performance of shrouded

by Bayu Rudiyanto

Submission date: 25-Mar-2019 08:23AM (UTC+0700)
Submission ID: 1099012863
File name: Performance_of_shrouded.pdf (1.09M)
Word count: 2511
Character count: 12648

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 158 (2019) 260–265

Energy Procedia

www.elsevier.com/locate/procedia

10th International Conference on Applied Energy (ICAE2018), 22-25 August 2018, Hong Kong, China

The Performance of Shrouded Wind Turbine at Low Wind Speed Condition

Riyanto[a], Nugroho Agung Pambudi[a,*], Rusdi Febriyanto[a], Kukuh Mukti Wibowo[a], Nova Dany Setyawan[a], Nyenyep Sri Wardani[a], Lip Huat Saw[b], Bayu Rudiyanto[c]

[a]*Mechanical Engineering Education Department, Universitas Sebelas Maret, Jl. Ir. Sutami No.36A, Surakarta, Jawa Tengah 57126, Indonesia*
[b]*Lee Kong Chian Faculty of Engineering and Science, UTAR, Selangor, 43000 Malaysia*
[c]*Energy Engineering Laboratory, Departement of Renewable Engineering, Politeknik Negeri Jember, Jl. Mastrip Jember, 68121, Indonesia*

Abstract

This study aims to investigate the performance of using a Diffuser on a horizontal wind turbine. Diffuser variation used has two different geometries : without an Inlet Shroud (L/D = 0.25) and with an Inlet Shroud (L/D = 0.39). The wind turbine's test is performed on a wind tunnel with a low wind speed ranging from 1 m/s to 5 m/s. The results showed that with the addition of a Diffuser, the power produced shows an increased. Variation of the Diffuser without an Inlet Shroud is able to increase power efficiency up to 20.5% while the Diffuser with an Inlet Shroud can increase power efficiency up to 41.1%. This suggests that the use of a Diffuser is capable of improving the performance of the wind turbines by improving produced power efficiency.

Keywords: Wind Turbine; Diffuser; Inlet Shroud; Power Efficiency

1. Introduction

At this time, fossil energy consumption has increased. In 2017, worldwide coal consumption reaches 3731.5 mtoe, nuclear energy reaches 596.4 mtoe, oil consumption reaches 4621.9 mtoe and natural gas comsumption reaches 3156 mtoe [1]. The magnitude of this energy use causes an environmental damage such as global warming. To overcome this problem, the use of renewable energy is considered to be an alternative that can be used. By 2017, the use of wind turbines worldwide had reached 539.123 GW [2]. The magnitude of wind turbines' usage is

* Corresponding author. Tel.: (0271) 718419; fax: (0271) 729928.
E-mail address: agung.pambudi@staff.uns.ac.id

10.1016/j.egypro.2019.01.086

influenced by the potential for high wind speeds in the area and this is a problem in the use of wind turbines especially in areas with low wind speed potential.

Nomenclature

mtoe	million tonnes oil equivalent
GW	Giga Watt
NACA	National Advisory Committee for Aeronautics
RPM	Rotation per minute
TSR	Tip Speed Ratio

At low wind speeds, the wind turbines tend to produce a non-optimal power. A lot of research had been done on the technology that can be used to improve the turbine's performance in this situation by installing a diffuser. In the diffuser, the mass flow rate passes through the rotor, is increased. Therefore, the power generated by the wind turbines also increases [3] – [9].

A research realized by Vaz and David [10] demonstrated that with DAWT (Diffuser-Augmented Wind Turbine) the wind turbine generated power had increased by 35% when compared to a conventional wind turbine. Kosasih and Andrea [11] conducted a research on Straight Diffuser and Nozzle Diffuser. The results show that a Straight Diffuser can improve the performance of a wind turbine by 60%, while a Nozzle Diffuser can improve wind turbine performance by 63% when compared to the conventional wind turbines.

Other research on Diffuser has also been investigated by Ohya and Karasudani [12], Ohya et al. [13]. In the study, they performed Wind Lens Technology testing on wind turbines. Wind Lens Technology is a combination of Inlet Shroud, Diffuser, and Brim. The results show that the wind turbine's power with a Wind Lens Technology is 2-5 times larger when compared to a conventional wind turbine. Some forms of Wind-lens have been studied [6], [7], [14] – [16]. All research results show that the Diffuser can increase the power generated by horizontal wind turbines.

