Harvesting Wind-Energy on the Ground via Piping for Household Usage

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Abstract: - The present paper investigates the utilization of some more or less conventional rotor installations for the harvesting of wind-energy for household usage. The investigated embodiment enquires the placement of the electrical generating machinery on the ground and the direction of air-flow there via piping. The monitoring of the performance of relevant devices aims at achieving increased efficiency and functional credibility with low maintenance requirements.

Key-Words: - Wind energy, wind turbine, HAWT, VAWT, Invelox, Fuller, PeriFun

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1 Introduction

Wind-energy is practically available at any location of the Earth [1], therefore, the efforts of humanity on harvesting the induced wind-power is millennia old, starting with sailing ships and windmill-type machinery. The first known machine of the latter type is believed to be Heron's wind powered organ (Fig. 1). This organ included a small wind-wheel that powered a piston, forcing air through the organ's pipes [2].

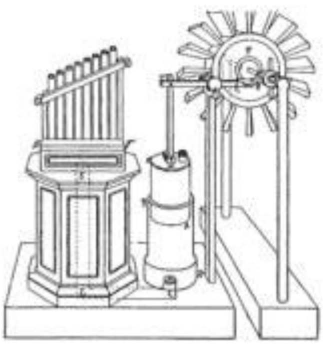

Figure 1. Heron's wind powered organ [2].

Nowadays, wind-energy is one of the lowest-cost renewable energy sources [3]. Wind-energy for the production of electricity is harvested mainly through the usage of wind-turbines, i.e., a device that converts the kinetic energy of wind into electrical energy [4]. Wind-turbines are classified in two major types, the horizontal-axis wind turbines (HAWT) (Fig. 2) and the vertical-axis wind turbines (VAWT) (Fig. 3).

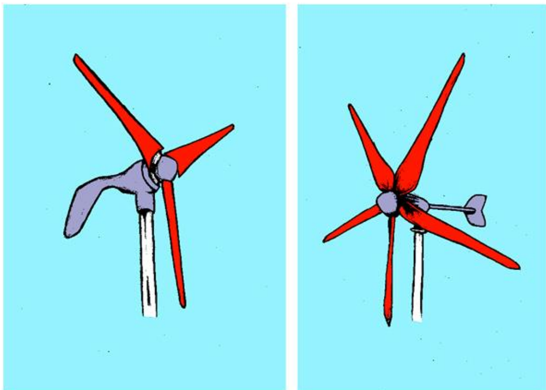

Figure 2. Horizontal-axis wind turbines [5].

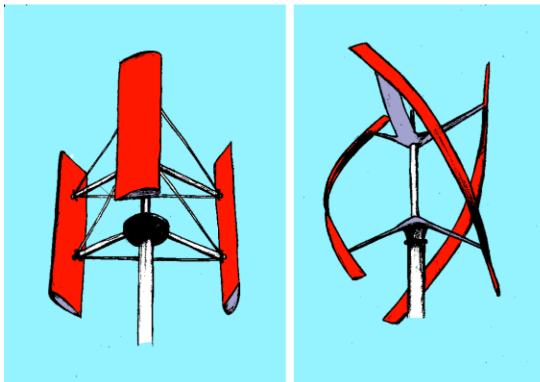

Figure 3. Vertical-axis wind turbines [5].

Both types have advantages and disadvantages that will be presented, along with their main technical/operational features, in the next section (2. Main Features). The aim of the present study was to investigate particular installations that could potentially exhibit the advantages of both types, while minimizing the corresponding disadvantages, for household usage.

2 Main Features

The horizontal-axis wind turbines have their main machinery assembly (i.e., rotor shaft, gearbox, brake and their electrical generator) at the top of a supporting tower/pillar and, mostly, their blades face the incoming wind. This type of wind turbine produces the overwhelming majority of wind power in the world today [6]. Their advantage is a relatively high efficiency, ideally reaching the level of 30-40%, in small wind applications (i.e., of smaller wind/air velocity < 7 m/s). Briefly, their main disadvantages are:

- Since wind turbines need regular maintenance [7], the difficult and thus expensive maintenance due to the placement of the turbine on top of a tower, which has an average height of 90 meters [8].
- The need for a rotating base on top of the tower, since the blades have to be pointed into the wind [9]; this particular installation requires extra construction (vane) and/or sensors that increase the maintenance requirements of the machinery.
- Being lift-driven, they are endangered at high winds by over-spinning that may lead to the destruction of the rotor due to centrifugal forces; thus, a brake is required to stop the rotor and consequently there is no energy produced at strong winds [5].
- Having smaller torque on rotors, they startup with difficulty at small winds [5].

