Installation of wind turbines on the smoke stacks of power facilities

R A Ilyin and N D Shishkin
Alternative Energy Laboratory of the Department of Energy Problems of Saratov Scientific Center of the Russian Academy of Sciences, 24 Rabochaya str., Saratov, 410028, The Russian Federation
E-mail: kaften.astu@mail.ru

Abstract. Currently, many works are devoted to the development of modern designs of wind power plants and improving the efficiency of existing ones. The work considered the issue of using wind energy by wind power plants, which are proposed to be installed on the chimneys of energy facilities. The original design of such an installation has been developed, which will allow using the phenomenon of free convection for its work even in the absence of an oncoming wind flow. The operation of the plant will partially or completely cover the costs of its own needs of the energy facility during its operation, which includes chimneys.

1. Introduction
The relevance of using renewable energy sources (RES) is currently quite high. The paper considers the use of wind energy for generating electric energy, the potential of which can be used to fully or partially cover the own needs of various power facilities that have chimneys, for example, boiler house stack.

2. Review of existing wind power installations
For example, we propose an installation for the rotary wind turbine (RWT) with the vertical axis of rotation on the top of the smoke stack used as a high support for generating electricity [1]. RWT consists of the vertical airfoil blades and horizontal blades of improved aerodynamic efficiency, the thin aluminum ring, the upper rotating ring with outer ring gear, the power rod, the lower fixed airfoil ring, at least two symmetrically located permanent magnet generators (PMG), PMG bearing support and gear wheel. The horizontal blade has a contour that has a ratio of the blade height to its chord of 0.35–0.45. The PMG bearing support is attached to the smoke stack, and the gear wheel is attached to the PMG rotor shaft.

There are also designs of wind turbine bearing supports with a horizontal axis and a vertical axis of rotation [2–5]. Typical schemes of bearing support installation contain the support pipe, which is inserted into the bearings support pipe.

There are also various methods of aerodynamic braking of wind turbines (stabilizer, protective-sail, centrifugal-aerodynamic, etc.) and installations for their implementation [1]. For example, the centrifugal regulator is used to regulate the speed of rotation of the wind turbine [6]. There are also installations for manual braking [2–4]. As a rule, a drum-type brake is used more often.

The rotary wind turbine (RWT) for generating electricity contains the blade propellers with electric generators mounted respectively at the output end of the pipe [7]. The blade propellers operate on air
flow organized inside the pipe. The main drawback is that the wind at a height of 30 meters, if the wind rose unfavorably, will slow down the air outlet from the pipe, and this will significantly affect the efficiency factor of the wind turbine. Another design of the RWT contains the vertical-axial rotor, a number of vertical blades and the hub located in the center of rotation, from which power bars closed in aerodynamic fairings radially depart, to which the given blades are attached up and down [8].

More advanced is the design of RWT [1], which increases the power and efficiency factor of the wind turbine, as well as the wind power efficiency in electricity generation. Figure 1 shows the placement of this RWT on the top of the smoke stack – side view. Figure 2 shows the top view of the RWT.

![Figure 1. The placement of the RWT on the top of the smoke stack – side view [1]:](image)

1 – vertical airfoil blade; 2 – horizontal blades of improved aerodynamic efficiency; 3 – rod; 4 – thin aluminum ring; 5 – stack; 6 – upper rotating ring with outer ring gear; 7 – fixed airfoil ring; 8 – bearing balls; 9 – toothed ring; 10 – rotor shaft of PMG; 11 – permanent magnet generators; 12 – hand brake drum-type; 13 – brake drum; 14 – spring; 15 – brake lever; 16 – cable; 17 – securing element of RWT to the pipe; 18 – brake arm; 19 – sector for fixing the brake arm; 20 – PMG bearing support; 21 – bearing support; 22 – brake pad; 23 – aerodynamic brake; 24 – weighted tail unit; 25 – articulated joint; 26 – vertical shaft; 27 – cap; 28 – spring; 29 – stem; 30 – cylindrical joint; 31 – support washer; 32 – horizontal rod; 33 – upper mount; 34 – lower mount; 35 – power element; 36 – support platform; 37 – O-ring; 38 – laby seal.

Located in the upper part of the smoke stack of RWT works as follows: the incoming air flow (wind) simultaneously affects the vertical and horizontal blades, which, rotating together, create a torque relative to the vertical axis, sufficient to rotate the RWT at a wind speed of 3.5 m/s. At the same time, the rotation speed of the PMG rotor increases by 7 or more times, depending on the diameter of the stack, than the rotation speed of the RWT from the active wind. Further, the rotation through the gear ring of the movable ring is transmitted to the gear wheel of the PMG rotor shaft. The horizontal blades create an additional torque relative to the vertical axis of rotation of the RWT, while the resulting lift increases the wind power efficiency, thereby increasing the power of the installation.

