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VERTICAL AXIS WIND MILL FOR DOMESTIC ELECTRIFICATION USING PIEZOELECTRIC GENERATOR

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ABSTRACT

The daunting challenges associated with the use of conventional techniques in small scale windmill turbine generators can be addressed by using synergetic methods pertaining to the basic design principle and by opting for different operating principle. Experimental investigations were carried out to study the feasibility of using piezoelectric generator to get enough power which can be used for just illumination purpose. The newly introduced LED bulb is a revolutionary technology as far as illumination is concerned. The low power requirements of LED bulbs has impelled this experimental investigation. The initial findings are too good to be ignored.

The cut-in speed, normally, of a conventional windmill turbine generator is seen to be around 5m/s. In the present experimental set-up a successful power output was obtained for wind speeds well below 5m/s. The power thus obtained was sufficient to charge a battery. The battery power was used to illuminate a small 5W LED bulb.

Key words: Small scale vertical axis windmill, low cut-in velocity, Piezoelectric generator, cam-follower mechanism, battery, 5W LED bulb.

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1. INTRODUCTION

1.1. Vertical Axis Windmill

A normal vertical axis windmill turbine generator consists of blades set-up, power transmission system, gear mechanism (in order to step-up the speed ratio) and an alternator generator (electromagnetic generator). The kinetic energy of flowing wind is transferred to the turbine blades and the blades start rotating. The blade motion is transferred through the gearing mechanism where the low speed of blades is increased to the alternator speed. Electric energy is produced in the alternator based on electromagnetic principal. Kinetic energy of wind is converted to mechanical energy in blades which is transferred and converted to electric in alternator. Such transfers and conversions of energy in each step entail losses.

Some of the types of vertical axis windmill turbine generator commonly used are Savonious rotor and Darrieus rotor. These are typically installed near to the ground. Their size is also a limiting factor for these machines to be used for commercial power production. As the size increases, the amount of material weight compared to the intercept area becomes too heavy to be self sustaining. But these disadvantages can be turned around into advantages if these machines are dedicatedly designed to power domestic units.

The biggest advantage of a Savonious rotor is it's self starting ability and low cut-in speed. These characteristics are very useful for a small scale unit.

Till date most of the research and experiments were carried out with a vertical axis wind turbine coupled to electromagnetic alternator generator. The electromagnetic coupling acts as a brake and increases the starting torque and cut-in speed.

By using piezoelectric generator instead of an electromagnetic alternator generator we explored the viability of a new technology.

1.2. Wind Power in India

By 2022 India has set the target of producing 175 GW of renewable energy. As per the plan 60GW will be contributed by wind energy. But the annual capacity addition of wind energy for last two years was below 2 GW. It is a drastic 60% decrease from the financial year 2016-17. This reflects a rather grim future for this sector.

Trend is to install windmills away from populated areas where high wind velocity is available uniformly and perennially. High rise hills, flat expanses, coastal areas or off shores sites are normally preferred. So the power that is used by urban areas is produced in remote locations. There is a lot of transmission losses to bring the remotely produced energy to the urban site of utilization.

In urban areas the residential buildings create obstructions to flowing wind. The wind velocity in the wake of the buildings reduces considerably. This restricts the installation of horizontal axis wind mill generator. But a vertical axis windmill generator which has a low cut-in speed can be successfully used in such situations. This will also help to utilize the urban land for producing power locally and thereby reduce the transmission losses.

All such small efforts will contribute to achieve the target producing the wind energy as per the plan.

1.3. Piezoelectric Generator

Using piezoelectric effect to produce energy is an old technique. But the electric charge produced is very small. It is used for only a few applications such as a gas stove lighter. It cannot be used as a power source from commercial point of view.

Earlier even a single fluorescent tube consumed around 36W. But with the introduction of LED technology, the method of illumination has been revolutionized. Now-a-days the residential units, schools, public places, schools, street lamps, government buildings and even vehicle are using LED bulbs for illumination. So the power requirements for these bulbs is reduced by up to five times.

The idea to explore the concept of collecting the small electric charge of piezoelectric crystal and using it to power a LED bulb has become possible and feasible.

2. PROBLEM DEFINITION

A vertical axis windmill turbine generator cannot be used to produce large power generation on commercial scale.

The urban land is under-utilized for wind power generation.

No technology, for producing power using wind energy, specifically dedicated for domestic electrification is developed.

3. OBJECTIVE

- To design and develop a vertical axis windmill system with a low cut-in speed.
- To fulfill the ever increasing energy demand and use of green energy.
- To produce power in accost effective and economical way
- To make the power producing system self sustaining.
- To promote the use of ‘Greener Energy’ and reduce pollution, global warming and carbon footprint.
- To develop a Green Energy system specifically dedicated for domestic illumination purpose.