In relation to the research on the use of a diffuser in this wind turbine is the study on the performance of a horizontal wind turbine was realized by using a new diffuser model with a more proportional dimension (compact). With more compact dimensions of a Diffuser, it will be more easily produced and applied to the horizontal wind turbine. A diffuser model used is with an additional Inlet Shroud and without an Inlet Shroud. The study was conducted with a Wind Tunnel on low wind speed variations are 1 m/s, 1.5 m/s, 2 m/s, 2.5 m/s, 3 m/s, 3.5 m/s, 4 m/s, 4.5 m/s, and 5 m/s. Then the results of this research are used to analyze the performance of a horizontal wind turbine in each test variation so as to obtain the wind turbine's design that produces an optimal electric power and can be applied in low wind speed area.

2. Research method

2.1. Experimental set-up

This research was conducted to determine the effect of a Diffuser usage on the performance of a horizontal wind turbine. The wind turbine's blade uses an Untwisted Blade NACA 6412 with a 160 mm blade length. NACA 6412 was chosen because this airfoil has a high lift and drag ratio on a low Reynolds Number [17]. The full specifications of the wind turbine used are shown in Table 1.

Table 1. Wind Turbine's Specification

Specification	Value
Generator	100 Watt
The Ratio of Rotating Rotor with a Generator	1 : 1
Rotor's diameter	1200 mm
Blade's length	600 mm
Total Blades	3
Blades' Material	Mahogany Wood

Diffuser's model used in this research consists of two models those are without an Inlet Shroud and with an Inlet Shroud. The Diffuser without an Inlet Shroud has a L/D ratio = 0.25 while the Diffuser with an Inlet Shroud has a L/D ratio = 0.39.

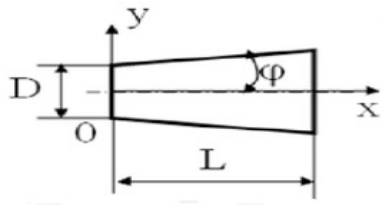

Fig. 1. L/D Ratio

The dimension of the diffuser used is shown in Figure 2. The result of the wind turbine's electric power without a Diffuser, a Diffuser without an Inlet Shroud and a Diffuser with an Inlet Shroud are compared to analyze the performance of the wind turbine.

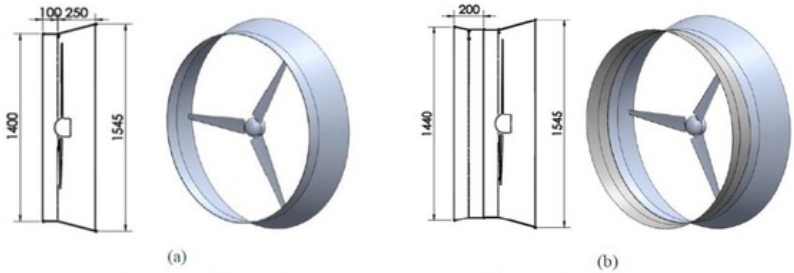

Fig. 2. (a) Diffuser without Inlet Shroud (b) Diffuser with Inlet Shroud

2.2. Experimental design

Research on the wind turbine's performance is realized with a Wind Tunnel with a wind capacity ranging from 1 m/s up to 8 m/s. To minimize the blockage effect, the wind tunnel is designed with an open side on the inlet and outlet (open-type wind tunnel). The wind turbine is placed on a wind tunnel that has a length of 3100 mm, a width of 2100 mm and a height of 2500 mm as shown in Figure 3.

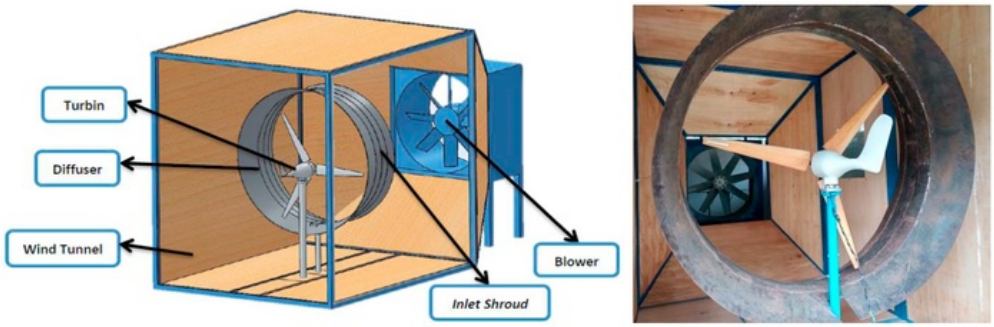

Fig. 3. (a) Wind tunnel design (b) Wind turbine with Diffuser

In this study, the electric power is measured with a digital multimeter in obtaining a test data in the form of the voltage (Volt) and electric current (Amp). Furthermore, a tachometer is used to measure the wind turbine's rotor rotation. The electric power and rotation of the rotor are used to evaluate the power efficiency of a wind turbine. The research scheme shown in Figure 4.

