Wind power plant with a wind power concentrator

BUBENCHICOV A.A., BUBENCHICOVA T.V.
Energy Department
Omsk State Technical University
Omsk, pr, Mira 11
RUSSIAN FEDERATION
privetomsk@mail.ru

Abstract: - The article considers the problems of wind power plants application on the Russian territory. The new design of a wind power plant with a wind power concentrator capable to work effectively in the regions with low wind load is proposed. The recommendations on the application of the developed wind power plant are given, advantages, disadvantages and further research ways are presented.

Key-Words: - wind power, concentrator, unsteady flow, low wind speed

1 Introduction

At present more attention is paid to the issue of renewable energy sources and their place in the state power grid. The power and environment problems are regularly discussed at governmental meetings and their solutions are not possible without a wide application of environmentally friendly wind power plants (WPP). Thus wind power plants find wider application for power generation over time. There is also a constant development of new areas, cottage settlements construction, country houses and farms. The electrification problem arises in the remote areas where there are no heat and electric grids. In addition, the interest of autonomous or "passive" houses and the problem of reserved or auxiliary power increase.

In spite of some negative factors wind power requires its development and application, in particular, one of the most important and complex field is the development of WPP capable to operate effectively in the regions with low wind speed.

2 Problem Formulation

After analyzing the Russian wind atlas, we have found that Russian regions are unsuitable for the wind power plants application, in particular, our Siberian region. The main problem of the plants application is low wind load, due to which the plants designed for the speed of 10 m/s in areas, where the wind speed does not exceed 3-5 m/s, generate not more than 10% of its commited capacity (1) [1].

where ξ -wind power application efficiency;

ρ - air density, kg/m3;

S – wind rotor area , m2;

v – wind speed, m/s.

There are several ways of the generated power augmentation according to expression (1):

- wind rotor swept area extension;
- wind power application efficiency increasing;
- WPP lifting at high altitude, where the wind speed is greater than on the surface.

All these ways lead to the complexity and price rising of the wind power plants construction and the negligible economic effect achieving.

The alternative of increasing the wind power plants size or their number is the wind power concentrators application [2-5].

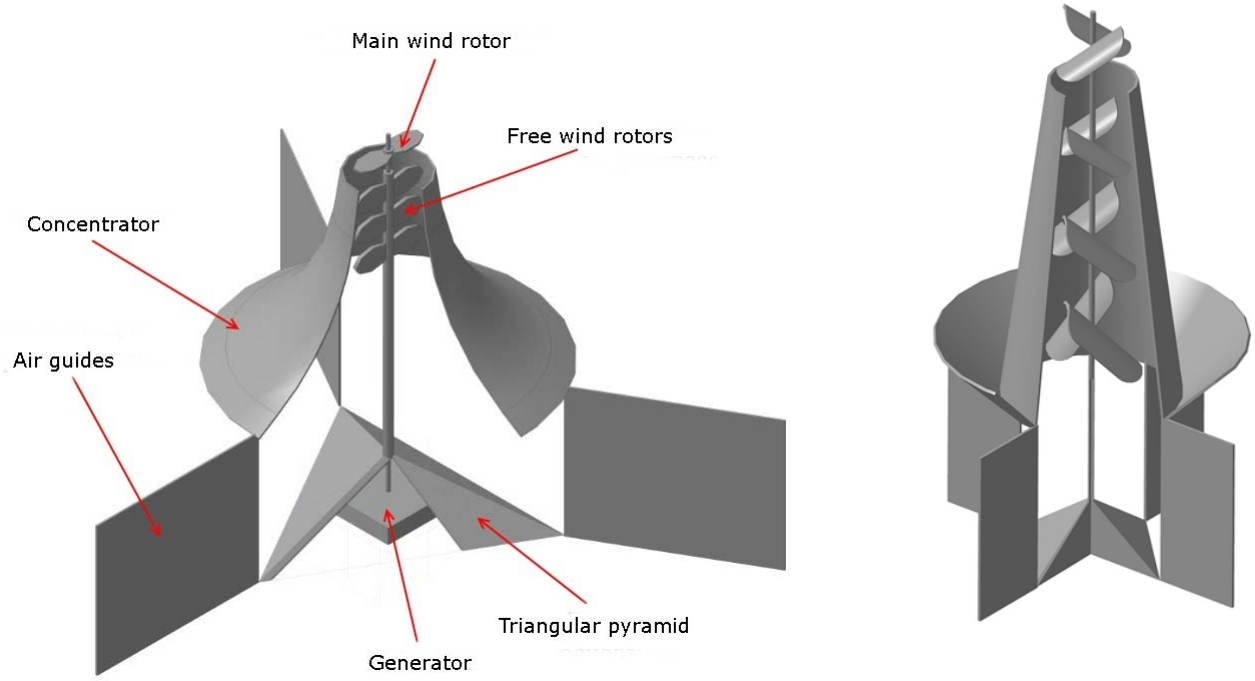
At present common models have found their application, but they have certain disadvantages such as the orientation and the additional stability providing. In addition the concentrator plants are bulky and complex constructions, which have the main disadvantage. The air flow on the way to the concentrator passes it on the path of least resistance perceiving the plant as a barrier. As a result the acceleration doesn't exceed 20-30%.

