Tikrit Journal of Pure Science Vol. 27 (3) 2022

TJPS

IASJ

المجلات الاكاديمية العراقية

Tikrit Journal of Pure Science

ISSN: 1813 – 1662 (Print) --- E-ISSN: 2415 – 1726 (Online)

Journal Homepage: http://tjps.tu.edu.iq/index.php/j

The design, construction and performance analysis of a portable vertical axis wind turbine (VAWT) generator

Hanaa E. Jasim[1], Ibrahim K. Salman[2], Abeer Ibrahim Ashawi[1]

[1]*Department of Physics, College of Science, Tikrit University, Tikrit, Iraq*

[2] *Department of Physics, College of Education for Pure science, Tikrit University, Tikrit, Iraq*

https://doi.org/10.25130/tjps.v27i3.49

ARTICLE INFO.

Article history:

-Received: 13 / 2 / 2022

-Accepted: 15 / 3 / 2022

-Available online: / / 2022

Keywords: Renewable energy, wind power, wind turbines, Savonius wind turbine, vertical axis wind turbine wind generator .

Corresponding Author:

Name: Hanaa E. Jasim

E-mail:

dr.hanaa.e.jasim@tu.edu.iq

Tel:

ABSTRACT

The increase demand for electric power, high consumption and little power station capacity has caused to reduce supplying hours of electricity in Iraq. Furthermore high bills prices especially in rural areas and cities faraway from electricity-generating power stations. In addition to the increase in pollution due to the use of fossil fuel sources. All those obstacles have led to the search for cheap, clean and renewable energy sources. In this research, wind turbine model operates at a low wind speed and high efficiency was achieved. The model was located and studied in Tikrit city where wind power need to be consumed. Here, the vertical turbine with an area of 0.49 m^2 was designed and then it was placed at least 8 meters above the ground without any disturbances within 100 meters in any direction. The system was observed to start rotating with wind speed of 1.5 m/s. However, the best turbine cycles per minute were 68 was obtained at wind speed of 6.6 m/s and the system torque was 60 N.m. Finally, 75 watts of power was produced from a multipurpose generator that was designed to run a single battery. and was used (Neodymium magnet), and also operated at low speed.

I. Introduction

Wind energy is a renewable and clean energy that does not produce any pollutants and it is constantly renewable. Interest in such kind of energy has recently increased as pollution has increased due to the use of fossil fuels. Many researchers have developed horizontal and vertical wind turbines to be use in electricity generation[1] .Some studies have compared the work of wind turbines with two blades and three blades, as a result of increased efficiency. where the ratio of the turbine width to its length equal one as well as the highest ratio of the blade tip speed equal one [2]. Moreover, the effect of the number of blades on the performance of the Savona's vertical wind turbine was found in the torque relationship and power factor with wind speed. The best ratio of blade tip speed for the turbine with three blades and the best ratio of blade tip speed was (0.55) at wind speed (7 m/s) [3]. Less weight and well-spaced blades vertical wind turbine was designed and manufactured by Niranjana in 2015. Such kinds of turbines were used on highways. The air velocity got from the moving vehicles was sufficient to turn the blades of the turbine that connected by the axle to the generator [4] . Designing of a three-blade with 0.6 m diameter wind turbine, and A direct generator was connected to the turbine where the greatest power factor of 0.26 was obtained at wind speed (10 m/s) and 651 RPM. Such kind of producing power was used for small houses[5].In another design, wind turbine blades were rotated using wind energy. The system consists of blades that connected to the shift. At the end of the shift the flywheel was set. Another shaft was linked at the edge of the flywheel that connected to a pump which is responsible to raise water from wells [6]. In such designs, consideration must be given to the relationship between the height of the rotor to its diameter H/D which is an important factor [7]. Electricity generated by vertical axis wind turbines (VAWT) powered by wind was installed on the fast streets, Electricity from wind power is cheaper than energy produced from conventional fuel, and it is also clear that an electromagnetic generator [8].Savonius wind turbine (VAWT) operates at low speed and produces good torque, enough to turn on a fixed-magnets inductive generator, producing electricity generated by incoherence [9]. Moreover, single Maglev wind turbine considers another concept for vertical axis wind turbine. In such design magnetic levitation was successfully utilized. Comparing to the conventional design for horizontal wind turbine, Maglev design having high capacity provides more power output. Magnets were used to improve the efficiency of the design by increase the rotation to fast speed [10]. Increasing growth in land-based wind turbine blades to enable higher machine capacities and capacity factors is creating challenges in design, manufacturing, logistics, and operation [11]. In this research, wind turbine model operates at a low wind speed and high efficiency was achieved.

