Triboelectric Nanogenerator technology potential in agricultural LED lighting

Ibragim M Bamatov¹ and Dzhabrail M Bamatov²

¹ FGBOU VO "Chechen State University", 32, Sheripova str., Grozny, 364024, Russia
² Centre of Collective Usage, Grozny State Oil Technical University named after Academician M. D. Millionshikov, Prospekt Kh. Isayeva, 100, Grozny, 364061, Russia.

E-mail: Ibragim-1991@mail.ru

Abstract. Nanogenerator Technology is gaining more and more popularity among the scientist society. The triboelectric nanogenerators in particular are already used in different industries. The aim of the work was to see the achievements in the field, and what the state of art of triboelectric technology can offer to solve some of the problems agriculture industry is facing today. A way to implement the technology to a greenhouse was introduced in the work, to reduce the cost for the usage of LED lighting in the greenhouse. It was calculated that triboelectric nanogenerator system that is a kilometre long and a metre wide can potentially support LED lighting in a greenhouse with an actual area of coverage of more than 650 hectares. The actual numbers are expected to be very different since there are no evidences of the technology being implemented at this stage of its development into the agriculture as a LED energy source. The system was suggested to be made near a busy motor way to convert the kinetic energy of the cars into the electrical power. The system is expected to have many advantages over the conventional electromagnetic power generating system, but due to obvious disadvantages of the dependence of the energy generated on the traffic, the technology is suggested best to be used in combination with electricity from public network.

1. Introduction

The modern age of technological advancement is going in the direction where the world we know today will change to the one where the usage of energy resources will be increasing exponentially. Scientist around the globe have been offering their solutions to the problem of predictable energy shortage. One of the offered solutions among the other is nanogenerators. Nanogenerator is a piece of technology that can convert mechanical, thermal, chemical, radiation force interacting with the generator into electrical energy [1].

Nanogenerators designed to produce electricity at low frequencies of a few Hz as compared to conventional electromagnetic generator that can produce electricity at only high frequencies (more than 50 Hz). Different types of nanogenerators have been created since 2006 when the first nanogenerator was introduced. There are four major types of nanogenerators namely triboelectric, piezoelectric, pyroelectric and electrochemical nanogenerators. These nanogenerators use a different type of physical effect to produce electricity and therefore have a huge variety of possible usage in different areas and of course the industry of agriculture should not be an exception as well [2].

Agriculture has been steadily developing and the usage of new technologies in the industry is drastically increasing. The energy consumption for the industry as a consequence is increasing as well.
The integration of the technologies reached such a state that it would be difficult to imagine today’s agriculture for example, without the usage of LED lights. The LED lighting alone can increase the quantity and the quality of crops by a few times.

However, nothing comes without disadvantages. LED lighting requires a lot of funds for power generation, and causes extremely large electrical bills, so much so that debates whether it is profitable to use LED lighting or not are very common amongst the agricultural society. The reason for which is the very compatibility feature of LED with conventional electromagnetic generator where the LED consumption of voltage is high and current is low, whereas the conventional generator is designed to produce high current and low voltage. The nanogenerator technology comes into play in this aspect since the nanogenerators are designed to produce high voltage and low current which exactly matches the needs of LED [3].

The aim of this work is to provide an answer whether the nanogenerator technology can be used to solve the problem of excessive energy consumption for LED lighting, to what extent it can be solved with the state of the art and what is the future potential of the technology in the industry. An implementation method for the technology was to be offered. The advantages and disadvantages of the offered system were to be stated.

2. Discussion
Nanogenerator technology is one of the fastest growing areas of scientific research. Triboelectric nanogenerators are already being used in different industries. Triboelectric effect is physical phenomenon that was first discovered for more than a millennium now and is a way of transferring electrical charge from the friction between two dielectric materials due to charge polarisation. The effect itself however was unfairly dismissed since in classical electromagnetic method of power generation, charge polarisation is considered a small effect with almost no benefits to gain from. However, with introduction of triboelectric nanogenerators this convention changed completely. In 2006 first triboelectric nanogenerator was introduced as a converter of mechanical energy from a simple finger motion into electrical power and since than the development of the technology is surpassing all predictions [2, 13].

Electrical power output of nanogenerators is depended on two factors, first it is the conversion efficiency and second it is the total harvesting surface area of the triboelectric material. The conversion efficiency coefficient is prone to change with time and more research, in 2006 it was less than one percent. Today’s researchers state that the energy conversion efficiency for triboelectric nanogeners can reach up to 90% with the technology present and that it can still be increased. Whereas the surface area can be tricky since some of the materials that increase the efficiency coefficient might be expensive. On the other hand, there is a huge variety of cheap and accessible materials for triboelectric nanogeners with only slightly less conversion efficiency which allows for greater area coverage. Power output of nanogenerators can vary depending on the type of the generator and surface area. For instance, the triboelectric nanogenerator energy harvesting system based on a single-comparator control algorithm can harvest energy of up to 40 W per meter squared in a second. If the nanogenerator harvesting surface coverage is a kilometre long and a meter wide, in ideal situation where all of the mentioned are is generating electrical power, it could potentially generate of up to 40 kW of electrical power in a second. Considering a typical greenhouse, a square meter of the greenhouse that is smartly using LED light support would require about 2 kW of power per annum. This would mean that the mentioned above triboelectric nanogenerator theoretical set up can generate energy enough to support a greenhouse with total area of 650 hectares. In a real world however, only some part of the nanogenerator surface area will actually be generating the energy and the actual electricity generated will much less, however the area of the greenhouse could easily be matched to the optimal interaction surface area of the triboelectric nanogeners [4,5,6].

