Main Constructive Solutions for Actual Wind Turbines Used for Green Power Generation

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Abstract: *It can be said that at the present time there is more than ever a need for energy at the global level to support the activities undertaken by the industrial branches as well as by the human communities. The possibilities of obtaining energy are limited and if we refer to the burning of fossil fuels, they have a direct effect on the environment, contributing decisively to the increase in global temperature values. Therefore, special attention must be paid to alternative methods that can be used to obtain energy; here we are talking about the action of the wind, the sun, or the force of sea waves. This paper presents the possibilities of obtaining energy from the wind action, on different models of wind turbines, with specific efficiency values for each of them, the main projects that have been carried out for capture both on land and offshore facilities, some of the most important onshore and offshore wind turbine parks established worldwide and for the Romanian area, but also the main results obtained at the present time in terms of energy amounts of these wind facilities.*

Keywords: *Wind action, turbine, constructive solutions, wind farm, power generation*

1. Introduction

The wind action can be used for power generation at the level of a turbine rotor that is able to convert wind mechanical energy into electric energy by means of an electric generator.
The turbine constructive solution result as an entire assembly that based on the wind force can generate energy in a constant manner.
The wind interaction with the turbine rotor takes place at the blades level, which are specially designed and constructed to be oriented directly towards the wind action direction to achieve a lift displacement and then rotation movement necessary for a continuous operation that coincides with the duration of the wind action.
Hence, the areas differentiation where the wind turbines facilities installation is indicated where the wind velocity values are constant and over a long period of time throughout the year.
The main types of wind turbines used mainly for wind farms with high production capacity (installed power) are three bladed horizontal axes (HAWT), while the vertical axis wind turbines (VAWT) are mainly used for smaller applications and where the wind speed is not very high, as they have the possibility to start and operate at low wind speeds.

2. The atmospheric masses movement and the winds action formation

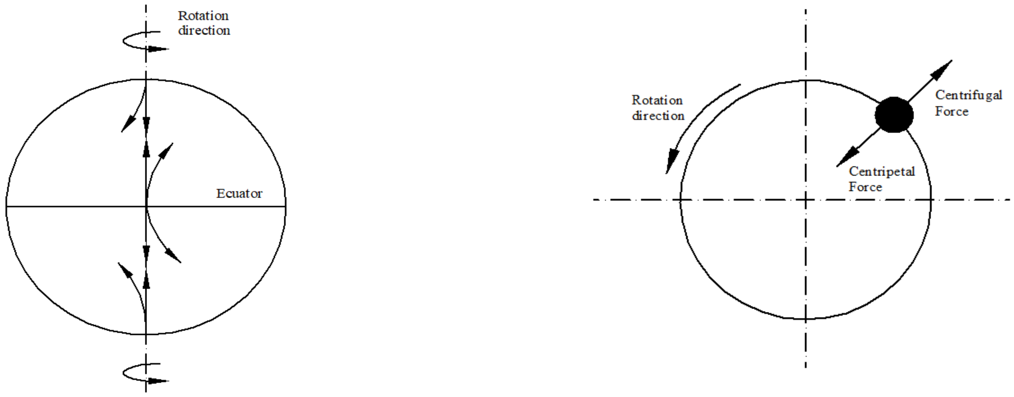
Due to the atmospheric pressure values, in conjunction with the uneven heating of the atmospheric masses and the Earth rotational movement, a continuous movement of the air masses at the planetary level is created.
It should be emphasized that the Earth rotation movement involves concerted actions between the Coriolis forces, the centrifugal force, the frictional force between the air particles that act differently depending on the non-uniform character of the Earth's surface, the pressure gradient, the effects of turbulence, as well as the possibility of atmospheric air masses to transport water vapor (advection).

Table 1: Specific involved efforts in air masses displacement

Current number	Effort type	Specific relation
1.	Coriolis	$F_{Cor} = 2\omega v \sin\phi$
2.	Centrifugal	$F_{Cen} = m\omega^2 r$

3.	Turbulence	$F_D = \frac{1}{2}\rho u^2 c_D A$
4.	Pressure gradient	$F_{PG} = \rho a dAdz$

In figure 1 are presented the Coriolis and centrifugal effects created at Earth level due to continuous rotation that have a direct influence in directing the air masses movement.