II. Theoretical Part

The fundamentals of wind power conversion include:

Kinetic Energy:

Kinetic energy is measured by joule through the following relation, equation (1, 2) [12,13].

$E_{air} = \frac{1}{2} m v^2$ ..... (1)

E_{air} is the energy of air, m is the mass that measured in kg, v is the speed and measured in units (m/s). To create the kinetic energy of wind turbines, the concept of density and volume will be introduced and the equation (1) will be as follows:

$E_{air} = \frac{1}{2} \rho V v^2$ ..... (2)

Here, ρ it is the density of air and it is measured in units of (kg/m^3), the value of the density of air is 1.225 and V volume that measured in units (m^3). Turbine capacity is kinetic energy divided over time and given the following equation(3):

$p = \frac{1}{2} \dot{m} v^2$ .... (3)

From the fluid mechanics, the concept of space as the area is caused by the rotation of turbine blades and given by the equation (4) [12]:

$\dot{m} = \frac{dm}{dt} = \rho A v$.. (4)

$\dot{m}$ is the time rate of mass flow measured in kg/s.

The capacity of the air is given in relation (5), where A is the area of the turbine rotor:

$P = \frac{1}{2} \rho A v^3$ ..... (5)

According to the relation $P = Fv$, where F is the forces of propulsion of the rotor are given the following relation (6,7). [13].

$F = \frac{1}{2} \rho A v^2$ ... (6)

But from the relation (6):

$T = R \times F$ .....(7)

Where T represents the torque of the rotor and is measured (N.m), R is the radius of the rotor, equation(7,8).

$T = \frac{1}{2} \rho A v^2 R$ .... (8)

$A = H.D$ .... (9)

Since , H represents the height of the rotor and D is the rotor diameter of the turbine, the capacity of the vertical turbine Savona's is given in relation(10) to:

$P = \frac{1}{2} \rho H D v^3$ ..... (10)

The Power Coefficient (C_p):

Not all wind energy is converted to electric energy by wind turbines, as there is a consumption of kinetic energy by rotor. From equation (10) the power factor, (CP), which represents the energy transfer efficiency by turbine [12, 13], as follows equation (11):

$C_p = \frac{p_m}{p} = \frac{2 p_m}{\rho A v^3}$ ... (11)

This factor is the efficiency of converting wind energy into turbine energy and then into electric power where p_m is the mechanical capacity on the rotor axle after passing on the turbine equation (12).

$P_m = \frac{1}{2} \rho A V^3 C_P$ ... (12)

Tip Speed Ratio(TSR)

The dimensions of the wind turbine rotor [.13] are defined as follows:

$TSR = \lambda = \frac{V_{tip}}{v} = \frac{\omega R}{v}$ ... (13)

ω represents the angle speed, R is the rotor radius and V_{tip} is the blade end speed without units .

Torque coefficient(Ct)

The ratio of torque in the rotary turbine to theoretical torque that wind, Where, T_W is theoretical torque [13].

$C_t = \frac{T}{T_W}$ ....(14)

III. Experimental part

All parts of the system are designed and fabricated locally; these parts are divided into mechanical and electrical. Here, figure (1) illustrates the structure of the system.

Fig. 1: Shows the wind turbine system

Mechanical parts:

1 - Metallic Structure

The frame was made using metal of iron with a thickness of (5 mm) and a height of (180Cm). It was used to secure all system components such as generator and turbine that provide the system strength to wind challenges. Figure (1) shows the structure of the system.

