A Review Paper on Electrostatic Wind Energy Converter (EWICON) Method of Utilizing Wind Energy

[1]Rahul T. Dhanore, [2]Yeshwant M. Jibhakate

[1]G.H. Raisoni College of Engineering and Management, Chas, Ahmednagar, Maharashtra
[2]Kavikulguru Institute of Technology & Science, Ramtek, Maharashtra
Email: [1]rah.dhanore@gmail.com,

Abstract : This review paper presents an alternative method of utilizing wind energy for generate electricity to reduce supply-demand gap. The increasing global demand for energy has rekindled the interest for various forms of renewable energy production, including wind energy. In addition to the conventional methods of extracting energy from the wind. One of these methods is the electrostatic wind energy converter in which wind energy is converted to electrical energy by letting the wind move charged particles against the direction of an electric field. Also, we discussed here about two possible implementation of EWICON principle of which one is chosen.

Keywords : Renewable energy, Electrostatic Wind Energy Converter (EWICON), charged Particle, Wind Energy.

I. INTRODUCTION

Energy needs of the country is growing at a very fast pace to meet high GDP growth rate. Present peak electricity demand of the country is 135GW which is expected to grow to about 200GW and 283GW by the end of 2016-17 and 2021-22 respectively. To meet energy growing demand and to reduce supply-demand gap, there is a need of large capacity addition through conventional as well as from renewable sources. Considering the depleting domestic fossil fuel reserves in the country as well as increasing demand for energy consumption along with environmental concern. There is a need to harness alternate sources of energy. Abundant renewable potential in the country, presents excellent solution to meet above challenges i.e. attaining energy security. Access and delivery at affordable price along with addressing climate change contents.

While wind energy is often viewed as an energy source on its own, technically speaking, wind energy is mainly a form of solar energy, because air flow is generated due to the uneven heating of the Earth's surface by the sun. About 1% of the solar energy reaching the earth is transformed into wind energy. Due to the uneven heating of the Earth's surface, there are some locations that are more suitable for the exploitation of wind energy, like at sea or oceans, on wide open plains or along coastal lines. Worldwide energy consumption is growing and as countries like China and India are rapidly industrializing towards western standards, the demand for energy will become even higher. Some examples of methods employing renewable energy sources are:

- Biomass energy
- Photovoltaic solar cells
- Hydro energy
- Tidal energy
- Wind Energy

Of all the various forms of sustainable energy generation, wind energy is one of the most utilized forms, together with hydro energy. It is a growing source of sustainable energy which has the potential to ease the pressure on fossil based energy sources. The fact that there is virtually no CO2 emission when generating wind energy also means that this form of power generation could play an important role in global energy supply especially considering the issue of global warming.

So, while wind turbines still are the main devices to convert wind energy to electrical energy, there are a number of drawbacks that limit the widespread use of wind energy. The main drawback is the high cost of maintenance. This need for maintenance arises primarily from the conversion of wind energy to electrical energy via mechanical energy, i.e. the rotational movement that drives the wind turbine. Especially gear box driven wind turbines are prone to wear and tear and need to be maintained on at least a yearly basis. Added to the cost of maintenance are the costs for, amongst other things, construction, land lease and permits which makes government subsidies a requisite to enabling wind energy projects. Thus, at this point, the choice for the wind energy is a political one. Other drawbacks include the fact that conventional wind turbines are bound to circular surface areas, because of the rotational movement. This rotational movement is also the cause of noise and intermittent shadow nuisance. Another often heard complaint is that these wind turbines are responsible for what is called "visual pollution", especially when large wind turbine farms in rural settings are involved. A solution for this problem is to build wind turbine farms at sea. This, of course, introduces problems such as increased construction and maintenance costs.

A new concept, a system with very little mechanical movement i.e. EWICON System

As stated before, in all of the methods, that are used to convert wind energy into electrical energy, some form of mechanical movement occurs, which is the primary reason for maintenance and usually the primary cause of failure. Therefore, a concept in which there is very little mechanical movement would be ideal with respect to system complexity and maintenance costs. The EWICON method (Electrostatic Wind energy Converter) is a method which is based on the principle that the wind transports electrically charged particles or charge carriers in an electric field. Without going into great detail on how we will go about creating these charge carriers, we will discuss the principles of the EWICON method and its possible implementations into an actual system. In principle, any object, that can hold or store a charge, could be used as charge carrier. It is important to mention that the concept of converting wind energy into electrical energy by having the wind move charge carriers in an electric field is not new.

There have been several patents that propose a similar idea; however, most of these patents do not have energy efficient solution for creating charge carriers.

Principle

When a force acts on a body that undergoes a displacement, that force does work on the body. In the case of the EWICON system, the body is a charged particle with a charge q and the force is the electric force on the charged particle due to an electric field E, given by

$$\vec{F} = q \cdot \vec{E}$$

By allowing the wind to force the charged particles against the direction of this electric force, the potential energy of these charged particles will increase, similar to pushing a rock up a mountain against gravity.

$$dW = -dU$$

These charged particles with increased electrical energy can then be collected using one of the methods explained in the next section. In this way, wind energy is directly converted into electrostatic energy and the intermediate step involving the rotational movement, which takes place in conventional wind turbines, is taken out of the process.

