POWER GENERATION USING SHROUDED WIND TURBINE FOR HIGH POWER OUTPUT

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Abstract - *The concentrated power generation of more efficient, low cost and clean power sources focused us in the direction of renewable energy sources which are the best substitute for future power generation. From renewable energy sources a wind energy is freely available for day & night. In general, a horizontal axis windmill is used in all over the world for power generation from wind energy. Normal wind turbines cannot be operated below the optimal wind speed. In this project, a bucket-shape ducted (shrouded) wind turbine is planned and past researches show that a sucking effect can be formed conferring to the Bernoulli's principle, and this significantly increases the wind speed inside the duct and substantially improves the efficiency of the wind turbine. So, we have established a new wind turbine system that consists of a diffuser shroud (nozzle) with a broad-ring brim at the exit boundary and a wind turbine inside it. The shrouded wind turbine with a diffuser has established power generation increased by a factor of about 2 – 3 compared with a bare wind turbine, for a given turbine diameter and wind speed. This technology is very useful to fulfil the quickly increased electricity demand at cheap cost.*

Key Words: **Shroud, Wind Turbine, Power Generation, Wind Energy, Renewable Energy**

1. INTRODUCTION:

Wind power is the use of air flow above wind turbines to mechanical power generators for electric power. Wind power, as a substitute to fiery fossil fuels, is abundant, renewable, widely circulated, clean, produces no greenhouse gas productions during operation, consumes no water, and uses less land. The net effects on the environment are far less difficult than those of non-renewable power sources.

Wind farmhouses contain of many singular wind turbines, which are connected to the electric power transmission system. Aground wind is a low-cost source of electric power, competitive with or in many places inexpensive than coal or gas plants. Offshore wind is balanced and stronger than on land, and offshore farms have less visual influence, but construction and maintenance costs are significantly higher. Trifling aground wind farms can suckle some energy into the grid or provide electric power to isolate off-grid locations.

National renewable power generation is expected to become an important supplier in reducing world's CO_2 emissions. National micro generation not only straight produces the power generation, but also cut down the transmission losses, which can quantity up to 65% of the energy input, in the supply system from the centralized power generation plant. Micro-wind turbines based national power generation is still a fresh technology and has numerous experiments containing high wealth costs and low performance difficulties. The technical challenges are mostly to overcome the high occurrence of changes of wind direction; the irregular and low wind velocity; and the high turbulence flow which are very site explicit. The start of micro-wind turbine built power generation can be motivated if the method can be made to harvest power in the difficult wind situations met in building environment and substitute consumption of the technology can be developed, for example: as the power source of rechargeable device, domestic sensor/automation smart technology, power for low energy consuming device in an urban environment. For the technology to be recognized in the urban environment, it must also be safe and not cause any undue embarrassments to the public. This may be related the safety of the device i.e. any defect or pieces from the turbine will not cause any injury and the effect on wildlife is minimal. The turbine need be quiet e.g. the noise is not significantly above the circumstantial level. And the turbines must blend beautifully with the environment.

2. LITERATURE REVIEW:

S. Zaghi et al. [2016][1] investigated the obstacle effect for wind tunnel experiments and simplified boundary conditions to be applied in numerical simulations. It was observed that the use of nozzle increases the velocity of the fluid exit it. And the power generation of wind energy depends mostly on the wind speed. The shape and size of the nozzle play a vital part in correct selection and efficiency of the nozzle. The streamline velocity of the fluid, volume current rate of the fluid and the pressure distribution across the nozzle at various inlet speed will be studied using CFD analysis on ANSYS WORKBENCH 14.5. An improved size and shape of the nozzle will be calculated with required specifications.

Dr. E. S. Prakash et al. [2014] [2] they obviously show that with shroud the velocity of the air increases and in turn increases the force acting on the blade. The power output lacking shroud P=19.5W. The power output with shroud P=58.65W. The shroud rises the power output for small scale wind turbine by nearly 3 times.

