

Vertical wind turbine with self-limitation system of speed

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Abstract. The proper work of vertical wind turbine Savonius typed may be negatively influenced by very high wind speed. Usually the wind turbine speed is limited by means of a brake. The turbine speed is limited, but the spindle of the turbine is still subject of increased torque. The paper proposes a new, innovative technical solution that does not counteract increasing the turbine speed above a limit value, but prevents it. The new concept is based on dividing the blade of the turbine into several parallel vertical strips, properly displayed, as to form the shape of a conventional blade. Each strip can rotate against its own vertical axis, to change its orientation in vertical plane. This brings the benefit that when the turbine speed tends to overcome a certain value (dangerous for the turbine) the strips orientation changes, and the surface of the blade becomes a non-continuous one. The area of the blade that faces to the wind reduces, and prevents increasing the turbine speed. When wind speed slows down, the strips are guided back to their initial position by means of some springs. Reorienting the blades is based on centrifugal force generated of turbine rotation, so, it can be concluded that this forms a self-limitation system of turbine speed.

1. Introduction

Wind turbines are green devices which produce electrical energy. They are quite various in design, but some types got a special development due to their advantages. One of them is Savonius typed wind turbine. Savonius turbines are vertical ones, and they are widely used for some specific features. The most important advantages of this type of turbines are, according to [1]: they are compact, can start by themselves even at low wind speed, have a low noise level, and are cheap and simple to assembly. Savonius turbines are suitable both for urban zones, and for insulated areas, like mountains, for instance.

Meanwhile, Savonius typed turbines have a drawback, their power coefficient is relatively low [1]. Both advantages and disadvantages make Savonius turbines an attractive research subject for scientists and engineers.

A survey of scientific literature reveals a large interest of scientist to study Savonius typed turbines. On ISI WoS can be found more than 200 papers dedicated to the subject. Because the relatively low power coefficient of these turbines, most of researchers focused on ways to increase it. Some samples of researches in the area are mentioned bellow.

In [2] a study related to the influence of number of blades on the performance of Savonius turbine is presented. The conclusion is that three is the optimum number of blades. In [3] a study on optimal



orientation of the blades in order to deflect the air flow to increase the power coefficient is presented. It was found that the performance of turbine can be increased in this way up to 30%.

A large category of research papers refer to numerical simulation and analytical studies on Savonius turbines [3-9]

Many articles approach the optimization of blades shape. In [1] is described how genetic algorithms are used to find an optimum shape of the blade. The result is that using the proposed optimized blades, an increase of 33% of power coefficient can be achieved. In [10] an inverse method to optimize the blade shape is presented. That is, the whole optimization process is carried on taking into account some targets to be obtained, i. e. a certain torque and power. The new found shape has been validated by experimental research, and the conclusion was the area of the blade can be reduced with up to 9%, compared to a classic shape, without affecting the power or torque of the turbine.

A small amount of academic papers study the ways to control the limit the turbine speed in strong wind [3, 11]. Usually, the solution proposed for high speed of wind is the usage of a brake to *stop* turbine from rotating.

2. The problem

Authors consider that using a brake to stop the turbine from rotating while wind becomes too strong is a non-effective approach, because of the following reasons:

- even if the turbine rotation stops, its spindle is still subject to big stress (torsion);
- an additional system is needed to detect when the wind speed slowed down enough, as the turbine may be restarted safely;
- this approach counteracts an unwanted event that already happened (over-speeding the turbine), instead of preventing it;
- stopping the turbine causes a loss of produced energy.

The present work proposes a new approach to the problem: prevent the over-speeding of turbine, instead of fighting against it.

3. The new concept of Savonius typed turbine

It is considered that it is much better to prevent an unwanted event as over-speeding the turbine, than fighting against it when it has already been produced or is going to occur. It is known that the speed of the turbine, depends directly (among other factors) on the area of the blades. Based on these statements a new concept of turbine was developed.

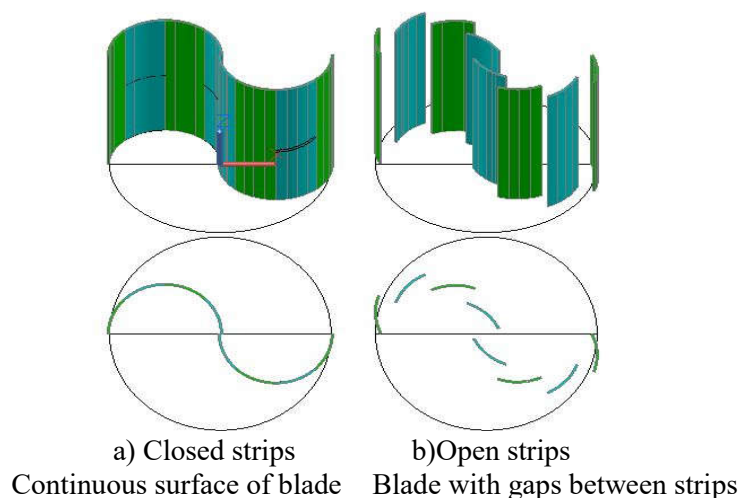


Figure 1. The concept of blade divided into strips.

