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Piezoelectric effect as an energy generator: A describal historic of its performance

Diogo de Souza Marinho, Fabiana Rocha Pinto, Emmanuel Rocha Baptista

Department of Engineering, Centro Universitário FAMETRO, Manaus, Amazonas, Brazil

***Abstract*— Knowing that world population, process automation, energy demand and environmental impacts increase every day, the energetic efficiency analyses the supply possibilities of the increasing electricity usage. Thus, the article describes the historical performance of the piezoelectric effect studies implemented in Brazil and worldwide, represented as an alternative for power generation in small and large applications, comparing with other existing renewable sources and listing their advantages and disadvantages. It has gotten as a result it is an old technology, however low used in energy generation. The generation by piezoelectric effect does not emit greenhouse gases, does not work with combustion and does not need renewable resources such as sunlight, actions from wind or water. The PZT ceramics are deployed in urban and busy locations such as highways, airports, railways, sidewalks, supermarkets, and soccer fields around the world, attending the demand in small daily applications, getting great strides in reducing greenhouse gas emissions caused by non-renewable sources and some renewable sources. It was concluded that there is a possibility of diversifying the energy matrix with existing technologies, in simple applications such as residential and public lighting, as well as encouraging the elaboration of research and projects that can decrease the environmental impact and increase the energy efficiency.*

Keywords— ***piezoelectricity, crystals, energetic efficiency.***

I. INTRODUCTION

Increasingly, the technology offers time and labor saving devices using just a power outlet or electric switch. Thus, any construction, new or reformed, causes an increase in demand [1]. The traditional sources are slowly decreasing their availability, so fossil fuels need to be reduced not only aiming its reduction, but also as an condition of mitigate the impact on the environment, which is primarily responsible for environmental change.

In the modern world, improved living conditions are linked to access to electricity, as per capita energy consumption is taken as a country's development index [2]. The importance of the energy matrix diversification, therefore, increases not only the energy offers, but also ensures the supply of demand.

According to [3], the energy issue in Brazil was only really felt in the early 2000s, with blackouts that lasted for hours. The [3] considers that generating a new MW costs 200% more than saving a MW. Given the energy incident in April 2001, a federal decree imposed emergency rationalization measures looking forward to demand reduction and electricity offer increases, determining to the federal government agencies the reduction of electricity consumption by 20% until December 31, 2002, which did not occur.

In addressing Energy Efficiency theme, the key question is how to innovate with as little environmental impact as possible and maximum performance, given the increase in energy consumption provenient from world population growth. The study of innovations in the field of power generation is justified, given the high demand of the current scenario, depending on non-renewable raw material and high cost works.

The most common examples are the wind actions, sunbeams, geothermal sources, hydro and biomass. A water turbine reaches up to 90% yield, a wind turbine can convert 59,3%, a steam turbine reaches 60% and a solar cell ranges between 6 and 40% [2].

The discovery of the piezoelectric effect occurred during 1880, by brothers Pierre and Jacques Currie, by attempting to electrify insulating materials to conductive crystals, being them aluminum paper, glue, wire, magnets, quartz crystals, topaz, sugar cane, Rochelle salt and tourmaline. The experiment resulted in creation of the piezoelectric quartz electrometer [4].

The following year, Gabriel Lippman discovered the existence of the reverse piezo effect through thermodynamic principles that occur in electronic circuits. The first piezoelectric effect applications were used by Paul Langevin in sonar development during the First World War [5].

In 1996, Thad Starner explored the possibility of harnessing energy eliminated during daily efforts to power computers and portable devices, while Mikio Umeda created a model to investigate the impact of a steel ball coated by piezoelectric material, in order to generate useful electricity [6].

The piezoelectricity is a phenomenon where certain crystal compositions generate electric charges, which appear as direct or reverse. The direct piezo effect generates the electric field when subjected to mechanical pressure action, already on reverse effect occurs deformations of the material resulting from an applied electric field [5].

The piezoelectric effect is applied at ultrasound devices, sound amplifiers, electric actuators, scales and impact detonators. [7] cite crystals as zinc sulphide, sodium chlorate, magnesium chloroborate or boracite, tourmaline, quartz, zinc carbonate or calamine, topaz, sugar and Rochelle's salt or Seignette's salt.

The objective of this study is aimed to describe the piezoelectric effect as an alternative energy source, evaluating the history of its performance over the years, seeking to describe a cost vs benefit ratio and possible reasons for their entry into the current scenario.

II. MATERIALS AND METHOD

The research procedure is based on a case study with a qualitative approach, when it comes to the energy efficiency theme in a contemporary situation focusing on the study of previous phenomena, research data and applications.

The evaluated basis seeks to describe the history of use of piezoelectricity, citing its main activities and where it can be operated, also make comparisons of costs related to other energy production models and characterize advantages and disadvantages.

Documentary data were collected to produce a descriptive table about the projects applied in cities at Europe, America and Asia.

III. RESULTS AND DISCUSSION

Each piezoelectric material has its own piezoelectric constant, the table 1 exemplifies some of these values for the respective materials, being the piezoelectric constant, given by 10^{-12} m/V and the dielectric constant measured in C^2/Nm^2.

Table 1: Main values of the piezoelectric constant and dielectric constant of important piezoelectric materials.

Material	Piezoelectric constant (d)	dielectric constant
Genuine piezoelectric		
Quartz (SiO_2)	-2,3	4,5
Tourmaline	-3,7	6,3
Ferroelectric		
Barium Titanate ($BaTiO_3$)	390	2,9
PZT ($Pb_{0,5}Zr_{0,5}TiO_3$)	370	1,7

Source: Adapted from [8].

