Journal of the Nigerian Association of Mathematical Physics
***Volume 55* (February *2020 Issue*), pp165 –168**
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DOMESTIC POWER GENERATION USING SAVONIUS WIND TURBINESIN INTERMITTENT LOW WINDSPEED CONDITIONS

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Abstract

In Nigeria, wind energy has primarily been used for mechanical work because of her low speed regime. Pursuant to the low availability of electrical energy in Nigeria, high-torque, low speed wind turbines, such as the Savonius wind turbine (SWT), can be utilized for power generation. This project seeks to investigate domestic power generation in intermittent low-windspeed using a SWT in the Faculty of Engineering. This will, on the long run, make electricity available and reliable. A Semi-cylindrical Savonius wind turbine was designed, fabricated and installed at a height of 12ft, in the faculty of Engineering, University of Benin. The SWT, which consisted of rotor blades, a rotor shaft, a nacelle housing, a wind tower, a generator, pulleys, a rope, bearings, and an ultra-capacitor, was tested for a period of three months, to obtain the minimum velocity needed to cause a rotation in the rotor blades at no load, and when it was connected to a generator. The results obtained show that 1.8m/s and 3.67m/s were the minimum windspeeds required for consistent rotation to occur in the rotor blades when the transmission system was disengaged and engaged, respectively. The average windspeed, voltage and power values were determined to be 4.009m/s, 16.436V and 363.136W respectively. Furthermore, the wind direction and speed needed to be consistent for about 10 to 15 seconds for rotation to occur.

Keywords: Savonius Wind Turbine, Power Generation, Low-Speed Conditions

1.0 INTRODUCTION

Electricity is as important as the major factors of production, since it fosters economic growth [1]. Nigeria's population of 181,562,056[2], is served by power plants with5,900MW capacity [3]. These plants - hydroelectric, and Fossil fuel, are obsolete and inadequate. Fossil fuel plants are capital intensive [4], may be sabotaged by vandalization of natural-gas bearing pipelines [5], and are fraught with environmentally harmful effects [6]. Furthermore, the generation, transmission and distribution of 1000MW of electricity has been pegged at $5.4 billion [7].Improving the performance and economic competitiveness of power generation from renewable energy is, therefore, necessary.

Although, solar energy is a mature energy resource[8], it is expensive and plagued with reduced period of availability due to cloud cover or rainfall. Nigeria lies in the doldrums, characterized by light and unpredictable wind. Her wind speed range, 2.5 – 6m/s, is considered unsuitable for power generation, resulting in the neglect of wind energy. The annual mean wind speed and power density for Benin were determined to be 3.506m/s and34.639W/m^2, respectively [9]. In the University of Benin, the highest and least mean wind speeds(1.975 and 0.977m/s), occurred in March and November, respectively, with a mean annual wind speed of 1.496m/s [10]. Using the Battelle PNL wind power classification scheme [11], the wind resource in Benin falls into Class-1, appropriate for non-connected electrical applications like battery charging, and mechanical applications like water pumping.

The Savonius wind turbine (SWT), possesses attributes that make it ideal for low wind speed conditions[6], but its efficiency is low. Some level of research has been carried out on the SWT. The average value for the C_p or η, and the optimal value of β, are 0.30 and 0.15 respectively [12].Double-stage rotors perform better than their single-stage counterparts, two-bladed rotors are more efficient than those with three or four blades, but those with three blades or more are self-starting, rotors without overlap ratio (β) perform better, those with end plates have a higher efficiency, and the C_p is directly proportional to the aspect ratio (α)[13].In an experimental study in[14],the torque generated by the S-shaped SWT wasn't enough to cause a rotation with the power transmission system engaged. In [15] the mass reduction of a three-bladed rotor was attempted, in order to reduce the amount of inertia needed to be overcome to achieve rotation. He, however, couldn't achieve this in the short time he had. In [16], a Vehicular Wind Energy Converter (VWEC) – an SWT installed on a moving vehicle, to charge batteries, was designed and fabricated. In [6], a review on electrical energy generation using SWT, despite its low C_P, as a potential source of in Nigeria was done, citing possible locations for its use. These studies were mostly carried out in wind tunnels or in locations other than open fields. Therefore, the effect of wind physics on power production has not been studied. An instance is how the consistency of the wind in a particular direction affects power generation in a wind turbine. The feasibility of the wind energy conversion system, as a stand-alone power plant, also has to be studied. Therefore, the aim of this work is to investigate domestic power generation using a SWT in intermittent low-speed conditions in the Faculty of Engineering, University of Benin. The subsequent sections focus on the methodology, results and discussion, and the conclusion.

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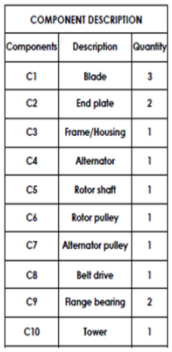
2.0 METHODOLOGY

2.1 MATERIALS

The SWT consists of a rotor, transmission system, a generator, and a wind tower. The isometric and pictorial views of the prototype are shown in Figures 1 and 2, respectively, while the components are listed in Table 1.



