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DEVELOPMENT, MANUFACTURE AND TESTING OF HORIZONTAL AXIS WIND MICROTURBINES WITH POWER OF 10 KW

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Abstract – **Under the circumstances of the total energetic recourses deficit in the Republic of Moldova appears the problem of non-traditional sources utilization recovered by energy. Important sources of renewable energy are the wind, solar and hydraulic energies. Wind energy is one of the most ancient forms of energy used by Homo sapiens. Concurrently with the emergence of new energy sources (fossil fuels, atomic energy etc.) this form of energy yielded up the priority and changed itself into alternative one, which, at present, begins to regain its positions not only from the ecological, but also from the economical point of view. Under the circumstances of the present energy crisis (even at worldwide level), the wind energy conversion systems could have a significant weight in the production of (mechanical, electrical etc.) energy in the Republic of Moldova, in particular, for providing the individual consumer with energy using wind turbines of low power (until 30kW). In order to redress the situation of the energy sector, the Government of the Republic of Moldova, through the agency of the Supreme Council for Science and Technological Development (Academy of Sciences of Moldova), initiated more State Programs, in which one of the directions is immediately related to the elaboration of renewable energy conversion systems. This paper deals with the elaboration and fabrication of the industrial prototypes of horizontal axis wind microturbines with power of 10 kW. Currently have been manufactured 10 horizontal axis wind turbine with power of 10 kW, concerning some novelty elements. These wind turbines will be installed in different geographic areas of the Republic and will be tested. Test results will be included in this paper.**

Keywords: blade, turbine, wind energy

1. INTRODUCTION

Wind energy has been used by mankind over thousands of years. For over 3000 years the windmills have been used for pumping water or grinding (milling). And nowadays, in the century of information technologies, nuclear energy and electricity, thousands of windmills are used for pumping water and oil, for irrigation and production of mechanical energy to drive low-power mechanisms on different continents. Nowadays, the phrase "*use of wind energy*" means, primarily non-pollutant electrical energy produced at a significant scale by modern *"windmills"* called *wind turbines*, a term that attempts to outline their similarity to steam or gas turbines, which are used for producing electricity, and also to make a distinction between their old and new destination.

The attempts to obtain electricity from the wind date back over a hundred years since the late nineteenth century. But a true flourishing of this technology is registered only after the 1973 oil crisis. An unexpected increase in oil prices has forced the governments of developed countries to allocate substantial financial resources for research, development and demonstration programmes. Over 20 years, worldwide, a new technology, a new industry and, in fact, a new market - the market of the Wind Energy Conversion Systems (WECS), have been developed.

Moldova's total dependence on imported energy resources severely affects country's energy security. Over 94,5% of primary energy sources are imported [1]. According to preliminary data from ANRE (National Energy Regulatory Agency), in 2007 only 23,6% of the electricity consumed was produced on the right side of the Nistru river, while 76,5% were imported from Ukraine. Therefore, the Government of the Republic of Moldova launched the "Energy Strategy of the Republic of Moldova until 2010", which plans to increase the share of renewable in the energy balance up to 10% in 2010 and 20% in 2020 [1]. Also, due to relatively arid climate (especially in the south region) the farm land needs to be irrigated. In order to improve this situation the Government adopted Decision No. 256 on "*Irrigation systems rehabilitation*" in 2001.

Number of blades and rotor diameter effect. Betz limit states that an ideal wind turbine can extract from the wind a power not exceeding 59,3%, but the analysis made above does not indicate the operating system of the turbine or the construction that the rotor must have in order that the maximum power factor is achieved. Next, we will undertake a qualitative analysis of the turbine operating mode and of the effect of the number of blades or the solidity factor on the value of power factor. Also, the dependence of the rated power on the commercialized turbine rotor diameter is analysed. The efficiency of air flow energy conversion into mechanical energy will be lower than the optimum value if:

1. The turbine rotor has a bigger number of blades (the solidity factor is big) or the rotor turns with a very high frequency and each blade moves in an air flow distorted (turbulent) by the front blade.