4. METHODOLOGY

- Normally in a small scale windmill turbine generator a permanent magnet is used for electromagnetic induction. The magnetic flux coupled to alternator coil loads the turbine blades and increases the cut-in speed. When the magnet and electric coil set-up is removed, the unloaded blades can rotate freely at low wind speed.
- The gear system used to step-up the speed ratio also reduces the efficiency.
- In unloaded condition (without the alternator coupled to it) the Savonious rotor with optimum design and proper bearing supports was tested to have a low cut-in speed of 0.6m/s.
- The electromagnetic generator was replaced by a piezoelectric generator matrix.
- A specially designed cam-follower pair is fixed between the transmission shaft and the piezoelectric matrix. The blade motion is directed to the piezoelectric matrix through the shaft and cam-follower only.
- Since there is no need to step-up the speed ratio the gearing mechanism was removed thereby reducing the losses associated. This also reduced the overall weight and cost of the set-up.
- The piezoelectric generator module comprises of piezoelectric transducers placed in stacked orientation.
- Following factors were considered while preparing the piezoelectric matrix-
    - for small load impedances the piezoelectric modules were connected in parallel to get higher current outputs and equivalent capacitance.
    - for large load impedances the piezoelectric modules in series give high voltage and low equivalent capacitance. The final piezoelectric matrix were constructed by taking into account these factors.

- A matrix of 8*6 layout was used comprising of a total 48 modules of piezoelectric transducers.
- The surface contours of the cam is so designed to give reciprocating vibratory motion in the piezoelectric matrix.
- The vibratory motion produces stress in the piezoelectric transducers to generate minute electric pulses. A frame used to load the piezoelectric modules in a stack orientation has a set of springs which helps to produce a cyclic stress.
- An electronic circuit with capacitors and rectifiers convert the electric pulse output of the matrix into a constant output which can be used for charging of the battery.
- A 5W LED bulb was operated using the battery power.

5. EXPERIMENTAL SET-UP

The prototype model consisted of

- A multi-bladed Savonious rotor mounted on vertical transmission shaft.
- A properly designed bearing system supporting the transmission shaft.
- A set of cam-follower mechanism with the cam having special surface contours.
- A frame with provisions for stacking the piezoelectric matrix
- A set of springs to produce cyclic stress in the piezoelectric matrix
- A matrix of piezoelectric transducers in stacked orientation
- A electronic circuit board with all the capacitors, rectifiers, etc connected as per the design.
- 12V battery
- A LED bulb of 5W
- All the electrical connections as per the requirements.

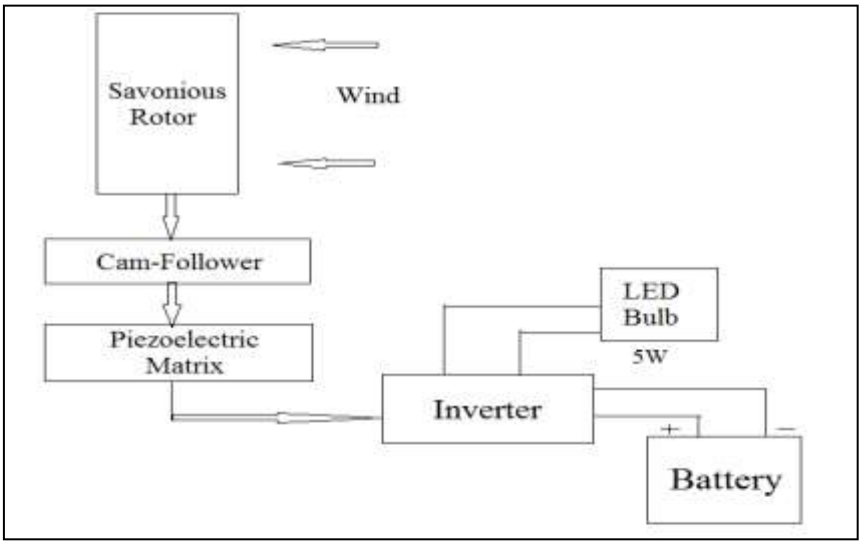


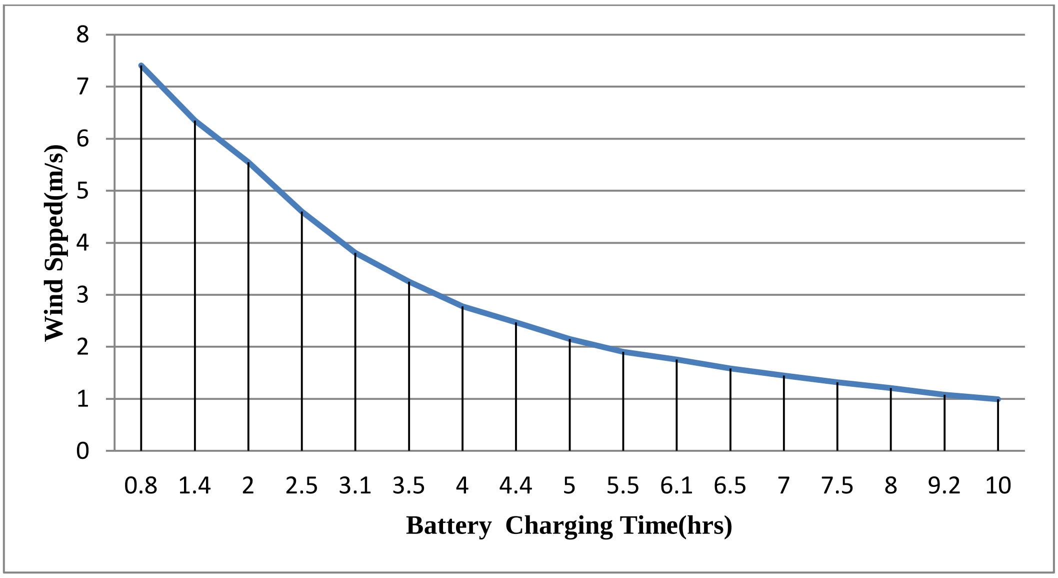
Figure 1 Experimental set up using Piezoelectric Module

