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Research Paper

MODIFICATIONS IN DOMESTIC WIND TURBINE

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An energy crisis is the major problem in all over world. Most of energy requirement is fulfilled by thermal power plants based on coal and diesel, which leads to environment pollution. To avoid these polluting power sources we have to adopt alternate energy resources like solar power, wind power, etc. But out of all these wind energy is preferred as domestic safe-economical energy resource. Wind turbine can be utilized on underutilized land or on lands currently in commodity crop production and which can be 'harvest' on the surface and 'harvest' above the surface. Then it will primarily be used for electricity generation for immediate end-use or as a 'driver' for hydrogen production. The traditional wind turbines are replaced by adopting the venturimeter shaped ducted turbine we can increase the wind velocity about three times (09-15 m/s) which is suitable for running the generator to its rated speed (200-600 RPM) without using the gear-box, so that the maximum power is generated from low velocity wind without loosing power in transmission system. The radial-flux PM machine with surface mounted magnets seems to be a good choice for the design of a large-scale directly driven wind-turbine generator. Small sized compact units of this kind of turbine may be constructed of throat diameter ranging between 0.5 m-01 m which can produce power from 100 W to 500 W with approximate cost ranging between Rs. 25,000 to Rs. 50,000, Which can be afford by a rural people easily.

Keywords: Wind Turbine Design (WTD), Wind Monitoring Stations (WMS), Mean Annual Wind Speeds (MAWS), Wind Power Density (WPD), Diffuser Assisted Wind Turbines (DAWT), Tip Speed Ratio (TSR)

INTRODUCTION

The development of wind power in India began in the 1990s, and has significantly increased in the last few years. India has the fifth largest installed wind power capacity in the world. As of October 31, 2009 the installed capacity of wind power in India was 10,925 MW, mainly spread across Tamil Nadu (4889.765 MW), Maharashtra (1942.25 MW), Gujarat (1565.61 MW), Karnataka (1340.23 MW), Rajasthan

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(738.5 MW), Madhya Pradesh (212.8 MW), Andhra Pradesh (122.45 MW), Kerala (26.5 MW), Odisha (2MW), West Bengal (1.1 MW) and other states (3.20 MW). It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2012. Wind power accounts for 6% of India's total installed power capacity, and it generates 1.6% of the country's power, it must be improved by adopting domestic wind mills (low power wind turbines) at rural areas.

CONSTRUCTIONAL COMPONENTS AND THEIR WORKING

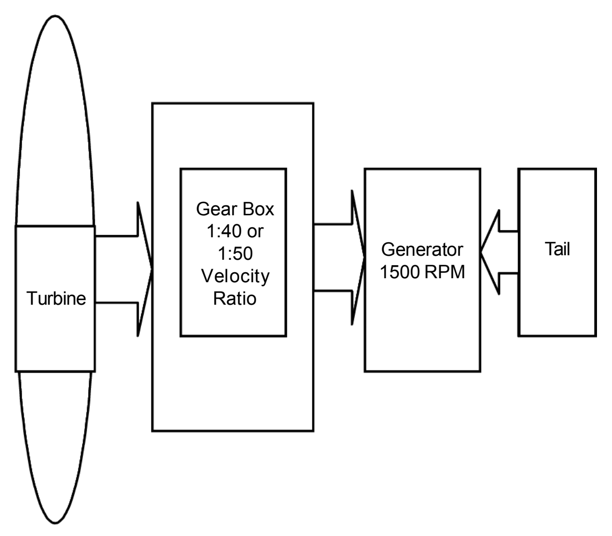
Wind is harnessed and converted into electricity using turbines called wind turbines. The amount of electricity that a turbine produces depends on its size and the speed of the wind. All wind turbines have the same basic parts: blades, a tower, and a gearbox. These parts work together to convert the wind's kinetic energy into mechanical energy that generates electricity.

- The moving air spins the turbine blades.
- The blades are connected to a low-speed shaft. When the blades spin, the shaft turns.
- The low-speed shaft is connected to a gearbox. Inside, a large slow-moving gear turns a small gear quickly.
- The small gear turns another shaft at high speed.
- The high-speed shaft is connected to a generator. As the shaft turns the generator, it produces electricity.
- The electric current is sent through cables down the turbine tower to a transformer that changes the voltage of the current before it is sent out on transmission lines.