Vertical-axis wind turbines have their rotor shaft arranged vertically (Fig. 3), while the rest of the machinery assembly (i.e., gearbox and their electrical generator) is placed on or near the ground. Their advantages are the following:

- Having their main machinery assembly placed on or near the ground, the accessibility for maintenance is much easier and thus cheaper.
- The rotor shaft does not have to be pointed into the wind, which makes the turbine effective wherever the wind direction is very variable [10].
- The drag-driven VAWTs (Fig. 4) produce strong aerodynamic forces at extreme wind conditions having no danger of over-spinning and turbine destruction, and being so much safer [5].
- The drag-driven VAWTs (Fig. 4) can startup at smaller winds, with a high torque [5].

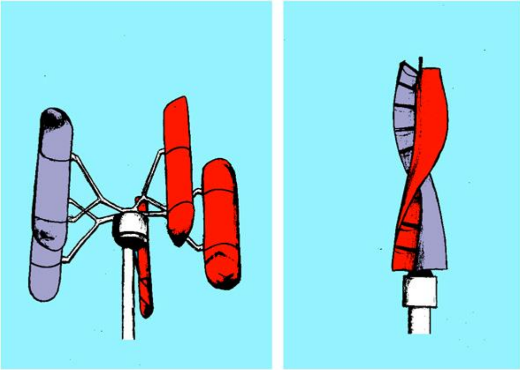

Figure 4. Drag-driven VAWTs [5].

However, the vertical-axis wind turbines have the major disadvantage of producing less energy, because of their much lower efficiency [11].

3 Technical Proposals

In general, small wind turbines generate up to 10 kW of electric power; however, the vast majority of large households that use wind turbines have about 3 kW of installed power [5]. By the end of 2015, almost one million small wind turbines were installed worldwide, mainly for household usage, with more than 945 MW installed. This particular market is increasing by 5% yearly [12].

Considering the above commercial and energy importance of small wind turbines, as well as the previous main features of the two major types of them, the quest for increased efficiency requires relevant designs that ideally combine their advantages, without having their disadvantages. Namely, we are looking for technical proposals for small wind turbines that exhibit the following requirements:

a) Have high efficiency even in small wind velocities (< 7 m/s).
b) Their main machinery assembly is placed on or near the ground, for easier accessibility and thus cheaper maintenance.
c) The rotor shaft should not be pointed into the wind, therefore, being independent of the wind direction.
d) Have no danger of over-spinning and turbine destruction at strong winds.
e) Can startup at smaller winds, with a high torque.

Three such unconventional designs that use wind-piping will be discussed next: Invelox, Fuller turbine, and PeriFun.

3.1 Invelox

This is a system developed by Daryoush Allaei of SheerWind, Inc. [13]. It is composed of a large intake on a tower (Fig. 5) that captures wind and funnels it to a Venturi section. The wind is funneled regardless of its direction (Fig. 6: 1). More than one HAWTs can be placed inside the Venturi section (Fig. 6: 4), where the dynamic pressure or kinetic energy of wind is converted to mechanical rotation.

Figure 5. Invelox demo tower [13].

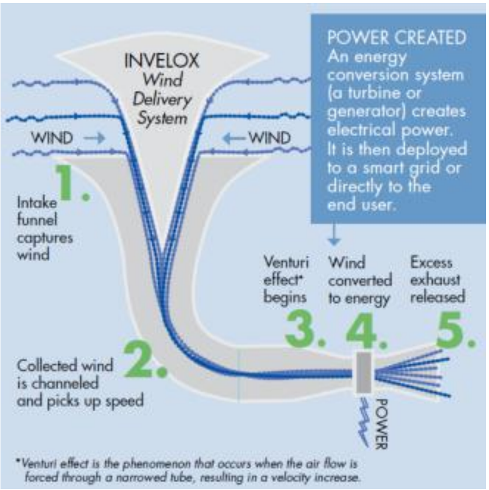

Figure 6. Invelox schematics [13].

Seemingly, this system meets requirements 3.b, 3.c and 3.e. It is not obvious how it can meet requirement 3.d, but presumably this can be achieved as in any HAWT, though brakes. Regarding the requirement of increased efficiency (3.a), the authors in [13] report an average total increase in energy production of 314% over a period of eight days, compared to a free-standing HAWT of the same rotor diameter as the one installed in the Venturi section of the funnel (Fig. 6: 4). Nevertheless, this result has been strongly criticized, because the comparison should have been done to a free-standing HAWT of a rotor diameter same as the swept area of the cross-section of the intake of the tower (Fig. 5, Fig. 6: 1). In that case, the efficiency would have been 28 times less [14]. In addition, no provision is visible for the protection of the rotors from intaking foreign objects (e.g., tree leaves and twigs or rain water inside the funnel).