2. The turbine rotor has a small number of blades (the solidity factor is small) or the rotor turns with a very slow frequency and the air flow crosses rotor's surface without interacting with it.

In order to achieve maximum energy conversion efficiency it is necessary to correlate the rotor's speed of rotation with the wind speed. To characterize the wind turbines with different aerodynamic parameters, the dimensionless parameter is applied, called the tip *speed ratio* λ. The speed ratio links in a single formula three important variables of the turbine: the rotational speed ω, the rotor radius (or diameter) R and the wind speed V, and is defined as the ratio between *linear* turbine *blade* tip *speed* U to the wind *speed*:

$$\lambda = \frac{U}{V} = \frac{\omega R}{V} \tag{1}$$

A turbine of certain design will operate in a large range of variations of the tip *speed ratio* λ, but will have maximum efficiency C_p only for an optimal value of the speed, or, if linear velocity U is equal to the wind speed multiplied to the optimal value of the tip *speed ratio*.

Figure 1 shows C_p–λ characteristics taken from [2] for turbines with different number of blades. Analysis of these characteristics allows drawing the following conclusions:

1. The smaller the number of blades the greater the optimum *tip speed ratio* for which the power factor or energy conversion efficiency is maximized.

2. Two equal power turbines, but with a different number of blades are distinguished by the fact that the multi-blade turbine will develop a higher moment and will have lower rotation speed and vice versa - the turbine with few blades will develop a small moment but will have a higher rotational speed.

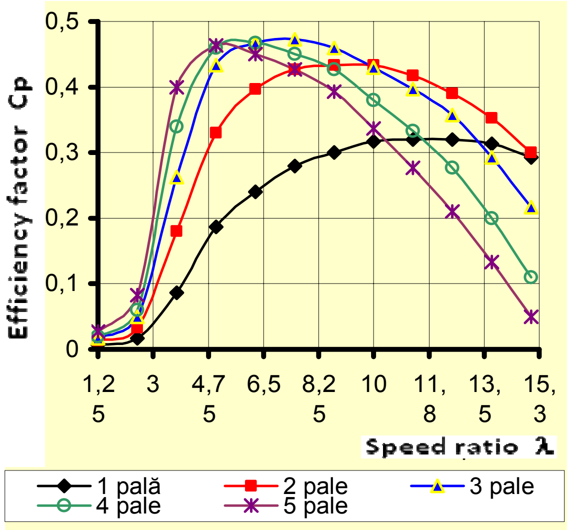

Figure 1: Aerodynamic characteristics of different turbines.

3. Three-bladed turbine has the biggest factor of efficiency. The differences between the factors of maximum efficiency of 2-5 blade turbines are not significant. Advantages of 1 or 2 blade turbines consist in the possibility of operation in a wider range of *tip speed ratio* variation, in which the efficiency factor is maximum or close to maximum.

The maximum efficiency factor (Betz) of the turbine with 12 – 18 blades is smaller than that of the turbine with 3 blades and does not exceed 0,35.

The rated speed of rotation of micro turbines is relatively high (200-500 min^{-1}) [3]and used in autonomous regime. Over 95% of turbines are equipped with low speed synchronous generators with permanent magnets (PMSG) and coupled directly with the rotor (Figure 2). At low speeds of rotation, the technical performance of synchronous generators decreases essentially and in isolated electrical systems requires special excitation equipment and voltage stabilization. The reference literature has not identified any examples of wind micro turbines equipped with asynchronous generator operating autonomously or supplying a remote power network.

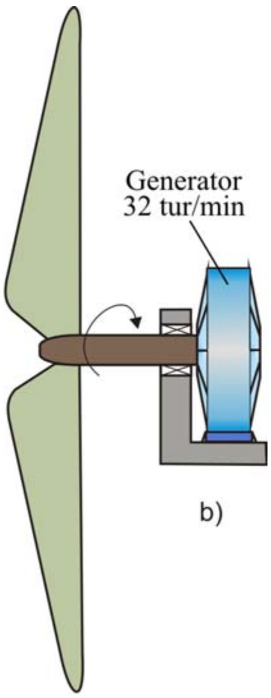

Figure 2: Wind turbine with direct coupling.

