Designing and modeling a system to production energy using PZT material

R. Mahdadi[1], Y. Benkrima[2], A. Achouri[1], H. Daoui[1], A. Kaddour[3] and L. Benmebrouk[1]

[1]Univ. Ouargla, Fac. des Mathématiques et des Sciences de la Matière, Lab. Rayonnement et Plasmas et Physique de Surface, Ouargla 30 000, Algeria

[2] Ecole Normale Supérieure de Ouargla, 30000 Ouargla, Algeria

[3]Unité de Recherche Appliquée en Energies Renouvelables, URAER, Centre de Développement des Energies Renouvelables, CDER, 47133, Ghardaïa, Algeria

*Corresponding author: b-amina1@hotmail.fr

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Abstract

In the case of energy production based on renewable energy, we have designed energy production system based on piezoelectric materials with the inclusion of GMR technology. The last is considered one of the phenomena of electronic spin and it is a modern technology science. In this work, we were able to design an effective system that gives a large profit in energy with piezoelectric material PMN-33%PT. The energy loss in the system designed with the inclusion of GMR was 14.56% , whereas it gave a large loss of energy 58.24% without the inclusion of GMR.

Keywords: piezoelectric materials, Nanotechnology, spintronics, GM technology, renewable energy.

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Introduction

In this work we base on the design and simulation of different systems in order to produce continuous electrical energy usable in daily life.

One of the spintronic techniques, represented by the GMR (Great Magnetic Resistance) technique is used in our design, piezoelectric materials are also used which have the advantage of producing electricity by Pressure on it, and in order to prove the correctness of the designs and the resulting energy production, we calculated the energy lost and compared it to the total energy produced.

Piezoelectric materials are now a great importance; piezoelectric materials produce a voltage when stress is applied (direct piezoelectric effect) or display a change of shape when a voltage is applied

(reverse piezoelectric effect). Piezoceramics have high stiffness and good piezoelectric coefficients for generation of both strain and voltage; they are used in both sensors and actuators.[https://www.sciencedirect.com/topics/materials-science/piezoelectric-material].

Piezoelectric transducers for assessing and monitoring civil infrastructures.[Y.-K. An, ... H. Sohn, in Sensor Technologies for Civil Infrastructures, 2014]. Also application of Piezoelectric to Roads in California 2013[1-18].

Many researches work it is realized since de discovered the GMR by ALBERT Fert (1988) in ORSAY university [19-27], where used the GMR technique to read and write in CD ROM, increase of storage value in devices memory and also as filter of current.

In these work we will use the GMR technique as filter of current in a new proposed designed system to production eclectic energy based a piezoelectric materiel.

The main objective of our works is harvesting more possible energy without big loss from the total produced energy.

In fact our work has a new idea where all found results it's from our researche that used these two technologies in one system.

We elaborated a numerical program to confirmation our results according all proposed design, it's based on scientific equation and logical design.

Design components:

- Piezoelectric sensor: Contains piezoelectric material (PZT).
- Chromium and iron cells: Monolithic layers of iron and chromium are used, Fe, Cr, where chromium is a non-magnetic material, while iron is magnetized in different directions in each layer.
- Electronic spin filter based a GMR technique:

The electronic filter is used as an electrical circuit, separating the lower spin down and the upper spin up of the electric current.

3- Experimental design to production continuous electricity:

Case 1-Design based on unilateral pressure:

In this case, mechanical pressure is first applied to the first piezoelectric material, electrical energy is produced. That creates a magnetic field which attracts the second end of the hammer and affects the second material, and therefore the process of producing electrical energy from the two piezoelectric materials continues.

