

Power Generation through the Wind Energy Using Convergent Nozzle

SANDEEP JAIN

MTech Scholar, SIRT Bhopal (M.P.)

ABSTRACT

The title power generation through the wind energy using convergent nozzle, is the new form of wind energy plant. Under this scheme new wind power plant is modified by using convergent nozzle. That nozzle increase the pressure of the wind, and that pressurized winds are sticks on the fan. That is increase the speed of the blade, and power generation ratio of the plants are also increase. There are major role of the nozzle in generation of electricity in large scales. In this plant nozzle is setup in the front way of the wind direction and the single base plant is moved according to the wind direction. That nozzles design is uniformly varying sectional view and concentrates at the wind blades. And remain all the instruments are setups in the single shaft. And plant is setups in the single base movable with base pillar. The pillar is fixed and energy generation plants are movable with the pillar.

Date of Submission: 10 October 2015



Date of Accepted: 16 November 2015

Wind power

Wind power is extracted from air flow using wind turbines or sails to produce mechanical or electrical power. Windmills are used for their mechanical power, wind pumps for water pumping, and sails to propel ships. Wind energy as an alternative to fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation and uses little land. The effects on the environment are generally less problematic than those from other power sources.

Large wind farms consist of thousands of individual wind turbines which are connected to the transmission net work. According to the recent EU analysis for new constructions, onshore wind is an inexpensive source of electricity, competitive with or in many places cheaper than coal, gas or fossil fuel plants. Offshore wind is steadier and stronger than on land, and offshore farms have less visual impact, but construction and maintenance costs are considerably higher. Small onshore wind farms can feed some energy into the grid or provide electricity to isolated off-grid locations.

Wind power is very consistent from year to year but has significant variation over shorter time scales. It is therefore used in conjunction with other sources to give a reliable supply. As the proportion of wind power in a region increases, a need to upgrade the grid and a lowered ability to supplant conventional production can occur. Power management techniques such as having excess capacity storage, geographically distributed turbines, dispatch able backing sources, storage such as pumped, exporting and importing power to neighboring areas or reducing demand when wind production is low, can greatly mitigate these problems. In addition, weather forecasting permits the electricity network to be readied for the predictable variations in production that occur.

Definition

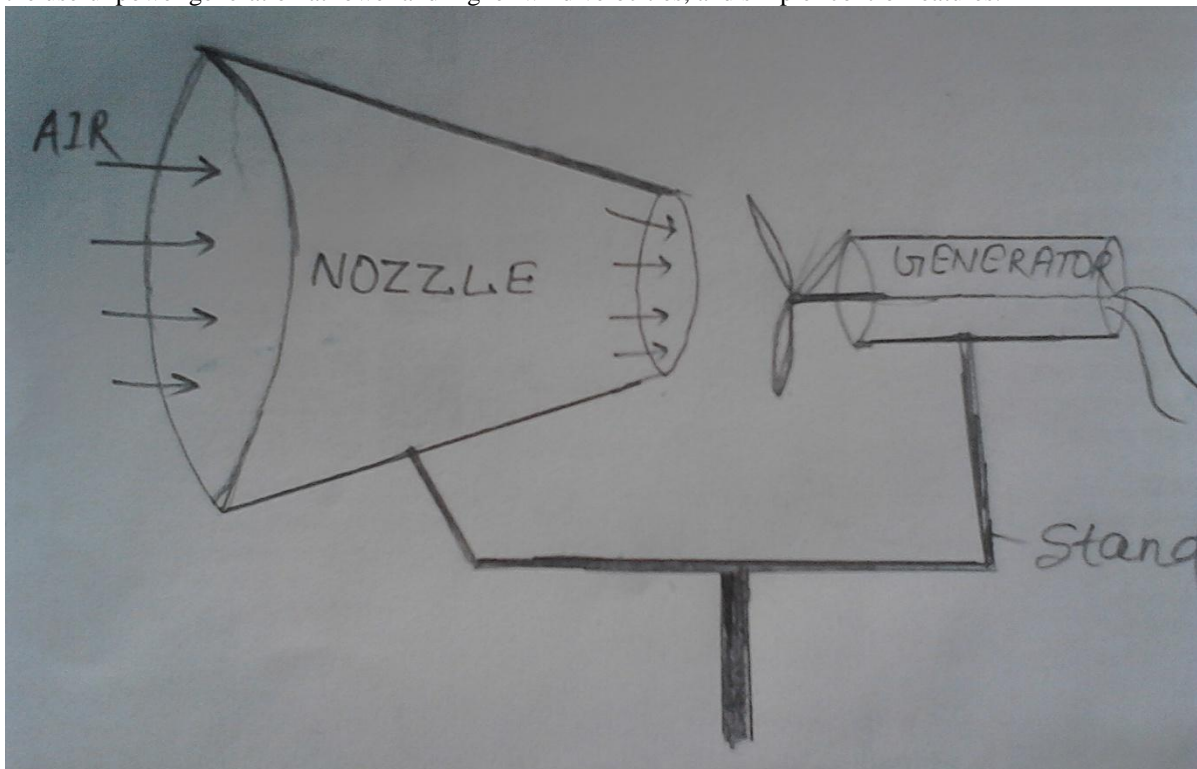
Power generation through the wind energy using convergent nozzle is the process of generation of electricity through the wind energy power generation plant by using convergent nozzle at the entrance of air at the blade of the wind energy plant.