The speed of rotation of the RWT is regulated by means of aerodynamic brakes placed inside the body of the horizontal blades. The placement of RWT on the top of the smoke stack provides for manual brakes of drum type, the main purpose of which – the complete stop rotational movement of
RWT to protect the destruction of RWT from wind speeds greater than 40 m/s, and also for the organization of carrying out of preventive works.

![Figure 2. RWT-top view [1] (see the symbols in figure 1).](image)

The method of placement of RWT in the invention [1] allows to use the wind speed at a height of 20 m, where the wind speed is 6–7% higher than surface wind speeds, which increases the production of electricity from PMG by 18–21%; the smoke stack is used as a good bearing; the diameter of the smoke stack requires the receipt of a transmission ratio of 7 times or more, as a function of the output diameter of the smoke stack that provides generation of electricity at wind speed from 3.5 m/s; the presence of two or more PMG, symmetrically located on the smoke stack provides reliable generation of electricity; dimensions of the upper part of the stack allow the use of vertical and horizontal blades of large dimensions, in this case, the power of RWT can range from 5 kW to 50 kW, and on the smoke stack of 50 meters height or more it is possible to install RWT with power up to 100 kW.

3. Proposed wind power design installation

In this paper, the authors propose to use the heat of the outgoing gases of energy facilities by using the phenomenon of free convection. For this purpose, the original design of the wind turbine (WT) is proposed, located in the upper part of the smoke stack, just before the exit of the flue gases, surrounded by light cap made of composite materials. Figure 3 shows the design of the proposed WT at the top of the smoke stack – side view. Figure 4 shows the top view of the WT.

The proposed installation of wind turbine works as follows: the air is heated in the annular region between the hot surface of the smoke stack and the cap. When the air is heated, according to the laws of heat and mass exchange, its density decreases, and it becomes lighter than the atmospheric air surrounding the cap. The natural convection occurs, resulting in lift force. The air rising in the annular region causes the wind turbine (WT) blades to rotate. The removal of the received electric energy in the proposed installation of wind turbine (WT) can be organized in two ways: the first (figure 4) - as in the invention [1]; the second (figure 5) – the location of the stator windings on the outside, in which the rotation of the blades and the associated permanent magnets leads to the induced electromotive force in the windings on the fixed part.

The winding is preferably placed on a fixed part of the structure. In this case, the connection to the external circuit is made using reliable, simple threaded connections (nut-bolt, etc.). If you place the winding on the rotating part of the structure, then you will have to use a sliding electric contact (brushes – contact rings) for connections to the external circuit. This option is less reliable and structurally more complex.
Figure 3. The placement of wind turbine (WT) on the top of the smoke stack – side view: 1 – smoke stack; 2 – top ring of the thrust bearing; 3 – cap of composite materials; 4 – rotor blade of the generator; 5 – rotor of the generator; 6 – bearing ball; 7 – the lower thrust bearing; 8 – thrust shoulder for mounting the bearing unit; 9 – screw hole mounting of the rotor with the top ring bearing; 10 – upper support cap; 11 – permanent magnet of the rotor; 12 – winding of the generator stator; 13 – thrust shoulder for mounting the stator windings; 14 – brake drum; 15 – friction pad of the brake block; 16 – brake block; 17 – return spring of the rotor braking system; 18 – brake drive lever; 19 – brake lever axle; 20 – drive cable of the rotor braking system; 21 – cable guide roller; 22 – lower support of the cap; 23 – sector with holes for fixing of the brake arm; 24 – brake lever; 25 – concrete support of the smoke stack.

Figure 4. Wind turbine (WT) – top views.
Figure 5. The placement of the WT on the top of the smoke stack when the stator windings are located on the outside-side view (positions 1–12 and 14–25 see figure 3): 13 – thrust shoulder for mounting the stator housing; 26 – stator housing.

4. Conclusion
Further work of the authors will be aimed at creating an experimental sample of the proposed WDPP and determining the optimal geometric proportions of the pipe and cap sizes, as well as conducting experimental studies to determine the operational performance and main technical and economic characteristics of the WT.

Thus, the installation of the WT proposed by the authors, placed on the stack, is an additional environmentally friendly renewable energy source for generating electric energy. Such WT will allow you to fully or partially cover own needs of various energy facilities, and in the future, the needs of residential and industrial premises, street lighting and other objects for various purposes.

References
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