Paulo [2013] [3] was developed Enhanced Wind Turbine project has emerged from the work. Main idea of Enhanced WT is enhance the productivity of urban wind turbines. Therefore, enhanced is achieved by encapsulating the wind turbine, accelerating the air flow and thus creating more electric energy. Previous work developed by Ribeiro et al. (2013) describe that Enhanced WT shows a yield 120 % higher than the small wind turbines conventional models. Enhanced WT is composed by a convergent - diffuser and a wind turbine, as can be seen in following Figure 1.

Also, at diffuser exit plane is accommodated a brim/flange, in order to exploit the suction effect. Moreover, in the phase of creation of the encapsulated parts of the structure sustainable materials are used. Materials like cork base products are integrated in the equipment. Due to the potential application in urban environments this equipment have a positive approach to urban space and the user. Moreover, initially enviable locations, low wind speeds or proximity of structures will become a favourable local to its installation.

Associated with the project Enhanced WT some research activities has been developed. The work from Paulo (2013), experimental and numerical studies for development and optimization of a shroud device for acceleration the wind to increase power in a wind turbine were performed. Through numerical simulations, one medium power increase of 71 % was obtained relative to standard wind turbine. Nevertheless, are verified higher values in the case of wind
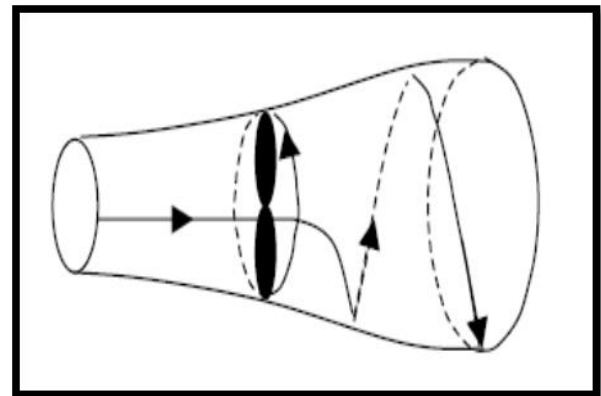

Fig - 2: Wake rotation structure

tunnel measurements. Therefore, the medium power increase of 107 % was obtained.

Jonkman [2003] [4] said that the true fluid flow transient through and around a wind turbine is governed by the main principles of Navier-Stokes equations.

Unfortunately, the equations are so complex that analytical solutions only have been found for simple cases. Although numerical solutions present abilities to solve these equations.

3. DESIGN AND CALCULATION:

3.1 COMPONENTS AND EXPERIMENTAL SETUP:

3.1.1 Shroud:

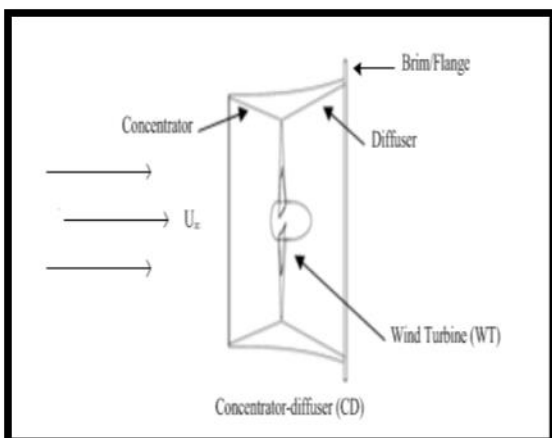Material: - Diffuser shroud is made from powder coated GI Sheet.

Fig - 3: Diffuser Wind Turbine Front view

Fig - 1: Schematic system representation composed by a concentrator-diffuser

Fig - 4: Diffuser Wind Turbine Side View

In this type of Shroud, the back pressure at the shroud exit is made equal to the pressure for the flow fully expand Isentropically, the flow accelerates throughout the diffuser part of the shroud and we get maximum velocity.

3.1.2 Fan:

Material: - Fan is made from Fiber.

A fan is a mechanism used to generate flow within a fluid, naturally a gas such as air. It contain of a revolving arrangement of blades which act on the fluid. The rotating association of blades and hub is known as an impeller, a rotor or a runner. It contains with in some form a hosing or case. This may direct the air flow or increase.

3.1.3 Motor/ Generator:

Motor Capacity: - 12 V

RPM: - 2400 RPM

Motor is an electrical machine that converts electrical energy into mechanical energy.

