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A New Design and Mathematical Analysis of Vertical Axis Wind Turbine for Smart Cities.

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Abstract:

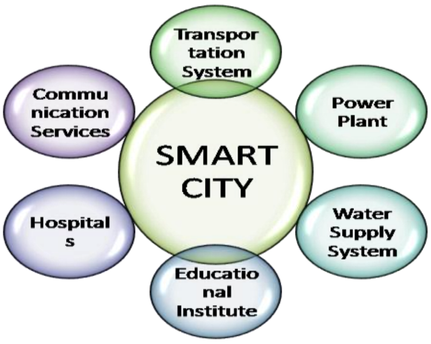
This paper represents the design and an experimental analysis of vertical axis wind turbine system. In India basically two types of wind pattern are available, known as high wind pattern and low wind pattern. As up growing country, electricity demand increases day by day. 4% of electricity demand is accomplished with wind energy sector. In this paper review of developed mathematical model for commercial use of vertical axis wind turbine and new physical model is developed to mitigate small electricity demands of smart cities, generated power is analyzed with different wind velocities.

Keywords

Electricity demand, VAWT, Flywheel, Power

Introduction

The cities in which to manage assets, resources and efficient services, a use of Internet of Things (IoT) by means of electronic equipments, sensors utilize for data collections called smart cities. This includes data collected from citizens, devices, and assets that is processed and analyzed to monitor and manage traffic and transportation systems [1], power plants, utilities, water supply networks, waste management, crime detection, information systems, schools, libraries, hospitals, and other community services. Diagram shows the important areas cover in smart cities.



Power to such a electronic equipments can be made available by different renewable energy sources viz. Solar thermal systems, Biogas Plants, Electric Vehicles, Wind turbines like Horizontal and Vertical Axis Wind Turbine (VAWT).
For small capacity wind to electricity conversion vertical axis wind turbines are advantageous because required less space for installation for limited height, generator assembly is on ground, robust construction and foundation, and generates electricity at minimum wind velocity and economically feasible. Wind turbines are a the source of renewable energy, which will help to the environment by not producing pollution while generating electricity

There are several types of vertical wind axis turbine system such as HAWT, Savonius, Darrieus, H-Rotor etc. For the experimental set up we choose the Savonius type wind turbine with four semi circular blades.

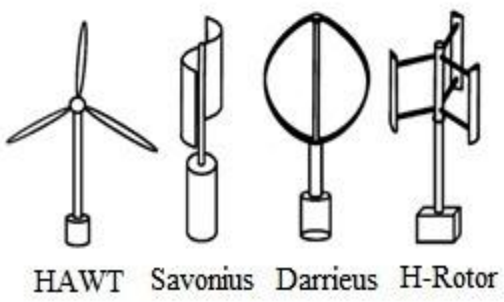


Fig. Major wind turbines type

Literature Study

1. Turbine size as a function of power required

The power of the wind (P_w) is proportional to air density (ρ), area of the segment (A) of wind being considered, and the natural wind speed (v). At standard temperature and pressure (STP = 273K and 101.3 KPa),

$$P_w = 0.647Av^3$$

A turbine cannot extract 100% of the winds energy because some of the winds energy is used in pressure changes occurring across the turbine blades.

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The mechanical power (P_m) that can be obtained from the wind with an ideal turbine is given as:

$P_m = ½ \rho (16/27 Av^3)$

The constant 16/27 from above equation is referred to as the Betz coefficient. So above equation can be re-written as

$P_m = C_p P_w$

The coefficient of performance(C_p) depends on wind speed, rotational speed of the turbine and blade parameters such as pitch angle and angle of attack. [2]

2. Wind Speed, Tip Speed Ratio and Solidity

The first step in wind turbine design is to select an operating tip speed ratio (λ) which can be expressed by

$\lambda = \omega r/V_\infty$

This is the ratio of the rotational velocity of the wind turbine ωr and the free stream velocity component (wind speed V∞??)

