Internal resistance of batteries for storing electrical power harvested using piezoelectric nanogenerators

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Abstract. The dependence of power transfer through a circuit on the internal resistance selected batteries. A practical way for calculating the battery property was suggested and using the method, the values for “internal resistance, power output, changes in the voltage and current” with the change in the loaded resistance were calculated for the three selected batteries with the purpose to store the electrical power harvested using piezoelectric nanogenerators. The results obtained showed that for the “Carbon Zinc” battery the internal resistance was of value of 0.31 Ohms, for the “Motorbike battery” it was 0.82 Ohms, and for the “Green Cell” battery the value was the highest, reaching 12.02 Ohms. The results obtained inverse proportionality between internal resistance and power transfer and as a consequence, the power stored by the battery relative to its capacitance was affected.

1. Introduction

Nanogenerators are finding their usage in many different industries and power generation is one of them. Scientific research in the area is sharply increasing and in a way is becoming the trend for the leading universities of the world. The Collective Usage Centre for Scientific Research “Nanomaterials and Nanotechnology” of the Grozny State Oil Technical University after acad. M.D. Millionshchikov is not an exception and is researching a way to harvest the mechanical energy of the moving cars at traffic lights and convert it to the electrical power in order to merge the existing traffic lights systems with the new piece of piezoelectric nanogenerator technologies with the aim of increasing both safety of the public roads and the efficiency of power regulation.

Nanogenerators 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 a field, that 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 [5].
Figure 1. A visual description of the structure of a piezoelectric nanogenerator that converts human motion into electrical energy [2].

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 [1].

With the state of art in the piezoelectric nanogenerator field, the power generation as was mentioned provides a strong enough power output to drive some conventional electronic devices, however due to the nature of the generated electrical energy, the storage of the electrical power can be tricky. Different types of batteries exist as of today and each having their own unique properties invoke a different approach to be used in order to design a smart way of storing the energy efficiently and safely. Of the different internal properties of the batteries - the internal resistance of the batteries is one of the most important aspects to be kept in mind when designing the “Electrical Circuit” to store the harvested energy [2].

Ideally, any electrical circuit has some components that deliver energy into the circuit. These components provide “Electromotive Force (emf)”, for example power supply. Similarly, every circuit has devices that take energy out of the circuit. Across these devices there is a “Potential Difference”. Both components have the unit of measurement called the volt (V). Volt is a measure of energy per coulomb of charge going through that section of the circuit that was put in or taken out. A device that maintains potential difference between two points is called a source of electromotive force. There are two principal devices that act as sources of electromotive force; battery and generators. Batteries transform chemical energy into electric energy and generators convert mechanical energy into electric energy to maintain continuous flow of electric charge [3].

The aim of the work is to present a practical way of calculating the internal resistance for different kinds of batteries, namely a motorbike battery, AA Carbon Zinc battery and a Green cell battery [6]. The criteria for selecting the batteries for storage of the harvested energy is to be stated depending on the internal properties of the batteries such as internal resistance and power output.

2. Discussion
The idea to present the practical way of calculating the internal resistance depending on the power output was considered as a necessity due to a problem faced when calculating the real values of the stored energy compared with the theoretical values since the numbers didn’t match up even including the error
range of the calculations. After many considerations it was proved that the values for internal resistance of the batteries provided by the makers were flowed by a small margin and therefore the calculations had to be fixed accordingly.

In any circuit there is resistance within every source of electromotive force. This resistance is called internal resistance and is presented as the symbol \( r \). It is usually thought of small resistor, \( r \) connected in series with a perfect power supply equal to emf. The load resistance is also called external resistance and is presented using the symbol \( R \).

In a circuit containing one source of electromotive force the current is equal to the emf voltage divided by the total resistance in the circuit as represented in the following expression \( I = \frac{E}{R+r} \), where \( I \)-current, \( E \)-electromotive force, \( R \)-external resistance and \( r \)-internal resistance. Following the expression for the current an electrical circuit containing an ammeter, a variable resistor, a voltmeter, a switch and an electromotive source (batteries) was designed (Figure 2) in order to calculate “\( r \)” for the source [4].

![Battery and Circuit Diagram](image)

Figure 2. A diagram description of the designed electrical circuit.

The battery under consideration was selected. The electrical circuit as per (Figure 2) was setup. The suitability of the setup was checked for safety. The current and voltage results were recorded from the ammeter and voltmeter respectively. The variable resistor’s resistance value was changed allowing to change the amount of loaded resistance. The load resistance could not be lower than 1 Ohm (Ω), as it would create a short circuit. The results of terminal potential difference and current were recorded. From these values the load resistance and electrical power were calculated and recorded. Load resistance varied to change current corresponding values of \( V \) recorded. These steps were repeated for the two remaining batteries.

The experiments investigating batteries properties for storing electrical power harvested using piezoelectric nanogenerators showed that the electrical power depends on the current and potential difference and obeys the law for power. According to the Table 1, the green cell battery has the largest “\( r \)” of 12.02 Ohms, Motorbike battery has “\( r \)” of value 0.82 Ohms and Carbon Zinc battery has the lowest “\( r \)” of all three batteries reaching a value of 0.31 Ohms. The values for the internal resistance “\( r \)” can be explained as a results of the material the battery was made from, however the issue itself is more complicated because the capacity and the power output of the batteries also play an important role in summing up the internal property of the batteries such as internal resistance.

Table 1. Calculated data for the Electromotive force and internal resistance of the batteries.

| Battery          | Electromotive Force, \( E \)(V) | Internal resistance, \( r \)(Ω) |
|------------------|--------------------------------|--------------------------------|
| Carbon Zinc      | 1.62                           | 0.51                           |
| Motorbike battery| 12.88                          | 0.82                           |
| Green Cell battery| 8.51                          | 12.02                          |
The internal resistance of the batteries play an important role in changing the values for current and voltage while passing through an electrical circuit as can be seen in Figure 3. The power transfer was changing with correspondence to the internal resistance with inversed relationship, which means that the decrease in the internal resistance of the batteries resulted in the higher the power transfer through the circuit. Leading to a conclusion that for the highest power transfer while storing the electrical power from the piezoelectric nanogenerators, the batteries to be used are suggested to have as small internal resistance as possible.

**Figure 3.** Graphical representation of the Current and Voltage differences between the three different types of batteries with change in the total resistance.

### 3. Conclusion

To sum up, three different power storing batteries were analyzed investigating the behavior of power storage depending on the internal resistance of selected batteries. Results obtained proved to have a direct relationship between power transfer to the battery and internal resistance. Any change in one variable corresponded to a change in the other. The batteries had different indications for electromotive force, internal resistance and power output. The internal resistance is different due to different materials used for batteries. Power transfer through the circuit is different due to difference in internal resistance, capacity and power output. Variable resistor allowed to vary the loaded resistance, which showed how the power, current and voltage changes with resistance. Overall, the results are complementing each other in the point to indicate that internal resistance and power transfer are in a codependent inverse relationship and that the higher the internal resistance the lower the power transferred for storage in the battery.

### References

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