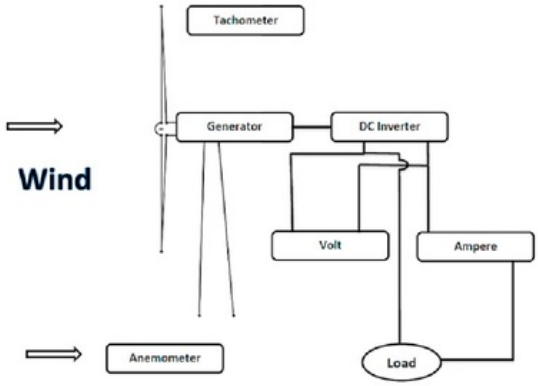

Figure 4. Data Input Scheme

3. Result and discussion

3.1. Effect of diffuser against power and rotor rotation

From the test results, Diffuser without an Inlet Shroud in this research is able to increase wind's speed up to 10% while a diffuser with an Inlet Shroud is able to increase wind's speed up to 13.3%. With the increase in wind speed, the power generated also increases. Wind turbine without the diffuser generates less electric power when compared to the wind turbine with an addition of diffuser. The wind turbine without Diffuser at a wind speed of 5 m/s generates 9.7240 Watt, while the wind turbine with diffuser without an inlet shroud able to produce 11.6742 Watt and the wind turbine with diffuser and inlet shroud able to produce 13.6523 Watt as shown in Fig. 5(a).

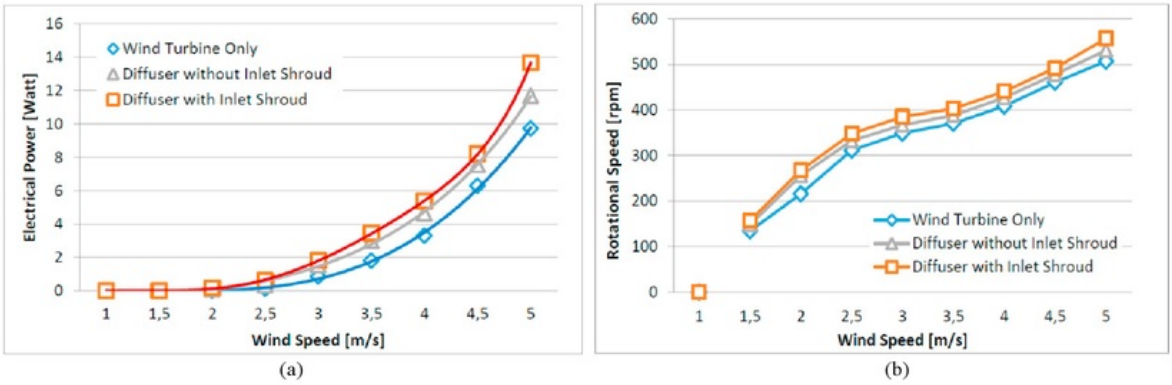

Fig. 5. (a). Comparison of Wind Turbine's Electricity Results (b). Comparison of Wind Turbine's Rotor Rotation Result

Thus, the use of a Diffuser in the wind turbine had increased the power of the wind turbine's rotor. The additional Diffuser also greatly affects the rotation speed of the resulting rotor. The highest rotor rotational speed produced by the wind turbine with an addition of diffuser and inlet shroud as shown in Figure 5(b).

The power and rotation of the resulting rotor increase according to the wind's speed. The use of a Diffuser with an Inlet Shroud on wind turbines shows a significant power increase at each wind's speed. A Diffuser without an Inlet Shroud on average is able to increase the generated power up to 81.7% while a Diffuser with an Inlet Shroud on average is able to increase power yield up to 151.3%.

3.2. NACA 6412 horizontal wind turbine's performance

The power efficiency measured in this study is the total power efficiency of a wind turbine's power after passing the generator and DC inverter. The results showed that the use of a Diffuser was able to increase the power efficiency in the wind turbine as shown in Figure 6.

