DESIGN AND FABRICATION OF A VERTICAL AXIS WIND TURBINE USING HYBRID POWER GENERATION ON HIGHWAY

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Abstract - *The objective of this project is to generate electricity via hybrid system which includes wind and solar energy. Our intention is to design a wind turbine compact enough to be installed on the divider on highways. In This paper we review the material of savonious type turbine vanes and effect on power output. The two materials which we are used are aluminium and PVC. the experiments used to compare aluminium type and PVC type vane which will show the maximum power output. The results of study show the material influence the performance of savonious type wind turbine. Savonious type having aluminium vane has better performance than made up of PVC.*

Key words - Vertical axis turbine, Battery, solar, renewable energy sources

1. INTRODUCTION:

One of the main important factors in modern civilization is energy. Energy is major input for economic development of our country. present, nearly 90% of the world's energy come from the combustion of fossil fuels, i.e. Coal, petroleum oils, natural gas, etc. People use fossil fuels to meet nearly all of their energy needs, such as powering vehicles, producing electricity for light and heat, and running factories. On the other hand, energy resources from earth's fossil energy are limited and also the global production of petroleum oils will come beyond their peak in the next a few decades. The population growth will need the more energy due to which price of fossil fuels. Will higher. At the same time there is a problem with the carbon-dioxide and sulfur-dioxide emission from the burning of fossil fuels. As a result global climate change. Nonrenewable source is natural substance that is not refilled with the speed at which is consumed it is finite resources. Fossil fuel such as oil, natural gas, and coal are example of nonrenewable resources. On renewable energy is energy obtained from resources that are inexhaustible. Example of renewable resources is tidal energy, wind energy, etc.

1.1 Energy recourses

1.1.1 Solar energy - Solar energy is that produced by the Sun's light for the generation of electricity. In exhaustible and renewable. since, it comes from the Sun, solar energy is trapped using panels and mirrors. Photovoltaic solar cells convert sunlight directly into electricity knows as photovoltaic effect, by which materials are able to absorb photons and evolved electrons, generating an electric current. into electricity knows as photovoltaic effect, Photovoltaic (PV) is that the conversion of sunlight into electricity using semiconducting materials that knows as photovoltaic effect, a phenomenon studied in physics. photovoltaic system consists of solar panels, each comprising variety of solar cells, which generate electric power, use a solar tracker to follow the sun across the sky. Solar PV has advantage It generates no pollution and no greenhouse emissions, It shows simple scalability in respect of power needs and silicon has abundant in the earth crust.

1.1.2 Wind energy - Wind is caused by the uneven heating of the atmosphere by the sun, due to variations in the earth's surface, and rotation of the earth.

Wind turbine - Wind turbine convert the energy in wind to electricity by rotating blade around rotor. The rotor turns the drive shaft, which result to turn electric generator.

Horizontal axis wind turbines (HAWT) with the blades upwind of the tower produce the wind power in the world today. .However various problems arrived in this design. The most significant ones are as Design of additional yaw control mechanism to turn blades towards the wind was difficult the cost is comparatively higher due to of rotor shaft and brake assembly. Heavy construction for supporting its bulky components.

Fig.1.1.2 (a) - HAWT Concept

Vertical axis wind turbines (HAWT) -

The vertical axis wind turbine is not suitable to install on top of a tall tower as many VAWTs require large bearings or supports at the top of the design to permit rotation of the shaft. The vertical axis wind turbine generators tend be located close to the ground in a region of relatively low wind speeds. There are different types of VAWT. e.g. Darrius, savonius, girromill.