The questions are then if there is a way to implement the technology into agriculture, how plausible it is, what are the limitations and what are the advantages and disadvantages. The implementation of the technique is to be started with the very beginning of choosing a location where the greenhouses would
be located. Since triboelectricity is a power that is generated due to friction, and therefore a proximity to a piece of a busy motorway is an ideal location. Smart placing and design of the nanogenerator technology underneath the road, would potentially allow a conversion of the kinetic energy of a passing car above the road into electrical power with a very high efficiency. The modern state of the art of the nanogenerator technology has everything needed for efficiency to reach above 70% with a very low cost for materials which shows that the integration of the technology is easily affordable. The nanogenerator energy conversion efficiency is proven to almost not deteriorate over a century, which would mean that the technology would require almost no maintenance other than the power saving station itself [7, 9].

There are a few advantages of the triboelectric nanogenerator system over the conventional electromagnetic generator. First of all is the fact that the nanogenerator system is to be built only once and it should be able to last for centuries without any decrease in energy harvesting efficiency. Second is the fact that the energy produced is matching the consumption needs of LED’s since the required and produced energies have high voltage and low current. Thirdly is reduced need for maintenance of the system as compared to conventional generators. Lastly, the produced energy is renewable and environmentally friendly [8, 10].

The disadvantages for the told technology would be its dependence on the traffic on the motor way, since the lower the traffic, the lesser the electrical power generated. The mentioned triboelectric nanogenerator technology so far has not been used in practice, hence might prove to have difficulties of implementation and hence would be wise to use as an additional energy source to reduce the actual coast for LED light electrical consumption from the external net.

The integration of the triboelectric nanogenerator technology could greatly reduce the cost for LED lighting and the reduce the burden on the public electricity network. This would mean there are lesser requirements for maintenance of the network. The energy that is usually wasted can be recycled and used for the global benefit. However, there are still some improvements to be done to the technology, and hence it can only be used as an addition to the conventional electricity source. On the other hand, there is still a possibility of the triboelectric nanogenerator technology to replace the usual public electricity network as the energy source for LED lighting in agriculture in the future.

A study on the output optimization criteria was done to understand the nature of power generation for triboelectric nanogenerators. The study stated that the improvement of the generation impedance of nanogenerators requires the enhancement of frequency, improvement of amplitude and obtaining conformal contact and complete separation between triboelectric nanogenerator, whereas the improvement for the output power requires increase in the triboelectric charge density and inversely proportional to the dielectric constant. This means that as long as these parameters can be put together in a material for the creation of the triboelectric nanogenerator, the output power of the told nanogenerator can be increased. On the other hand, currently there are many investigations on topic of integration of the nanogenerator technology into a different kind of generation technology. One the most acknowledgements so far received the integration of the solar power generation technology into the triboelectric nanogenerators [11, 12].

These studies suggest that there is still a long way to reach the peak of the power output for the triboelectric nanogenerator technology. The conversion efficiency for of the materials has already reached about 90% and there is only some room left for the coefficient to increase. On the other hand the integration of nanogenerator technology and other types of generation technology have potential to make the agriculture greenhouses that use LED lighting, independent from the public electric network, and make the greenhouses self-sustainable energy wise. These improvements can only be done after extensive research, both fundamental and applied research and given the circumstances the triboelectric nanogenerator technology can be used to reduce the cost for LED lighting, however only as an addition to the existing system, and not as a replacement.

3. Conclusion
To summarise, the aim of the work was to investigate the state of art of the triboelectric nanogenerator technology and what are the possible usages of the technology in LED lighting in agriculture. The energy
conversion efficiency of the technology was found to have reached about 90%. The nanogenerators can be used from a variety of materials which can be either expensive or cheap. These two factors can be manipulated in order to reach the required energy output from the technology. One possible method of implementing the triboelectric nanogenerator system was introduced in the work since, the voltage and current of the produced electrical power matches the energy needs of the LED better compared to electricity from conventional electric network used in greenhouses. The introduced triboelectric nanogenerator system predicted to have some advantages over the electricity from public network: It is the renewability and environmental safety; it is also the reduced need for maintenance. On the other hand, the total independence from the public electric network is not seen in the foreseeable future, and there still have not been any live examples of implementing the told technology into the real live.

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