2- Turbine and blades.

Turbine designed consists of two metal discs with a diameter of (30 cm) that secured from the center by a metal spindle of (180 cm) length. The blades are fixed between the two discs, and the rotating blades are made of carved iron plates with thickness of (3 mm) and dimensions (30 x 70 cm) as illustrated in Figure (2);

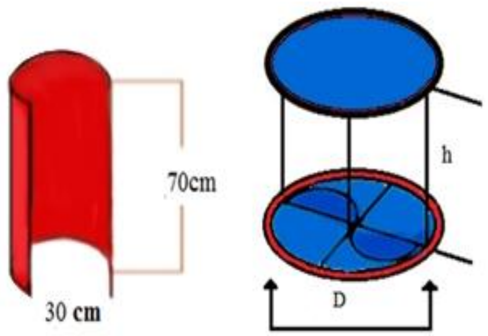

Fig. 2: shows the base of the turbine and blade

Electrical part

1- Generator:

The generator was designed using a permanent magnet generator (axial) that supports small wind turbines for electrical power generation. This type consists of two basic elements:

A- magnets

The magnets' carrying disc consists of two bakelite-discs that are designed for magnet mounting. Multi-hole punch matches the magnet's size, with equal distances and diameter (1.9 cm) to be placed and protected from ingestion during rapid rotation, as shown in figure (3).

Fig. 3: Shows the magnet Inhibition disc and how to install the rotors magnet for the generator.

Bakelite-discs were painted in dyes to protect them from moisture and atmospheric effects, and are well-connected and not reversible during rotation. The neodymium magnets are then placed in its designated location and secured with a gum material. A number of magnets have been used and distributed on the rotor plate in a couple of pairs of magnets with the same polarity and then the second pair is placed with another polarity, i.e. each pair of magnet is one magnet. The magnet distribution for the first rotor is in a form (north-south) and the second rotor is the order of the magnet pairs to reverse the magnet polarity in the first rotor (south-north). The magnetic field line cycle between the plates is completed by the coils, the diameter of the single magnet (1.75 cm) and the thickness (9 mm) which is a suitable size for the turbine generator. Both discs have holes in the center to be placed and the screws are operated by the axle to carry the second rotor, where the first magnetic disk is attached to the axle that transmits movement from the gears and the second disk that holds the magnet is attached to the screws that are mounted on the first dial to control the distance between the two rosters figure (3).

B- Coils:

Copper coils are designed to be approximately as large as the magnet used to fully cover the coil by the variable magnetic fluid and are attached to the static board and arranged so that the coil wires are perpendicular to the direction of the magnetic fluid change. The coils are also arranged in disk format with the size of the spinner and the stator plate is attached to the main board that holds both the spinner and the coil as shown in the figure(4).

Fig. 4: Shows the parts of the electric generating

Gear box

The gears are made of two discs as shown in figure (5), one of which is large with a disk of 164 sprockets and is bolted to the spindle, and the small disc is attached to the generator spindle of the number of sprockets (9). The sprockets are designed to be easy to engage with each other to transfer mechanical energy from rotor to generator to generate electric power and the figure below shows how the gears are designed.

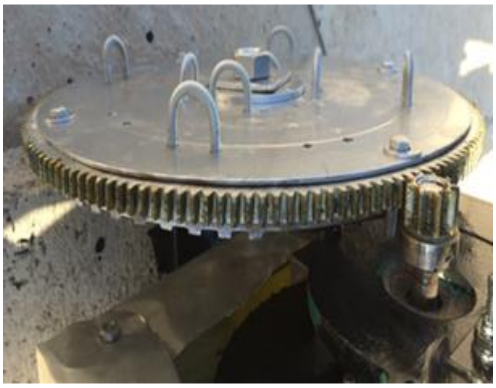

Fig. 5: The gearbox

IV. Result and discussion

The wind speed of the system was measured practically before and after the system. The power for wind and turbine was calculated using the equation (5) also measured the Rpm as demonstrated in figure (6). We notice the difference between the wind power and the turbine power obtained from the variable wind. Also note that turbine capacity increases with wind speed and power increasing at load constant also increasing the Rpm with increasing wind velocity , which is why higher power is obtained this agreement with the [14,15].