Savonious VAWT -

As this type turbine is the focus of our project, The Savonious turbine is one of the simplest turbines. Aerodynamically, it is a drag-type device; The Savonius turbine uses drag to push the curved blades to generate a torque that will make the rotor turn. Aerodynamically it is the simplest wind turbine to design and build which reduces its cost and compared to the aerofoil blade to the other VAWTs

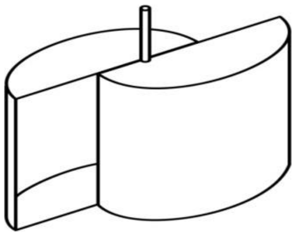


Figure 1.1.2(b) - Savonious VAWT

2. PROPOSED CONCEPT

Horizontal axis wind turbine is the turbine which is most reliable and advantageous for the power generation hence it is used mostly in case of power generation from wind energy. But the reason of rejection of this type of turbine is that it requires high wind velocity which is not available near to the ground level hence it is mounted on big height using big towers as well as it requires the big blades of fan to cover major air impact. In our project we are having less floor area and we cannot afford the big height columns and there expensive maintenance. We are getting the good air stream velocity at 5 foots from the ground level. This height is less for the horizontal axis wind turbine hence we have rejected this type of turbine. Hence we have selected vertical axis wind turbine which is favorable in our case. Selection of type of vertical axis wind turbine: Savonious, Darrius and girromill are the type of vertical axis turbine. Darrius vertical axis wind turbine requires the external support and they do not have self-starting property hence they require the external motor for initial start but in case of Savonious vertical axis wind turbine if we are using 3 number of blade then it will have the self-starting capacity, it does not require external support and as well as its height does not matter. Hence we have selected Savonious vertical axis wind turbine for our project.

Trial1: Firstly we have tried for two blade savonious vertical axis wind turbine.

Specification of Turbine Blade:

Material: PVC

Thickness: 2 mm.

Height of blade: 2 feet

Length of blade: 15 cm Shaft:

Type: Hollow

Material: PVC Outer Diameter: 3.2 cm Inner Diameter: 3cm

Height: 4.5 feet Turbine

Speciation

Blade angle=0 degree

Overall diameter 33.5cm height of turbine 2 foots

Aspect ratio h/c =2

Bearing type: single row deep groove ball bearing number =6408

Result: Design of turbine mentioned above was failed due to its bulky nature and weight. This design of vertical axis wind turbine is failed due to the bulky nature of turbine. Due to its inertia of turbine increased, required torque for rotation increases but we are not getting the input torque from the air so the turbine is failed in rotation.

Trial 2:

In this trial we have changed the complete material and design of turbine to make it light in weight. Logic of reduction in weight is that if turbine having larger weight then it will require large torque to rotate and if we will reduce the weight then less torque will be sufficient to rotate the turbine. We have maintained aspect ratio over hear as h/c=2, for efficient operation of turbine.

Design specification of turbine blade

Material of blade= 24 Gauge aluminium sheet

Length of blade=15cm

Height of blade= 30 cm

Thickness of blade=0.47

Fig. 2 : Rough Design of Aluminium Blades

Result: Aluminium is light weight material as well as we have taken small gauge of it for weight reduction purpose. SPVC material pipe of dimension mentioned above was used as shaft. This turbine was rotated at the rpm of 55-60 but problem was that it was not self-starting and imbalance for balancing purpose we have gone through another design mentioned below.

Trial 3:

In this trial we have changed the complete dimensions of the turbine to make it sustainable and light in weight.

Design specification of turbine

Material of blade= 24 Gauge aluminium sheet

Length of blade=65cm

Width of blade=13 cm

Thickness of blade=1cm

Figure 2.1: Aluminium Blades

Result: Aluminium is light weight material as well as we have taken small gauge of it for weight reduction purpose. MS material pipe of dimension mentioned above was used as shaft. The above dimensions of the blade improved the performance of the blades and efficiency of the turbine shaft.

3. DESIGN OF HYBRID ENERGY GENERATION SYSTEM

3.1 Design of shafts

Material Selection

Material=Mild Steel

Diameter=17mm

Length=950cm

Maximum Shear Stress in shaft=$16T_{max}/\pi d^3$

=16 *2.310*10^3/π*(17)^3

=2.208N/mm2

Allowable Shear stress for mild steel= 200 N/mm^2.

Maximum Shear Stress in shaft > Allowable Shear Stress

Hence, Design is safe.

