THE CONSTRUCTION AND CALIBRATION OF A THREE-CUP ANEMOMETER

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Abstract

The objective of this study is to analyse the process of construction, calibration and installation of a three Cup Anemometer and Wind Vane which can be used in taking data for wind analysis. It is a project that is specifically built for analyzing the speed and direction of wind within the premises of Federal Polytechnic Offa, Kwara State, Nigeria. The cup anemometer was situated at latitude: N8^o 7.9075'-longitude: E4^o 42.7352' at different strategic locations. A 12V DC motor (0.25watt) was connected to the spindle of the cups for the purpose of obtaining voltage readings for analyzing wind speed through further calculations. The calibration for the cup anemometer was carried out with the help of two (2) DC fans placed at a distance of 60mm apart. After installation, the cup anemometer was tested and data taken. The constructed anemometer gave the minimum driving wind speed of 0.4032m/sec.

Keywords: *Anemometer, Wind vane, Wind speed, Calibration.*

Introduction

The recent developments in the installation of small-scale wind turbines for urban areas highlight the need for implicit understanding and detailed wind resource assessment in a complex terrain like Offa (situated at latitude: N8^{o}7.9075'-longitude: E4^{o}42.7352'). The objectives of the project are to estimate appropriately, the expected wind resource within the location; to assess and facilitate the commercial viability of the project as well as to determine the possibility of installing the turbine at a specified location.

According to ICEED (2006) in Nigeria, wind energy reserves at 10m height are classified into the following four regimes; 4.0 m/s; 3.1-4.0 m/s; 2.1-3.0 m/s; and 1.0-2.0 m/s. Hence, Nigeria falls within a poor/moderate wind regime. It was also observed that the wind speeds in the country are generally weak in the South except for the coastal regions and offshore, which are windy. In States like Lagos, Ondo, Delta, Rivers Bayelsa and Akwa Ibom, there are potentials for harvesting strong wind energy throughout the year.

Different wind speed regimes in Nigeria.

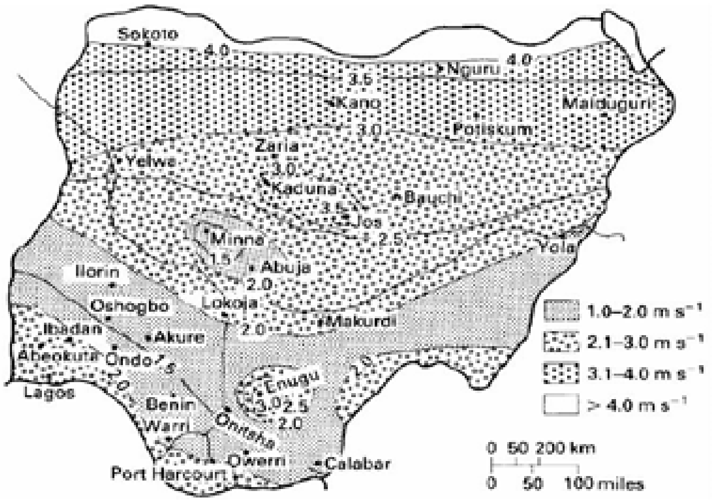

Figure 1: Nigeria average wind speed distribution (isohyet at 10 m height) showing four different wind speed regimes. Source: (Ojosu and Salawu, 1990)

The most accurate instrument for measuring the mean-wind speed had so-far been the cup anemometer. A cup anemometer was derived from Greek (anemos, "wind"; metron, "measure"). It is an instrument used to measure wind. It was invented in 1846 by the Irish Astronomer T. R. Robinson, (Middleton, 1969 & Wyngaard, 1981). The instruments as created by T. R. Robinson, had four cups until the end of the 1920s when it was modified. After 1900s, some researchers went into experimenting with the number of cups and the arm lengths. Brazier (1914) and Patterson (1926) found that shorter arms improved the linearity of the calibration and that a three-arm cup rotor is optimal with respect to sensitivity and suppression of the unevenness in the rotation ("wobbling").

The most common kind of anemometer consists of three or four cups attached to short rods that are connected in most cases, at the right angles to a vertical shaft. There are also the sonic anemometer and laser Doppler anemometer; but these are not commonly used. (Anemometertypes.com 2012). As the wind blows, it pushes the cups, which turns the shaft connected to a DC motor. Hot wire anemometer that is mainly made of tungsten material is also used to calculate the velocity of wind. As the wind flows across the hot wire and cools the wire, it gives variation in the glowing effect of the wire.