Once (λ) has been chosen, the geometry of the VAWT can be defined through a dimensionless parameter known as the solidity (σ).

σ=Nc/d

which is a function of the number of blades N, the chord length of the blades (c), and the diameter of the rotor (d) [3].

Problem Statement

Problem with Vertical Axis wind turbine is due to lack of lift generated at low speed cause by undistributed wind un uniform torque distribution while operating and has very low power generation.

Problem Solution

Instead of odd number of blades, even number of blades is design and assembles rotating shaft assembly at middle which will provide starting torque. Blade designing, physical model and test on the model is perform on the model and verify with the help of software.

Analysis and Design

In order to make our hybrid design work at any wind speed, we need to design Savonius blades which would provide that amount of torque.
Selecting MS material for rotor shaft and polycarbonate sheet with 2mm width for blades, dimension obtained:

D= 390 mm

R_0= 50 mm

Using Empirical Relations:
2d-e=D and m = e = (d/4), we get
e = a = 55 mm
d = 220 mm
H = 950 mm
$P_{max}= C_p \rho R_0 H(V_w$^3)
where, C_p= power coefficient =0.3 ρ = density of air = 1.215
we get,
P_{max} = 1.821 W for single unit.
Generally, assuming Tip speed ratio = 1
$\lambda = (\omega R_0)/V_w$
Torque = $P_{max} /\omega = 0.2025 * 10^{-3}$ N-m
Shaft Selection*:* Considering buckling and standard size available for material MS; let d = 20 mm.
Bearing Selection*:* Bearing chosen was roller bearing with no. F204 which was based on the shaft diameter. Includes gray cast housing, radial insert ball bearing with socket set screws, seal with slinger. The bearing has 20 mm internal diameter and 22 mm external diameter.

Motor Selection*:* Motor chosen was Direct Current Permanent Magnet motor with voltage rating 12 V and RPM rating 300 to match with the highest maximum theoretically calculated RPM of the turbine.

Testing and experimental set up is as shown in the picture. Ammeter is connected in series with turbine, resistive load is connected across the turbine. Voltmeter is connected across load. Same model is simulate with the help of

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Fig 1:- Testing and Experimental set up

Mat lab Simulation

The model of Vertical axis wind turbine is designed in mat lab. In which a Dc machines is used as a generator and a mechanical torques gives to the generator. The constant resistive load is connected across armature of generator.

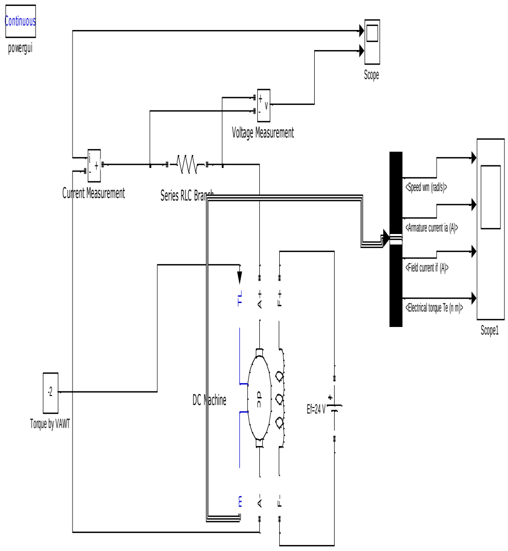
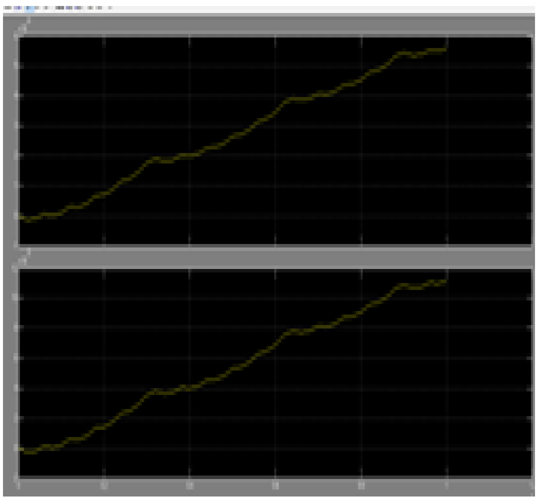


Fig. 2:- Test Simulation

The designed model simulates in through the Mat lab software and got result of armature voltage and armature current of generator. The result is shown as below.

