Modular Vertical Axis Wind Turbine Project

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Wind energy offers the potential to generate substantial amounts of electricity without the pollution problems of most conventional forms of electricity generation. It environmental costs, mainly in the form of visual intrusion, are different from those of conventional electricity generation. The scale of its development will depend entirely on the core with which wind turbines are selected and sited. Wind energy has been used for thousand of years for milling grains, pumping water and other mechanical power applications. Today, there are over one million windmills in operation around the world; they are used mainly for producing electricity. The cost of wind turbine fell steadily between the early 1980's and the early 1990's.

The technology is continually being improved to make it both cheaper and more reliable, so it can be expected that wind energy will tend to become more competitive.

The task of the research carried out, was to design a low cost vertical axis wind turbine. The aim of the design is to make a wind turbine to operate in very windy condition or even during cyclones. The Unit could be manufactured locally with the local labour force. The wind energy is converted into a mechanical drive and the drive is at ground level and this power could produce electricity and be used for many other purposes.

Wind Turbines

The variety of machine that has been devised or proposed over the years to harness wind energy is considerable and include many very unusual devices.

Apart from a few innovative designs, modern wind turbine comes in two basic configurations - **horizontal axis turbine and vertical axis turbine**. The majority of modern wind turbines are electricity generating devices. They range from small turbines that produce a few tens or hundreds of watts of power to relatively large turbines that produce 1 mw or more. Larger, multi-megawatt wind turbines have also been built, but these have almost been research prototypes.

Horinzontal Axis Wind Turbines.

Horizontal Axis Wind Turbines (HAWTs) generally have either two or three blades or else a large number of blades. The large number of blades have what appears to be virtually a solid disk covered by solid blades and are described as high-solidity devices. The modern wind turbine with one to three blades are more common and these type of turbine are commercially manufactured in power rating of up to around 1 Mw.

Vertical Axis Wind Turbine

Vertical Axis Wind Turbine (VAWTs) have an axis of rotation that is vertically and so, unlike their horizontal counterpart, they can **harness winds from any direction without the need to reposition the rotor when the wind direction changes**. The modern VAWTS evolved from the ideas of the French designer ***George Darrius*** who invented the vertical axis turbines in 1925. This device which resembles a large egg beater, has blades curved with a symmetrical aerofoil cross section. However, the shape causes great difficulties in manufacturing, transportation and installation of the curved blades. Presently very little work is being done to vertical axis wind turbines, but recently on a visit to the RAL in oxford, I found that they had started further research work on the Savonius technique.

Modular Vertical Axis Wind Turbine

My design of the Modular Vertical Axis Wind Turbine (MVAWT) is to make the rotor area in module of one metre by two metres high. Each module consists of eight vertical flaps. The flaps are one meter by thirty three centimeters wide, there are four flaps upper and four lower, hinged to one side of the module.

Much of the research work carried out were on the opening and closing of the flaps, this is to increase the drag when the rotor is down wind and reduces the drag when up wind. The direction of rotation will always be constant to whichever the direction of the wind is blowing.

The modules make it unique. The power required will depend on the number of modules bolted together to each rotor arm.

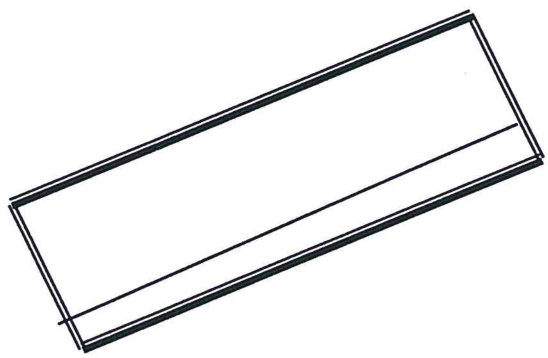
With reference to the previous report, the work carried out was mainly to the construction of the wind turbine, bearing housing, vertical shaft, drives and tower.

Models

A model of the flaps made on a frame to fit to the side of a car window. Driving the car during a calm day at various recorded speeds to observe the behavior of the flaps. The flaps mounted vertically giving a much better result. Unfortunately as we do not have a wind tunnel, the entire modeling test had to be done with a vehicle.