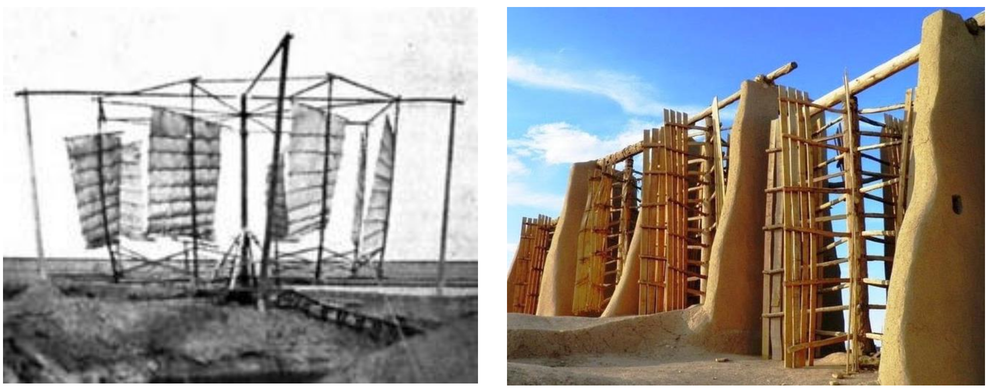
Coriolis effect Centrifugal force effect

Fig. 1. Coriolis and centrifugal Earth effects schematically representation

A continuous exchange in heat and humidity amounts is thus achieved through the transport of water vapor produced by evaporation between different areas, there being a general tendency to balance the values between the different terrestrial areas of the globe.
It is established that atmospheric air particles move along 3 components, horizontal with meridian orientation, vertical and zonal.
The meridian component of the movement of atmospheric masses defines their movement along terrestrial meridians in the direction from the poles to the equator and vice versa, the zonal one is described as the atmospheric exchange that takes place between the different areas, and the vertical component is limited to low values compared to the other two components being represented by raising or lowering to ground level at a certain covered area.

3. Brief history of wind action harvesting solutions

The use of the wind energy resource has been used since ancient times by humans to pump water, irrigate farmland, or for navigation.
In ancient Egypt sail boats were also propelled by wind (5000 IH), also in China and Persia windmills were used to grind grain and pump water (200 IH).



Chinese windmill Persian windmill

Fig. 2. Ancient wind utility applications

It can be observed that for the presented wind application models used in antiquity, the principle of operation with a vertical axis was adopted.
Later in Europe, windmills were developed adopting the rotor horizontal axis principle in operation, which means the transition from drag to lift force at the level of the wind blades.
Such applications using the wind force have been developed in the Netherlands to pump water from dammed plots and taken from the coastal area of the sea. They feature significant wind direction improvements to streamline operation and ensure optimal performance even when the wind changes direction.
Later, in the United States, wind turbines have been used to pump water from the depths and to irrigate agricultural land with a steel multiblade rotor representing a practical solution based on the wind action.

Traditional Dutch wind applications

American multiblade

Fig. 3. Dutch and American Wind turbines

An improved wind turbine was built in 1888 by the American scientist Charles Bush, which featured a large rotor constructive solution, being one of the first applications meant for wind power production (figure 4).

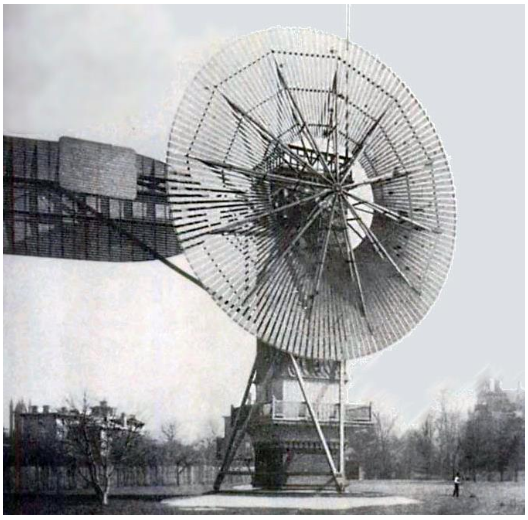


Fig. 4. Wind turbine constructed by Charles Bush in 1888

In the 20th century, while the airplane was invented by the Wright brothers (1903), and the principle was further used to develop a wind turbine that would work for power generation, using the airplane wing model to develop the turbine blades.
For the generation of electricity, there were attempts at the end of the 19th century, and then in the following century, with applications of wind turbines with a horizontal axis (HAWT), and for the variants with a vertical axis (VAWT), the Savonius (1922) and Darrieus (1931) turbines were developed (figure 5).