3.2 Selection of bearing

For low and medium radial loads we select- Ball Bearings

Bearing Selected- Bearing number=6202

Bearing type=Deep-groove ball bearing

Static load on bearing

Load acting on bearing when shaft is stationary $C_0=P_1M$

Z=no. of balls

$M=(1/5)\ z\ P_1$

$C_0=(1/5)P_1$

Dynamic load on bearing= $P=XVF_r+YF_a$

Where,

X & Y= radial and thrust Factor

V= race rotation factor

F_a= axial load, F_r=radial load , $P=XF_r+YF_a$

Bearing life for industrial application L10h= 12000= 200000hrs

Hence,

We can calculate, from

$L_{10h}=60nL_{10h}/10^6$

n=speed of rotation of shaft at high wind velocity

n=3000rpm

L10=288 million revolutions

Reverse Calculations

SKF Bearing catalogue

6202

d=17mmD=40mm

B=12mm

Limiting speed=24000

Max=38000

Dynamic load Capacity(C)=9.95KN

Co=4.75KN

L_{10} =288 million revolutions

P=1506N

3.3 Swept Area of Savonious Turbine

A_{st}= Height × Diameter

=0.65 ×0. 65

=0.4225

3.4 Wind Power at Turbine

$P = 1/_2 \rho A^3 C_p$

Where,,

ρ=air density

C_p=for Savonious

V=for maximum air velocity

$P=1/_2 \times 1.225 \times 0.4225 \times 6^3 \times 0.4$

P=22.3587 Watts

Torque available on turbine shaft N=100 r.p.m

P=2 ×π ×N ×T/60

T=2.1350N-m

3.5 Gear ratio

Dia. Of gear 1=45mm

Dia. Of gear2=10mm

No. of teeth on gear1=38

No. of teeth on gear2=18

GEAR Ratio (G)=t_1/t_{12}=38/18=2.11

4. WORKING OF THE SYSTEM

4.1 CONSTRUCTION

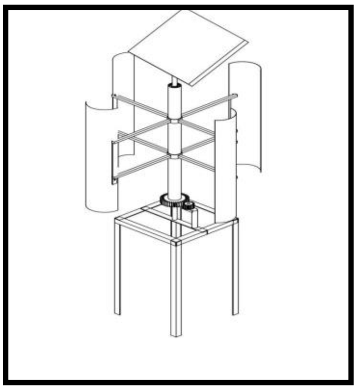


Fig 4.1 System setup

First we manufactured stand of mild steel angle bars. Angle bars are joined by arc welding. To mount Savonious VAWT after that shaft of the turbine is extend by 1.5 cm with internal threading is provided in it. Shaft is extended for connecting alternator with gear mounted on shaft. To multiply rotations given by shaft to alternator and Spur gear train is used. To increase torque and rotational motion of turbine, we attached savonious vertical axis wind turbine. On top side of turbine Vanes of savonious turbine are twisted to 15 degree to increase torque and efficiency due to which rotations of turbine get increased. To multiply rotational speed of the main shaft of turbine we have provided a gearbox having one stage first one is spur gear and another one is Pinion gearbox mounted between the main shaft and PMDC motor. PMDC motor consists of movable armature fixed magnet with two poles. This motor has brushed system. It produces DC voltage output .To connect motor with gear, shaft issued . In this system epicyclic gear train issued that means it consist of one ring gear, one sun gear, three planet gear. By using gear mechanism we are increasing speed input of PMDC motor to generate power at low air drag velocity.