Wind turbines are most efficient when they are built where winds blow consistently, at least 13 miles per hour (21 Kmph). Faster winds generate more electricity. High above ground winds are stronger and steadier, so wind turbines should be placed on top of towers that are at least 30 meters (100 feet) tall. Wind turbines available in different sizes, based on the amount of electrical power they can generate. Small turbines may produce only enough electricity to power one home. Large turbines are often called utility-scale because they generate enough power for utilities, or electric companies, to sell. Large turbines are grouped together into wind farms, which provide bulk power to the electrical grid.

The real cost of energy from wind turbines is falling dramatically. Nowadays more than 10,000 MW wind power capacity has been installed world-wide. The installed capacity will be 37 MW including 63 wind turbines in Finland at the end of 1999. The machines now entering the market generate 300-1500 kW per turbine rather than the 100kW average of the late eighties. This up-scaling is foreseen to continue at least one step more to a 4-6 MW offshore turbines. A present day typical and a new directly driven wind power plant are illustrated in Figure 1. The electromechanical system of a wind power plant usually consists of three main parts: turbine, gearbox and generator. The rotor of a typical wind turbine rotates at a speed of 20-200 rpm. In conventional wind power plants, the generator rotational speed is usually 1000 or 1500 rpm. This means that a gear is needed between the turbine and the generator. A standard

Figure 1: Shows the Block Diagram of Wind Turbine



asynchronous generator can be used in conventional wind power plants. The constant speed operation is commonly used in this type of the wind turbine. The generator can be connected directly to the grid, which results in a simple electrical system. However, the gearbox adds to the weight, generates noise, demands regular maintenance and increases losses.

The wind power plant can be simplified by eliminating the gear and by using a low-speed Generator the rotor of which rotates at the same speed as the rotor of the turbine. Many disadvantages can also be avoided in gearless wind turbines. The noise caused mainly by a high rotational speed can be reduced. The advantages are also high overall efficiency and reliability, reduced weight and diminished need for maintenance. However, the diameter of a low-speed generator may be rather large because a great number of poles is needed in a low-speed machine. Due to the multi-pole structure, the total length of the magnetic path is short. The winding overhangs can also be shorter and stator resistive losses lower than those in a long pole pitch machine. The output frequency is usually lower than 50 Hz, and a frequency converter is usually needed in low-speed applications. The converter makes it possible to use the machines in variable speed operation. The speed can be variable over a relatively wide range depending on the wind conditions, and the wind turbines can extract maximum power at different wind speeds. The advantages of the variable speed operation are, for instance, the reduction of the drive train, Mechanical stresses, the improved output power quality and the increased energy capture. In the gearless turbine has variable-speed operation and the geared turbines have constant Speed operation. The annual energy production is higher and the total weight of the rotor and nacelle lower in the gearless turbine than the average values in the geared turbines.

The generator is a four pole induction machine. The gear is a combined planetary and parallel stage design: planetary in the first stage and parallel in the second and third stages. The gear contains the main shaft bearing and the gear ratio is 50.

OVERVIEW OF DIRECTLY DRIVEN WIND GENERATORS

There are different alternatives for the design of a directly driven generator (Lampola, 2000). It can be, for example, an asynchronous machine, a permanent-magnet synchronous machine or a synchronous machine excited by a traditional field winding. Furthermore, the machine can be a radial an axial or a transverse-flux machine. The stator core can be slotted or slot less, and there can, for example, be a toroidal stator winding in an axial-flux machine. Many different generators have been proposed in the literature as directly driven wind-turbine generators.

- Generators with Field Winding.
- Axial-Flux Permanent-Magnet Generators.
- Radial-Flux Permanent-Magnet Generators.
- Special Generators.

Some special directly driven generators have also been proposed, for example, a linear induction machine, transverse-flux machines, reluctance machines and a split-pole machine. Gripnau and Kursten (1991) and Deleroi (1992) have presented a linear induction generator for direct grid connection. This machine is a double-sided axial-flux generator. The two stator sides form a segment of the circumference and the stator is fixed to the turbine tower. The rotor is a disc which is directly coupled in or parallel to the turbine rotor. The construction of the machine is relatively simple and light compared with the conventional design. Due to the fact that the rotor diameter may be large, the air gap in the discrete stator sector will be large. The generator has a great slip, 11 to 15% and the efficiency will not exceed 81-85%. A 150 kW prototype machine has been made and its efficiency is over 64%. The diameter of a 500 kW machine designed is about 9 m. The machine is still in a developing stage.