Fig - 5: 12V DC 6000 RPM Motor

3.1.4 Shaft:

Material: - Shaft is made from Mild Steel.

Fig - 6: Shaft

Fig - 7: Base Structure

Bearing supported rotating shaft has a two end where one end fix with bearing and the other end is free where the thing we can fix.

3.1.5 Cloud:

Material: - Cloud is made from Mild Steel.

Cloud is supporting device where the motor is fitted in its hollow section

3.1.6 Base:

Material: - Base is made Mild Steel Strip and Hollow Pipe.

It is a massive structure which is supporting the whole body of wind turbine.

Fig - 8: Bearing

3.1.7 Bearing:

A bearing is a machine element that constrains the relative motion to desire motion. It reduces friction between moving parts. The design for bearing give free linear moment of moving parts or for free rotation around the constrain axis.

Applying the flanged diffuser model to a small-size wind turbine, we observed the power output rise compared to a standard small wind turbine. Figure shows the new preparation. It needs to be completed into a compact structure to some degree if commercialization is to be understood. We used a short circular diffuser of L/D = 1.25 in this demo experiment. The entrance diameter was D = 49 cm if a wind turbine is not installed inside the diffuser shroud. Though, if a wind turbine is mounted and works on the wind as a form of resistance, it was originate that when a wind turbine is mounted in the diffuser arrival, it plays the role of a resistance body and controls separation of the flow inside the diffuser.
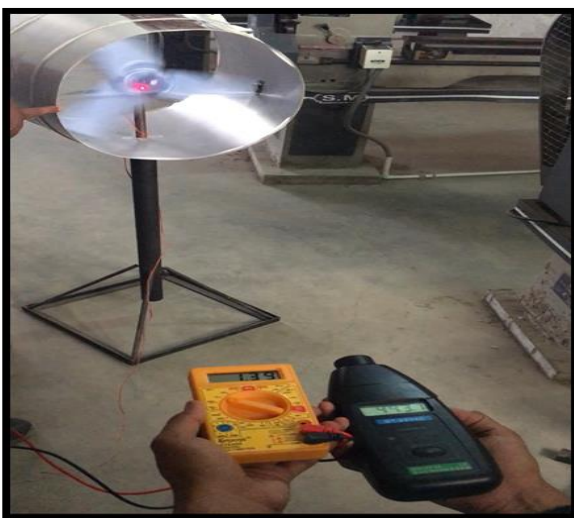

Fig - 9: Experimental Model

3.2 CALCULATIONS: [5]

As per continuity equation

$$A_1V_1 = A_2V_2$$

$$\frac{\pi}{4}D_1^2\,V_1 = \frac{\pi}{4}D_2^2\,V_2$$

$$(38)^2 \times (2.6) = (49)^2 \times (V_2)$$

$$[\because \text{Let Inlet Air Velocity } V_1 = 2.6 \text{ m/s}]$$

$$V_2 = \frac{38^2 * 2.6}{49^2} = 1.56 \text{ m/s}^2$$

As per Bernoulli's equation

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

- There is no heat transfer in nozzle while considering it as insulated. So we take Q=0

- There is no work done so we take W=0

- Height is same, so Z1=Z2

$$\frac{p_1}{\rho} + \frac{v_1^2}{2} = \frac{p_2}{\rho} + \frac{v_2^2}{2}$$

$$\frac{1.01}{1.22} + \frac{(2.6)^2}{2} = \frac{p_2}{1.33} + \frac{(1.56)^2}{2}$$

$$0.8278 + 3.38 = \frac{p_2}{1.33} + 1.21$$

$$\boxed{p_2 = 3.98 \ N/m^2}$$

Therefore,

$$A_2 < A_1, V_2 > V_1$$

$$V_2 > V_1, P_2 < P_1$$

Decrease area α Increase Velocity.
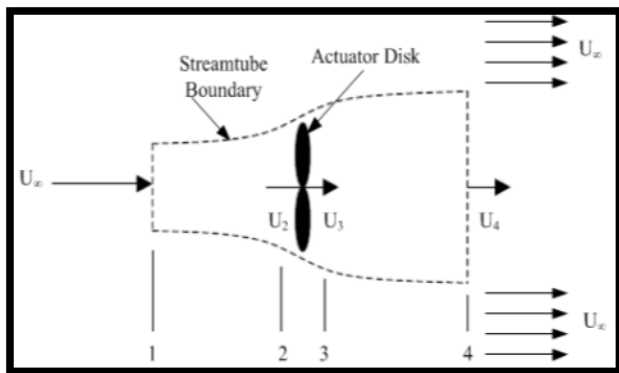
Increasing velocity α Decreasing pressure.