6. RESULTS

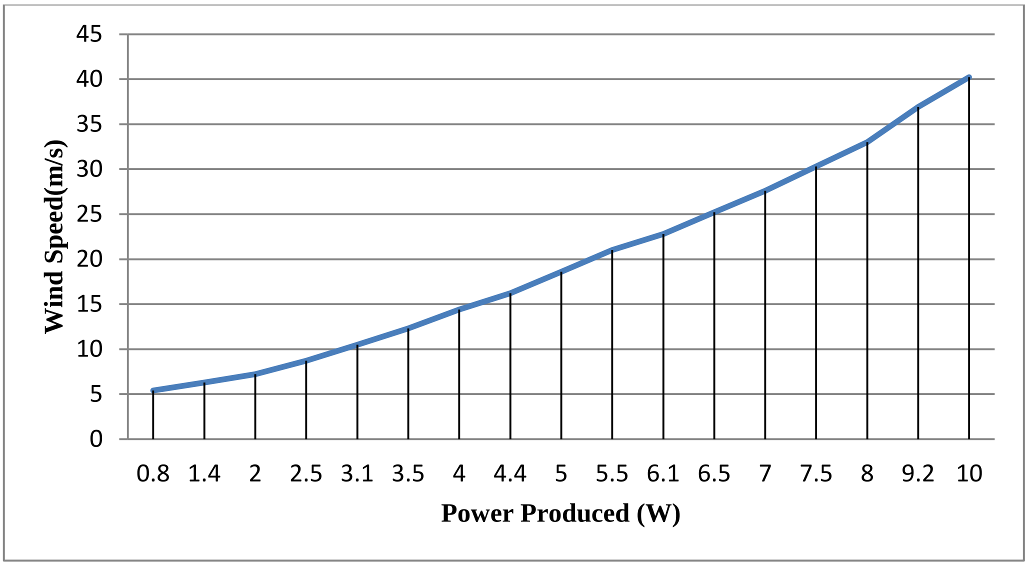
At different wind speeds time required for charging of 1,44000J

Table 1 Table Wind Velocity, Charging time and Power Produced

Sr. No	Wind Velocity (m/s)	Blade speed (rpm)	Power produced (W)	Charging time (hours)
1	0.8	16	5.4	7.407
2	1.4	21	6.3	6.349
3	2	24	7.2	5.555
4	2.5	29	8.7	4.597
5	3.1	35	10.5	3.809
6	3.5	41	12.3	3.252
7	4	48	14.4	2.777
8	4.4	54	16.2	2.469
9	5	62	18.6	2.15
10	5.5	70	21	1.904
11	6.1	76	22.8	1.754
12	6.5	84	25.2	1.587
13	7	92	27.6	1.449
14	7.5	101	30.3	1.32
15	8	110	33	1.212
16	9.2	123	36.9	1.08
17	10	134	40.2	0.995



Graph 1 Wind Speed vs Charging Time



Graph 2 Wind Speed vs Power produced

7. SAMPLE CALCULATIONS

- Capacitor capacity = 600 µF
- Total Piezoelectric module in a matrix of 8 × 6 = 48
- Output per module = 2.5 V
- Total taps obtained from cam-follower with each rotation of transmission shaft = 200

Energy stored in the capacitors

$E = 1/2\ V^2\ C$

$\therefore E = 1/2\ (2.5)\ (600 \times 10^{-6})$

$\therefore E = 0.001875$ J/tap/module

With 48 modules

$E = 0.001875 \times 48$

$\therefore E = 0.09$ J/tap

When the wind velocity was 1 m/s, the rational speed of rotor was 24 rpm.

Energy produced $E = 0.09 \times (24/60) \times (200)$

$\therefore E = 7.2$ J/s

Energy required by a 5 W LED bulb for 8 hours = 5 × 8 × 3600 = 1,44,000 J

Time needed to produce 1,44,000 J = 1,44,000/7.2 = 20000 s

Charging time = 20000 / 3600 = 5.55 hours

8. CONCLUSIONS

- A vertical axis windmill piezoelectric generator can be used for illuminating a LED bulb even at low wind velocities. This is specifically advantageous in urban areas.
- The set-up can also be used in remote and offshore locations.
- The vertical axis windmill piezoelectric generator is sturdy enough to withstand even turbulent wind conditions.
- A single windmill generator can produce sufficient power necessary for illumination.
- A number of windmill generators can provide for the basic power requirements of the entire household.

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