SUMMARY OF DIRECTLY DRIVEN GENERATORS

Many different generator designs for gearless wind turbines have been presented, i.e., Electrically-excited synchronous machines, surface-magnet and buried-magnet radial-flux PM machines, axial-flux PM machines, transverse-flux PM machines, switched reluctance machines and a linear induction machine. Some directly driven generators are used in low power commercial gearless wind turbines. The first commercial directly driven generator in the power range of some hundreds kilowatts is a synchronous machine excited by a traditional field winding. Many low-speeds experimental machines have been built and tested. The transverse-flux machine is small, efficient and light compared to the other designs, but the mechanical design is very complicated. The electrically-excited synchronous machine is larger, heavier and less efficient than the PM synchronous machine. The radial-flux PM.

Synchronous machine has smaller outer diameter and it is cheaper than the axial-flux machine. Cheap ferrite magnet material can be used in the buried-magnet machine, but the rotor is heavier and the mechanical design more complicated than those in the surface-magnet machine with high energy magnets. The radial-flux PM machine with surface mounted magnets seems to be a good choice for the design of a large-scale directly driven wind-turbine generator.

DESIGN OF DUCTED SECTION OF TURBINE

As the capability of domestic users is limited from 5 feet dia. to 15 feet dia. Because of the restrictions due to space availability and infrastructure availability. So the main aim of the research is to utilize the available low atmospheric wind by increasing it about three times by using the convergent and divergent sections of the venturimeter. The convergent section increase the pressure of the available wind and the divergent section create vacuum at the throat of the venturimeter, which creates the maximum throat velocity. The convergent operates as a funnel to push air through the rotor blades and the divergent serves to create vacuum and pull air through the rotor blades. This push-pull augmentation increases both the pressure differential and the air stream velocity many times that possible with the simple diffuser augmentation associated with older generation Diffuser Assisted Wind Turbines (DAWT). Now the domestic small sized turbine is placed at the throat which generates sufficient power at normal wind velocity. We added an optimized convergent to compress, align and accelerate the wind in the ducted channel, creating a ventury. The push-pull effect created by the convergent and divergent greatly increases the air stream flow velocity through the turbine blades—a critical process parameter. The wind energy then available for conversion is proportional to airstream flow velocity cubed. Triple the wind speed, and the energy produced increases by cube of 3 or 27.

Velocity at entry of the convergent section = 1 m/s

Velocity at throat (around turbine blades) = 3 m/s

Velocity at exit of the divergent section = 0.5 m/s

This result is based on theoretical calculation on actual practical application due to mechanical reasons and compressibility of air the throat velocity can be achieved about 2.8 m/s. now we can use two or three turbines at throat in place of single increase the efficiency of the unit. As discussed in theory the increase in length of divergent may leads the increase in the pull effect caused by divergent, because of the increasing area in the direction of wind flow the minute friction loss may be neglected. So we kept the divergent length 07 meter constant during the test. Then we test the unit by changing the length of convergent section with difference of 01 meter. It has been observed that the throat velocity increases with decrease in convergent length up to 03 meter length. This occurs due to frictional losses by decreased section, because the friction loss is directly depends upon the length of convergent section. But below 03 meter, at 02 meter and 01 meter again downfall in throat velocity observed. The reason behind this is the insufficient pressure rise which pushes poorly the wind threw the throat.

So the optimized length of convergent is kept 03 meter (smallest as possible) and the Length of divergent is kept 07 meter due to costing and space availability reasons.

CALCULATION FOR DESIGN OF THE TURBINE'S DUCT STRUCTURE

The duct is so constructed that the maximum air can enter in the convergent section of area ($4 * 4 = 16\ m^2$) and converges up to throat dia. 3 m (area $7.065\ m^2$) the throat is 2 m long. From the exit of circular throat the divergent part starts and diverges up to the exit section of the divergent part of area ($6 * 4 = 24\ m^2$). As shown in Table 1 convergent section with difference of 01 meter. It has been observed that the throat velocity increases with decrease

Table 1: Shows the Effect of Convergent Length on the Throat Velocity

Length of Convergent (M)	Throat Velocity in m/sec	Divergent Length (M)
07 Meter	5.50 m/sec	07 Meter
06 Meter	5.75 m/sec	07 Meter
05 Meter	6.00 m/sec	07 Meter
04 Meter	6.50 m/sec	07 Meter
03 Meter	6.79 m/sec	07 Meter
02 Meter	6.00 m/sec	07 Meter
01 Meter	5.00 m/sec	07 Meter

in convergent length up to 03 meter length. This occurs due to frictional losses by decreased section, because the friction loss is directly depends upon the length of convergent section. But below 03 meter, at 02 meter and 01 meter again downfall in throat velocity observed. The reason behind this is the insufficient pressure rise which pushes poorly the wind threw the throat. So the optimized length of convergent is kept 03 meter (smallest as possible) and the Length of divergent is kept 07 meter due to costing and space availability reasons.