Fig - 10: Schematic of Control Volume

In order to study this control volume, four regions need to be considered as: 1: free-stream region; 2: before rotor; 3: after rotor and 4: far wake region. In free-stream region is assumed that $V\infty = V_1$.

Applying the conservation of linear momentum to the control volume, and considering a steady-state flow, the thrust is equal to

$$T = m^* \times (V_1 - V_4) \tag{1}$$

Where, m^* is the mass flow rate, and is equal to $m^* = (\rho AV)_1$ = $(\rho AV)_4$, representing, ρ, air density, A the cross sectional area and, V, the air velocity.

The thrust is constructive, so the velocity after the rotor, V_4, is lower than the V_1.

Subsequently the flow is frictionless and there is no work or energy transfer is done, Bernoulli equation can be applied on both sides of the rotor.

$$p_1 + \frac{1}{2}\rho V_1^2 = p_2 + \frac{1}{2}\rho V_2^2 \tag{2}$$

$$p_3 + \frac{1}{2}\rho V_3^2 = p_4 + \frac{1}{2}\rho V_4^2 \tag{3}$$

Where it's expected that the extreme upstream and extreme downstream static pressures are equivalent ($p_1 = p_4$) and the velocity across the rotor stays equivalent ($V_2 = V_3$).

The thrust on the rotor disk, T, is also the differential pressure between stations 2 and 3 multiplied by the disc area:

$$T = A_2 (p_2 - p_3) \tag{4}$$

Using Equations 2 and 3 and substitutes that into Equation 4 is obtained:

$$T = \frac{1}{2}\rho A^2 (V_1^2 - V_4^2) \tag{5}$$

Recognizing now that $m^* = A_2 V_2$ and equating the thrust

$$V_2 = \frac{V1 + V4}{2} \tag{6}$$

Thus, the wind velocity at rotor plane, is the average of the upstream and downstream wind speeds an axial induction (or interference) factor, a, measure the influence of the wind being slowed down as a result of power extraction by the rotor. It's defined as the fractional decrease in wind velocity between the free stream and the rotor plane:

$$a = \frac{V1 - V2}{V1} \tag{7}$$

$$V_2 = V_1 (1 - a) \tag{8}$$

$$V_4 = V_1 (1 - 2a) \tag{9}$$

The power extracted from the wind by the rotor, P, is the product of the thrust, T, and the wind velocity at the rotor plane, V_2.

$$P = TV_2 \tag{10}$$

$$P = \frac{1}{2}\rho A_2 V_2 (V_1^2 - V_4^2) = \frac{1}{2}\rho A_2 V_2 (V_1 + V_4)(V_1 - V_4) \tag{11}$$

Substituting for V_2 and V_4 from Equations 6.8 and 6.9 gives:

$$P = \frac{1}{2}\rho A V_2 4a (1 - a)^2 \tag{12}$$

Where the control volume, A_2, is replaced with A, the rotor area, and the free stream velocity V_1 is replaced by V. Wind turbine rotor performance is usually characterized by its power coefficient, C_P, representing the fraction of available power in the wind that is extracted by the turbine, is defined as:

$$C_P = \frac{P}{\frac{1}{2}\rho AV^3} \tag{13}$$

Substituting the extracted power form Equation 12 into Equation 13:

$$C_P = 4a (1 - a)^2 \tag{14}$$

The theoretical maximum power coefficient from an idealized rotor, C_{Pmax}, known as Betz limit, can be found by

setting the following derivative with respect to a equal to zero, and solving for a:

$$\frac{dC_p}{da} = 4\,(1 - 3a^2) = 0$$

Substituting into Equation, yielding:

$$C_{Pmax} = \frac{16}{27} = 0.59259 \qquad (15)$$

For an idealized wind turbine, the maximum efficiency is equal to 59.3 %. In practice, some considerations can be listed for real wind turbines do not present this efficiency: Rotation of the wake caused by the rotor; finite numbers of blades; viscid flow causes nonzero aerodynamics drag.