2. SMALL POWER WIND TURBINES DESIGNED AT TUM

Given the topical interest and relatively high costs of imported wind turbines, a team of authors developed two types of small power wind turbines. The wind turbines with servo motors have the ability to track wind direction and remove the bladed rotor out of the wind action at wind speeds exceeding 15-25 m/s. The advantages of these turbines compared to vane wind turbines are:

- angular positioning stability of the bladed rotor at dynamic fluctuations of air currents direction;
- bladed rotor protection from overloads, caused by wind speeds exceeding the highest allowed values.

Fig. 3 shows a 3D model of a rotor and an overview of the servo motor wind turbine, developed by a team of authors [4-5]. Both wind direction rotor orientation and its removal out of the action of air currents is done by means of a device, called servo motor, which performs the kinematical liaison of gondola with tower and which is controlled by a wind vane electronic transducer. When the wind direction is changed the vane performs an angular re-positioning, a deviation signal occurs and the control system starts the servo motor, that rotates gondola with rotor in one direction or another until the rotor axis coincides with the direction of air currents. Angular positioning stability is ensured by a certain time delay of the servo motor switch depending on the wind flow action in one direction or another. Repositioning period of bladed rotor perpendicular to airflow velocity vector depends on the kinematical characteristics of the driving mechanism (the servo motor), and actually determines time repositioning stability of the gondola. Kinematical characteristics of the servo motor were determined by the dynamics of the airflow velocity vector variation that is specific to the wind characteristics in the Republic of Moldova. Table 1 presents the basic parameters of the servo motor wind turbine. The wind turbine with servo motor, shown in Fig. 3 is installed at the Râşcani campus of the Technical University of Moldova and is designed for lighting and irrigation system of the adjacent dendrologic park.

Figure 3: Industrial prototype of the wind turbine and his 3D rotor’s model.

Parameters	
Bladed rotor diameter	8,6 m
Rotor swept area	58 m^2
Number of blades	3
Blades profile	aerodynamic asymmetric
Rated capacity at 10 m/s wind speed	10 kW
Wind guidance	actuator
Blades positioning	fixed
Voltage	240 V c.c.
Starting wind speed	2 m/s
Calculated wind speed	10 m/s
Generator	three-phase, permanent magnet
Generator driving	direct
Rotation frequency	160 min^{-1}
Blade material	Resin-based composite material reinforced with glass fibre
Turbine weight	392 kg
Variable height modular telescopic tower	7 - 18 m
Modular tower weight	708 kg
Accumulator battery	12V, 200Ah x 20

Table 1: Basic parameters of the servo motor wind turbine.

The wind turbine project, developed by authors, was implemented at the Scientific Technical Centre for Implementation of Advanced Technologies at the Technical University of Moldova in cooperation with INCOMAS SA, Chişinau, SA Topaz, Chişinău, Electromaş SA, Tiraspol. It was produced series of 10 wind turbines with an output of 10 kW at wind speed of 12 m/s.

The team developed the manufacturing technology for blades and gondola parts from composite material reinforced with glass fibre. The outer coverage of blades featuring asymmetric aerodynamic profile, also the gondola cone and the vane are manufactured from composite materials reinforced with glass fibre employing modern technologies in the CESCER laboratory, TUM. Composite materials components resistance is comparable to that of the metal structures and has competitive properties advantages such as small weight, corrosion resistance, fatigue resistance, low starting torque, and relatively low costs of small series production.

The CESCER Laboratory at TUM is endowed with modern equipment, fully fitted for the production

a. *b.*

c. *d.*

Figure 4: Blades- (a,b) and gondola parts (c,d) manufacturing from composite material in the CESCER Laboratory, TUM.

a. *b.*

c.

Figure 5: Gondola parts (a) and blades (c) manufactured from composite material in the CESCER Laboratory, TUM; tests of the generator with permanent magnets, Electromas, Tiraspol (b).

