL Institute, Research & Development Centre of Electrical Machines, *The three-phase synchronous generator AC voltage activated by the permanent magnet*, User manual (Technical and motion documentation) [in Polish].
- [8] "SWIND" Wind turbine. *Wind turbine 3.5m*, User manual and safe exploitation [in Polish].