Wind Nozzle Design

Our proposed method of improving turbine efficiency is to put a duct around the turbine, often termed as Nozzle Augmented Wind Turbine (NAWT), an improvement to the conventional open rotor Horizontal Axis Wind Turbine (HAWT). NAWTs employ a duct around the HAWT that decreases in the area as it extends after. The purpose is to increase the mass flow through the blades and hence increase the power extracted for a given rotor size. The Wind Nozzle concept is a ducted rotor design. In contrast to an open rotor, such as the Bergey Turbine the rotor is enclosed in a duct. The Wind Nozzle also utilizes an increased blade number and does not need an additional tail to keep it aligned into the wind. The current configuration utilizes a nozzle to increase the

power produced by an open rotor turbine. This concept combines several concepts into a functionally attractive design to eliminate the need for higher wind velocity and larger height. This design improves efficiency by accelerating the wind through turbine blades and carries more dynamic energy. One such method of improving turbine efficiency is a nozzle augmented wind turbine (NAWT) as an improvement to the conventional horizontal axis wind turbine (HAWT). A nozzle augmented wind turbine (NAWT) has a bucket-shaped duct that surrounds the wind turbine blades and this enhances the turbine to run more efficiently than traditional open-bladed systems by extracting more energy from the wind. In nozzle type arrangement the inlet diameter is larger than the outlet diameter; due to this the air velocity at the inlet is low. When it comes to the outlet, the velocity gets increased due to a reduction of area, at the same time air starts to flow in all directions. In order to bring the air in the horizontal direction cylinder is connected at the outlet side of the nozzle. So the air is concentrated to the narrow path of the cylinder with increased velocity.

In nozzle type wind turbines this principle is used to increase the wind velocity. From Figure the velocity of air at the inlet is V_1 . This wind is concentrated to the cylinder with a velocity of V_2 . Due to the Bernoulli's principle velocity of air at the cylinder is greater than the inlet velocity (V_1) by using nozzle type wind turbines. The diameter of the nozzle of its inlet is D_1 ; Diameter of the cylinder at its outlet is D_2 . Tapering angle is denoted as θ . Length of the nozzle and the cylinder is L_N and L_C . In case of conventional wind mills, blades are directly driven by wind. When wind velocity decreases the blade speed also decreases. This decrease in the blade speed is insufficient to produce power but in nozzle type wind mills the velocity of the air is increased by the nozzle and it operates at low wind velocity also. So we can generate power even at low wind speed. This nozzle utilizes a decreased number of blades and does not need any tail to keep it aligned into the wind. Studies on NAWT show that a sucking effect can be produced according to the Bernoulli's principle and this significantly increases the wind speed inside the duct and substantially enhances the efficiency of the wind turbine. NAWT equipped with an aerodynamically designed nozzle demonstrated power augmentation for a given turbine diameter and wind speed by a factor of about 5–6 is compared to standard micro wind turbine. Our NAWT design is also safer due to the shroud with no lunar or solar flicker, blade/ice throw and is avoidable to birds and bats. Even more attractive is the potential for operational flexibility afforded by the nozzle, enabling the useful power generation at lower and higher wind velocities, and simpler control features.



Analysis of nozzle velocity

The relation between velocity and radius in free vortex is obtained by putting the value of external torque equal to zero or the time rate of change of angular momentum is moment of momentum must be zero. Consider air particle of mass 'm' at radial distance r from the axis of rotation having a tangential velocity V . Then,

Time rate of change of angular momentum = $t(mVr) / \partial t$

Integrating we get

$$mVr = \text{constant or } Vr = \text{constant} / m = \text{constant} \dots (1)$$

Equation of motion for vortex flow

Consider a wind element ABCD shown in Figure 2 (shaded), rotating at a uniform velocity in a horizontal plane about an axis perpendicular to the plane of paper and passing through O

. Let r = Radius of the element from O

$\Delta\theta$ = Angle subtended by the element at O

Δr = Radial thickness of the element.