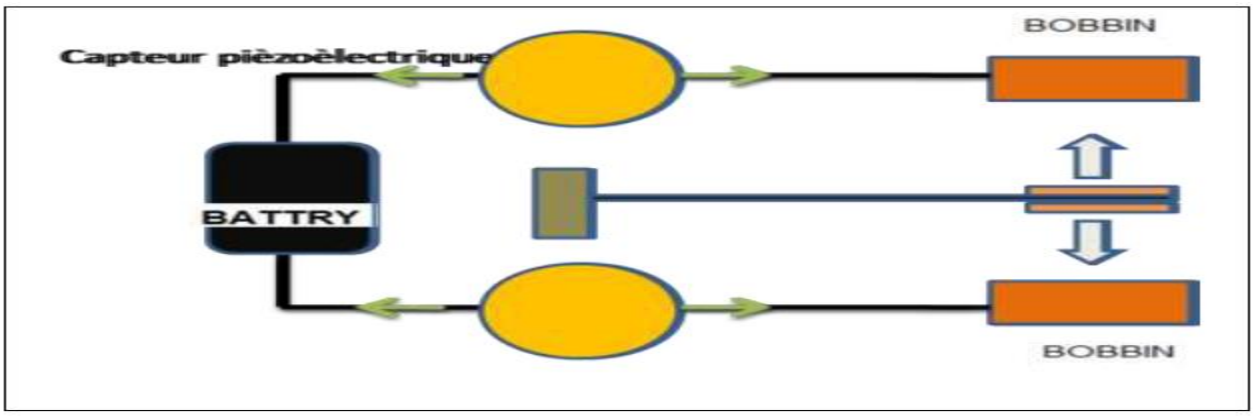

Figure 1: Diagram of production electrical energy in the case of a single pressure.

Case 2: Design based on double pressure

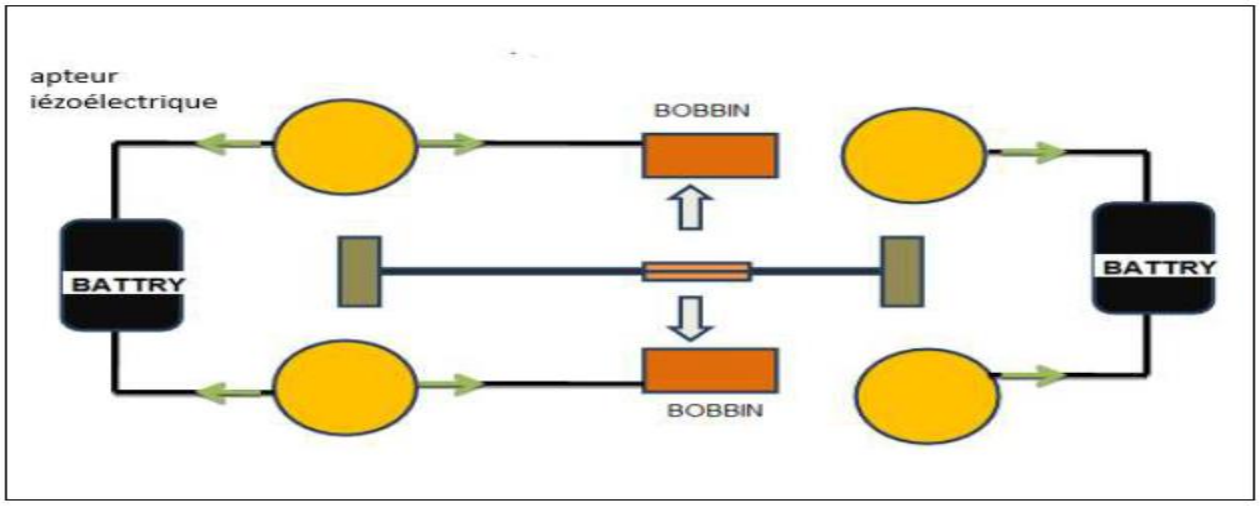

Figure 2: Diagram of production electrical energy in the case of a double pressure.

Case 3 Design using GMR before application of mechanical pressure (single pressure)

