DESIGN OF SEMI AUTOMATIC VERTICAL AXIS WIND TURBINE FOR POWER GENERATION AND IRRIGATION

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Abstract - *The imminent depletion of fossil fuels, increasing global warming, rising greenhouse effect, increasing demand of energy resources, low availability of power supplies moves us towards renewable source of energy like wind energy. In India, agriculture plays a vital role in development of food production. Groundwater pumping using electricity is the most common method of irrigation. But frequent power cuts is one of the most common problem source for farmers in our country and they also do not invest in fossil fuel run pump sets, due to high cost. Hence the main goal of our project is to design and fabricate a wind turbine for generating electricity, pumping water from the reservoir and supplying it to farms via drip irrigation. We used 3-bladed vertical axis wind turbine and reciprocating single acting pump in this project. With the aid of bevel gears, the wind turbine shaft is used to run the reciprocating pump. The wind imposes the lifting and dragging type of driving forces on turbine blades. As these forces act on the blade, it rotates and this rotating blade transforms rotary wind turbine movement into reciprocal pump movement. These is also an automation mechanism where a solenoid valve is used to regulate the water supply. Opening and closing of the valve is controlled by an arduino and soil moisture sensor. The water is effectively discharged this way.*

***Key Words*: Wind Energy, Irrigation, Vertical Axis Wind Turbine, Reciprocating Pump, Solenoid Valve, Soil Moisture Sensor**

1. INTRODUCTION

Wind is environment friendly, cost free and easily available renewable energy source. Every day, in most countries, wind turbines are continuously capturing energy obtained from the wind and converting it to electricity. Power generation using wind energy plays an important role with the way we power our world – in a very clean and sustainable manner. With wind energy being untapped throughout the country and declining wind energy cost India is now moving forward in the 21st century with an aggressive initiative to accelerate the progress of wind technology and reduces its cost, to create new job, and to improve quality. But how is wind energy created? Wind turbines harness kinetic energy from wind and convert it into electrical energy. When the wind blows, the blades spin clockwise and capture this energy. This triggers the shaft of the turbine, connected to a gear. The gear transmits motion and electricity is produced using a generator. The mechanical energy can also be used to run a reciprocating pump for irrigation in areas having continuous and comparatively high wind speeds.

The vanes or blades of the vertical axis wind turbine rotate around a vertical axis. The important feature is that it can get hold of wind from any direction, so when the wind changes, the wind turbine of this kind has no need of an additional steering device to deviate the rotor. Since there is no need of a guidance device, the shape of the vertical wind turbine is simplified. Another advantage of this type is that the gear mechanism and the generator is that they can be set up on the ground.

Savonius vertical axis wind turbine is the slow rotating high torque machine with two or even more scoops are used in high reliability lower efficiency power turbines. Most turbines use lift generated by airfoil-shaped blade to drive a rotor, the Savonius uses drag and thus, cannot rotate faster than the approaching wind speed. So the task is to be increase the efficiency.

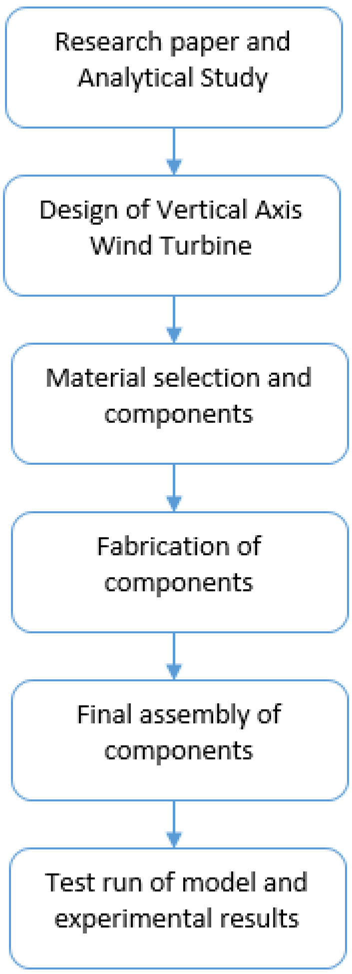
A Darrieus is a high speed low torque type of turbine used for generating alternating current. Darrieus generally requires manual push thus some external powers source to starting the turning as the starting torque is very low. Darrieus has the two oriented blade revolving around a vertical shaft.