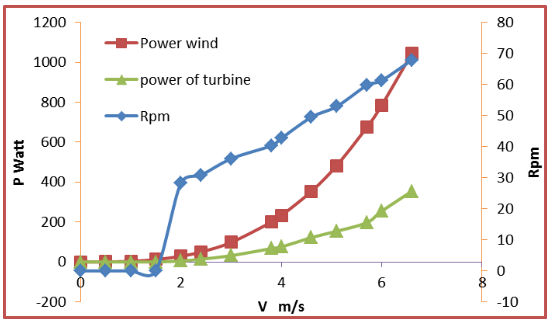

Fig. 6: Relation between wind speed and power and Rpm.

The power coefficient for the wind turbine is calculated from the equation (11). The power factor has been increased by increasing wind speed as illustrated in Figure (7). It then decreases at higher wind speeds although this feature is desirable as it ultimately regulates power output automatically and prevents over-speed [16, 17].

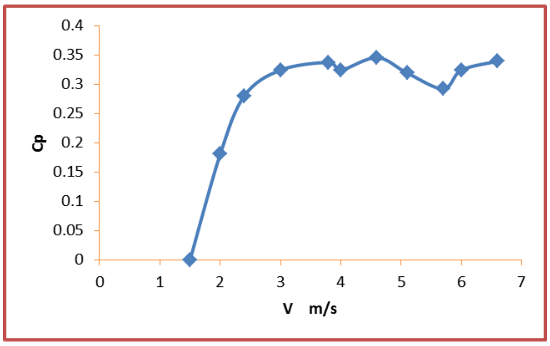

Fig. 7: Shows the relationship between wind speed and power coefficient

The TSR is calculated to show the relationship between the CP and TSR power factor as in figure (8), using the equation (13). The performance of the wind turbines depends on the CP power factor, which states the amount of energy in the wind absorbed by the wind turbines. The theoretical maximum power factor is called the Betz limit (0.59) for wind turbines, The CP appreciation can be explained to some extent by the appropriate design such as improved blade profile and improved angle, plus turbine stiffness and turbine self-starting from low wind speed [18,19].

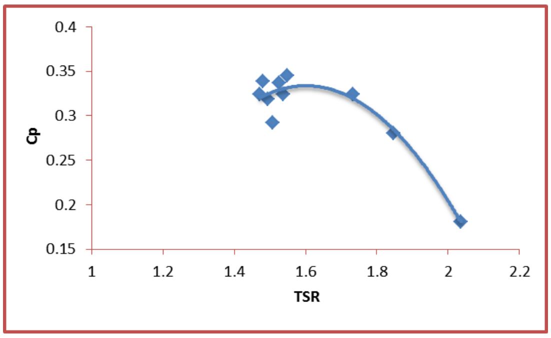

Fig. 8: Shows the relationship between the power factor CP and TSR.

Wind speed, turbine, generator, and torque output due to the addition of a gearbox and slow turbine speed from slow wind speed have been practically found. The gearbox is used to increase generator speed while adding the proper torque to maintain the generator speed sufficient to generate the required electricity. Thus, the electricity produced by the generator has increased. Table (1) indicates values obtained from the practical experiments and is consistent with [20, 21].

Further work is therefore needed to identify principal drivers of main bearing failures, allowing for the development of appropriate design standards and best practice specific to this component, which, in turn, will lead to improvements in reliability [22].

Table 1: The experimental result for system .