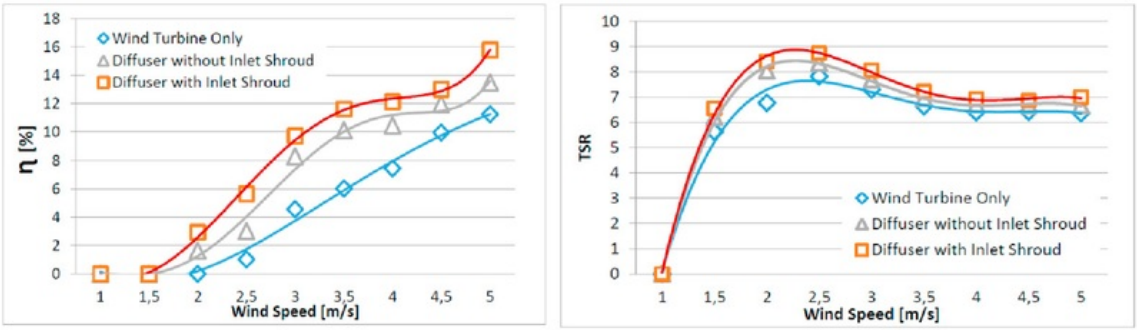

Fig. 6. (a) Wind's Speed Relationship with η (b) Wind's Speed Relationship with TSR

The efficiency of the wind turbine's power continues to increase according to the wind's speed while for TSR (Tip Speed Ratio) at wind's speed ranges from 1 m/s to 2.5 m/s obtains an increase, but at wind's speed ranges from 3 m/s to 5 m/s tend to suffer a decrease as shown in Figure 7. Based on Figure 6, under the initial conditions of power efficiency continues to increase as TSR increases, once it reaches its maximum value, the resulting power efficiency decreases. This efficiency decreases because at high TSR the wind turbine rotates too fast and is like a solid disc so that the wind passing through the rotor is perfectly blocked by the rotation of the rotor. Thus, the tip speed ratio impacts directly on the power generated [14]. Based on Figure 6, the relationship between the power efficiency and Tip Speed Ratio of the wind turbine shown in Fig 7.

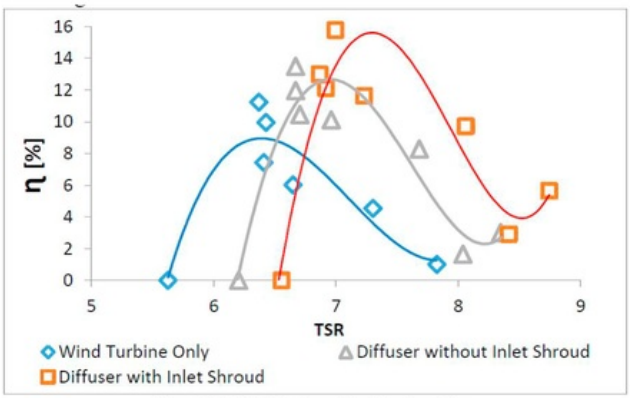

Fig. 7. TSR Relationship Chart with η

As shown in Figure 7, on the variation of the wind turbine without a Diffuser, the highest power efficiency is obtained at 11.2% with an optimal TSR value of 6.37 whereas with the additional Diffuser without an Inlet Shroud, the power efficiency increases to 13.5% with an optimal TSR of 6.67 or an increase power efficiency of 20.5%. On the Diffuser variation with additional Inlet Shroud, the power efficiency generated increased to 15.8% with an optimum TSR value of 6.99 or an increase in power efficiency of 41.1%.

4. Conclusion

In this research, the use of a Diffuser in wind turbines can increase the power and rotation of the rotor generated by wind turbines. The increased of power generated is due to an increase in wind's speed. A Variation Diffuser Without an Inlet Shroud with L/D = 0.25 can increase wind's speed up to 10% while a Diffuser with an Inlet Shroud with L/D = 0.39 can increase wind's speed up to 13.3%. This condition directly impacts the efficiency of the wind turbine. In the variation of wind turbines without a Diffuser, the produce of power efficiency 11.2%, with the

additional Diffuser without an Inlet Shroud generated a power efficiency of 13.5% or a power increase of 20.5%. The highest power efficiency of 15.8% is generated on a Diffuser variation with the additional Inlet Shroud, which means that the Diffuser and Inlet Shroud can increased power efficiency by 41.1%.