1.1 Objective

Our aim is to fabricate a Vertical Axis Wind Turbine that meets the following objectives:

- Recapture maximum amount of wind energy by use of deflectors for self-starting of turbine at low wind speeds.
- Portability, in order ensure that the turbine can be used for irrigation in required locations.
- To pump water from bore wells entirely through the mechanical energy produced by the turbine.
- To create a low cost and eco-friendly power generation source.

2. METHODOLOGY



3. COMPONENTS OF VERTICAL AXIS WIND TURBINE

The components of the full-scale Vertical Axis Wind Turbine include base plates, shaft, Aluminium blades, connectors, neodymium magnets, deflectors, gears, bearings, reciprocating pump, arduino, solenoid valve, soil moisture sensor, jumper wires.

3.1 Base Plates

The two base plates are made of MS-steel and the structure stands approximately 3 feet high. The bottom-most base plate has a diameter of around 48cm and the other has a diameter of around 40cm. By itself the bases will not support the torque and moments produced from our wind turbine, so three base extensions are provided to maintain stability.

3.2 Shaft

There are two shafts-Outer hollow shaft and inner solid shaft having diameters 1.5 cm and 1 cm respectively. It is made of Aluminium material and the shaft contains two ring magnets (10mm*20mm) at a distance of about 1.2-1.4 cm between them.

3.3 Blades

Once a profile was selected, 3 blades will be machined from Aluminium flat-plate of 12mm thickness into an accurate representation of the selected airfoil. The machining process includes grinding the 12mm plate to 5-6 mm thickness. The blades are then twisted to the required angle by fixing one of the ends to a vice and using a wrench to achieve the required blade angle followed by cross cutting of extra portion.

3.4 Blade Shaft Connectors

Aluminium will be used for the six radial connecting arms to maintain a lightweight assembly with minimal inertial, moment, and centrifugal forces. The connecting arms provide a means to mount the blades to the center mounts and thus the center shaft. Tig-welding is performed to keep the blades in-tact with the connectors.

3.5 Neodymium Magnets

Eight neodymium magnets are provided on either side of the base plates. The neodymium magnets are installed to provide the extra torque and reduce the coefficient of friction. This concept is inspired by maglev magnetic train levitation of placing alternating like and unlike poled magnets to produce additional torque.

3.6 Deflectors

Two deflectors are used for self-staring of the turbine at low wind speeds. Sheet metal is made into a hemispherical shape. These deflectors are welded onto the main shaft.

3.7 Generator

A generator is a device that is used to convert mechanical energy into electrical power which can be used in an external circuit. The specification of the generator used in our VWAT is 12V-500rpm.

3.8 Reciprocating Pump

Reciprocating pump is a positive displacement pump where some volume of liquid is collected in the enclosed volume and discharged to the appropriate application using pressure. Reciprocating pumps are ideally suited to low flow volume at high pressures.

3.9 Arduino

Arduino is an open prototyping platform -source used to create electronic projects. It consists of both a programmable physical circuit board and a software, or (Integrated Development Environment) running on your device, where you can write and upload the computer code to the physical board. Arduino boards are capable of reading inputs and turn it into an output.

3.10 Soil Moisture Sensor

The sensor for soil moisture is one form of sensor used to evaluate the volumetric content of water in the soil. As the straight gravimetric aspect of soil moisture includes extraction, drying, as well as weighting of samples. Such sensors calculate the volumetric water content not explicitly using any other soil laws such as dielectric constant, electrical resistance and change of the moisture content.

3.11 Solenoid Valve

A solenoid valve is a valve which is operated electromechanically. The valve features a solenoid, which is an electric coil in its middle with a movable ferromagnetic center. This is called the plunger. In rest place, a small orifice is closed off by the plunger. The electric current induces a magnetic field through the coil. The magnetic field at the plunger exerts a force. The plunger is then pushed into the middle of the coil so that the orifice opens. This is the basic concept used for opening and closing solenoid valves. The valve opens, and the liquid will flow in, by applying a voltage over the coil.

4. DESIGN CALCULATION

4.1 Design for strength

Design of VAWT begins with swept area (A) calculation and it is calculated by Multiplication of height of rotor (H) and diameter of rotor (D).