The piezoelectric constant has a higher index in ferroelectric materials, as they are made and synthesized in piezoelectric ceramics, obtaining better yield than genuine crystal. The Lead Zirconate Titanate (PZT), despite smaller constants than barium titanate, it is the most efficient material, reaching the 80% generation yield, being the most applied in large scale projects and works. The table 2 shows the estimated power per converter type.

Table 2: Estimated power in ideal model situation.

Conversion mechanism	Estimated power - ideal model
Piezoelectric converter using PZT	277
Piezoelectric converter using PVDF	260
Electrostatic converter	42,7

Source: Adapted from [9].

According to [9], a PZT piezoelectric converter prototype, on ideal situation, applying 100Hz frequency and 2,26 m/s² acceleration, can generate even 277 μW, value quite above a conventional electrostatic converter. It is still possible to consider the use of fluorine polyvinyl in the same applicability, reaching an index five times higher than the electrostatic converter.

The sun contributes directly to the source of photovoltaic and thermal solar energy, wind energy, biomass and the water and tides course [10]. The various renewable sources have lower environmental impact, allowing to decrease greenhouse gas emissions and

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improve the air quality, a necessary factor in the current scenario. Even decreasing the aggressions on the environment and diversifying its matrix, it is still visible that there are some instabilities (Table 3).

Table 3: Advantages and disadvantages of renewable energy

Advantages	Disadvantages
Infinite source of power generation	Biomass Bureaucracy for implementation Uses combustion method
Does not emit greenhouse gases	Hidroelectric Soil erosion Impacts on the local ecosystem
Energy matrix diversification	Wave energy High deployment cost Depends on coastal area Wind energy
Investments in more jobs	High deployment cost Depends on locations with high airflow index
Lower risk than nuclear power	Nuclear energy High risk of explosion High deployment cost Solar energy
Increased energy autonomy of the country, besides investment in studies (new alternatives)	High upfront costs Thermal energy CO_2 emitter Diesel oil usage

Source: Adapted from [10]

As seen in the table, renewable sources can be clean and inexhaustible. However, in terms of quantity, there is a time and place to use each one of them. Like the water resource, the hydroelectric plant imposes the displacement of an entire ecosystem. Tidal energy is limited only in the country's coastal area; Solar and wind power are the fastest growing today, but still have high implementation cost.

The piezoelectric power generation does not require sunlight for its generation, the place to be deployed can be in busy places inside the city and depending on the material achieves higher yield than other sources. The problem faced is low crystal production, often for restricted use, as well as high investment for large-scale projects due to the difficulty of storing energy.

Despite being a clean, profitable and old technology, its development was limited to the creation of sonar and ultrasound devices, explained by its piezoelectric coefficients and frequency ranges. Among the studies and applications that contribute to the growth of piezoelectricity, table 4 shows the works applied in the world for power generation.

Table 4: Piezoelectricity applications in the world

Project description	Year	Company / Origin
Road, airport and rail studies and testing in Haifa, Israel	2007	Innowattech / Israel
Creation of Watt night club. The technology was titled Susteinable Dance Club (SDC) in Rotterdam, Netherlands	2008	Eindhoven University of Technology, Netherlands
Self-supporting system installation at Club Surya in London, England	2008	Andrew Charalambous and engineers in England
Piezoelectric installation at two train stations in Tokyo, Japan	2008	Soundpower / Japan
Floor installation on Bird Street sidewalk in London, England	2017	Pavegen / England
Ceramic installation in supermarket entrance of Barcelona, Spain	2019	Pavegen / England

Source: Own authorship, 2019

In the present scenario, international companies are the flagship for producing PZT ceramics applying at train stations in Tokyo, nightclubs in London and Rotterdam and the streets of Toulouse [7]. The companies apply case studies and projects to adopt energy efficiency through sustainable and durable solutions.

In Brazil, the British company Pavegen, in partnership with Shell Brasil, created a soccer field at Morro da Mineira, in Rio de Janeiro, with 200 plates, responsible for the generation between 20 and 30% of 2 kWh, capable of keep the reflectors on for up to ten hours [11]. Brazil has recently started piezoelectricity projects through partnerships between national and international companies, government and town hall (Table 5).

Despite being an old technology, Brazil only entered this branch of power generation from the 2010s, as a consequence of high investment for installation and difficult energy storage. However, important partnerships were obtained with international companies, in order to achieve better energy efficiency and matrix increase results, besides including Brazil in the group of countries with piezoelectricity projects.

Table 5: Applications of piezoelectricity in Brazil

Project description	Year	Company / Origin
Sustainable soccer field at Morro da Mineira in Rio de Janeiro, RJ, Brazil	2014	Pavegen / England, together with Shell Brasil
Creation of the 'ciclovia do futuro', installing the system for public lighting in Curitiba, PR, Brazil	2018	Soundpower / Japan

Source: Own authorship, 2019

One of the problems faced in using large scale flooring is the difficulty of storing energy. It would be necessary to invest heavily in capacitor banks or find a more cost effective alternative. Another problem would be the durability of the ceramic, knowing that with the use and excessive stimuli, the material loses malleability, reaching up to five years of useful life.

IV. CONCLUSION

The importance of the piezoelectric effect phenomenon encourages the use of renewable resources in a less costly manner, depending on the material used, as in the case of PZT application, which occurs in sonar and ultrasound devices. However it would be appropriate to use to generate energy in applications that require low voltage and current levels. The case of residential and public lighting sectors being supplied with piezoelectric ceramics could give greater room for other demands.

With the need to increase the efficiency of energy production and consumption, electrical engineering is important, given the support and knowledge that the distributed generation sector observed in view of the expansion of its energy matrix, seeking income, economy and preservation of the environment, independent of the generation of plants that give high expenditure to the government and pollution to the environment, in addition to being the basis for new research finding alternatives that have less impact on.

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