Wind Vane

Wind vane gives the wind direction. Most wind vanes consist of a long arrow with a tail that moves freely on a vertical shaft. The arrow points into the direction of the wind flow. However, when considering the site for a wind turbine, one must firstly compare the utility-scale to the community-scale. It is observed that the wind energy project cannot typically count on a large amount of fiscal resources for the resources assessment phase of the project. It can mostly be used as a backup. Investment in measuring equipment may therefore be limited. As a result of this, making a measuring instrument like the cup anemometer and wind vane is preferable to purchasing some other sophisticated devices. This study is therefore restricted to the analysis of construction, calibration, installation of cup anemometer and wind vane; which will be used in taking data for wind analysis and give results that may help in recommending the use of wind turbine in Offa, Kwara State Nigeria.

Methodology

The stages involved in the construction, calibration and installation of the cups and wind vane include sourcing for the materials/devices needed, data collection and assemblage; installation and wiring. Some materials were constructed and some were purchased. Doing this was not actually aimed at cost reduction only but to also determine the working principle of each of the materials/devices.

Materials Used
The materials used include: Float ball, Aluminum pipe, Rubber tube, Metal plate, wire, AC motor and DC motor.

Limitations
Many hindrances were encountered during construction, calibration, installation and testing. One of such was the inability to get a data logging device. This caused a lot of stress during the data collection. However, this was overcome through manual taking of reading, using multimeter

Parameters Used in Construction The cup anemometer was designed in the ratio of length of arms to radius of the cups (L/R) of 2.5. (Lindley 1975). For instance, the radius of the cup anemometer is 430mm (0.43m).
Therefore,
Length of Arm = 2.5 x 430 = 1075mm.

The Assemblage The construction of the cup anemometer was done by incorporating an AC motor and a DC motor. The AC motor was opened up and the rotor was removed from the motor spindle, the coil was also removed from the stator and the motor was left with only the motor spindle (shaft), the bearings and the casing. This was done to reduce the friction between the spindle and the motor casing.

After accomplishing the removal of the rotor, it was discovered that the spindle slides up and down due to the absence of the rotor, to solve this problem, a plastic pipe was inserted to replace the removed rotor and it was locked to the spindle with the help of a screw clip. The end of the AC motor spindle was attached with a small diameter pin capable enough to tightly accommodate the rubber tube of the biro ink. This pin attachment could not be welded to the bottom end of the spindle due to the diameter of the pin. However, it was soldered and served the intended purpose. The AC motor and the DC motor was linked together with the aid of the rubber tube through which the rotation from the AC motor spindle was directly transmitted to the DC motor without any increase or decrease in speed. A DC motor which gives a direct current was incorporated with the aid of a rubber tube fitted below the AC motor spindle to propel the DC motor which otherwise has no effect on the initial design.

Cup Anemometer Construction
Considering the importance of the weight ratio, an aluminium sheet was chosen instead of brass in the construction of the anemometer. This is done to ensure efficient propelling of the cups. The float ball to be used as the cups was cut into two halves. The cup anemometer was attached to the top of the guy pole. See figures 2-5

Schematic Diagram of Cup Anemometer and DC Motor

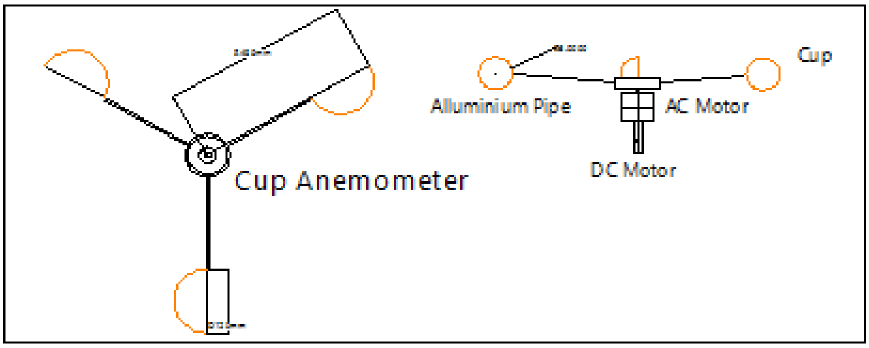

Figure 2: Cup anemometer and DC motor.

Schematic Diagram of the Wind Vane

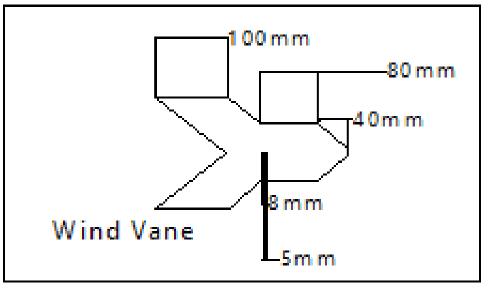

Figure 3: Wind Vane.