3.2 Fuller Turbine

Inventor Howard J. Fuller presented a patent of a “Wind Turbine for Generation of Electric Power” in 2010 [15]. His device consists of a Tesla turbine, enclosed in a housing with a wind/air inlet, positioned on top of a pipe (Fig. 7). The air is driven through the inlet (Fig. 7: 25) to the Tesla turbine, while the entire housing (Fig. 7: 11) can rotate to the direction of the wind (Fig. 7: 27), having the inlet facing the wind flow through a vane (Fig. 7: 13).

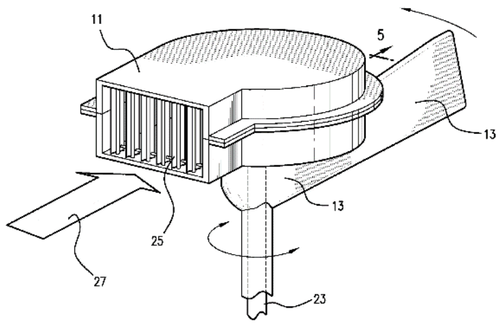

Figure 7. Tesla turbine’s housing [15].

This particular design meet requirements 3.d and 3.e, due to the technical nature of the Tesla turbine, and requirement 3.b, when having the gearbox and the generator on the ground. Again and because of the nature of the Tesla turbine (a series of parallel disks, horizontally arranged), it partially meets requirement 3.c as well, although the housing (Fig. 7: 11) has to rotate. In the patent, there are no specific measurements of efficiency (requirement 3.a). Consequently, any comparison has to be conducted regarding a HAWT of a rotor diameter equivalent to the swept area of the cross-section of the inlet of the housing. The rotor (Tesla turbine) is protected from intaking foreign objects (Fig. 7: 25).

3.3 PeriFun

This particular design has been introduced by E.C. Papakitsos in 2013 [16]. It consists of a perimetrical funnel (Fig. 8), similar to the one of Invelox, capable of intaking wind from any direction (requirement 3.c).

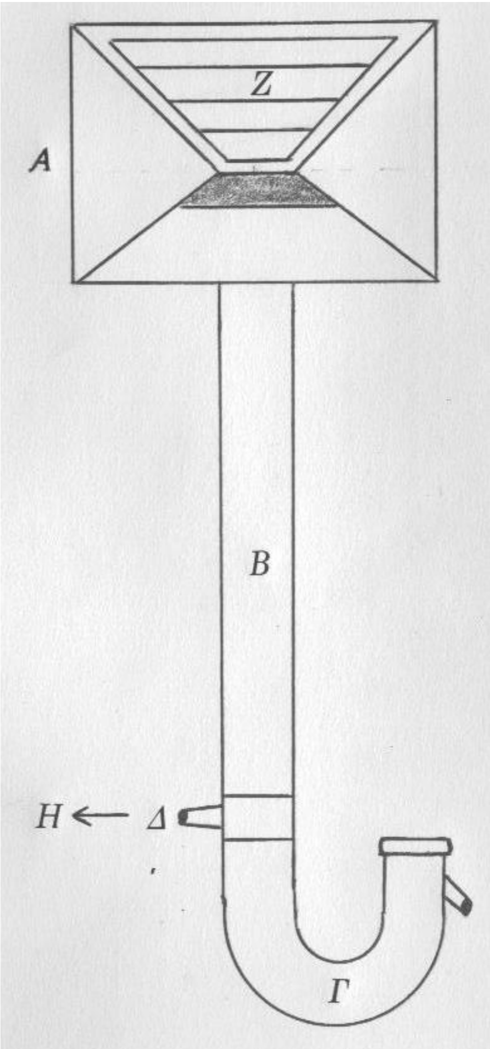

Figure 8. Perimetrical funnel of PeriFun [16].

The inlet (Fig. 8: A) is protected by a metallic net to prevent foreign objects from entering the funnel. The perimetrical inlet has opening grilles on top (Fig. 8: Z), which open to protect the construction from strong winds (requirement 3.d). The funnel has a piping (Fig. 8: B) that leads the incoming air-flow to a nozzle (requirement 3.e), near the ground (Fig. 8: Δ). At the bottom of the piping there is a siphon/trap (Fig. 8: Γ), for collecting the potentially incoming rain water to prevent overflowing. The accelerated air is fed through the nozzle to a Tesla turbine (Fig. 8: H), connected to an electrical generator (requirement 3.b). Once more, there are no specific measurements of efficiency (requirement 3.a). Therefore, any comparison has to be conducted regarding a HAWT of a rotor diameter equivalent to the swept area of the cross-section of the perimetrical funnel.