4.2 Working

Fig.4.2 block diagram of hybrid power generation system

The curved vanes of the turbine convert the kinetic energy of wind into the angular velocity of the turbine and it starts rotating. The shaft is rigidly connected to the turbine and it starts rotating, hence this rotational speed of the shaft provided to the motor as an input and it starts generating the voltage. The setup of the system is as shown in fig.4.2

Various components used in setup are as follows:

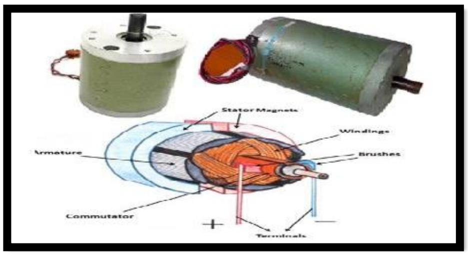
4.2.1 Savonious VAWT - Air drag generated from fast moving vehicle contains kinetic energy into it. When this air drag strikes on outer tip of vertical axis wind turbine blade then it produce torque into it and turbine starts rotating about its central axis like this the kinetic energy of air drag is converted into the mechanical energy in the form of rotation of turbine. As the turbine rotates shaft is also rotates with turbine due to the connection via gearbox.

The shaft held between the two ball bearings with the spur gear of gear box. Spokes also provides the support to the turbine and another end of shaft is connected to the coupling. The turbine we used is shown in fig. no.

4.2.2 Shaft - Shaft is used for transmitting power from gear box to motor. In our project we have used mild steel shaft having higher strength. Due to usage of light weight shaft ,inertia is reducing and efficient power transmission occurs.

4.2.3 PMDC Motor - In a DC motor , an armature rotates inside a magnetic field. Basic principle of DC motor is whenever a current carrying conductor is placed inside a field, there will be mechanical force experienced by that conductor. All kinds of DC motors work in this

Fig. 4.2.3: PMDC Motor



Principle. The Magnetic field is means of magnet. The magnet can be any types i.e. it may be electromagnet or permanent magnet. When permanent magnet is used to create magnetic field in a DC motor, the motor is referred as permanent magnet dc motor or PMDC motor. If you open any battery operated in toy, then you found a battery operated by motor inside it. This battery operated motor is a permanent magnet dc motor **or** PMDC motor. These types of motor are simple in construction. Applications of PMDC motor are as windshield wipers starter motor in automobiles, , washer, and air conditioners, to raise and lower windows. As the magnetic field of a permanent magnet is fixed it cannot be controlled externally, field control of this type of dc motor is not possible. Thus when there is no need of speed control then permanent magnet DC motor is used.

4.2.4 Inverter Kit - An inverter is an electrical device that converts direct current (DC) to alternating current (AC). Solid-state inverters has no moving parts and are used in a wide range of applications, from small switching power supplies in computers, electric utility high-voltage direct current applications. Inverters are used to supply AC power from DC sources. The electrical inverter is a high power electronic oscillator "inverted", to convert DC to AC.

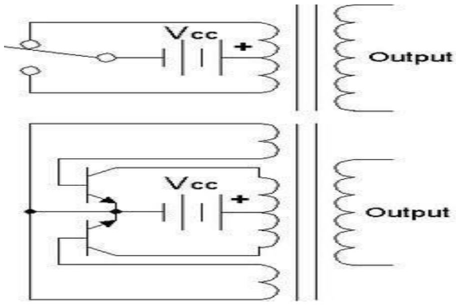


Figure 4.2.4: Circuit Diagram of Inverter

5 RESULT -

From IMD (Indian Meteorological Department, Nasik) Observations were taken for wind power calculation. Anemometers installed for measurement of wind speed in m/s. The project setup is mounted on divider of road, where there is no obstruction to air drag flow. Wind speed is measured by anemometer and simultaneously rpm of turbine shaft is measured by tachometer. The each observation was taken after 10 minutes. The observations are taken for different cases, and turbine shaft RPM at respective wind speed is tabulated in table no. 5.1.1.Then from this collected data the average shaft RPM at particular wind speed is calculated. Once we find the shaft RPM at respective wind speed, further analysis can be done. The different cases for observation are:-

Case 1 - Simple turbine

First reading for shaft RPM with respective wind speed are taken for simple turbine. No auxiliary system (gear box, alternator) is connected to turbine. The turbine spins freely without any load on it.