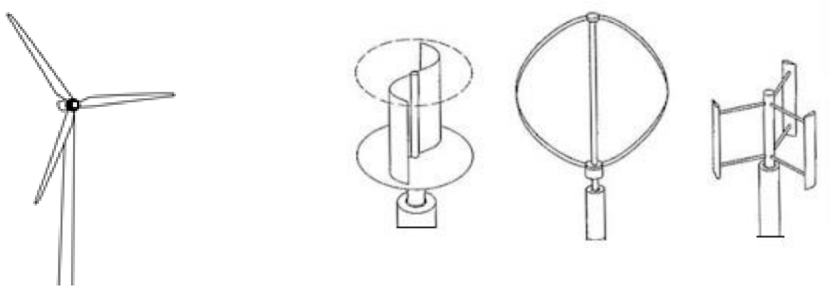
Savonius turbine rotor Darrieus turbine rotor

Fig. 5. Vertical axes wind turbine rotors constructive variants

The current trend of producing and harnessing energy based on wind turbines has existed since the 90s. This trend has continued since then until the present time, during which remarkable results have been achieved in terms of the development of constructive models of wind turbine rotors, an increase regarding the possibility of energy production through the continuous optimization of the turbine rotor designed blades and based on these facts today it is possible to obtain significant amounts of energy per turbine unit.

4. Wind turbine main types and their efficiency criteria

The modern wind turbines currently used to harvest energy from the wind action are based on two main typologies that challenge their operation, namely the positioning of the turbine rotor axis in horizontal and vertical direction.
In principle, horizontal axis turbines (HAWT) benefit from advantages in terms of efficiency obtained in operation that clearly exceeds the energy efficiency values recorded at the level of vertical axis wind turbines (VAWT).
On the other hand, the advantages of using vertical axis turbines are also highlighted in the sense that they can be used for lower values of wind speed, as well as advantages related to the direction of wind action, as they can work independently of the wind action direction and for this reason they can remain in action even when the wind direction changes.



Horizontal axis three bladed wind turbine (HAWV)

Vertical axis wind turbines (VAWV) of SAVONIUS, DARRIEUS and H-rotor types

Fig. 6. Main constructive solutions for wind turbine applications

The main wind turbine constructive types are shown in the figure 6, being emphasized that the operation is based on lift force type for the constructive version with a horizontal axis and of the drag force type for those with a vertical axis.
A graphical situation representing the obtained power values for the main constructive solutions of wind turbines is presented in figure 7, being emphasized the proper values produced by different rotor types.

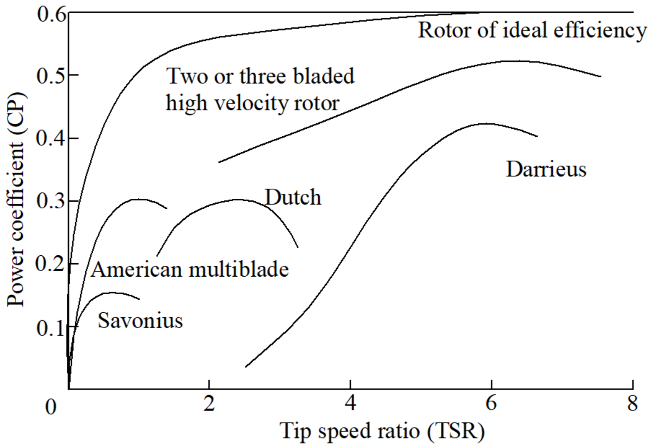
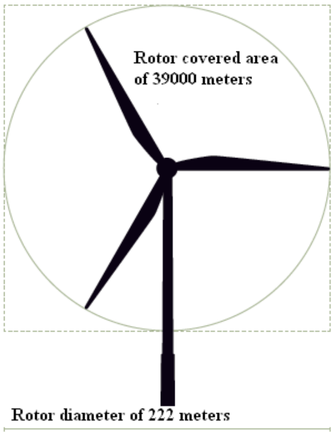


Fig. 7. Specific efficiency values as a function of TSR for the main constructive rotor typologies of wind turbines

5. Prospects for the actual and future efficiency results in the field of wind energy

Constructive solutions for wind turbines are currently being developed and designed so that they can be implemented in the coastal and marine area by continuously increasing the constructive dimensions and the installed power.
Such prototype models are offered by established world manufacturers such as Siemens, Vestas or General Electric which who have developed models that represent the top of the range in terms of wind power generation.



Siemens Gamesa 14-222 DD wind turbine rotor

General Electric Haliade X constructive solution

Vestas V236 prototype for offshore wind applications

Fig. 8. Ultimate constructive models for wind turbine rotors

For the presented models, high values are expected to be obtained in terms of energy produced on a single turbine unit, considering the impressive overall dimensions at which these wind turbines are designed and produced.
Table 2 shows the specific dimensions and energy values for each constructive type presented.