ΔA = Area of cross section of element

The forces acting on the element are

(a) Pressure force, $p\Delta A$, on the face AB.

(b) Pressure force, $(p + r \frac{p}{\partial r}) \Delta r \Delta A$ on the face CD.

(c) Centrifugal force, mV^2/r acting in the direction away from the centre O.

Now, the mass of element = mass density \times volume

$$= \rho \times \Delta A \times \Delta r$$

$$\text{Centrifugal force} = \rho \Delta A \Delta r V^2 / r$$

Equating the forces in the radial direction, we get

$$(p + r \frac{p}{\partial r}) \Delta r \Delta A - p\Delta A = \rho \Delta A \Delta r V^2 / r$$

Cancelling $\Delta r \times \Delta A$ from both sides, we get

$$r \frac{\partial p}{\partial r} = \rho (V^2 / r) \dots (2)$$

Equating (1) gives the pressure variation along the radial direction for a forced or free vortex flow in a horizontal plane. The expression $\partial p / \partial r$ is called pressure gradient in the radial direction. As $\partial p / \partial r$ is positive, hence pressure increase with the increase of radius 'r'. The pressure 'p' varies with respect to r. $\partial p = \rho \partial r V^2 / r$... (3)

Consider two points 1 and 2 in the air (wind) having radius r_1 and r_2 from the central axial respectively as shown in Fig.2. Integrating the above equation for the points 1 and 2, we get

$$\int_{r_1}^{r_2} \partial p = \int_{r_1}^{r_2} \rho \frac{V^2}{r} dr$$

$$\frac{p_2}{\rho g} + \frac{v_2^2}{2g} = \frac{p_1}{\rho g} + \frac{v_1^2}{2g} \dots (4)$$

Equation (4) is Bernoulli's equation. Hence in case of free vortex flow Bernoulli's equation is applicable in the nozzle velocity is increase in the pressure decrease.

Design Analysis of Nozzle Using CFD

The tapering angle plays a key role in determining the output wind velocity of nozzle. Hence it is important to choose this angle properly while designing the nozzle aerodynamically. With the help of the well-known CFD software FLUENT (by ANSYS) we analyzed various tapering angle and which has the maximum constant output velocity. The constant wind velocity of 27.309 m/s is obtained by the input wind velocity of 5 m/s when it is applied in the nozzle wind turbine with the taper angle of 38.66 degrees. Here the range of the output velocity is constant, and hence no oscillations are present and it is shown in Figures The diameter of the front end of the cone is 2m. The diameter of the rear end of the hollow cylinder is 0.4m. The length of the hollow cylinder is 0.4m and that of the tapering length of the cone is 1m. The total length of the nozzle wind turbine with tapering angle 38.66 degrees is 1.4 m.

Combined with the wind turbine, the frame structure and the enhanced nozzle shape of the duct design, a model of the ducted wind turbine was designed and manufactured. This turbine consists of a rotating part, and the completed installation is tested for its practical use. The crucial dimensions of the structure decided are as follows: the work consists of two diameters, the outlet small diameter is 0.4 meters and the inlet large diameter is 2 meters and the overall height is 3 meters. The ratio of the inner and outer diameter of the turbine has to be designed in the ratio of 5:1. We adopted turbulent wind powered permanent magnet synchronous motor for the experiment. The nozzle design is thus economically and dimensionally compromised due to machine capabilities and cost considerations. The nozzle shape is illustrated as in Figure it is concluded that any new profile can be derived from scaling known optimal results. Despite the trivial difference between the experimental and typical designs.

The stationary part consists of the turbine, the nozzle and their supporting structure, while the rotary part includes a nozzle with a window and a set of rollers providing the rotating abilities for the nozzle to orientate its inlet toward the wind. All the features mentioned above tie as the final design of the nozzle wind turbine, a corresponding CFD model in FLUENT was established to verify the final design. Due to the manufacturing limitations, the wind speed is increased by a factor of 0.95 rather than 1.6 of the optimal nozzle

in Figure. The vibrant energy of the passing airflow is raised by 5 times with respect to input velocity and it should also be noticed that the outer halves of the blades divert most of the dynamic energy.

Since the final design of the nozzle duct is verified, the detailed mechanisms are designed and assembled in the CFD Fluent software and the whole installation is realistically set up as shown in Figure.