Wind speed m/s	RPM of Turbine	RPM of generator	Torque N.m	Power (W) of generator
1.5	0	0	0	0
2	28	516	2.76	3.0
2.4	31	561	6.39	6
3	36	658	11.78	11
3.8	40	734	19.78	19
4	43	778	20.94	24
4.6	50	902	29.81	38
5.1	52	964	33.45	42
5.7	60	1088	37.81	62
6	61	1117	47.12	67
6.6	68	1237	60.069	76

V. Conclusion

Through the design and installation of the vertical wind system, practical experience in this field has been gained. Through the research, the ideal blade curvature was found to be suitable in the process of exploiting wind energy despite the low wind speed. Through the practical results, it was found that the efficiency of the generator despite its small size and suitable torque in converting rotation into electrical energy is good. According to the design, we got suitable tip speed and sufficient rotation speed at low speed due to low noise. The generator was good and gave adequate power compared to others with the same dimensions sufficient to operate a light source. The system was inexpensive, environmentally, friendly to use in remote highway areas. Moreover, such system is suitable for use in agricultural areas.

References

[1] Lee K-Y, Tsao S-H, Tzeng C-W, Lin H-J. Influence of the vertical wind and wind direction on the power output of a small vertical-axis wind turbine installed on the rooftop of a building. *Applied Energy*. 2018;209:383-391. doi:10.1016/j.apenergy.2017.08.185

[2] Experimental Comparison Study for Savories Wind Turbine of Two & Three Blades At Low Wind Speed. *International Journal of Modern Engineering Research*. 013;3(5):2978-2986.

[3] Wenehenubun F, Saputra A, Sutanto H. An Experimental Study on the Performance of Savonius Wind Turbines Related With The Number Of Blades. *Energy Procedia*. 2015;68:297-304. doi:10.1016/ j.egypro.2015.03.259.

[4] Power Generation by Vertical Axis Wind Turbine. *International Journal of Emerging Research in Management &Technology*. 2015;4(7):1-7.

[5] Otieno SC. Design and Fabrication and Testing of a Low Speed Wind Turbine Generator Using Tapered Type Rotor Blade Made from Fibre Reinforced Plastic. *International Journal of Renewable and Sustainable Energy*. 2014;3(1):20. doi:10.11648/j.ijrse.20140301.14.

[6] P.Chinnamani S, S.M.Hariprakas B, . Design and fabrication of windmill reciprocating water pumping system. *International Journal of Advance Research and Innovative Ideas in Education IJARIIE*. 2016;2(3):312-317.

[7] Rabei , Guțu M. Analysis of the influence of the aspect ratio on the vertical axis wind rotor performance. *IOP Conference Series: Materials Science and Engineering*. 2019;564:012076. doi:10.1088/1757-899x/564/1/012076.

[8] Gajanan Teli H, Ramchandra Kokare Y, M. T PS. Design of Vertical Axis Wind Turbines for Electricity Generation H. *International Journal for Scientific Research & Development*. 2018;6(9):523-526.

[9] Gaoture A, Deok S, Kokate T, Mahawadiwar A. Design of Savonius Wind Turbine with Magnetic Levitation. *International Research Journal of Engineering and Technology (IRJET)*. 2017;4(3):376-380.

[10] Ernesto C, Evan A, Josh P, Pietro B, Roland F, and Nick J. Land-based wind turbines with flexible rail-transportable blades – part 2:3Dfinite element desing optimization of the rotor blades. *WIND ENERGY SCIENCE* (eawe)., 7,19-35, 2022.

[11] Manoj L, Nithesh J, Manjunath T, Gowreesh S S .Power Generation using Magnetic Levitation Vertical Axis Wind Turbine. *International Journal of Engineering and Advanced Technology*. 2019;9(2):365-369. doi:10.35940/ijeat.b3153.129219

[12] Aissaoui AG, Tahour A. *Wind Turbines*. BoD – Books on Demand; 2016.

[13] Shen WZ. *Wind Turbine Aerodynamics*. MDPI; 2019.

[14] Wu B, Song M, Chen K, He Z, Zhang X. Wind power prediction system for wind farm based on auto regressive statistical model and physical model. *Journal of Renewable and Sustainable Energy*. 2014;6(1):013101. doi:10.1063/1.4861063.