$$P = \frac{1}{2}\rho\,A\,V_2{}^3\,C_p \qquad (16)$$

So as per above theory

$$V_2 = \frac{V1 + V4}{2} = \frac{5.5 + 3.7}{2} = 4.6 \text{ m/s}$$

$$a = \frac{V1 - V2}{V1} = \frac{5.5 - 4.6}{5.5} = 0.1636$$

Thrust T

$$= \frac{1}{2}\rho A^2\,(V_1{}^2 - V_4{}^2)$$

$$= \frac{1}{2}\,1.33\,\left(\frac{\pi}{4}(0.42)^2\right)^2\{(5.5)^2 - (3.7)^2\}$$

$$= 0.2114 \text{ N}$$

Power Coefficient C_P

$$= 4a\,(1 - a)^2$$

$$= 4 \times 0.1636\,(1 - 0.1636)^2$$

$$= 0.526$$

Power P_{shroud}

$$= \frac{1}{2}\rho\,A\,V_2{}^3\,C_p$$

$$= \frac{1}{2}\,1.33\,\left(\frac{\pi}{4}(0.42)^2\right)(4.6)^3\,0.526$$

$$= 4.72 \text{ W}$$

3.2.1 Power calculation for simple wind turbine:

$$A_{fan} = \frac{\pi}{4}(D^2) = \frac{\pi}{4}(0.39)^2 = 0.1194 \text{ m}^2$$

$$Q_{fan} = A_{fan} \times V_1 = 0.1194 \times 5.5$$

$$= 0.6570 \text{ m}^3/\text{s}$$

$P_{atm} = 1.01 \text{ N/m}^2$

Power = $Q_{fan} \times P_{atm}$ = 0.66 W

3.2.2 Power Increment:

% Power Increases = $\dfrac{Pshroud - P}{Pshroud} \times 100$

$$= \frac{4.72 - 0.66}{4.72} \times 100$$

$$= \boxed{86 \%}$$

3.2.3 Results Outcome:

Shroud Power = **4.72 W**

Simple Wind Turbine Power = **0.66 W**

% Power Increase **= 86 %**

4. RESULT AND ANALYSIS:

4.1 RESULT:

Experimental work has been done without duct and with diffuser at three different inlet air velocity. For this experiments, experimental results as rpm of fan and output voltage has been tabulated in table 1. And comparison has been done between two different conditions as with diffuser and without duct.

Table -1: Result table at free air

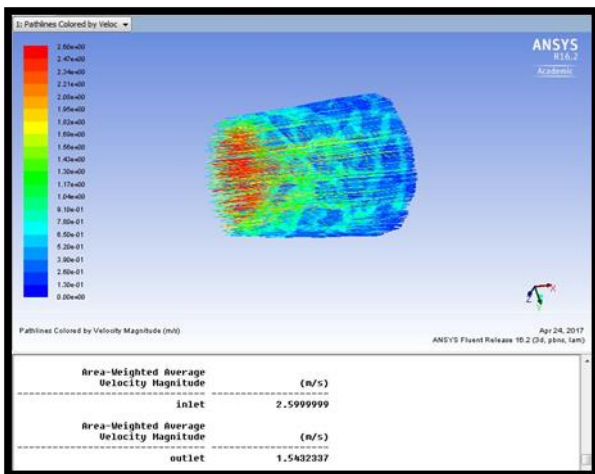| Name of Shroud	Inlet Air (m/s)	RPM	Voltage (Volt)
Diffuser	5.1	471	2.32
	5.3	547	2.59
	5.5	905	2.94
Without Duct	5.1	352	0.92
	5.3	481	1.02
	5.5	583	1.25

Fig - 3: Analysis of Diffuser

4.2 ANALYSIS:

On the basis of practical result inlet and outlet velocity difference is 0.85 m/s in diffuser and 0.6 m/s in concentrator. With the help of analysis in ANSYS Fluent 16.2 inlet velocity is 2.59 m/s and outlet velocity is 1.54 m/s at diffuser. Applying same concept inlet and outlet velocity are respectively 2.59 m/s and 3.81 m/s at concentrator. So, that change in inlet and outlet velocity in diffuser is 1.05 m/s and in concentrator is 3.81.