Test carried out, with a model made out from the designs of flaps. A metal frame made of flat steel bar 3 mm x 20 mm, with a flap made of aluminum sheet, size was 300 mm x 100 mm x 1mm hinged vertically on the frame. The unit was placed outside the window of a car, driven at a given speed of 10 km/h to 160 km/h.

The result proved to be very good, but at 50 to 60 km/h, the flaps would tend to oscillate. Different type of thickness and metals were used, such as galvanized steel sheet, the result was slightly better. This is to make sure later on, steel sheet could be use mainly for the strength, aluminum will not stand the pounding of closing. The best material was 0.8 mm aluminum sheet, with a slight bend to the edges to create a better lift. These tests were to make sure that the flaps would give a very low wind drag when the rotor arm is up wind.



The vertical axis wind turbine is a drag technique, with a lot of torque. However, when the opposite rotor arm is up wind, it means that the rotor will be travelling at twice the wind speed. Mounting the flaps horizontally, gave a very good result, although the wind resistant is a little bit higher, but no need to control the opening of the flaps.

The flaps become, more or less self-adjusting according to the wind speed, this means that the flaps will not open more than an angle of 90 degrees. The major problem is to control the flaps, from the opening to closing, that is the change of the rotor position from up wind to down wind, and the flaps bring to close at a higher speed.

A full-scale unit built with 12 modules, three modules mounted on each of the four rotors, with flaps hinged horizontally. During the test carried out, the behavior of the flaps was very different. The flaps will overshoot when open in high wind velocity of twenty m/s. causing the flaps to flip over the top moving down wind.

Further modification carried out to the modules, by mounting the flaps vertically, and metal brackets welded to the upper part to stop the flaps opening more than an angle of fifty-five degrees. This is to keep the opening gap equivalent to the air pressure flowing through the flaps, when the rotor is up wind.

Situated near Candos target practice, the turbine was made of three rotor arms of six modules per arm, the rotor was mounted on top of a six-meter tower. Although the site is not really ideal for wind turbine, it has been very convenient for easy access to and from the workshop.

In view of the previous test carried out, and the results looks very promising, a vertical shaft was added with a right angle gearbox to drive an alternator.

The Ministry of Public Utilities and Central Electricity Board has been approached for help. They provided the project with an old alternator complete with a gearbox which has been taken out from a broken wind turbine in Rodrigues. The Central Electricity Board has been most helpful, by providing three phases to the mains supply of the wind turbine alternator. This includes the installation of metering and cabling.

Test Procedures

Equipment used is hand-held Anemometer, stopwatch, counter, and smoke.

The test was carried out at Candos about five hundred meters from Candos Hill. The modular vertical axis wind turbine consists of eighteen modules, with six modules on each rotor arm and the unit is mounted on a six meters tower. Although the location was not the ideal place but was enough to carry the test required for the flaps.

The wind speed was taken close to the top, just below the rotor arm. A fire made to create enough smoke, this is to see the flow of the wind over the rotor with all the flaps closed, and the rotor moving down wind. During this test, the wind velocity was fluctuating between 2 to 10 m/s.

This test carried out was to find the rotor tip speed. As the wind, speed varies so much; many attempts made to achieve a close reading. The wind speed was taken from the anemometer, visually by one person and another with a stop watch, to take the time per revolution. The tip of the rotor travels 113 meters per revolution.

Below are the reading taken at different intervals per test. As the wind fluctuates so much, average wind speed taken with the time taken per revolution.

Test 1

Wind speed Km/h	Average Wind speed	Sec.	Rpm
21,22,19,21	20.7	11	1
22,30,25,12,13	20.00	9	1
32,26,30,31	29.00	9	1
26,24,22,7,11	18	11	1
22,23,24,25,26	24	11	1
22,20,17,15,12	17	12	1
Total Average	**21.33**	**10.5**	**1**

Average Wind Speed = 5.9 m/s
Tip Speed = 10.76 m/s

Test 2

Wind speed Km/h	Average Wind speed	Sec.	Rpm
23,25,30,33	27	9	1
15,30,14,13	18	11	1
15,12,15,13,14	13.8	12	1
20,22,19	20	12	1
23,27,20,22,23	23	13	1
19,15,12,17,20,25	18	13	1
Total Average	**20**	**11**	**1**