Component/segment wise dimensions of the duct are given as:

Convergent section length along the X-axis = 3 m

Left end (entry point of air) along Y-axis = 4 m

Left end (entry point of air) along Z-axis = 4 m

Junction point at the end of convergent part at throat entry (dia. 3 m) = 9.42 m (perimeter)

Length of throat along X-axis = 2 m

Junction point at the start of divergent part at throat exit (dia. 3 m) = 9.42 m (perimeter)

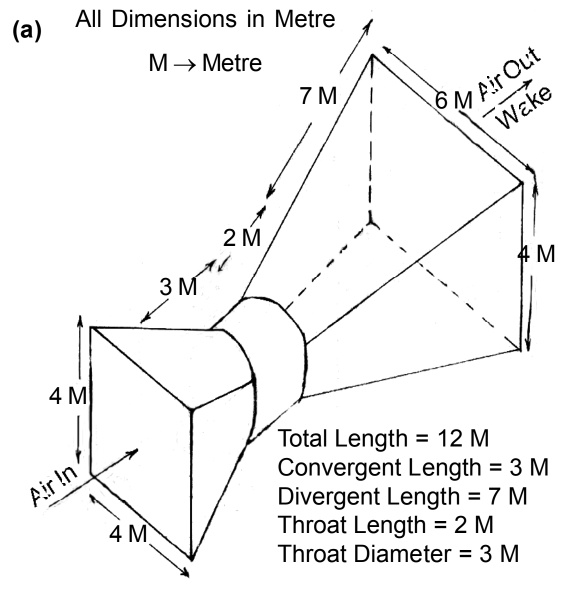
Length of divergent section along X-axis = 7 m

Right end (exit point of air) of divergent along Y-axis = 6 m

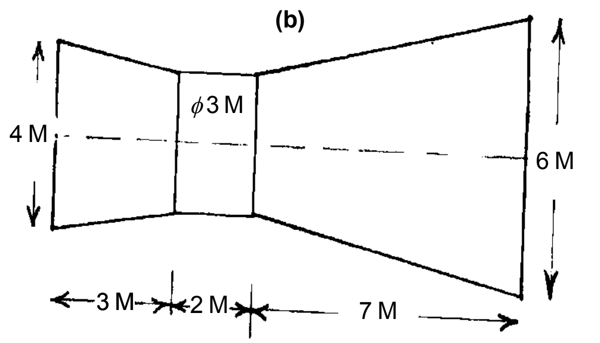
Right end (exit point of air) of divergent along Z-axis = 4 m

The detail drawing of the turbine shown in Figure 2.

Figure 2: Shows the Complete Assembly of the Turbine (Duct)



Isometeric View of Ducted Turbine



Top View

The total cost (Approximately) of the turbine system = 1,00,000 Rs.

RPM AND TIP SPEED RATIO

Tip Speed Ratio (TSR)—The blade tip velocity divided by the wind speed. The tip speed ratio is how much faster, than the wind speed, the blade tips travel. The speed of the tips of the windmill blades should be about 5 times the speed of the wind. For a 10 m/s wind, the tips move at 50 m/s. If the windmill has a large diameter, then 20 RPM is adequate, but if the diameter is small, a high RPM is required. Now according to this criterion at normal available velocity the throat velocity ranges from 07 m/s to 21 m/s and corresponding RPM of the turbine (03 m dia.) may be calculated and given as in tabular form (Table 2). Now the RPM range achieved from the below given table is 200-600. The alternators are available in the range of rated as 500 RPM or 1000 RPM or 1500 RPM. Now either the special gearing arrangement is to be required to match the rated speed or the DC motors (permanent magnet) can be used as generator as discussed earlier in this chapter. There is some ideal size for a windmill such that the windmill RPM and the generator RPM are pretty well matched; unfortunately, that size is in the range of one-meter diameter. That device can produce a little power (400 w). The voltage and current variations may be controlled by using power electronics circuits.