Case 2 –PMDC motor is connected to turbine

In this case the alternator is connected to turbine shaft. Due to increase in load on turbine the shaft RPM get reduce by 10-20 RPM with respective wind speed. Hence to increase the power and speed of turbine we can use twisted blades of 15 degree having light weight material.

Case 3 - Savonious turbine made of PVC

material with aspect ratio 1

Secondly we used PVC material so as to reduce the self-weight of turbine. This turbine gave slightly good result than turbine with aluminium 20 gauge material. Weight of savonious turbine made of foam is 400 gm.

Case 4 - Savonious turbine made of aluminium material with aspect ratio 2

As wind turbines work by converting the kinetic energy in the wind into rotational kinetic energy in the turbine and then electrical energy. The energy available for conversion mainly depends on the wind speed and the swept area of the turbine. Hence we have use 26 gauge aluminium material for turbine with Aspect ratio (H/D) 2. Which have given better result to increase the turbine power and shaft RPM to generate the electrical power

5.1 OBSERVATION TABLE FOR DIFFERENT CASES

Table no. 5.1 -RPM for various cases

Wind speed (m /s)	Case1 (RPM)	Case2 (RPM)	Case3 (RPM)	Case4 (RPM)
1	-	-	-	-
2	10-15	-	30-35	40-45
3	15-20	-	45-50	50-55
4	20-30	5	55-60	70-75
5	30-40	5-10	90-100	100-105
6	40-55	10-15	120-125	125-130
7	55-65	15-30	140-150	150-155
8	65-75	30-40	180-185	190-195
10	85-95	50-65	210-220	230-235

From table 5.1 we conclude that shaft speed increases with increase in wind speed. Also we can say that shaft speed is maximum at maximum wind speed. Shaft speed is directly proportional to wind speed

Wind velocity assist to the air drag generated from the fast moving vehicles and it velocity is again increased due to the summation of wind velocity and air drag, that's why we get better result and performance of the system.

6. FUTURE SCOPE -

The explicit use of renewable sources for energy production is a requirement of the time now with the energy crisis we are about to face in the distant future. For many years the development of various methods for generation of power using renewable source is under work. Thus, the development of cost effective and hybrid energy systems is not only a need but also a business opportunity

Hybrid energy systems, as in our case, a solar-wind hybrid system have been designed to power small utilities in houses or street lights on highways. The system has the capacity to power the highway street light system almost independently. Considering all the difficulties and efficiency losses we can safely say that the system can stably support the street light system with minimal support from the main grid. The product was so designed both parametrically and dimensionally so that it would fit within the limits and constraints of the highway system and simultaneously be cost effective at the same time. The solar-wind hybrid system has a wide range of applications as well as a broad scope for innovations. Various innovations in blade design and the setup structure have been seen for many years now. The blade design being the most integral part of the system has the maximum potential for innovation. As seen in our project, altering the blades dimensions and design has a direct impact on the overall output of the system. The future work in this system involves designing of battery charge controller for more reliable operation in a hybrid energy system. Neutral networks can be applied in the systems to control switching of solar and wind system individually

Use of SCADA systems can be used to store the historical sun and wind profile of any geographical location and analyze the power demand in that place. Artificial Intelligence techniques may also be incorporated in the proposed system to achieve better performance.

7. CONCLUSION -

After making this system we conclude that, this system is potentially great ability to generate electricity by Savonius vertical axis air drag operated wind turbine. The most benefit of project is to utilize increased air drag generated by fast moving vehicles on high way roads to produce the electrical power.

Future there will be lack of electric power to avoid that, we use by this principle to produce alternative energy at low cost sources for daily. The aluminium vane with aspect ratio 2 has better performance than vanes made up of PVC, foam and aluminium having aspect ratio 1. It is due to turbine power depends on wind speed and swept area of turbine. Therefore turbine RPM are increased with respect to wind speed as compare to turbine with aspect ratio 1. Finally we have conclude that vertical axis air drag operated turbine with aluminium vane of aspect ratio 2 is selected to generate the maximum power output.

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