Piezoelectric Nanogenerators for energy harvesting at traffic lights

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Abstract. The existing traffic lights systems as it is, still have many problems which can directly expose to danger the health of civilians and can even endanger their lives. The aim of the work was to suggest a solution to these problems and to show what potential might hold the piezoelectric nanogenerator technology and piezoelectric nanogenerator road pads in particular that are being developed by the Collective Usage Centre for Scientific Research “Nanomaterials and Nanotechnology” of the Grozny State Oil Technical University after acad. M.D. Millionshchikov. In order to so a new piece of nanogenerator technology in the form of road pads was presented in the work. The mini generators are being designed to harvest the mechanical energy of the moving cars at traffic lights and convert it to the electrical power using piezoelectric nanogenerators. The research is still in its initial phase, but the results gained already show promising power output of 6kW per cubic metre of the piezoelectric nanogenerator area. The output power currently is not enough to create traffic lights system independent from the electrical public network, however the integration of the two power sources is considered possible.

1. Introduction

Today’s age of technological advancement is achieved through the use of astronomical amount of resources. Whether we should consume so many resources or not is a question that cannot be easily answered, but the question whether we should waste any of the resources or not does not even arise. There are different kinds of resources, but ultimately all of the resources are used to produce energy. Energy is what allows the humanity to move forward, and the more we advance the more energy is being consumed, the more energy is being consumed the higher the need to recycle the used energy.

Considering the universe, the most powerful source of energy are the stars. For example, our closest star Sun, it produces 3.846 *10²⁶ W per second, which means it produces about 0.000075 watts per second per square meter. Comparing to it for example to the energy human body produces, it easily can output energy that is 10000 times higher on a normal gym session. Another example would be the mechanical energy of the car movement, the energy which is again wasted without recycling [1].

The question is then if we can use this energy that so far has always been wasted? As it turns out, yes we can. Recent inventions of scientists in the field of nanotechnologies and nanomaterials allowed to turn the movements of human body or any other low frequency mechanical oscillations into electrical
energy using the so called nanogenerators. Nanogenerators are devices that generate electrical energy from subpar influences, either thermal or mechanical, experienced by it [2].

Piezoelectric nanogenerators (figure 1) are promising pieces of technology on nano scale made of piezoelectric materials based on piezoelectric effect. The most commonly used piezoelectric material in nanogenerators until recently have been materials containing lead. However, because of the damage that these materials can cause to the environment and biological species, more environment friendly piezoelectric materials have been invented such as zinc oxide or barium tritanate. The investigation of the piezoelectric materials is the field, which is still highly in demand of constructive research, but even the results that exist today show much promising future to the technology since the power output became strong enough to drive conventional electronic components [3].

Figure 1. A visual description of the structure of a piezoelectric nanogenerator that converts human motion into electrical energy [3].

The piezoelectric nanogenerators are introduced to more and more new industries and one the most promising industry is the power generation. The ability of the nanogenerators to self-power is sought after in many industries, such as sensorics or technologies that are totally depended on the conventional public electricity network, and the lack of which can endanger the civilian lives. One of such type technologies are the traffic lights. It is a very common occurrence where the traffic lights stop working due to the disconnection of the traffic lights from the public electricity network or disturbance of the network itself. The allocation of the traffic lights can also be problematic when the public network is not available in the immediate surroundings of piece of the road where the traffic light is supposedly needed [4].

The aim of the work is to show what potential might hold the piezoelectric nanogenerators in increasing the safety of the traffic light system and to see what the power output limitations are according to the state of art in the piezoelectric nanogenerator area of research according to the research of The Collective Usage Centre for Scientific Research “Nanomaterials and Nanotechnology” of the Grozny State Oil Technical University after acad. M.D. Millionshchikov.

2. Discussion
Nanogenerators can gift us a new energy source that potentially could solve the energy problem that is becoming bigger and bigger with every piece of electrical equipment created every year. First of all, it is the tremendous need for materials that can be used as a source for batteries, the limitation of which can already be felt today. Secondly, it is dependence of the absolute majority of electrical equipment on
the public electrical network, which then means that places that are not in close proximity to the network cannot be powered [5].