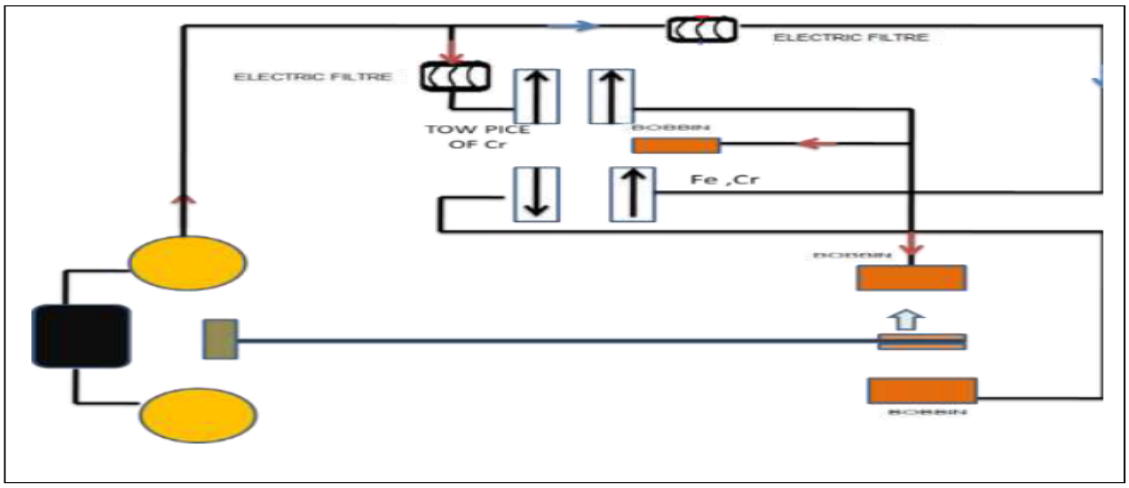

Figure 3: Diagram of production electrical energy in the case of a single pressure using GMR before application of mechanical pressure.

Case 4 Design using GMR after application of mechanical pressure (single pressure)

After application of a mechanical pressure on the first piezoelectric material, an electrical energy is produced, when the current passes through an electronic filter no. (1) which allows the passage of the upper current to spin up, when the upper current passes through the coil (1) creates a magnetic field affecting the layer of iron (1). It reverses its direction so that it prevents the current from passing and at the same time affects the layer of iron no. (2) Changing its direction allows the current to flow while the other part of the upper current affects the coil (2) which in turn attracts the magnetized side of the rod and thus pressure is applied to the piezoelectric material (1) on the hammer side, when the direction of the iron layer changes (2), the lower current flows to the coil (3), and a magnetic field is created to attract the rod, and pressure is applied to the piezoelectric material (2), and so the process of production electrical energy will be continuous.

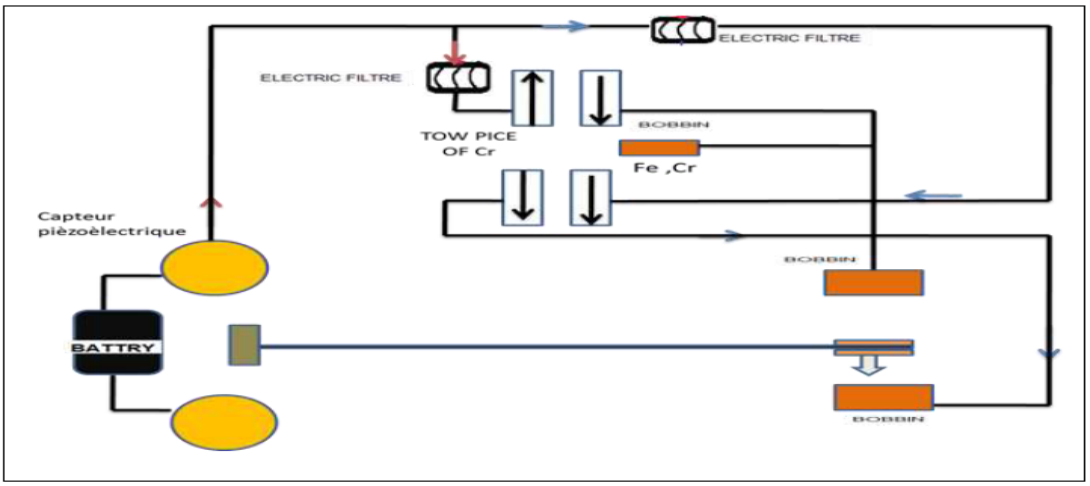

Figure 4: Diagram of production electrical energy in the case of a single pressure using GMR after application of mechanical pressure.