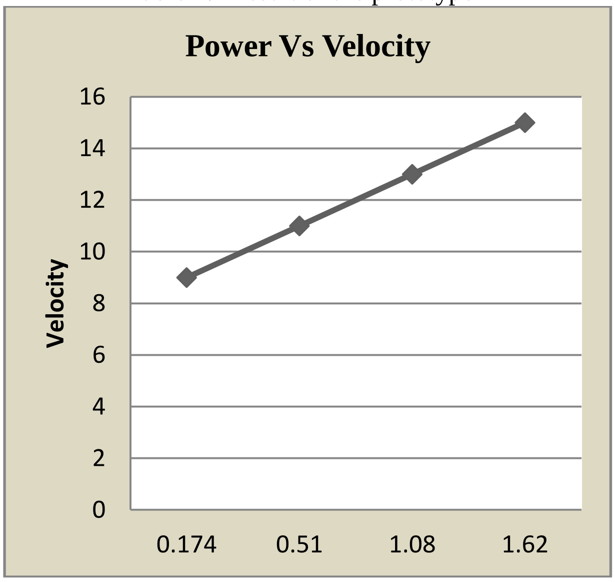


Graph 1:- Voltage and Current profile.

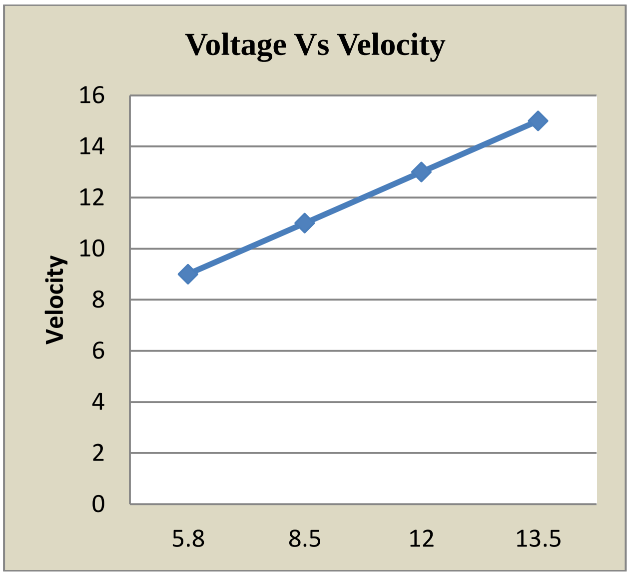
Voltage and current profile are shown in the plot as wind velocity is increases maximum voltage is generated hence maximum power is available. 5ohm resistance is connected across the generator, at different wind velocities voltage and current measures. power is calculated with the help of measured reading. Test Result is as follows,

Sr No	R	w	N	Voltage	Current	Power
1	5	9	260	5.8	0.03	0.174
2	5	11	290	8.5	0.06	0.51
3	5	13	300	12	0.09	1.08
4	5	15	312	13.5	0.12	1.62

Table 1:- Result of the prototype



Graph 1 :- Generated Power Vs Velocity



Graph 1 :- Voltage Vs Velocity

Conclusion:-

As requirement of electronic sensors and supply module is very low and can be operated in 5V, 9V, 12V dc power, such type of small power requirement can be mitigate if number of vertical axis wind turbines are connected in grid on the divider of the roads of smart cities, roof of houses, garden areas etc.

In this paper VAWT is design for commercial applications in which as wind velocity increases more power generates. Undistributed wind flow is advantageous for four blade and tested in open area at different wind velocities and different height on ground level. As blade height is increases generation increases.

Physical model is verify with the help of simulation.

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