The wind vane was made of steel metal sheet of 0.20mm thickness.

Installation and Wiring

Installation:

The tower was laid out based on safety considerations and ease of installation. The tower was erected close to the existing building; but the task was much difficult as the mounting was done manually.

Wiring:

Communication cable was used to transfer the voltage generated by the DC motor. A flexible wire was doubled to reduce the risk of brakeage and consequently open circuit. The doubling has no effect on the resistance of the cable since its resistance is considerably low and thus prevents possibility of voltage drop. Guy Wire was used under proper tension to keep the tower system in equilibrium and thus vertical. This is essential to properly align the wind speed and wind vane. As a rule, it should be ensured that all guy wire tension adjustments are coordinated and are made smooth.

Figure 4: Tower Erection

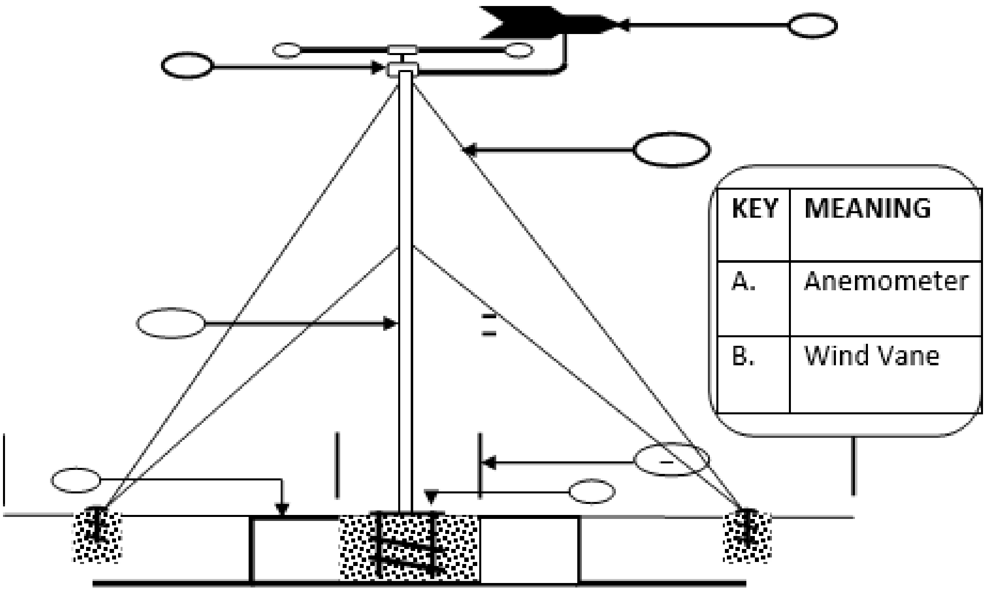

Figure 5: Schematic Diagram of Tower Installation

Tower Placement

Figure 6: Top View of Mini Campus Federal Polytechnic Offa, Kwara State Nigeria (source: Google Maps)

Calibration

The calibration was carried out in a sequential manner that portrays a good and accurate sensitivity checks. This stage cuts across every form of the setup needed for the proper function and operation of the cup anemometer and the wind vane. To determine the revolution per minute (rpm), the number of turns the cup makes per minute can be recorded with the use of either a tachometer or manual counting. This can be done by counting the number of times the marked cup turns in a minute from a starting point. The following were used for the calibration of the cup anemometer:

a) DC fans,
b) Measuring tape,
c) Multi-meter

Below are the steps in the calibration process which was done manually.

Step 1. The jet wind was set up and all doors and windows closed to prevent air disturbances. Also, the anemometer was placed 60mm away from the jet opening of the DC fan.

Step 2. One out of the three cups was marked as datum.

Step 3. The fan was put "ON" for about 15 minutes before taking the readings.

Step 4. In line with Richards (2009) postulation, the orifice of the anemometer was placed into the clamp and it was closed. After the cup shapes had been mounted in position, the wind tunnel apparatus was turned on and data recorded for both the number of turns of cup and the corresponding voltage readings. The readings were taken for six (6) different speeds and also in reverse order. The average voltage and measured data were then calculated as shown in table 1.