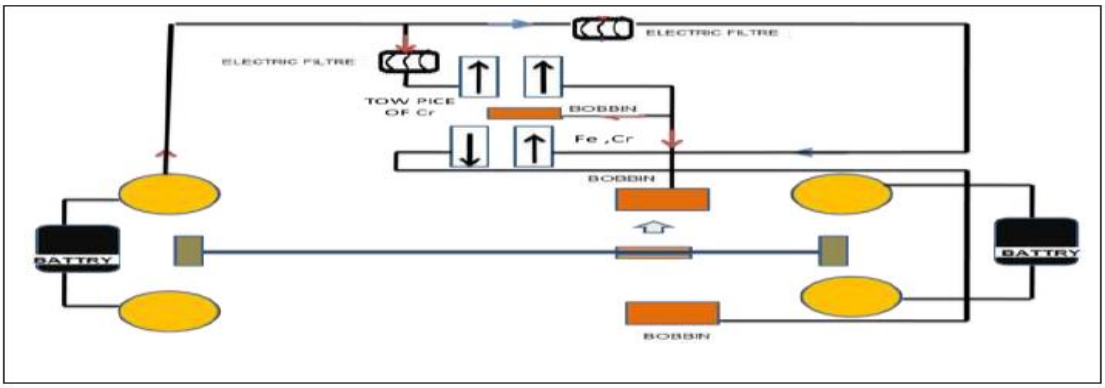

Figure 5: Diagram of production electrical energy in the case of a double pressure using GMR before application of mechanical pressure.

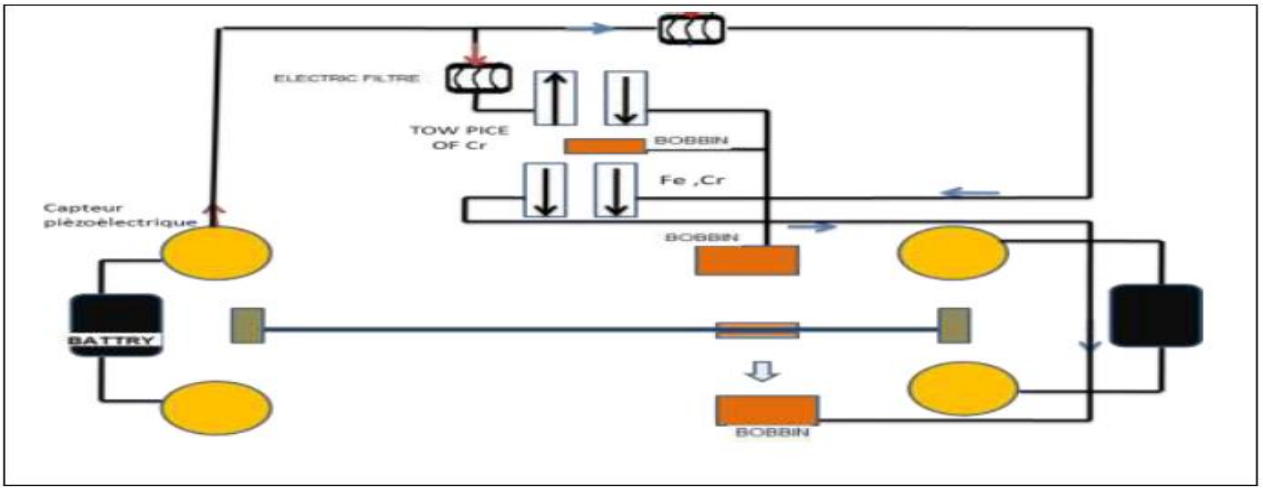

Figure 6: Diagram of production electrical energy in the case of a double pressure using GMR after application of mechanical pressure.

Study the performance of designs to production energy:

In order to complete this study, we base on the following law of energy production for piezoelectric materials[27]:

$$U = \frac{1}{2}QV = \frac{1}{2}(d \times \delta \times s) \cdot (g \times \delta \times t) \quad (1)$$

$$= \frac{1}{2} d \times g \times \delta^2 \times \text{Volume}$$

Where

And

$$F = \left(\frac{4\pi r^2}{\mu 0}\right) \times B0\ B \quad (2)$$

And

$$B = \left(\frac{\mu 0 \times N}{L}\right) \times I \quad (3)$$

$$\frac{a^2 \times N^2}{18 \times a + 40 \times l} \quad (4)$$

$$UL = L \times \frac{I^2}{2} \quad (5)$$

The following table shows the properties of some piezoelectric materials.

	$BaTiO_3$	PZT-4	PZT-5A	PZT-5H	PZT-8	PVDF	PMN-33%PT	PZN-6%PT
d31 (10–12 C/N)	-78	-123	-171	-275	-97	-23	-920	1400
d33	149	289	374	593	225	33	2200	2.400
d15	/	496	584	741	330	/	/	/
g31 (10–3 Vm/N)	5	-11.1	-11.4	-9.1	-11	216	17.1	24.3
g33	14.5	26.1	24.5	19.7	25.4	330	44	41.7
g15	/	39.4	38.2	26.8	28.9	/	/	/
k33	0.48	0.7	0.71	0.75	0.64	0.15	0.93	0.9
Mechanical QM	300	500	75	65	1.000	3-10	69	/
Dielectric loss	/	0.4%	/	%2	0.4%	/	0.42%	/
Curie temperature (°C)	115	328	365	193	300	100	145	100

Table 2 shows the values used in our program to the energy calculation.