- $A = H*D$ .... (4.1)

  $A = 0.56 * 0.38 = 0.2128\ m^2$

Design and calculation of straight bladed VAWT is performed by considering the speed of wind that will hit the blade, and also kinematic viscosity (⍰), air density (⍰) and no. of blades.

For this project we have considered,

TSR (⍰) = 1

TSR = 1-4 for small scale generation

TSR = 5- 9 for Large scale generation

Number of blades (Nb) = 3

Wind velocity, (v) = 6 m/s

Kinematic viscosity, (⍰) = 0.0000178 kg/ms

Air density, (⍰) = 1.29 kg/m^3

Power in the wind is,

- $Pw = 1/2 *$ ⍰ $* A * v^3$ .... (4.2)

  $Pw = 1/2 * 1.29 * 0.2128 * 216 = 27.57\ W$

Mechanical power can be calculated by formula,

- $Pm = 1/2 *$ ⍰ $* A * 16/27 * v^3$ .... (4.3)

  $Pm = 1/2 * 1.29 * 0.2128 * 16/27 * 216 = 16.34\ W$

Where, 16/27 is Betz limit, this value was given by Albert Betz who was physicist in 1919, and he proposed that 16/27 = 0.599 is maximum power of efficiency of wind turbine that converts kinematic energy to mechanical energy.

Angular velocity (⍰) can be calculated as,

- ⍰ = ⍰ $* v/R$ .... (4.4)

  ⍰ $= 1 * 6/0.19 = 31.57$ rad/sec

- $N =$ ⍰ $* 60/2$⍰ .... (4.5)

  $N = 31.57 * 60/2$⍰ $= 301.55$ rpm

Chord length, (C) can be calculated as:

- $C =$ ⍰ $* R/Nb$ .... (4.6)

  $C = 0.6 * 0.19/3 = 0.04\ m$

Where solidity, ⍰ = 0.6 as Reynolds no is 1.6*10^5

Lift force which causes blade to lift,

- $Fl = 1/2 * Cl * \rho * C * V^2$ .... (4.7)

  $Fl = 1/2 * 0.80 * 1.29 * 0.04 * 31.57 * 31.57 = 20.57$ N

Where Cl = coefficient of lift = 0.80

The drag force that resists the wind speed is given by,

- $Fd = 1/2 * Cd * \rho * C * V^2$ .... (4.8)

$Fd = 1/2 * 0.04 * 1.20 * 0.04 * 31.57 * 31.57 = 1.02$ N

Where Cd= coefficient of drag =0.04

Torque to be transmitted is,

- $T = Pm * 60/2\pi * N$ .... (4.9)

  $T = 16.34 * 60/2\pi * 301.55 = 0.517$ Nm

4.2 Discharge in Reciprocating Pump

- $Q=ALN/60\ m^3/sec$ .... (4.10)
- $A=(pi/4)*d^2$ .... (4.11)

Minimum discharge (2 lpm)

2 lpm=0.0000333 m^3/sec

$0.0000333= (pi/4)*(3/100)^2*(7.2/100)*N$

N=40 rpm

Maximum discharge (5 lpm)

5 lpm= 0.000083 m^3/sec

$0.000083\ m^3/sec= (pi/4)*(3/100)^2*(7.2/100)*N$

N=97 rpm

Therefore, we expecting the slider to move at a minimum speed of 40 rpm to 97 rpm to pump 2 and 5 litres of water per minute respectively.

Table -1: Calculation results

Serial no.	Wind speed (m/s)	Power generated (W)
1	7	28.2
2	8	42.09
3	9	59.93

Table -2: Turbine Specifications

Wind rotor	Rated power	35 W
Left	Rated speed	6 m/s
	Rated diameter	0.38 m
	Swept area	0.2128 m^2
	Gear box type	Spur gear
Generator	Type	DC Generator
	Speed	500 rpm
	Voltage	12 V
Turbine blade	Type	Darrieus
	Number of blades	3
	Blade material	Aluminium 6061
Blade dimension	Length	0.56 m
	Radius	0.38 m