Figure 6: Industrial prototype of the wind turbine.

cycle of composite materials machine parts using modern technologies. IT-supported technological and infrastructural equipment provide mobility and diversity in terms of timely implementation of various technical and technological solutions, as well as design and research solutions in the field of machine special wind monitoring system ECO 21B produced by Netherlands EcoPower system and integrated with LabView. Measurements performed over 9 months have allowed the development of 10 kW wind turbine power characteristics, presented in Fig. 7.

Developed wind turbines will be integrated into various systems. Fig. 8 shows the connection schemes of the wind turbine for electricity supply to the dendrologic park lighting system of the Technical University of Moldova.

The choice of three blade rotor scheme provides a greater dynamic stability, minimizing related vibrations and sonic background, thus resulting a longer life period of all components. Direct connection of the rotor to the generator ensures rotor start up at lower wind speeds, production of a larger amount of energy, requires less demanding maintenance compared to turbine multiplier case. Specially designed permanent magnet generator combines efficiency with the simplicity of construction.

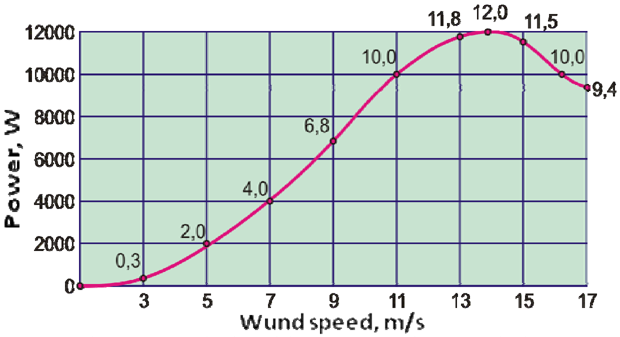

Figure 7: Wind turbine power characteristic.