Finally the change in velocity difference between practical and analysis result is 0.20 m/s in diffuser and 0.62 m/s in concentrator.

From the Comparison graph, it can be shown that diffuser can give better output at same air flow other than concentrator and windmill without a shroud.
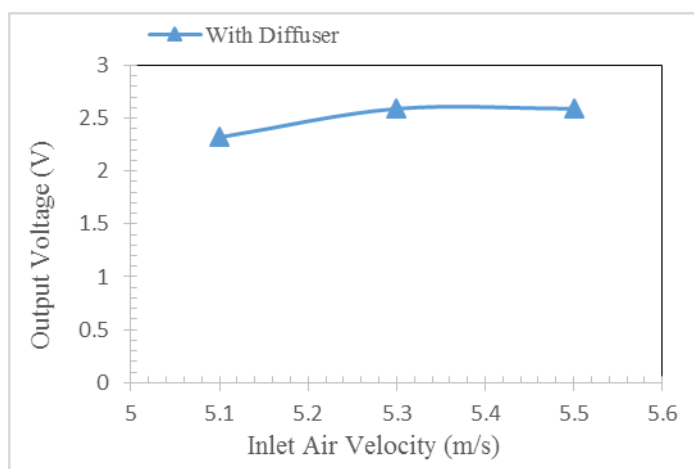

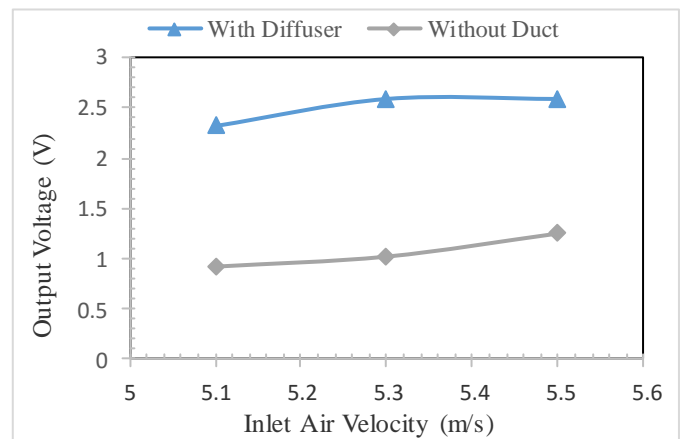**Chart -1**: Graph of Wind mill with Diffuser

Chart -2: Comparison Graph

5. CONCLUSION:

- A bucket-shape ducted (shrouded) wind turbine is projected and historical investigates demonstration that a removing effect can be produced permitting to the Bernoulli's principle, and this significantly increases the wind speed inside the duct and significantly improves the efficiency of the wind turbine.

- The shroud is constructed to increase the wind power distributed to the rotatable blades of the wind turbine by producing an effective pressure.

- It is used to produce electric power as of wind energy using a shroud shaped to constructively modify a wind flow to increase a power of the flow within the shroud comparative to an actual turbine generator.

- The shroud is improved to direct and accelerate wind comparative to the turbine. The shroud successfully accelerates the wind and increases the power proportion of the wind at the rotating blades of a related wind turbine using negative pressures developed by the shroud structure and the blades thereby significantly improving efficiency of the related turbine it should be 6.5 to 7 % from the simple wind mill.

- A wind shroud is provided for use with an associated wind power generator including a wind turbine for generating electricity.

6. FUTURE SCOPE

- In future due to wind blowing from anywhere, it can be solved and redesign of shroud or 360 degree rotated shroud after that it will give more electricity.

- It can be used to illuminate a passage light at night to minimize the power bill.

- If the proper machine is available so we can make curvy shape diffuser or concentrator so this design is resulting smooth air flow in diffuser or concentrator.

ACKNOWLEDGEMENT:

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