Data in	values	unit
Voltage constant g33	$44x10^{-3}$	Vm/N
Current constant d33	$2200x10^{-12}$	C/N
Distance r between the coil and the rod	0.04	m
Volume of the piezoelectric material V	$6x10^{-4}$	m^3
Vacuum permeability μ_0	$4\pi x10^{-7}$	T/A*m
magnetic inductance L	0.2	mH

For our design to be small in size, we have chosen the eigenvalue of the coil L = 0.2 mh because when the eigenvalue of the coil increases the size of our design increases, using the following website: http://www.circuits.dk/calculator-multi-layer-aicore.htm

We obtain the following values for the dimensions of the coil.

l=10mm ,N=121 , a=0.54mm

Results and discussion

In order to study the efficiency of designs in the production of energy, we group and program all the necessary equations, as well as all the data using a program developed in the Fortron language, an illustrative diagram of this program is shown in figure 7 below:

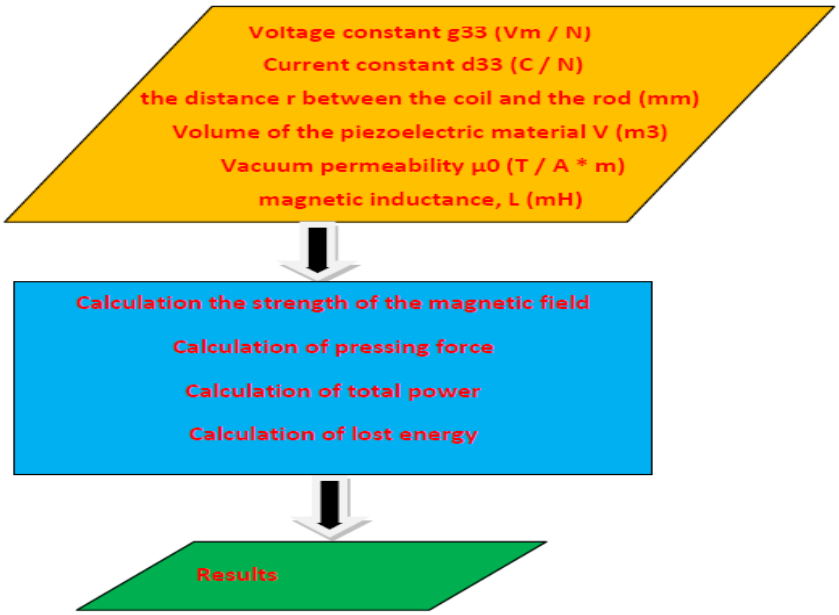

Figure 7: Program diagram of calculation.

After performing the calculations in the program, we obtained the results shown in the following curves for design (1) and (3) and for the material PMN-33%PT.

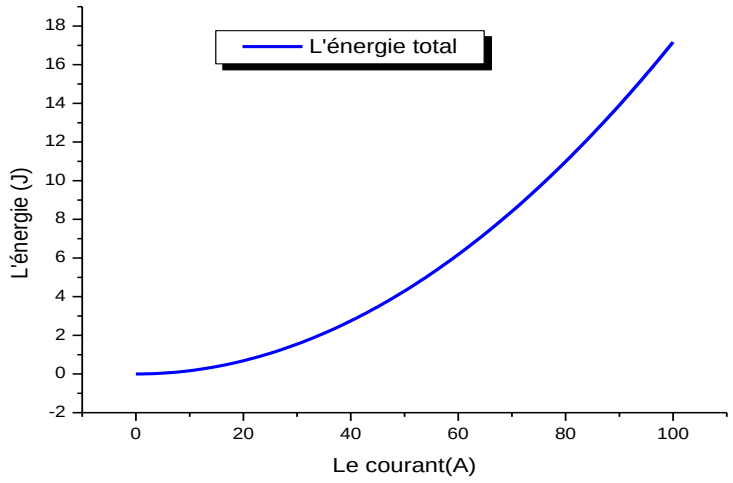

Figure 8: A curve representing the evolution of the energy produced by a piezoelectric material as a function of current.