Average Wind Speed = 5.5 m/s
Tip Speed = 10.27 m/s

Test 3

Wind speed Km/h	Average Wind speed	Sec.	Rpm
27,30,25,27	27.5	8	1
15,20,22,25,23	21.6	10	1
19,24,30	24	8	1
29,30,32,3	30	7	1
34,17,27,22	25	8	1
18,17	17.5	11	1
22,17,15,25	19.7	9	1
27,30,37,29,37	32	9	1
Total Average	**24.4**	**8.7**	**1**

Average Wind Speed = 6.6 m/s
Tip Speed = 12.98 m/s

Test 4

Wind speed Km/h	Average Wind speed	Sec.	Rpm
25,22,27	24	10	1
22,27,25	24	9	1
40,32,30	34	7	1
30,37,29	32	8	1
25,20,24	23	10	1
27,30,27	28	10	1
29,27,19,30	26	10	3
27,15,24,25	22	10	1
Total Average	**26**	**11**	**1.25**

Average Wind Speed =7.22m/s
Tip Speed = 12.84 m/s

Test 5

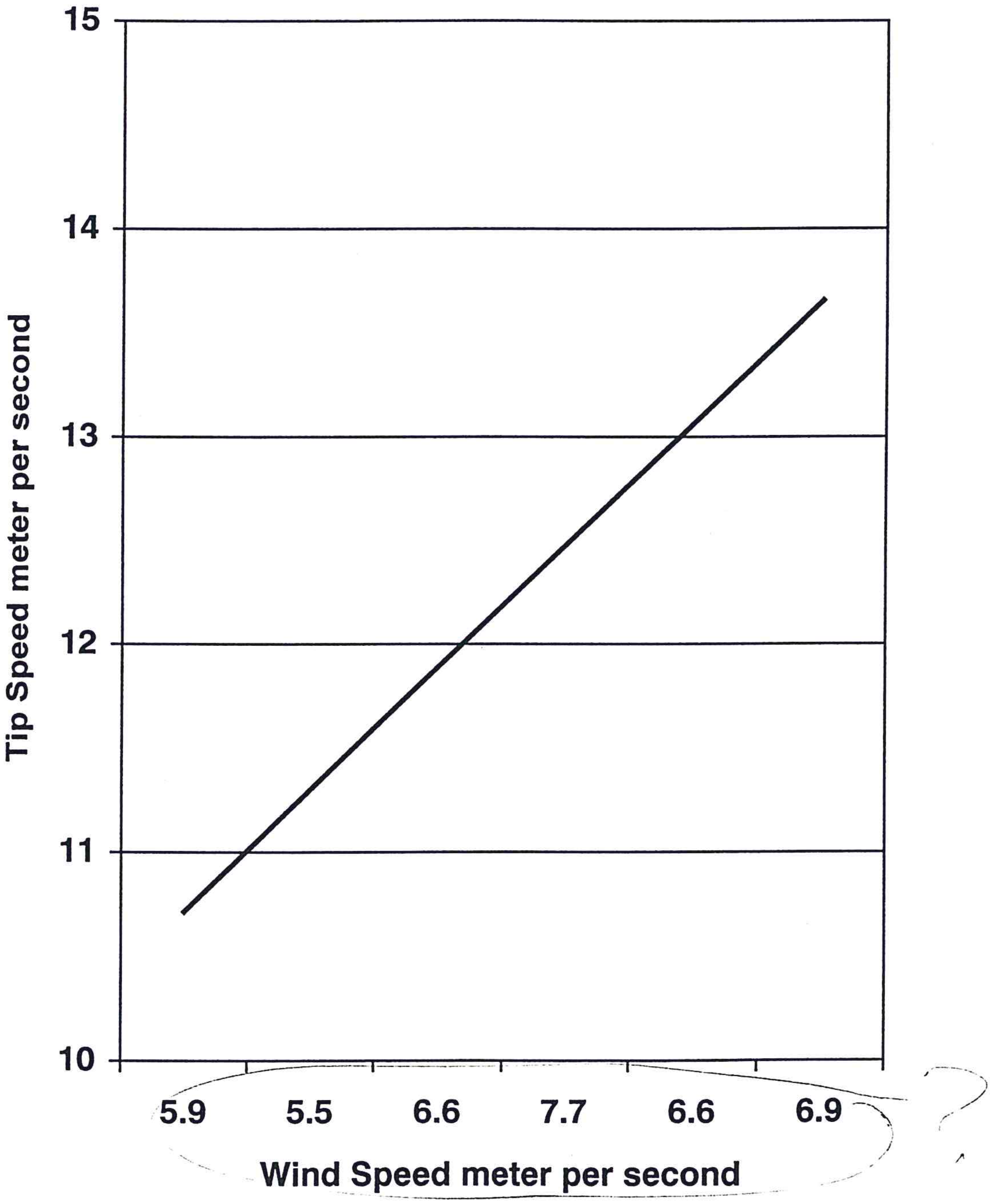
Wind speed Km/h	Average Wind speed	Sec.	Rpm
27	27	8	1
25,27	26	17	2
26,30	28	9	1
30,26	28	6	1
25,30	27	7	1
25,30	27	8	1
30,22	26	10	1
20,15	17	10	1
25,27	26	9	1
Total Average	**24.4**	**8.7**	**1**