5. CAD DESIGN OF VERTICAL AXIS WIND TURBINE

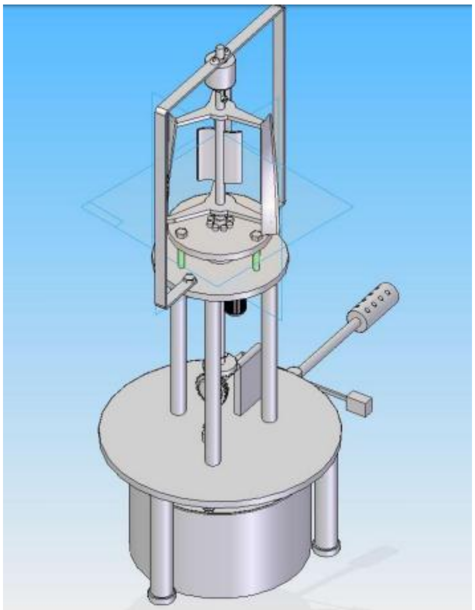


Fig -1: Isometric view

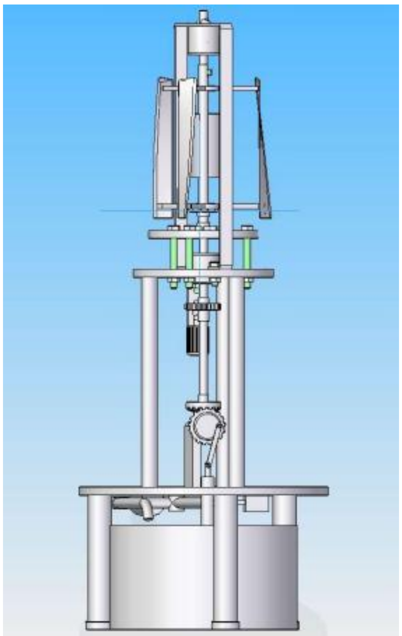
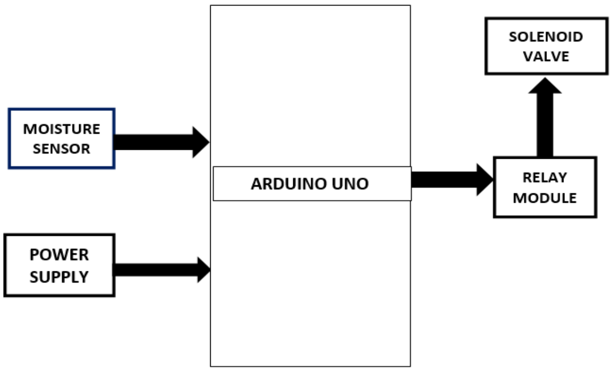


Fig -2: Front view

6. APPLICATION OF ARDUINO



Block Diagram

The Model works as follows:

The results of the level of humidity, temperature and threshold can be measured through the sensors used in the project. Soil parameter analysis can be performed, and the necessary nutrients for the soil can be determined. The need for soil water supply can be measured, and thus sufficient irrigation is performed using smart techniques.

Moisture sensor detects the level of moisture content in the soil and sends signals accordingly to the Arduino which are then further transmitted to the relay module. When the soil moisture content is less, valve opens and vice-versa.

7. LIST OF SYMBOLS

V- Air Velocity [m/s]

A - Turbine Swept area [m^2]

D - Rotor Diameter [m]

H - Rotor Height [m]

ρ - Air Density [kg/m^3]

ω - Angular Speed [rad/s],

R - Rotor Radius [m]

N - Number of Blades

c - Blade Chord [m]

L - Blade length [m]

⍰ - Tip speed ratio

Pw - power in wind [Watts]

Pm - mechanical power [Watts]

⍰ - solidity

Fl- Lift force which causes blade to lift [N]

Cl- coefficient of lift

Fd - drag force which resists the wind speed [N]

Cd - coefficient of drag

T - Torque [Nm]

Q – Discharge [lpm]

a – Area of piston [m^2]

L – Stroke length [m]

N – Speed of crank [rpm]

d – Diameter of piston [m]

8. CONCLUSION

VAWT technology undoubtedly will be with us in the future, and can be seen all around us, as has happened with other renewable technologies for electricity production and irrigation. In order to do that we will convert the acquired rotational energy from our VAWT into a linear compressed form to be able to run a sprinkler.

The following would be the most important feature of the VAWT:

- Electric generation and Irrigation in areas with no power.
- Compact size and portability

- Lower noise and vibration.
- Cheap and easy to manufacture with materials available in local market.

In villages these wind mill can be used for pumping of water in places where there is no power supply available easy and pump the water from easily without any power.

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