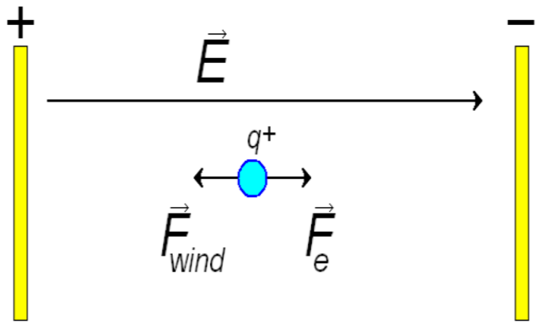

Fig1. A positively charged particle is pushed towards the positive electrode by the wind against the direction of electric field.

Type A: the patent of Alvin Marks et al.:

As we can see in Figure 1.7, in this implementation of the EWICON system, the charged particles are created by a charging system, which usually consists of a number of nozzles and electrodes, which is grounded. A stream of charged particles, which can be considered as an electric current, is then transported by the wind to a separate insulated collector, which is initially neutral. When the charged particles touch the collector, they will deliver their charge to the collector. This causes the potential of the collector to rise. This potential will have the same polarity as the charged particles cloud, thereby creating an electric field. Due to this field, an electric force will push the charged particles away from the collector. Initially, the wind force will be larger than the electric force and therefore the charged particles will still arrive at the collector. As long as this process occurs, however, the electric field generated by the collector will continue to increase, causing the charged particles cloud to either move back against the wind or around the collector. When the charged particles come in contact with the charging system or earth, the charge is lost and the net current decreases. Therefore, the wind has to overcome this repelling electric force and depending on the speed of the wind, the size of the collector and the load, the collector potential attains a maximum that further depends on possible leakage currents to earth via the insulator surface. If all produced charged particles are captured by the collector, then the maximum power of the EWICON has been attained.

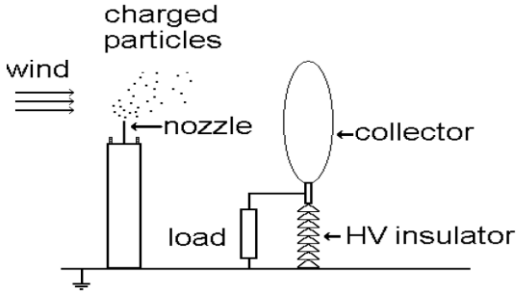

Fig2. Type A implementation of the EWICON system with an insulated collector.

Type B: the collector-less EWICON system:

In this implementation, depicted in Figure 1.8, the charging system itself is insulated from earth. There is no separate collector present. Since the charging system starts in an electrically neutral situation, dispersing charged particles will cause the potential of the charging system to rise. To be more precise, the potential will rise in case of negatively charged particles, it will decrease in case of positively charged particles. However, this time, the polarity of this potential is opposite to the polarity of the charged particles. This means that in the absence of wind, the charged particles will be forced back to the charging system resulting in a charge loss or net current decrease.

Again, depending on the speed of the wind, the quality of the insulation of the charging system and the load attached to the system, the system itself will reach a maximum potential. Basically, the earth acts as the collector for the charged particles and if all of the charged particles are transported to earth, then the maximum power that can be delivered is attained.

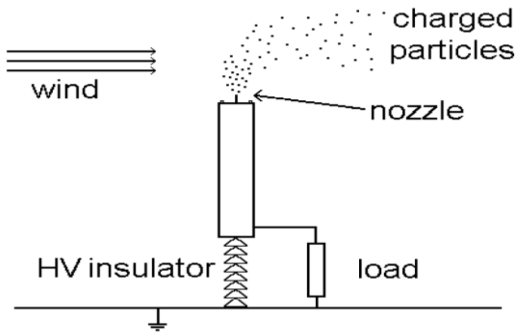

Fig3. Type B implementation of the EWICON system without collector.

	Type A	Type B
Charging system	Grounded	Insulated
External collector	Yes	No
Extra building effort	Yes	No
Alignment with changing wind direction	Only with both charging system and collector on a single rotational platform	Yes

Table 1. Comparison of the two implementations of the EWICON system.

Fig 4. EWICON System in Delft University, Netherlands [9].