[15] Han S, Yao D, Wei W. Mechanical Power Calculation of Wind Turbine in Mountainous Wind Farm Model Utilizing Variation Coefficient of Wind Speed. *2019 IEEE Sustainable Power and Energy Conference (iSPEC)*. 2019. doi:10.1109/ ispec48194. 2019.8975019.

[16] Miettinen J, Holttinen H, Hodge B. Simulating wind power forecast error distributions for spatially aggregated wind power plants. *Wind Energy*. 2019;23(1):45-62. doi:10.1002/we.2410.

[17] Fertig E. Simulating subhourly variability of wind power output. *Wind Energy*. 2019;22(10):1275-1287. doi:10.1002/we.2354.

[18] Sagharichi, A., Zamani, M., & Ghasemi, A. (2018). Effect of solidity on the performance of variable-pitch vertical axis wind turbine. *Energy*, *161*, 753-775.

[19] Ansari M, Nobari M, Amani E. Determination of pitch angles and wind speeds ranges to improve wind turbine performance when using blade tip plates. *Renewable Energy*. 2019;140:957-969. doi:10.1016/j. renene. 2019.03.119.

[20] Ajamloo AM, Ghaheri A, Nasiri-Zarandi R. Design and Optimization of a New TFPM Generator with Improved Torque Profile. *2019 International Power System Conference (PSC)*. 2019. doi:10.1109/psc49016.2019.9081559

[21] Ahrori AH, Kabib M, Wibowo R. Perancangan dan simulasi turbin pelton daya output generator 20.000 watt. *jurnal crankshaft*. 2019;2(2). doi:10.24176/crankshaft.v2i2.3834

[22] Guo Y,Bankestrom O, Bergua R, Keller J, and Dunn M. In vestigation of main bearing operating conditions in athree-Point mount wind turbine drivetrain, Forsch. Ingenieurwesen, 85,405-415, 2021.

تحليل التصميم والاداء والبناء لمولد توربينات الرياح ذات المحور الرأسي المحمول (VAWT)

هناء عيسى جاسم [1] ، ابراهيم خلف سلمان [2] ، عبير ابراهيم اعشوي[1]

[1] قسم الفيزياء, كلية العلوم ، جامعة تكريت ، تكريت ، العراق

[2] قسم الفيزياء , كلية التربية للعلوم الصرفة ، جامعة تكريت ، تكريت ، العراق

الملخص

ادى الطلب المتزايد على الطاقة الكهربائية والاستهلاك المرتفع وقلة سعة محطة الطاقة الى تقليل ساعات التزويد بالكهرباء في العراق. علاوة على ارتفاع الفواتير خاصة في المناطق الريفية والمدن البعيدة عن محطات توليد الطاقة الكهربائية. بالإضافة الى زيادة التلوث نتيجة استخدام مصادر الوقود الاحفوري . كل هذه العقبات ادت الى البحث عن مصادر طاقة رخيصة ونظيفة ومتجددة. في هذا البحث , يعمل نموذج توربينات الرياح بسرعة رياح منخفضة وتم تحقيق كفاءة عالية. تم تحديد موقع النموذج ودراسته في مدينة تكريت حيث يجب استهلاك طاقة الرياح. وهنا تم تصميم التوربين الرأسي بمساحة 0,49 م^2 ثم تم وضعه على ارتفاع 8 امتار على الاقل فوق سطح الارض دون حدوث أي اضطرابات في حدود 100 م في أي اتجاه. لوحظ ان النظام يبدأ بالدوران بسرعة رياح تبلغ 1,5 م/ثا. ومع ذلك, تم الحصول على افضل دورات التوربينات في الدقيقة 68 عند سرعة رياح 6.6 م/ثا وكان عزم دوران النظام 60 نيوتن متر . اخيرا , تم انتاج 75 واط من الطاقة من مولد متعدد الاغراض مصمم لتشغيل بطارية واحدة. وكان يستخدم (مغناطيس نيوديميوم), ويعمل ايضا بسرعة منخفضة.