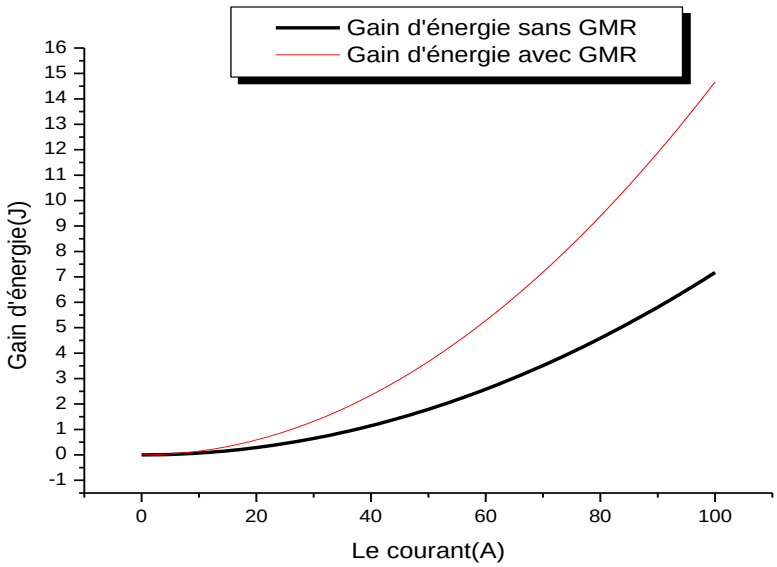

Figure 9: Curve representing changes in energy gain with and without GMR.

Through the two energy gain curves in terms of current, we notice that the energy gain curve without GMR gave values much lower than the energy gain curve in the presence of GMR, due to the presence of GMR where the upper spin or lower spin of the current is allowed to pass. Thus, only part of the current passes to be consumed by the coil, which means that the current drawn from it is greater than the current consumed by the coil. So the value of the energy gain is large, but without GMR, the total current produced by the piezoelectric material passes through the coil, therefore the coil consumes a large amount of current, and therefore the energy consumption increases and the gain decreases.

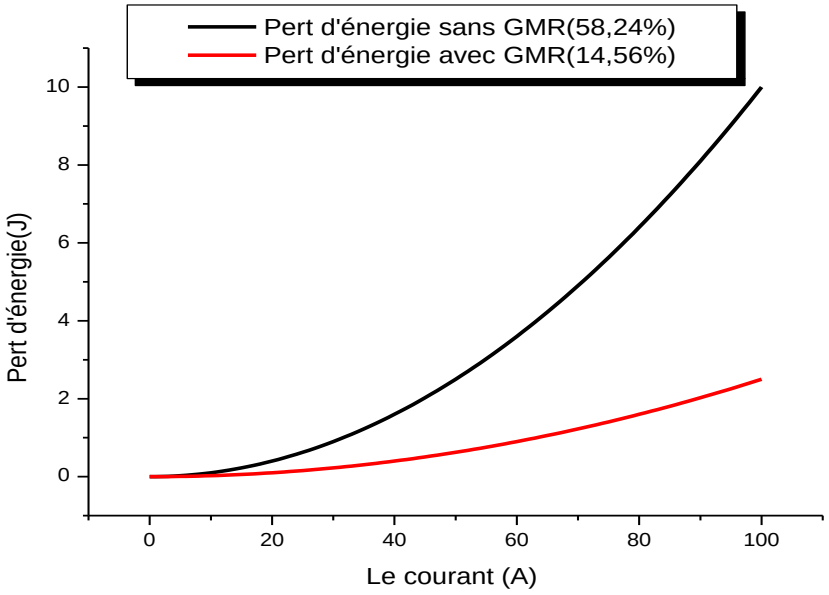

Figure 10: A curve representing the energy loss changes with and without GMR.

Through the energy loss curve in the presence of GMR, we notice that a small percentage of energy loss (14.56%), compared to the energy loss curve without GMR, which gave a loss energy of (58.24%), because in the presence of GMR there is no significant loss of the passage current.This is due to the presence of the electronic filter which allows the passage of one of the upper spins or lower electric current.