References

[1] *BP Statistical Review of World Energy 67th Edition*, 2018.

[2] GWEC.*Global Wind Report*, 2018.

[3] Abe, Ken-Ichi dan Yuji Ohya. (2004). *An Investigation of Flow Fields Around Flanged Diffuser Using CFD.* Journal of Wind Engineering and Industrial Aerodynamics 92, 315–330.

[4] Asl, Hamid Ahmadi, Reza Kamali M. and Manouchehr Rad. (2017). *Experimental Investigation Of Blade Number And Design Effect For A Ducted Wind Turbine*. Renewable Energy 105, 334-343.

[5] El-Zahaby, Aly M., A.E. Kabeel et al. (2017). *CFD Analysis of Flow Fields for Shrouded Wind Turbine's Diffuser Model With Different Flange Angles*. Alexandria Engineering Journal 56, 171-179.

[6] Govindharajan, Raju, Dr.K.M. Parammasivam et al. (2013). *Numerical Investigation and Design Optimization of Brimmed Diffuser-Wind Lens Around a Wind Turbine*. APCWE-VII ISBN 978-981-07-8011-1.

[7] Kannan, T. Saravana, Saad A.M., dan Y.H. Kenny Lau. (2013). Design and Flow Velocity *Simulation of Diffuser Augmented Wind Turbine Using CFD*. Journal of Engineering and Science and Technology Vol. 8 No.4 (2013) 372-384.

[8] Kosasih, Buyung dan H.Saleh Hudin, (2016). *Influence Of Inflow Turbulence Intensity On The Performance Of Bare And Diffuser-Augmented Micro Wind Turbine Model*. Renewable Energy 87, 154-167.

[9] Mansour, Kamyar dan Peyman Meskinkhoda. (2014). *Computational Analysis of Flow Fields Around Flanged Diffuser.* J. Wind Eng. Ind. Aerodyn. 124, 109–120.

[10] Vaz, Jerson R.P., dan David H. Wood. (2016). *Aerodynamic Optimization of the Blades of Diffuser–Augmented Wind Turbine.* Energy Conversion and Management 123, 35-45.

[11] Kosasih, Buyung dan Andrea Tondelli. (2012). *Experimental Study of Shrouded Micro-Wind Turbine.* Procedia Engineering 49, 92-98.

[12] Ohya, Yuji dan Takashi Karasudani. (2010). *A Shrouded Wind Turbine Generating High Output Power with Wind-lens Technology.* Energies: ISSN 1996-1073.

[13] Ohya, Yuji, Takashi Karasudani et al. (2008). *Development Of A Shrouded Wind Turbine With A Flanged Diffuser.* Jurnal of Wind Engineering and Industrial Aerodynamics 96, 524-539.

[14] Kishore, Ravi A., Thibaud C., dan Shasank P. (2013). *Small-Scale Wind Energy Portable Turbine (SWEPT)*. J. Wind Eng. Ind. Aerodyn. 116, 21-23.

[15] Pambudi, Nugroho A., Danur Lambang P. et al. (2017). *Experimental Investigation of Wind Turbine Using Nozzle-Lens at Low Wind Speed Condition.* Energy Procedia 105, 1063-1069.

[16] Wang, Wen-Xue, Terutake Matsubara et al. (2015). *Experimental Investigation into The Influence of the Flanged Diffuser on the Dynamics Behavior of CFRP Blade of a Shrouded Wind Turbine.* Renewable Energy 78, 386-397.

[17] Sutikno, Priyono dan Deny Bayu S. (2011). *Design and Blade Optimization of Contra Rotation Double Rotor Wind Turbine.* International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS Vol: 11 No:01.

performance of shrouded

ORIGINALITY REPORT

20%	13%	16%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.mdpi.com Internet Source	2%
2	eprints.soton.ac.uk Internet Source	2%
3	repository.tudelft.nl Internet Source	2%
4	www.vibgyorpublishers.org Internet Source	1%
5	Bayu Rudiyanto, IbnuAtho Illah, Nugroho Agung Pambudi, Chin-Chi Cheng et al. "Preliminary analysis of dry-steam geothermal power plant by employing exergy assessment: Case study in Kamojang geothermal power plant, Indonesia", Case Studies in Thermal Engineering, 2017 Publication	1%
6	M. A. Bramantya, Hermawan, Andre Febrianto, Nur Kholis Majid. "Experimental study of the effect of diffuser length to mechanical power generated by counter rotating wind turbine with variation of	1%