Testing of Nozzle Augmented Windmill The nozzle augmented windmill which we designed and implemented is tested for the analysis of the speed (rpm) versus wind velocity (m/s) in our laboratory with the help of blower fans. Table 1 shows the characteristics of the nozzle augmented wind turbine, that wind velocity is directly proportional to the speed of the rotor. The change in wind velocity directly affects the speed of the rotor. A set of readings is taken comparing the output wind velocity of the windmill and speed of the rotor. The voltage generated by the nozzle augmented wind turbine for various rotor speeds shown in Table 2. The output wind power obtained from nozzle type wind turbine is compared with the wind power obtained from open type model no: bsl-yz-500W18. The comparison is literally discussed in the figurative illustration is shown in Figure. The illustration clearly explains the efficient, increase in output wind power with the increase in velocity. The comparison shows that there is a 40% increase in output power in nozzle type proportionately when compared to open type.

Conclusion

The Nozzle Augmented system has been reported to have a greater efficiency than the HAWTs based on the structural design. The above illustrated graphs show the performance of the nozzle augmented wind turbine for various wind velocity and its power generation capacity. Thus, it is clear from the results and discussion that the proposed system can generate more power at the lower wind velocity than the conventional horizontal axis wind turbine. In this nozzle augmented system the length of the blades are made shorter and the nozzle is made up of mild steel because of cost considerations. In nozzle augmented system, the output power depends upon the tapering angle of the nozzle and the wind flow at the inlet. Hence, if it is possible to determine more accurate tapering angle and if the nozzle is designed for a larger diameter it is possible to generate more power. The nozzle augmented system works effectively where the wind velocity is even. In future with the help of large nozzle and standard ratings of alternator the nozzle augmented system can be mounted to generate more power than the conventional systems

References

- [1] João V A, Horácio A V & Adriane P P, A review on the performance of Savonius wind turbines, *Renew Sustain Energy Rev*, 16 (2012) 3054–3064.
- [2] Gilbert B L & Foreman K M, Experiments with a diffuseraugmented model wind Turbine, *Trans ASME J Energy ResourTechnol*, 105 (1983) 46–53.
- [3] Ohya Y, Karasudani T, Sakurai A, Abe K & Inoue M, Development of a shrouded wind turbine with a flanged diffuser, *J Wind Engine Indus Aerodynam* 96 (2008) 524–539.
- [4] Ohya Y & Karasudani T, A Shrouded Wind Turbine Generating High Output Power with Wind-lens Technology, *Energies* 3 (2010) 634–649.
- [5] Leonardo P, Chamorro & Porté-Agel F, Turbulent Flow Inside and Above a Wind Farm: A Wind-Tunnel Study, *Energies*, 4 (2011) 1916–1936.
- [6] Kang C, Yang X & Wang Y, Turbulent Flow Characteristics and Dynamics Response of a Vertical-Axis Spiral Rotor, *Energies*, 6 (2013) 2741–2758.
- [7] Lewis R I, Williams J E & Abdelghaffar M A, A Theory and Experimental Investigation of Ducted Wind Turbines, *Wind Engine*, 1(2) (1977) 104 – 125.
- [8] Van Bussel G J W, *Power Augmentation Principles for Wind turbines. The World Directory of Renewable Energy* (1998).
- [9] Igra O, Research and Development for Shrouded Wind Turbines, *Energy ConvMgmt*, 21 (1981) 13–48.
- [10] Chua L P, Yu S C M & Koh P K, An experimental investigation of two stream mixing flow with a single delta tab, *Int J Heat Fluid Flow*, 22 (2001) 62–71.
- [11] Foss J K & Zaman K B M Q, Large- and small scale vortical motions in a shear layer perturbed by tabs, *J Fluid Mech*, 382 (1999) 307–329.
- [12] Ssu-Yuan Hu & Jung-Ho Cheng, Innovatory designs for ducted wind turbines, *Renew Ener* 33 (2008) 1491–1498.
- [13] Matsushima T, Takagi S & Muroyama S, Characteristics of a highly efficient propeller type small wind turbine with a diffuser, *Renew Ener*, xx (2005) 1–12.
- [14] Philips D G, Flay R G J & Nash T A, Aerodynamic analysis and monitoring of the Vortec 7 diffuser-augmented wind turbine, *IPENZ Transact*, 26 (1999) 13-19.
- [15] Lawn CJ, Optimization of the power output from ducted turbines, *J Power Energy*, 217 (2003) 107-117.
- [16] Frankovic B & Vrsalovic I, New High Profitable Wind Turbines, *Renew Ener*, 24 (2001) 491-493.
- [17] Bet F & Grassmann H, Upgrading Conventional Wind Turbines, *Renew Ener*, 28 (2003) 71-78. 18 www.image.made-in-china.com/2f0j00W
- [18] G Balaji*1 and I Gnanambal2 Wind power generator using horizontal axis wind turbine with convergent nozzle