3.4 Discussion

As presented previously, two of the three technical proposals (Fuller turbine and PeriFun) include a Tesla turbine for the rotor, the overall characteristics of which being summarized in [17]. Even Invelox can be modified to have a Tesla turbine installed, in the Venturi section. Tesla turbine is a bladeless rotor composed of parallel disks, where the inlet nozzle blows the air towards their gaps between, thus producing work based on the boundary layer effect (Fig. 9).

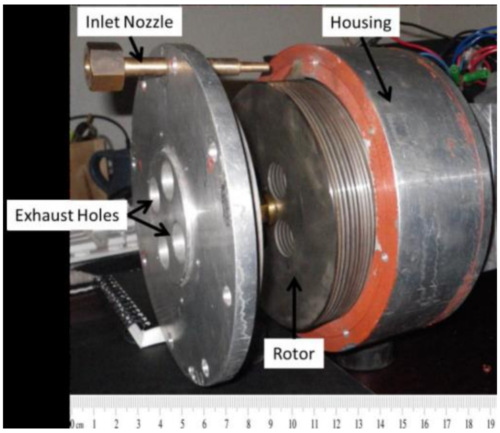

Figure 9. The basic parts of a Tesla turbine [18].

The many advantages of the Tesla turbine include [19]:

- easy and thus low-cost manufacturing,
- low wear and thus better durability and cheaper maintenance,
- low vibration and thus low noise.

Despite the above advantages, Tesla turbine has been criticized for having lower efficiency than conventional turbines with blades that reach a 90% performance [20]. Yet, it has been argued that this turbine is more efficient for power generation at a small scale, compared to conventional small-scale turbines, which have high losses. Working on renewable sources, it may soon act as an alternative to batteries in locations where full charging or replacement is not feasible on slightly larger scales. The Tesla turbine has been mentioned as a way to produce clean renewable energy to supply small settlements with water reserves [17]. The research towards increasing the efficiency of Tesla turbines include:

- efforts on the overall optimization of performance by using computational methods [21],

- the design of more efficient nozzles [22],
- and the installation of multistage machines [23].

The latter approach includes the installation of more turbines in series, where the direction of flow of the air happens from stage to stage, through the discs and the intermediate sections (Fig. 10).

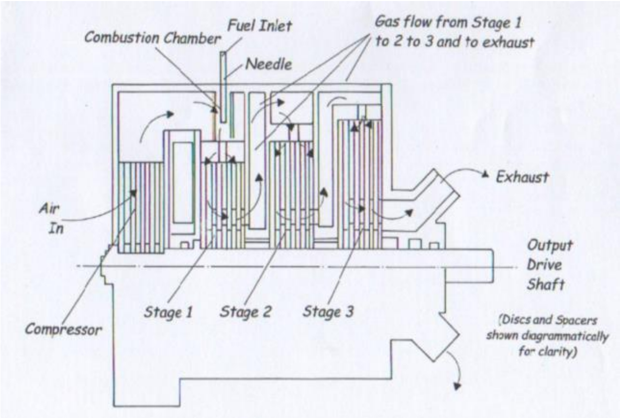

Figure 10. Multistage machines [23].

Other installations after the nozzle are also feasible, with drag-driven devices for the harvesting of wind-energy, like anemometer-type rotors. A relevant three-cup rotor will exhibit increased efficiency, since it will be enclosed in a housing where the air will be directed only to the hollow side of the cup through the nozzle and, therefore, the opposing drag of the spherical side will be negligible. Recent ongoing research at the University of West Attica, Greece, investigates the installation of modified Turgo turbines [24] (and potentially other similar types), for the same purpose above.

4 Conclusion

Primary energy sources are being depleted and energy consumption is increasing rapidly with the development of society. Critical issues such as energy shortage and environmental concerns are coming to the fore. The utilization of wind-energy electrical generators for household usage are gaining wide attention. In this respect, piping for the harvesting of wind-energy on the ground is an interesting solution, worthy of investigation. Accordingly, the installation on the ground of traditional axial or radial flow turbines would not be that suitable for small-scale applications, as the flow loss would be significantly large. Traditional high-speed turbines with low mass flow are not practical. In this case, the Tesla turbine could provide a low-cost and reliable alternative. Researchers are always looking for new and sustainable ways to manage the world's energy demands. This leads to the analysis of new machines that could address new forms of production as well as energy transformations.

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