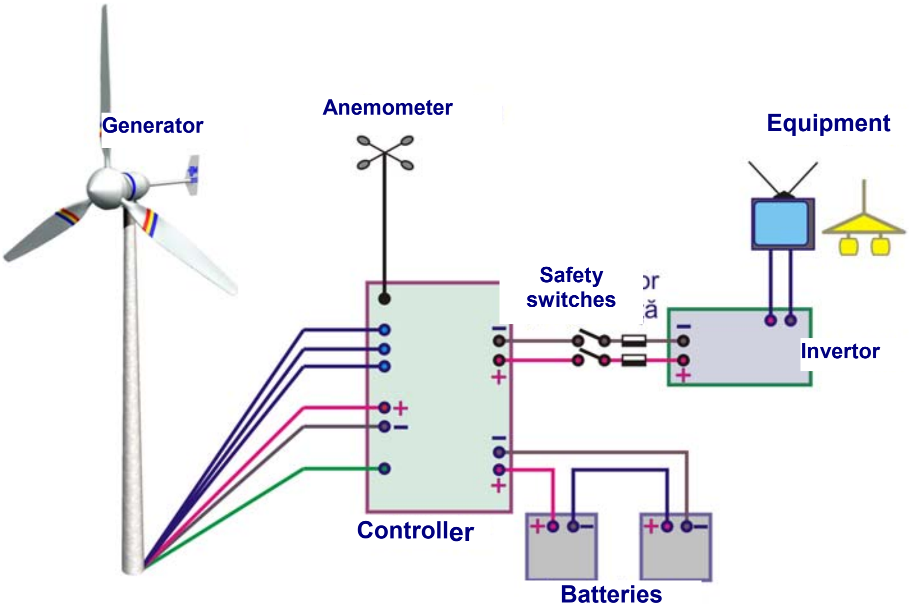

Figure 8. Wind turbine connection schemes for lighting system supply

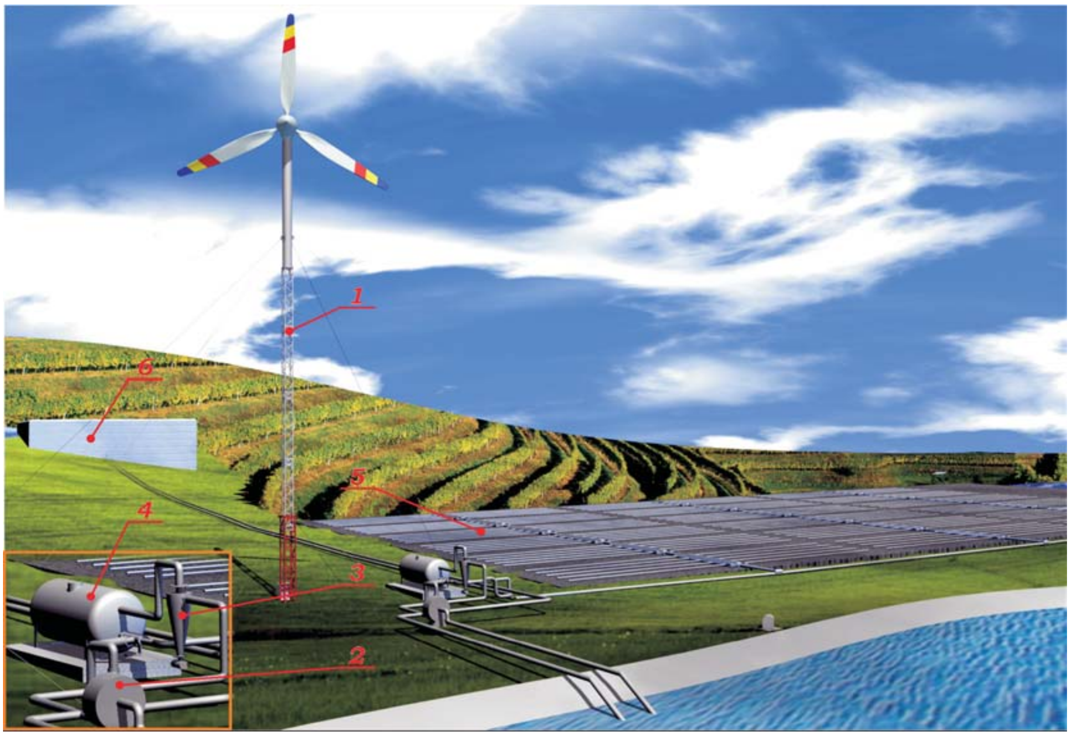

Figure 9**:** Drip irrigation system powered with electricity produced by the wind turbine.

3. WIND ENERGY SUPPLY OF THE DRIPPING IRRIGATION SYSTEM

The electricity supply of agricultural land irrigation systems from the public power grid becomes inefficient, that is why various autonomous sources of energy are becoming more widespread [5]. Fig. 9 shows a drip irrigation system powered by electricity from a wind turbine 1 designed by the authors and described above. Centrifugal pump 2 with productivity parameters Q (m^3/h) and pumping height H corresponding to the needs for irrigation is supplied with electricity from a wind turbine generator 1. Centrifugal pump 2 sucks water from the lake (or river) and pumps it into the system through the fertilizing dispenser 3 and filtering device 4 connected consecutively in the pump discharge pipe. Fertilized and filtered water under pressure is pumped into the pipe network 5. The irrigation system must include a water storage tank 6 located at an altitude higher than the irrigated ground. Water in the tank may be used during the periods when the wind speed is insufficient to produce the demanded electricity. Subject to the launch of a new generation of electric batteries on the market, more efficient and cheaper, the irrigation systems equipped with batteries could be an alternative that will load at times when irrigation is not appropriate.

CONCLUSIONS

In conclusion, we state that the direct connection of the rotor to the generator ensures rotor start up at lower wind speeds, production of a larger amount of energy, requires less demanding maintenance compared to turbine multiplier case.

Experimental testing of the wind turbine in real field conditions confirmed that the aerodynamic rotor assures the conversion of the wind energy at the rotor shaft to the generator clams with high efficiency.

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