The blade of the turbine is divided into several vertical strips, each of it, being able to rotate against its vertical axis. At repose, and low wind speed they are placed as to form a continuous surface, as a classic blade is. At a certain turbine speed, the strips begin to rotate against their own axis to form gaps between them. These gaps will let the wind escape through it, so a part of it dissipates, and no longer contributes to speeding up the turbine.

Figure 1 presents schematically the concept.

Rotation of strips is controlled by centrifugal force. Several ways are available to use centrifugal force to drive the strips rotation. One of them is based on the uneven distribution of the mass of strip against the rotation axis. That is obtained by moving the rotation axis of the strip from its symmetry axis, as can be seen in figure 2. This design has the disadvantage that does not benefit from any flexibility. The dissymmetry of the strip must be exactly determined theoretically to produce the wanted output. Even if the computations are accurate, once the strips are built and assembled on the turbine, no further adjustment is possible.

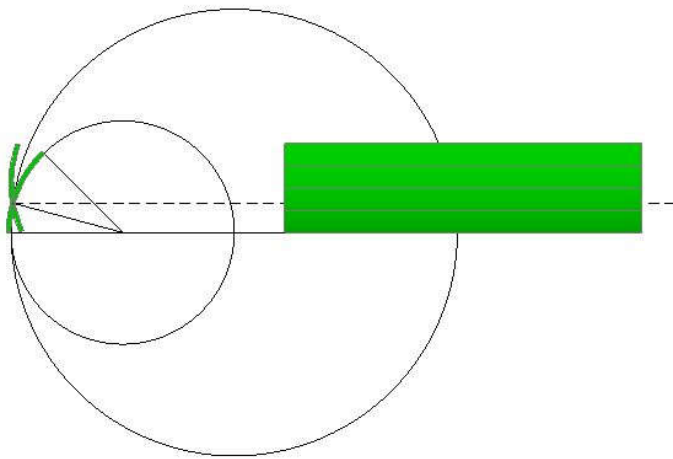


Figure 2. Rotation axis of the blade differs from the symmetry one.

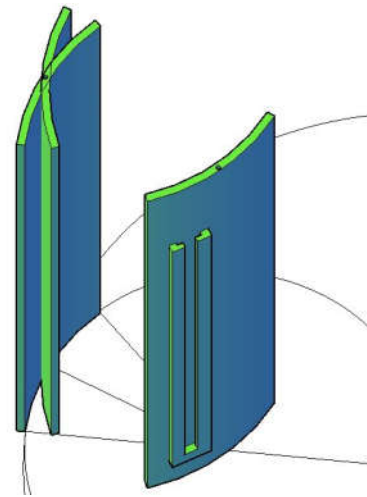


Figure 3. The pocket on the backside of the strip.

Figure 3 displays another way to unbalance the mass of the strip related to the rotation axis. This is placed even in the symmetry axis, but on the backside of the strip a pocket is placed. In this pocket several parts can be stored. This solution is better than the first presented one, because it allows a better flexibility: the mass imbalance can be controlled through the number and mass of the parts stored in the pocket. After the optimum is determined experimentally, its value can be applied to a single part strip. On the other hand, if the solution with pocket is kept as a final one, it allows controlling the turbine speed which determines the opening of strips by adding or removing parts from the pocket.

Another way to drive the rotation of strips is presented in figure 4. A rod that slides along a radial stem under the action of centrifugal force is connected by flexible cables to each strip. The flexible cables are guided by a reel.

Other systems used to convert sliding of a centrifugal mass into rotation of strips can use gears or levers.

Whichever the way to rotate the strips is chosen, they have to be led to their home position when the speed of wind slows down. This action is performed by torsion springs mounted on the axle of each strip. The extent to which the springs are strained can play a role in setting up the turbine speed that triggers the opening of strips.

The concept presented here can be adapted for other types of turbines, as well.