Table 2: Main dimensions and power values of novel wind turbine for on and offshore wind energy applications

New generations of wind turbine rotors						
Current number	Provider/Model	Power in nominal value (MW)	Rotor covered area (m2)	Rotor blade lenght (m)	Diameter of the rotor (m)	Functional options
1.	Siemens Gamesa/14-222 DD	14	39000	108	222	Variable rotational velocity, pitch control
2.	General Electric/Haliade X	12/13/14	38000	107	220	Digital velocity and pitch control
3.	Vestas/V 236	15	43742	155.5	236	Variable velocity, pitch control

Some of the main offshore wind farms currently operating in northern Europe had an installed capacity of around 23.2 GW for 2018, while the total is expected to increase to around 140 GW by 2030.
Table 3 shows some wind farms currently operating offshore in the northern area of Europe.

Table 3: Offshore wind farms in operation in northern Europe (UK)

Current number	Offshore wind farm	Installed power capacity (MW)	Number of turbines	Turbine type	Turbine power (MW)
1.	Walney Extension	659	87	Vestas	7-8
2.	London Array	612.5	175	Siemens Gamesa	3.5
3.	Hornsea 1	1218	174	Siemens Gamesa	7
4.	Gemini Wind	600	150	Siemens Gamesa	4
5.	Beatrice	588	84	Siemens Gamesa	7

Various other offshore wind farms are in progress for the near future, such as the one at Dogger Bank in the north-east of the UK which will have a capacity of 3.6 GW using HALIADE X turbine types from General Electric (GE) of 12 MW power each.
For the onshore area, the Gansu wind farm located in central western China, which has an estimated installed power of 20 GW benefits from a desert area with wind potential. At the end of 2015, this wind farm was operating at less than half of its potential (40%) since there is a low demand for energy in the production area and the transmission and distribution network to the large cities in the east is not being developed.
In addition, for the onshore area, the Mojave wind farm is the largest wind farm in America in terms of installed power capacity, with 1550 MW, with 600 Vestas turbines of 1.55 MW each.
For the near future there it is predicted that over 355 GW of new capacity will be added until 2024, representing over 71 GW for new applications each year until 2024.
At the offshore locations, the predictions are to rise from 6 GW for 2019 to nearly 80 GW for 2024.
For the 2019 compared to the 2018 global development of new wind power installations was achieved a 19% growth exceeding 60 GW, reaching the total installed capacity to 650 GW. In the onshore locations, wind applications raised at 54.2 GW, while also developing the offshore wind farms that were achieved 6 GW installed power.

At the world level, there are the first places for 2019 new installations attributed to China, the US, the UK, India and Spain.
In Romania, there are wind turbine parks in operation located mainly in the Dobrogea area with the largest installed power capacities. Investors' interest in developing these parks is high due to the existing possibilities to take over the produced energy by the national energy system. The total capacity of energy produced and delivered in the national grid of Romania is approximately 1529 MW.

6. Conclusions

There is obvious interest in developing wind power generation capabilities in locations where there is a high wind action potential. In addition, the share of wind energy is increasing, being possible through the continuous modernization of the production units made either through innovative design solutions of the turbine blades, or by increasing the dimensions of the rotor made in the last period, especially for the units that are located on offshore areas. The main turbines typologies that were and are currently used for wind production facilities were presented in the paper, with an emphasis, on horizontal axis turbines that show increased efficiency at certain values of the wind speed. However, the vertical axis variants of turbines can be used to produce energy from the wind action, especially where the wind speed is lower, while also having the possibility to start and operate regardless of the wind direction.
The turbines constructive models from the world's leading manufacturers that offer impressive production capacities per unit are highlighted, which are currently available and are being installed for wind farms, especially in marine areas where there is high wind potential with constant values over time. A review of some of the largest wind farms in terms of installed power that exist or are currently being built worldwide is also carried out.
The example of Romania is also presented, which has the largest wind farm in the Dobrogea area where there is an area suitable for wind energy applications, currently in operation delivering a significant percentage of energy obtained from renewable sources to the national grid.
All these activities undertaken in the past as well as the current ones in terms of setting up wind energy production units represent a good start and a continuous path to follow in the direction of development aiming to achieve the goal of replacing the fossil fuels in energy production and implicitly to avoid releasing gases into the atmosphere and affecting the environment.

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