Table 2: Air Velocity of Turbine vs. Turbine's Rotor RPM

Air Velocity (Turbine)	07 m/s	14 m/s	21 m/s
Rotor (RPM)	222	445	668

CONCLUSION

In this research we find that the output power is mainly depends upon the wind speed and the swept area of the turbine blades. The power output increased eight times if the wind speed is doubled. In the area of Haryana and Rajasthan the wind speed is low (three to five meter per second) generally. By adopting the venturimeter shaped ducted turbine we can increase the wind velocity about three times (09-15 m/s) which is suitable for running the generator to its rated speed (500-1500 RPM) by using the gear train of suitable velocity ratio. As discussed the relation with size of the blade should have to give an appropriate speed of rotation versus wind speed (called TSR, the tip-to-speed ratio). As a rough guide a 6-foot prop should turn at about 500 RPM and a 9-foot prop should turn about 300 RPM. This will give you some idea what you're up against when coupling various alternators to your blade rotor. In the installations of large size wind power plants must requires the large size tower construction, which consumes a huge part of capital this problem is overcome by adopting this modified low velocity roof top wind turbine. The turbine of throat diameter ranging (01 m-03 m) may be used as per requirement. The 01m size can be used by a small domestic consumer (below 01 kW). The consumer of high requirement must need to install 02 m or 03 m diameter throat turbine. This turbine requires the roof area of about 40 ft × 20 ft (800 Sq. ft). The type of generators used is mainly depends upon the capacity of the turbine and type, i.e., directly derived or by using some gear train as discussed in the fourth's chapter different generator designs for gearless wind turbines have been presented, i.e., Electrically-excited synchronous machines, surface-magnet and buried-magnet radial-flux PM machines, axial-flux PM machines, transverse-flux PM machines, switched reluctance machines and a linear induction machine. Some directly driven generators are used in low power commercial gearless wind turbines. The first commercial directly driven generator in the power range of some hundreds kilowatts is a synchronous machine excited by a traditional field winding. Many low-speeds experimental machines have been built and tested. The conventional asynchronous machine and the switched reluctance machine are large and heavy and they will not be very suitable designs for a large directly driven generator compared to the other designs. The transverse-flux machine is small, efficient and light compared to the other designs, but the mechanical design is very complicated. The electrically-excited synchronous machine is larger, heavier and less efficient than the PM synchronous machine. The radial-flux PM synchronous machine has smaller outer diameter and it is cheaper than the axial-flux machine. Cheap ferrite magnet material can be used in the buried-magnet machine, but the rotor is heavier and the mechanical design more complicated than those in the surface-magnet machine with high energy magnets. The radial-flux PM machine with surface mounted magnets seems to be a good choice for the design of a large-scale directly driven wind-turbine generator. If you want to charge 12 V batteries and run things off of them you might go with homemade or other permanent magnet alternator (with an efficiency of around 70%) or a car alternator (although these need to be turned at about 1800 RPM) with an efficiency of about 50% (plus the loss from the belts or whatever needed to turn it at 1800 RPM, plus the loss needed to run the field coils, about 40 watts). Another item is surplus computer tape drive motors, available for about Rs. 2,000. These have brushes, so there is a little bit more than just bearings to wear out, but they'll make good power for a long time for a reasonable price. Some small engine starters have permanent magnets and would probably make suitable direct-drive generators. These have the advantage of being common and repairable. Look for ones with bearings instead of bushings, which might be a bit rare. But the starters with bushings won't do well under continuous duty.

Adopting this modified roof-top wind turbine the 50% of the rural families becomes self dependent on power production they need not another kind of power connection (i.e., from Thermal power plants). Because the wind power is available through out the year during day and night also. This adds the great wealth to the nations by saving energy and environment. The nature of wind energy is important to take into account when you're planning to capture and utilize it. Too small a unit won't capture enough to do a lot of good, and too large a unit is too expensive to make sense: you would be better off investing the money and paying your electric bill with the interest. Because wind power is not particularly reliable over the short term, the storage/use of the power has a lot to do with how much good you'll get out of it. Your situation will determine what best to do with your wind power. The power must be stored by using battery system of suitable ratings (i.e., 12 volt rating).

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