If we consider the concentrator plants application in the regions with low wind speed, there is the flow unsteadiness problem along with the wind load one. Wind blasts often don't have time to affect on blades long enough to spin the generator to the required speed. Because of this, even with the average wind speed of 5 m/s energy output is comparable with the speed of 2.5-3 m/s, which is 5 times less according to (1).

Therefore the task of designing a wind power plant concentrator capable to increase the wind flow speed not less than 30% is set and the following requirements are met:

- airflow flattening or averaging;
- high resistance;
- no wind orientation;
- noise and vibration reducing.

After analyzing existing designs the following solution has been proposed (Fig. 2). A concentrator wind plant is a cone mounted on three vertical fins (air guides), located as a star, shifted relative to each other at the angle of 120 degrees. Inside the cone freely rotating blades of the special shape, which are driven by air coming from bottom, are installed. At the base of the plant a pyramid containing the electronic assembly with a gear and a generator is established. Passing between the guides the airflow meets the pyramid as a barrier and rises up. At the concentrator inlet it drives freely rotating blades using wind power to spin. In the flow speed decreasing they are rotated by inertia and draw in the air into the concentrator. Then the air is directed upwards and accelerated in the pipe throat. Then the airflow enters the upper wind rotor, which is connected to the generator by the shaft at the structure base.



a) wind power plant prototype with the wind power concentrator

b) wind power plant experimental design

Fig. 2. The wind power plant development model with a wind power concentrator.

The effect achieved is similar to a tornado, when the flow is accelerated and twisted. The same effect is provided by the free blades and the accelerator cone-shaped design.

3 Problem Solution

A few concentrator plant development models have been built for the experiment. After a series of experiments the design has been selected according to figure 2b, which doesn't have the best aerodynamic performance, but is easy to install and sufficient for the investigated effect analysis. A concentrator form has been modified to the simple cone 1.2 m high and the inlet radius of 0.6 cm and the outlet radius of 0.35 m. For the flow directing into the concentrator the apron has also been added. The set airflow at the concentrator inlet equals to 7.2 m/s.

At the first stage the airflow speed at the outlet without the free blades in the concentrator has been determined. The flow acceleration is 35%.

After the free blades adding the acceleration decreasing has been observed by 2-3% at the steady flow.
The main task has been to determine the flow changes nature at the outlet in the unsteady flow at the inlet. For this purpose the conditions, in which the flow speed at the inlet decreases every 10 seconds to 1.5 m/s and boosts up to 7.5 m/s, have been observed. In the experiment result the airflow speed change average pattern at the concentrator outlet has been obtained (Fig. 3):

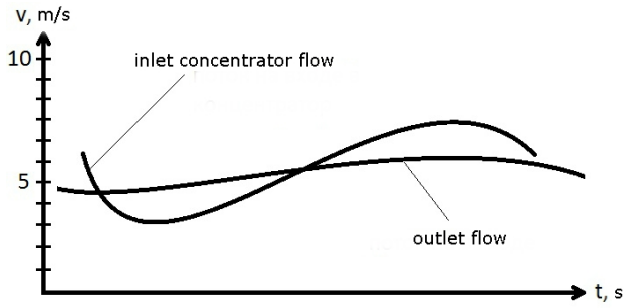


Fig. 3 Airflow speed averaged values at the inlet and at the outlet of the concentrator plant.

The conducted research has shown that the concentrators using can increase the airflow speed by 30-40%, however, in strong unsteadiness and low wind speed a large amount of energy is spent on the wind generator blades acceleration, whereby the generator fails to spin to the required optimal efficiency of the rotor speed. To reduce the negative impact of such processes it is advisable to use the installations under consideration.
The resulting construction speeds up the flow worse than a simple cone, but helps to maintain the certain main wind rotor air stream level necessary for the generator operation in the steady power generating.

4 Conclusion

The resulting design has the following advantages:
-airflow accelerating, leveling or averaging
- no need for wind orientation
- no need for additional system installation stabilization
-noise reducing, vibration and protection of human rights, as the main moving parts are hidden in the concentrator.
The plant under consideration requires additional research aimed at the optimal geometry determining, the strength improving, the exciting frequency decreasing and the ease in manufacturing. The separate and very important issue is the main rotor blades shape determining on the generator shaft. It must catch airflows in two projections – raising from the concentrator and from side wind.
It is recommended to apply the developed concentrator wind power plant in regions with low wind load.

References:
[1] A.A. Bubenchikov, E.Y. Artamonova, R.A. Deichman, L.A. Phifer, F.V. Katerov, T.V. Bubenikova, Problems of wind power plants application in regions with low wind load, *International scientific-research journal*, Vol. 36, 2015, pp. 39-43.
[2] M. Ragheb, *Wind Energy Converters Concepts*, 2012.
[3] V. F. Rakowski, *Wind turbine*, Patent for useful model, RF No 2043536, 07.05.1990.
[4] V.S. Botsvin, *Wind power plant*, Patent for useful model No 2024781, 28.03.1991.
[5] N.V. Seleznev, *Wind rotor for a wind plant*, Patent for useful model RF No 2237822, 20.02.2003.