COMPONENT DESCRIPTION		
Components	Description	Quantity
C1	Blade	3
C2	End plate	2
C3	Frame/Housing	1
C4	Alternator	1
C5	Rotor shaft	1
C6	Rotor pulley	1
C7	Alternator pulley	1
C8	Belt drive	1
C9	Flange bearing	2
C10	Tower	1

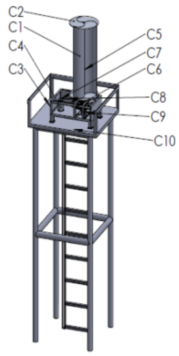


Figure 1: Isometric view of Savonius wind turbine

Figure 2: Pictorial view of the Savonius wind turbine

Table 1: Parts list

S/N	COMPONENT	MATERIAL	DIMENSIONS (mm)	QTY
1	Blades	Aluminum	Thickness: 2.5	1
2	Shaft	Alloy steel	h, ϕ, t = 1524, 40, 2.5	1
3	Rotor Pulley	Alloy steel	Diameter: 530	1
4	Generator pulley	Alloy steel	Diameter: 78	1
5	Bearing	Stainless steel	d, D = 40, 90	2
6	Housing covers	Stainless steel	l, h, w = 950, 270, 620	1
7	Wind tower	2-inch Mild steel	l, w, h = 1219, 1219, 3657	1
8	Generator	N/A	h, ϕ = 240, 85	1
9	Rope	Cotton		1
10	Ultra-capacitor	N/A	h,ϕ =10, 5	1

2.2 METHODS

The SWT was installed in an open field, on a wind tower 12 feet above the ground level. The rotor blades were then left to rotate under the action of natural wind currents, with two different settings – the rotor pulley disengaged from the rope drive (No-load), and the rotor pulley engaged to the rope drive. The value of the voltage produced by the generator, with the rotor blades in setting-2, was then recorded for different wind speeds. The wind direction and consistency were measured, as well as the time it took for a rotation to occur. The voltage readings were measured with an Alda DT-830D digital multimeter set to voltage function, while the corresponding wind speeds and direction were measured a digital hand-held anemometer.

The power in the wind, P_w, is given by:

$$P_w = \frac{1}{2}\rho A v^3 \quad [17] \qquad (1)$$

The power extracted by the turbine, P_T,

$$P_T = \frac{1}{2}\rho A v^3 C_P = P_w C_P \quad [17] \qquad (2)$$

with, $A(\mathrm{m}^2)$, ρ $(\mathrm{kg/m^3})$, and v (m/s^2). C_P, is the ratio of power extracted by the turbine to the total contained in the wind resource.

The electrical power produced by the generator is given by:

$$P = I \times V \qquad (3)$$

with, P (W), I (amps), and V(volts). I for the PMDC generator = 22.1 amperes.

3.0 RESULTS AND DISCUSSION

The minimum wind speeds required for rotation to occur in the rotor blade from rest, while disengaged and engaged from the transmission system were recorded to be 1.8m/s and 3.7m/s. Rotation was observed to occur when the wind speed and direction was consistent for at least 10 - 15 seconds. Abrupt changes in the wind direction resulted in a starting torque being cancelled by a braking torque. Table 2 shows the voltage, and electrical power produced by the generator at different winds speeds, while Figure 3 is a plot of wind speed vs electrical power generated.

Table 2: Results of voltage, and power produced at different wind speeds

S/N	Wind speed(m/s)	Direction	Duration(t)	Voltage(V)	Power(W)
1	4.42	W	12	18.42	407.08
2	3.78	SW	15	15.49	342.33
3	4.05	W	13	16.44	363.32
4	3.92	S	12	16.11	356.03
5	4.24	W	11	17.35	383.44
6	3.73	W	15	15.23	336.58
7	4.29	S	12	17.46	385.87
8	4.11	SW	13	16.93	374.15
9	3.85	W	14	15.83	349.84
10	4.27	W	11	17.42	384.98
11	3.67	SW	15	15.47	341.89
12	3.84	S	13	15.69	346.75
13	3.92	S	13	16.35	361.34
14	4.10	S	11	16.72	367.51
15	4.15	W	12	17.32	382.77
16	3.77	W	13	15.42	340.78
17	3.85	SW	15	15.75	348.08
18	3.96	SW	12	16.21	358.24
19	4.08	W	13	16.27	359.57
20	4.17	S	13	16.84	372.16

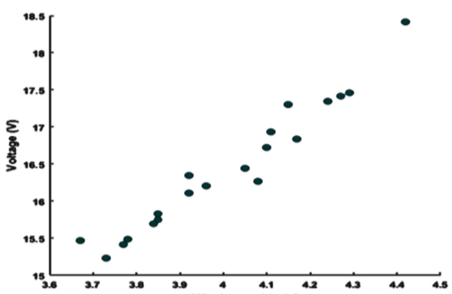


Figure3: A plot of Wind speed versus Voltage

The results show that at 12 feet above ground level, the amount of voltage needed to charge a 12V battery was generated at relatively low wind speed, and the voltage readings were directly proportional to that of the wind speed. Furthermore, while the SWT harnesses wind from all directions, the wind stream must be consistent in a particular direction per time. When the wind direction quickly changes, or is erratic, the rotor blade oscillates back and forth, as opposed to attaining full and consistent rotation.

4.0 CONCLUSION

The SWT, as fabricated and tested, is a good option, as a power generation device, in areas characterized by low average wind speed. It possesses the ability to rotate at a relatively low wind speeds, and utilizes wind in any direction, provided the wind is consistent in that direction. Open spaces are usually ideal when siting turbines, this allows for a build-up of the needed force inherent in the wind to cause a rotation in the turbine. It would appear that wind power in the site under investigation is not sufficient for a stand-alone system due to its erratic nature. Hence, a hybrid system may be adopted, comprising solar and wind energy conversion system.

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