STAGE 1			STAGE 2			Average	
Measured Data	Voltage (Mv)	Rev/min	Measured Data	Voltage (mV)	Rev/min	Voltage (mV)	Rev/min
TEST			TEST				
1	44	21	1	43	21	43.5	21
2	40	21	2	41	20	40.5	20.5
3	53	23	3	48	23	50.5	23
4	51	24	4	52	23	51.5	23.5
5	57	27	5	58	29	57.5	28
6	62	27	6	62	28	62	27.5

Table 1**:** Calibrated Data

Anemometer cup radius = 0.43m

Circumference = $2\pi r$ (Chemistry club 2012)

= $2 \times 22/7 \times 0.43$

Circumference = ***2.7028*** m

Dividing each of the mean number of revolution in minute by 60 converts it to rev/sec multiplied by the circumference to give the speed. See blow:

Speed (velocity) = N x linear distance/60 (Chemistry Club, 2012)
Where:
N = Revolution per minutes (rev/min), But N/60 = (rev/sec)
r = Radius of anemometer

S/N	Calibrations	
Fan Speed No	Voltage (Mv)	Speed (m/s)
Fan Speed1	43.5	0.9450
Fan Speed 2	40.5	0.9225
Fan Speed 3	50.5	1.0350
Fan Speed 4	51.5	1.0575
Fan Speed 5	57.5	1.2600
Fan Speed 6	62	1.2375

Table 2: Calibration Results

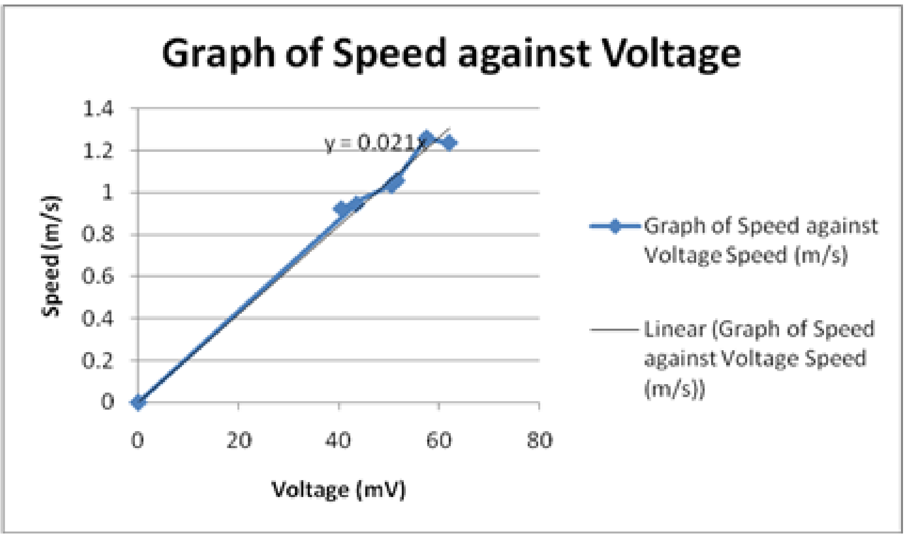

Figure 7: *Graph of Voltage Against Speed*

Graph equation: y = 0.0209x

Where:

y = speed (m/sec)

x = Voltage (mV)

Results and Discussion

Equation of the graph will help in construction of the speed range in m/sec in relation to the voltage readings from a multimeter.

Voltage (mV)	**Voltage (mV)**	**Voltage (mV)**	**Voltage (mV)**
57.4	93.5	100.2	30.4
19.2	98.3	48.2	49.9
79.5	75.5	***19.2***	
89.6	100.5	2.02	
52.5	28.1	2.11	
88.5	90.8	2.25	
52.2	100.2	64.7	
80.3	30	75	
70.5	62.8	65	
55.3	92.9	30.2	
31.2	42.7	34.8	
84.3	86	45.2	

Table 3: Starting Threshold Reading

The minimum voltmeter reading is 19.2mV which corresponded to 0.4m/s, also known as starting threshold.

Findings and Conclusions

It is our finding in this study that the anemometer including the wind vane is exposed to the same wind flow. To guarantee this, we discovered that care must be taken that the cup anemometer does not interfere with the wind vane. It is also found that data for analysis can be obtained or generated on ground calibrations by using a cup anemometer mounted in front on a DC fan at a distance of 60mm apart using six different regulated speeds. When the number of turns made by the cup was noted with the corresponding voltage reading, the minimum voltage immediately after 0 V starts up was at 19.2 mV corresponding to 0.4032m/sec (Starting Threshold). It is our conclusion therefore, that it is possible to manually construct, install and calibrate a three cup anemometer and a wind vane if one follows the methodology adopted in this study.

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