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The Era of Micro-windmills

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Abstract: *From the very existence of human civilization, there has been unprecedented lust to harness various energy resources for the betterment of the society. Traditionally, wind energy was used by erecting windmills in the potential areas. In late 90s, when wind power started its ascent, the rotating diameter of actual turbine was about 17 metres. As we say Bigger is better, the size of windmill blades grew from 17 metres to a whopping 126 metres. But a major breakthrough that revolutionized the pinwheel's harvesting principle was with the coming of MEMS [1]-based nickel alloy devices, which can be effectively placed in the pocket of a cell phone. An ambient wave could effectively recharge the phone's battery. This paper aims at reviewing the various developments in the field of micro windmill energy harvesting. The semiconductor wafered structure makes the design suitable to be prefixed in a phone case. The paper also aims to highlight inadvertent challenges of micro windmill structure as posed by the prevailing technologies, which are a major field of research in near future.*

Keywords: *pinwheel, semiconductor wafered structure, MEMS.*

1. INTRODUCTION

With the improvement in the field of science and technology an increasing lust for mechanisation, there has been an ever increasing demand to meet the needs of ever increasing population, and to meet these demands, there has been a never ending tussle between mankind and natural resources. Overutilization of non-renewable resources, added with pollution, has made it mandatory to look for renewable resources.

Human civilisation from its very roots have known to harness these resources, but effective utilisation is yet another major concern. The cheapest available resource is wind, and if potential devices fabricated for the same are properly utilized, it will be a stupendous success.

The wind turbine system began with a few kilowatts of power in the 80s whereas this power has reached to multi-megawatts. Infact wind turbines upto 8MW have been widely installed. The power electronic technologies used in wind power generation have changed dramatically during the last 30 years [2-5].

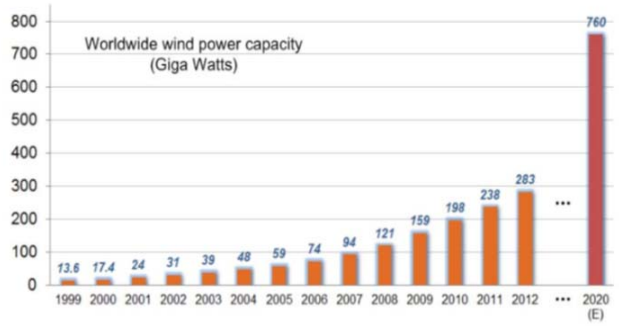

Figure 1. Global cumulative installed wind power capacity from 1999 to 2020.

Traditionally, wind energy was used by erecting windmills in the potential areas. A wind turbine, which is a rotating machine, converts the kinetic energy of wind into mechanical energy. If this energy is then transformed to electricity, the machine is referred to as wind generator, wind turbine, wind power unit, or wind energy converter. In late 90s, when wind power started its ascent, the rotating diameter of actual turbine was about 17 metres. The future developments, from MEMS structures to micro structures brought about significant changes in the existing scenario, thereby rubbishing the fact that - "Bigger is better".

2. HOW TRADITIONAL WINDMILLS WORK?

The windmills consist of metallic blades mounted on a supporting structure. The wind blowing at the speed greater than 15km/hr rotates the turbine.

Applying the principles of physics, force applied on the blades is converted into the sum of its centrifugal and centripetal force. Thus, it was quite sensible to make the blades as large as possible. The size of windmill blades grew from 17 metres to a whopping 126 metres. For the massive structure to work efficiently and to increase the uptime made during high velocity windy conditions, it was a basic requirement to install a strong framework which not only covers the essentials of power generation, but can also be the reason of reduction of the effect of damage in case of strong currents. But this further complicated the wind-energy harvesting.

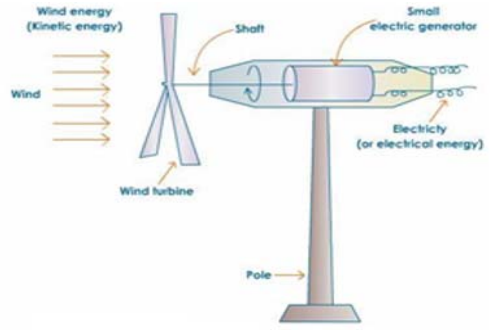

Figure 2. Working of the windmill

3. TRADE-OFFS WITH USING MASSIVE STRUCTURES

Firstly, it was difficult to install and maintain the massive structure in residential areas. Moreover, installation in the remote areas also creates a negative impact on underground habitats. Secondly, the so-called non-polluting turbines create a lot of noise pollution. Thus, "The Bigger is better" anecdote is not always the solution for everything.

4. MEMS TECHNOLOGY

Micro-Electro-Mechanical Systems (MEMS) is a technology that can be defined as miniaturized mechanical and electro-mechanical elements (devices and structures) that are made using the technique of micro-fabrication. MEMS devices generally range in size from few micrometres to a millimetre. They usually consist of a central unit that processes data (the microprocessor) and several functional elements that interact with the surroundings such as micro-sensors [6], microelectronics, microstructures and micro-actuators. Micro-sensors and micro-actuators are appropriately categorized as "transducer", devices that convert one form of energy to another form. In the case of micro-sensors, the device typically coverts a measured mechanical signal into an electrical signal.