addition of inlet nozzle", AIP Publishing, 2018
Publication

7	Submitted to Higher Education Commission Pakistan Student Paper	1%
8	Min-dan Liu, Shen Luocheng, Zhang hongjun. "Simulation of the characteristic of wind turbine based on DC machine", 2011 International Conference on New Technology of Agricultural, 2011 Publication	1%
9	jestec.taylors.edu.my Internet Source	1%
10	www.evalue-project.eu Internet Source	1%
11	N S Utami, T A Kusmayadi, B Usodo. " Learning Line and Angle at 7 Grade Students ", Journal of Physics: Conference Series, 2017 Publication	1%
12	Wen-Xue Wang, Terutake Matsubara, Junfeng Hu, Satoru Odahara, Tomoyuki Nagai, Takashi Karasutani, Yuji Ohya. "Experimental investigation into the influence of the flanged diffuser on the dynamic behavior of CFRP blade of a shrouded wind turbine", Renewable Energy, 2015 Publication	1%

13	Li Zhiqiang, Wu yunke, Hong Jie, Zhang Zhihong, Chen Wenqi. "The Study on Performance and Aerodynamics of Micro Counter-Rotating HAWT", Energy, 2018 Publication	<1%
14	www.docstoc.com Internet Source	<1%
15	www.ijariit.com Internet Source	<1%
16	hal-mines-paristech.archives-ouvertes.fr Internet Source	<1%
17	Jerson R.P. Vaz, David H. Wood. "Aerodynamic optimization of the blades of diffuser-augmented wind turbines", Energy Conversion and Management, 2016 Publication	<1%
18	Aly M. El-Zahaby, A.E. Kabeel, S.S. Elsayed, M.F. Obiaa. "CFD analysis of flow fields for shrouded wind turbine's diffuser model with different flange angles", Alexandria Engineering Journal, 2017 Publication	<1%
19	Arshad, Azim, Shahrani Anuar, Ahmmad Shukrie, and Rosdi Hussin. "CFD Study of Tidal Current Turbine Shroud for Initial Design Evaluation", Applied Mechanics and Materials, 2014. Publication	<1%

20	Mahmoud Huleihil, Gedalya Mazor. "Chapter 1 Wind Turbine Power: The Betz Limit and Beyond", InTech, 2012 Publication	<1%
21	M.J. Blanch. "Wind Energy Technologies for use in the Built Environment", Wind Engineering, 2016 Publication	<1%
22	Takahashi, Shuhei, Yuya Hata, Yuji Ohya, Takashi Karasudani, and Takanori Uchida. "Behavior of the Blade Tip Vortices of a Wind Turbine Equipped with a Brimmed-Diffuser Shroud", Energies, 2012. Publication	<1%
23	Chang, Su-Huei, Qi-Hong Lim, and Kuo-Hsin Lin. "Design of a Wind Energy Capturing Device for a Vehicle", 2014 5th International Conference on Intelligent Systems Modelling and Simulation, 2014. Publication	<1%
24	Wang, Wen-Xue, Terutake Matsubara, Junfeng Hu, Satoru Odahara, Tomoyuki Nagai, Takashi Karasutani, and Yuji Ohya. "Experimental investigation into the influence of the flanged diffuser on the dynamic behavior of CFRP blade of a shrouded wind turbine", Renewable Energy, 2015. Publication	<1%
25	Buyung Kosasih, Andrea Tondelli.	

	"Experimental Study of Shrouded Micro-Wind Turbine", Procedia Engineering, 2012 Publication	<1%
26	Hasim A. Heikal, Osayed S.M. Abu-Elyazeed, Mohamed A.A. Nawar, Youssef A. Attai, Maged M.S. Mohamed. "On the actual power coefficient by theoretical developing of the diffuser flange of wind-lens turbine", Renewable Energy, 2018 Publication	<1%
27	Ohya, Yuji, and Takashi Karasudani. "A Shrouded Wind Turbine Generating High Output Power with Wind-lens Technology", Energies, 2010. Publication	<1%
28	Mona Abdelwaly, Hesham El-Batsh, Magdy Bassily Hanna. "Numerical study for the flow field and power augmentation in a horizontal axis wind turbine", Sustainable Energy Technologies and Assessments, 2019 Publication	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		