Performance Index of the EWICON system

In order to compare the various implementations of the EWICON with the existing wind turbine technology and with each other, we have to clearly define numbers that characterize the system performance. This number, which will be called the EWICON Performance Index *(EPI)*, should include the efficiency ratio, η*EWICON*, of the converted output power, *Pout*, and the sum of the input power,

$$\eta_{EWICON} = \frac{P_{out}}{\sum P_{in}}$$

Where Σ*Pin* consists of the maximum recoverable power in the wind, the electrical power needed to charge the droplets and mechanical power to pump the liquid to the desired height with the desired flow rate.

$$\sum P_{in} = P_{\max} + P_{electrical} + P_{mechanical}$$

First of all, since the maximum output power of the EWICON system depends on the wind surface area, *A*, it stands to reason that the performance of a particular implementation is rated higher when it can convert more power from the same wind surface area.

Furthermore, since liquid droplets are used as charge carriers, the liquid flow rate, *Q*, also is an important parameter, which needs to be factored into the *EPI*. Lastly, in the case that the efficiency ratio, the liquid flow rate and the wind surface are equal, we want to rate an implementation as higher when it is able to produce a higher output power. All these considerations result in an *EPI* as follows

$$EPI \equiv \log\left(P_{out} \cdot \frac{\eta_{EWICON}}{A \cdot Q} \right)$$

Where we have taken the logarithm to manage the otherwise high values of the *EPI*, which could occur if *Pout* reaches the order of current conventional wind turbine.

Advantages of EWICON Systems

1. Apart from the floating charged particles, there are no moving/rotating parts present in the EWICON system.

2. The wear and tear commonly found in the gearbox systems of wind turbines will not be present in the EWICON system

.3. Due to the lack of moving/rotating parts, there is less noise originating from the EWICON system.

4. Due to lack of moving/rotating parts, gearbox system and other mechanical parts, maintenance cost and investment cost will be low.

5. There is no rotational movement in the EWICON system, increasing the wind surface area does not necessarily have to go hand in hand with an increased circular wind area.

CONCLUSION

In this paper, the EWICON concept has been introduced as an interesting future alternative to the conventional wind turbine generator. In the paper, the theoretical foundation was provided on which, in the subsequent topics, the practical aspects could be built, such as droplet creation and charging methods or the choice of spraying liquids. In general, the EWICON concept has been proven to be able to achieve a net gain in terms of output power depending on the used methods and more importantly, the used spraying liquid. Using mixtures of water and ethanol in combination with the EHDA method proved that it was possible to generate high droplet currents which resulted in positive conversion efficiencies. However, using tap, salt or demineralised water, yielded lower conversion efficiencies, even when considerable amount of effort was put into the design of the charging system.

Therefore, the EHDA method needs to be optimized to spray water with high currents, in order to develop a commercially viable wind energy converter based on the EWICON concept. In general, the EWICON concept has been proven to be able to achieve a net gain in terms of output power depending on the used methods and more importantly, the used spraying liquid. Using mixtures of water and ethanol in combination with the EHDA method proved that it was possible to generate high droplet currents which resulted in positive conversion efficiencies. However, using tap, salt or demineralised water, yielded lower conversion efficiencies, even when considerable amount of effort was put into the design of the charging system. Therefore, the EHDA method needs to be optimised to spray water with high currents, in order to develop a commercially viable wind energy converter based on the EWICON concept.

REFERENCES

[1] Williams, P., Lansdorp, B., and Ockels, W., “Flexible Tethered Kite with Moveable Attachment Points, Part II: State and Wind Estimation,” AIAA Atmospheric Flight Mechanics Conference, 2007

[2] Keith, D.W., DeCarolis, J.F., Denkenberger, D.C., Lenschow, D.H., Malyshev, S.L., Pascala, S., Rasch, P.J., “The influence of large-scale wind power on global climate”, PNAS, volume 101, no. 46, 2006

[3] Visschedijk, B, Graduate thesis “Electrostatic Generators”, NanoStructured Materials Group, Faculty of Applied Sciences, Delft University of Technology, 2005

[4] Sato, M., Nakayama, Y., Pan, R., Ueta, K., Shimada, Y., “Study on EHD Wind Power Generation Utilizing Charged Water Droplets due to Contact to Electrode”, International Symposium on Electro hydrodynamics, pp.33-36, Argentina, 2006

[5] Cloupeau, M. “Research on Wind Conversion by Electrofluid Dynamic Processes”, Arch. Mech., vol. 5, no. 6, pp.529-538, 1986

[6] Lawson, M.O., von Ohain, H., Wattendorf, F., “Performance potentialities of direct energy conversion processes between electrostatic and fluid dynamic energy”, Aviation Research Laboratory, vol. 178, 1961

[7] Bodega, R., Sonneveld, P.J., Morshuis, P.H.F., van Rooij, R., van Eldijk, L.G.M., ”Conversion of wind into electrical energy without the need for moving parts”, 8th International Symposium on High Voltage Engineering, Millpress, Rotterdam, 2003

[8] Peskin, R.L., Raco, R.J., “Ultrasonic Atomization of Liquids”, Journal of Acoustical. Society of America, vol. 35, pp.1378,1963

[9] http://wonderfulengineering.com/ewicon-the-worlds-first-blade-less-wind-turbine/

◈◈◈