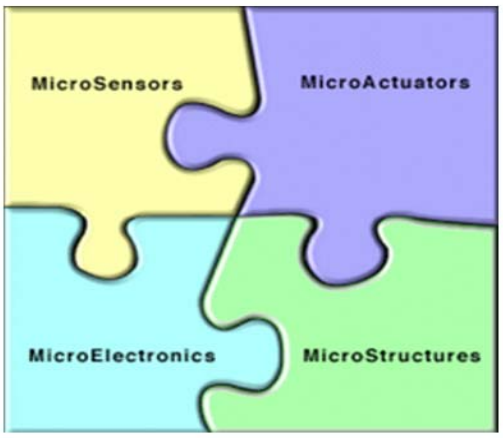

Figure 3. Components of MEMS

5. HOW MEMS BASED WINDMILLS WORK?

With the advent of smart era, need was felt to make windmills smarter. The windmills were conceived using MEMS materials [7]. Windmills were equipped with MEMS sensors and transducers, it though complicated the design but the overall output efficiency increased manifold. The sensors would sense changes in wind pattern and auto-calibrate the inherent mechanical circuitry which enhanced overall performance. The attachment of storage cells further allowed wind energy to be used for posterity.

6. ADVANTAGES

- Better efficiency and output.
- Low inertia and high starting torque is well compensated by use of transducers.

7. DISADVANTAGES

- The use of associated circuitry, even chip size components anyhow increased the size.
- More power requirements.
- Increased expenditure in maintenance.

8. TRANSITION TO MICRO-WINDMILL STRUCTURE

In our current gadget-centric culture, one limiting factor for mobile devices is the capacity of the batteries that power them, we for sure cannot stop their usage, and thus we need to formulate devices which could overcome this very limitation. Wind turbines are a viable clean energy solution, but most of the innovations in wind energy, as we have seen so far have been large scale, and since those devices aren't exactly portable, they don't lend themselves to mobile device charging. The research began with development of vertical axis wind turbines (VAWT), which brought a wave in the market due to its portability and design. The renewable based distributed technologies in urban areas are generally implemented as small scale and micro-system because of the space limitation and comparatively lower levels of primary energy resources. In order to participate in U.K. Micro generation energy mix together micro-hydro, biomass, PV, and solar-thermal generation, wind-based electricity generation is considered as one of the preferred technologies, as per the U.K. Micro-generation Strategy [8].

The Trinity wind turbine, often called "portable Wind Turbine Power Station" carries an onboard battery, thereby making it portable enough to power personal gadgets.

9. MICRO WIND TURBINE FOR HOME

Figure 4. Rutland 504 micro-wind turbine

Keeping in mind the shortcomings of massive windmill structures, mini wind turbine- little Rutland 504 comes to rescue. Low power consumption, small size, noise immunity and portability have made it quite popular over time. The low start up speed of 5km/hr and excellent output, it has brought an alarming wave in the industry. If we allow for an average daily wind speed of around 10 mph over a 10 hour period, we would have a 6 watt output, trickling half an hour into a 12 volt battery. Thus, over the 10 hour period (10 × 0.5 amps) we would harvest 5 ampere hours on such a day.

Examples of their useful applications include: trickle chargers for battery top-up and maintenance, home stand-by lighting, small water pump operation, low energy garden lights and many others.

These turbines are very suitable for built-up areas, and on apartment terraces, particularly in locations exposed to adequate winds. The modern commercially produced mini wind turbine is a big improvement on the old farm and hobbyist models, in terms of efficiency, size, weight, and output. But a turn off in this case is over pricing.

10. MICRO-WINDMILLS FOR PHONES

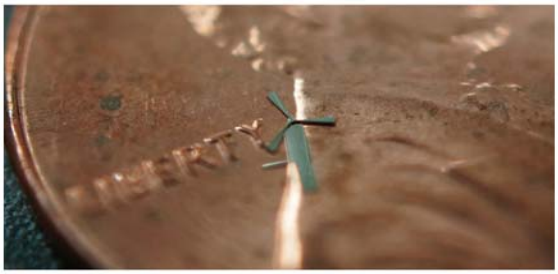

Figure 5. Micro-windmill

The major breakthrough was brought when the scientists at University of Texas, Professor of Electrical Engineering, J.C. Chiao and UT undergraduate student, Dr. Smitha Rao brought out a prototype for micro-windmills. These micro-windmills serve as a pristine and innovative alternative to cell phone battery charging. The researchers have filed for patenting the device which is about 1.8mm at the widest point. The pinwheels developed are about one-tenth the size of a single grain of rice. It is believed that hundreds of devices can be fixed in phone sleeve to recharge the phone. As per statistics 2040 devices can be planted in i-phone 4 in which each device generates electricity using wind currents. These tiny wind turbines amalgamate origami concepts into stereotypical wafer-scale semiconductors device scheme. It exploits planar multilayer electroplating principles. The day is not far when one can recharge the phone's battery by waving it simply in air for a few minutes. It is a matter of great concern if one could embed hundreds of such devices in a sleeve of a cell phone.

The aerodynamic design of the nickel-alloy-based micro-windmills can extremely increase the life of machines. The windmills can tolerate prolonged exposure to strong winds without any rough and tough in the material. Some parameters are required to be calculated while constructing a design namely chord length, angle of attack, power coefficient etc. by using Blade Element Momentum Theory [9-11].

The fabrication of micro-windmills is relatively an easy task. The fabrication cost of making "one device is the same as making hundreds or thousands of devices on a single wafer. So it is a cost effective method.

11. CHALLENGES TO MICRO-WINDMILLS

- There is a major problem of synchronization and wind variability with micro wind turbine. Due to this problem, stability of turbine gets reduced.
- MEMS designers face a lot of problems as materials are too brittle.
- The researchers are still examining potential challenges which can limit the design, like jamming of mini-rotor blades due to piece of dust can cause friction problems.

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