Average Wind Speed = 6.6 m/s
Tip Speed = 12.98 m/s

Test 6

Wind speed Km/h	Average Wind speed	Sec.	Rpm
27,30,25,27	27.5	8	1
15,20,22,25,23	21.6	10	1
19,24,30	24	8	1
29,30,32,3	30	7	1
34,17,27,22	25	8	1
18,17	17.5	11	1
22,17,15,25	19.7	9	1
27,30,37,29,37	32	9	1
23,20	22	9	1
30,23	26	9	1
Total Average	**25**	**9.27**	**1.09**

Average Wind Speed = 6.9 m/s
Tip Speed = 13.28 m/s


15
14
13
12
11
10
Tip Speed meter per second
5.9
5.5
6.6
7.7
6.6
6.9
Wind Speed meter per second

The wind energy converted to power in watts

Kinetic energy/sec

$P = ½ \boldsymbol{P} A\ v^3$

$\boldsymbol{P}$ = Kilograms per cubic metre = 1.20

A = Square metre

V = Velocity of wind speed m/s

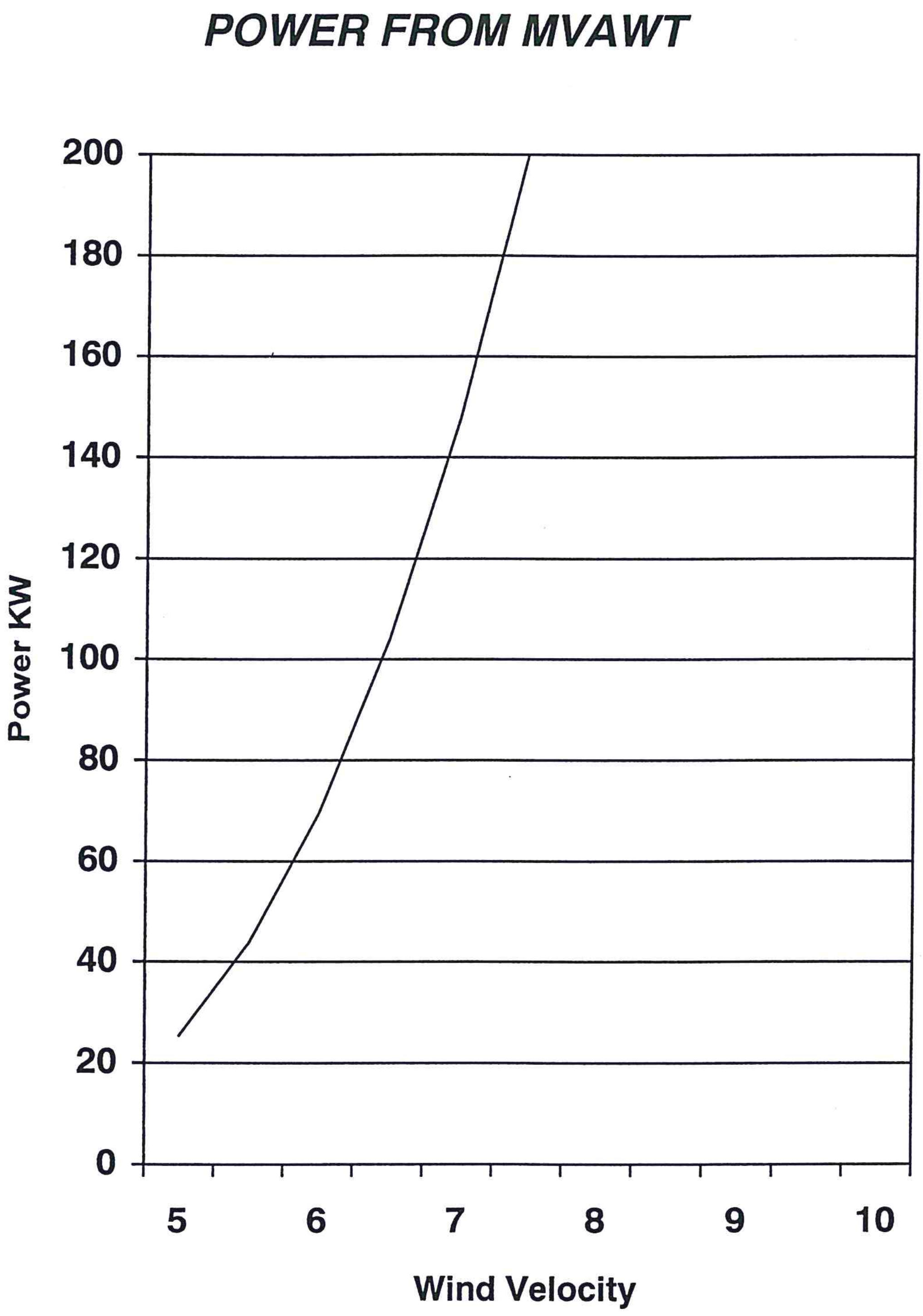
P = Power

Sweeping area $\frac{113}{4}$ = 28.25 m

Area = 28.25 x 2 m x 6 m = 28.25 x 12 = $339m^2$

P = ½ 1.20 AV^3

½ 1.20 339^2 6^3 = 43.9 KW


POWER FROM MVAWT
200
180
160
140
120
100
80
60
40
20
0
Power KW
5
6
7
8
9
10
Wind Velocity

Conclusion

Electrical energy is very much part of our life style, the power requirement will always be on the incline. There are so many ways of producing electricity, but at the same time we have to look after our fragile planet. The prospect of producing clean, sustainable power is substantial qualities from renewable energy sources is now arousing interest worldwide . The wind energy is a must for the Island. Once the idea is there, a search had to be done to see if ever this design is already registered, then from the drawing calculation of power output to a model.

The learning curve of aerodynamics with the vertical axis wind turbines energy converted into mechanical force has been extremely helpful. Tests carried out from the model to a full-scale machine, give lots of variables. Driving the wind turbine from low wind velocity to high speed give a very different results.

Although much of the research work has been concentrated mainly on the flaps, model test carried out with the flaps mounted horizontally was very good. The flaps mounted horizontally to the full-scale unit, has given a poor result of high wind velocity, vortex effect causing the flaps to oscillate.

The metal frames of the modules was modified to cater for the vertical flaps and stops bar fitted for stopping the flaps opening up to 45°.

The flaps was replaced with a 0.8 mm galvanize steel sheet and mounted vertically.

Further test carried out to the MVAWT with three rotors of eighteen modules with vertical flaps. The end results was extremely good, the flaps opening up wind and closing down wind was simply perfect. The vertical shaft was driving a small alternator of 3 Kw or a large water pump of 500 litre per minute.

I do hope that the Mauritius Research Council could see that the MVAWT is producing electricity at a very low cost and totally free from pollution and that a full grant could be made available to complete the Modular Vertical Axis Wind Turbine Project.