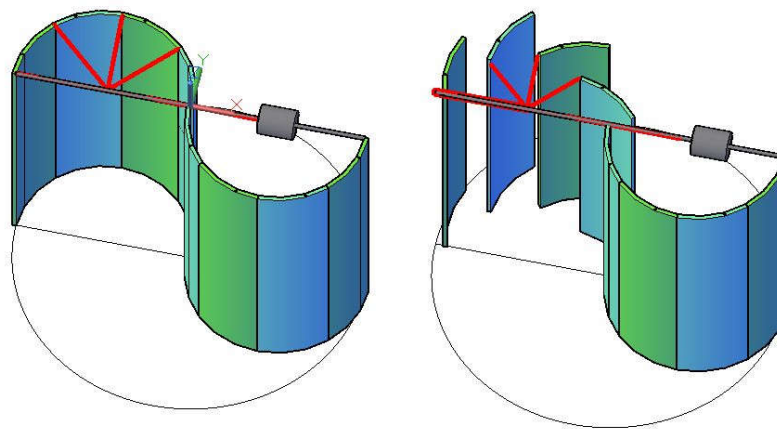


Figure 4. Central drive of the strips.

4. Concluding remarks

The turbine speed self-limitation system is a new, innovative one, which was not yet mentioned in the literature. Being based on centrifugal force that depends on turbine speed, one can conclude that it is a natural one. It prevents over-speeding the turbine, rather than counteracting high dangerous speed. The turbine speed self-limitation system offers some important advantages in opposition to using brakes that stop turbine from working if wind speed becomes too high:

- keeps turbine far from spindle overloading;
- the negative influence of high speed wind is avoided;
- losses in electrical power production are diminished, since the turbine does not need to stop when wind speed increases dangerously; problems that usually occur when restarting the work of turbine, are as well, avoided;
- the value of speed of turbine that triggers the protection system can be set up by means of springs.

The new concept of turbine blade can be applied to other types of wind turbines. For Savonius typed turbines, the new concept fits best to small turbines (up to 0.5 kw), suitable to be mounted and to work in insulated areas

What authors claim to be the novelty of the work is the concept itself, which splits the blade of the turbine into parallel strips, and uses the centrifugal force to rotate these strips against their own vertical axis. Wasting a share of wind stream through the gaps between the strips limits the turbine speed automatically.

The prototype can be improved experimentally, adjusting the mass that unbalances the mass distribution of the strips, as the limitation of turbine speed to be very effective. Scaling the prototype opens new research directions for different sizes of turbines. Research can be extended to identify some other systems to control the rotation of strips, more effective, reliable, and designed for manufacturability and assembling.

Acknowledgement

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References

- [1] Chan C M, Bai H L and He D Q 2018 Blade Shape Optimization of the Savonius Wind Turbine Using a Genetic Algorithm *Apl. Energ* **213** 148
- [2] Wenehenubuna F, Saputraa A and Sutanto H 2015 An experimental study on the performance

- of Savonius wind turbines related with the number of blades *Energ Proc.* **68** 297
- [3] Ogawa T, Yoshida H and Yokota Y 1989 Development of Rotational Speed Control Systems for a Savonius-Type Wind Turbine *J. Fluids Eng* **111**(1) 53
- [4] Kumar P M, Purimitla S R, Shubhra S and Srikanth N 2017 3rd International Conference on Power Generation Systems and Renewable Energy Technologies (PGSRET), Univ Teknologi Malaysia, Johor Bahru, MALAYSIA 107
- [5] Belabes B, Youcefi A and M Paraschivoiu 2016 Numerical investigation of Savonius wind turbine farms *J Renew Sustain Ene J Renew Sustain Ener* **8**
- [6] Ducoin A, Shadloo M S and Roy S 2017 Blade shape optimization of the Savonius wind turbine using a genetic algorithm *Review Energ* **105** 374
- [7] Ferrari G, Federici D, Schito P and Izoli F 2017 CFD study on Savonius wind turbine; 3D model validation and parametric analysis *Review Energ* **105** 722
- [8] Liang X T, Ou Fu S C Bx, Wu C L, Chao C Y H and Pi K H 2017 *Review Energ* **113** 329
- [9] Mereu R, Federici D, Ferrari G, Schito P and Inzoli F 2017 Parametrical numeric study of Savonius wind turbine interaction in a linear array *Review Energ* **113** 1320
- [10] Roy S, Das R and Saha U K 2018 An inverse Method for optimization of geometric parameters of a Savomius-style wind turbine *Energ Convers Manage* **155** 116
- [11] Pite H D 1986 *J Atmos Ocean Tech* **3** 3 487