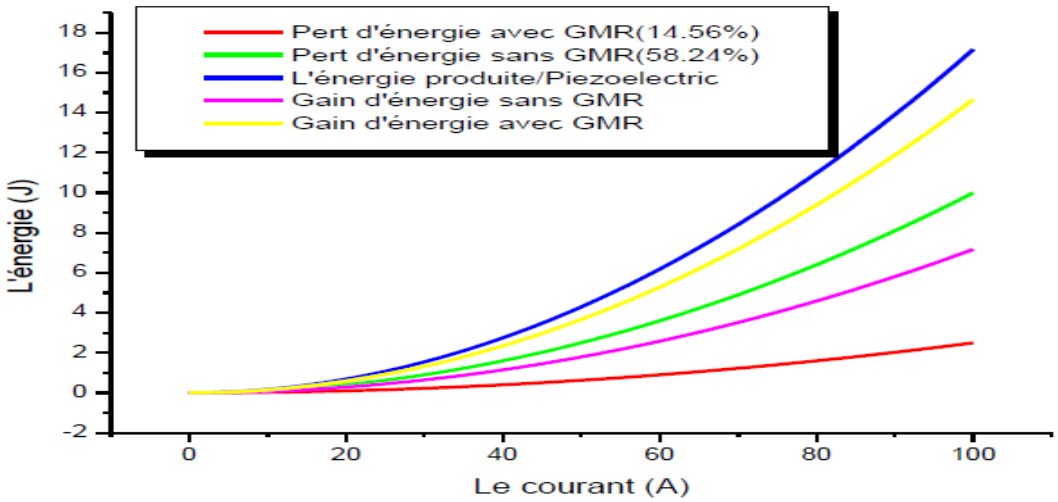

Figure 11: A global representation of the evolution of energy as a function of current.

By comparing the gain and loss curves in electrical energy with and without GMR with the total energy curve resulting from piezoelectric material, we noticed that the energy gain curve with GMR gave results very close to the total energy curve in contrast to the energy gain curve without GMR, which gave results very far from The curve has the total energy produced and therefore the percentage of energy lost without GMR was very large (58.24%). In the presence of GMR, the percentage of energy loss was small (14.56%) and this is due to the role of the electronic filter in working to improve the value of the energy generated and reduce the percentage of loss in it.

And through the curve of energy evolution as a function of magnetic field shown in figure 12.

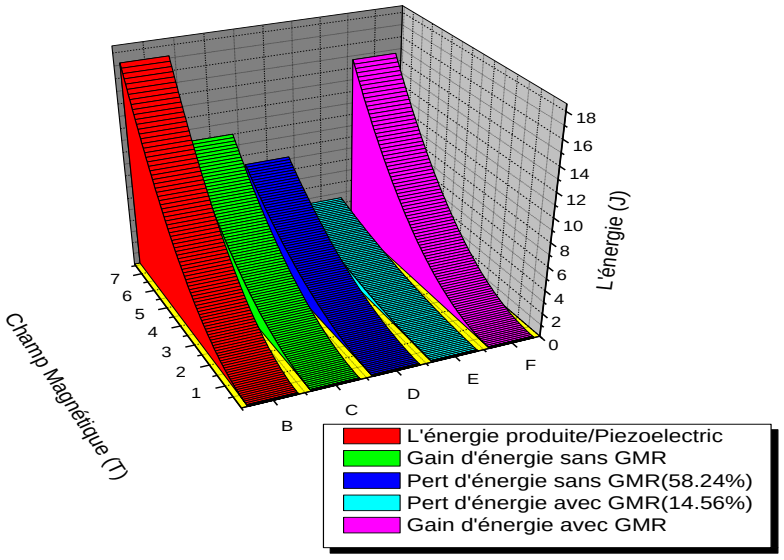

Figure 12: Energy evolution as a function of magnetic field.

We note that the energy produced from the piezoelectric material approximately corresponds to the energy gain curve in the presence of GMR, because when the intensity of the magnetic field is high, the value of the energy produced is higher also. This curve corresponds to the change in power as a function of current.

Conclusion

In order to produce energy by relying on clean renewable energies, during this work we made designs for continuous electric power generation. Based on piezoelectric materials and we used the GMR technology of the spintronic. Our results mainly depend on the types of piezoelectric materials chosen and the designs using either with or without GMR technology. After discussing the results, we found that there is a significant energy gain with the presence of GMR. We have also found that the properties of piezoelectric materials have a major role in the generation of high energy without large energy loss. It can therefore be concluded that there is a large scope for research in this field to be able to produce devices with greater efficiency.

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