A single solution cannot solve the problem of increasing needs for batteries with the increase in the amount of different types of sensors we use, and in fact it is not even clear how it can be solved given the state of art in different research fields, however, it can be assumed that nanogenerators can solve the problem [8]. In this work, a way for energy harvesting is introduced in order to potentially limit the dependence of the traffic lights on the public electrical network and a solution to create an independent power source for the traffic light sensors is suggested.

The Collective Usage Centre for Scientific Research “Nanomaterials and Nanotechnology” of the Grozny State Oil Technical University after acad. M.D. Millionshchikov is currently developing a piece of technology based on the piezoelectric nanogenerators in order to harvest electrical energy at active pieces of roads such as traffic lights. The technology is planned to be made of high performance flexible piezoelectric materials in the form of road pads and is predicted to turn the traffic lights into micro power generators. These road pads are being designed in such a way, that they will not be disturbing the car driving process in any way and the roads will not be needing any modifications. The technology is still being developed in its initial phase, but even in the initial stages the power output is at 6 kW per cubic metre of the piezoelectric nanogenerator material. The power output potentially allows the integration of the piezoelectric nanogenerator road pads into the existing traffic light system in order to modify and improve the system to a revolutionary new level. Of course, there are still many problems to be solved before the technology is being finalised such as creation of novel and cost-effective high efficiency piezoelectric materials that can be fabricated via scalable production process, while providing high power output and making the final nanogenerator flexible, finalising the design of the nanogenerator maximizing the efficiency, comfort of the user while minimizing the cost for creation and so on.

Currently, the occasional failure in the power supply at the traffic lights lead to thousands of car accidents annually. Drivers rely on the traffic lights to safely get around the streets and such a failure or malfunction in the power supply system drastically increases the probability of car accidents and as a consequence increase the danger to human lives. Another problem with the traffic lights in the presence of the power supply malfunction is that the sensors responsible for sending the signal to inform about the malfunction cannot be sent without electricity. This might lead to delays in fixing the malfunction which further increases the risk of car accidents. These occasional failures substantially reduce the live time of the traffic lights and since the power systems are tested every time the power is supplied again the live time is reduced even further [6].

The traffic lights that are connected to the public electrical network on the other hand consume a huge amount of electrical energy even when there is no malfunction of the power system. It is done when no cars present on the roads, meaning no traffic lights required, for example deep into the night, when most of the time the roads are empty. The powering of the traffic lights consumes about 15% percent of the total energy consumption and considering that on average at least 2-3 hours a day roads are almost empty, the wastage of the energy is about 2% of the total energy is wasted [7].

Integration of the mentioned nanogenerator technology into the power supply system of the traffic lights will increase the live time of the traffic lights reducing the need for testing, it will allow conversion of the mechanical energy of the cars present at the traffic lights into the electrical energy to power up the traffic lights when there is a malfunction, and will power up the sensors to send the required signals to inform about the failures. The traffic light system then can be modified in such a way that the traffic lights will be using the energy harvested from a car as the power source for the sensors to inform the traffic light to work during the night times significantly reducing the wastage of the electrical energy [9]. This will allow to reduce the load on the public electrical network which then again would mean that less maintenance of the public network is required.

Unfortunately, the state of art in the piezoelectric nanogenerator field is not allowing for the total independence of the traffic lights from the conventional electrical network but as was discussed, there are many benefits to gain from merging the piezoelectric nanogenerators and conventional electrical
network in increasing the safety and efficiency of traffic lights for the general public while reducing the need for maintenance.

3. Conclusion
To summarize, the current traffic light systems are flawed in many ways, especially in cases when the power supply is interrupted or when the power supply should be limited to avoid the energy wastage. The Collective Usage Centre for Scientific Research in nanotechnology and nanomaterials investigating a potential solution to some of the listed problems even with the technical development at the moment in the form of piezoelectric nanogenerators. The piece of technology is to be made of high performance flexible piezoelectric nanogenerators in the form of road pads. The promising piece of mobile power generators in the form of road pads even in the initial phase give out a power output of 6 kW/m$^3$ which is considered to be of a good enough value to try out the merging of the introduced system into the existing traffic light system in order to increase the safety and stability of the traffic light systems that currently totally depend on the conventional public electric network as the energy source. The integration of the mentioned technology into the traffic light system is predicted to solve most of the mentioned problems and is considered as necessary modification for the existing traffic light system in order to increase the safety and comfort of the roads while reducing the energy wastage by the traffic lights and cars as well.

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