Nano Generator Simulation Using Fuzzy Logic

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Abstract: This papar presents the design, modeling and simulation of nanogenrator. Nano structure based energy genrator is used to convert the small physical motion into electrical energy such as body part motion, heart beating, vibrating parts of the factory machines walls, floors and thrilling parts of transports. In the present study, two input parameters like force and thickness and two output parameters like voltage and current have been considered and simulation was performed using the fuzzy logic technique. This approach helps to optimize the durable, accurate and efficient nano-generator. Basic Madami model of the fuzzy logic is used for calculations. The input and output parameters have been assigned three membership functions (MFs). The device works according to the instructions well-defined in the fuzzy inference system (FIS). On the basis of simulation we observed operational diagrams. Surface viewer were used to observe the curves and to analyse the results of all defined MFs. Diverse rules by making various group were defined in MATLAB rule managing editor and AND logic is adopted for simulation. Mamdani's expression is used for the calculation of the outputs. The calculation based results and simulated results show very littile variation for fuzzy logic (FL) nanogenrator. There is present 1% error in simulated and theoretical values that shows that FL based nano-generator controller is very efficient to harvest the energy from nano structure based device.

Key points – Nano generator, Fuzzy logic, Fuzzy inference system, Membership function.

I Introduction

Nanomaterails are waslty used in the modern technologies due to very effective functionality. Piezoelectric properties of the nanostructured materials are used to change the mechanical vibrations into the electrical signals which are the basics of the microelectromechanical system (MEMS) based nanogenretors. Small mechanical vibrations are one of the most important aspects of our physical nature. These vibrations exist at all the time, everywhere and every field of life. The basic idea of MEMS based nanogerator is to detect the small mechanical motion and vibrations. If a piezo material is coated on a flexible surface then the energy can be easily produced by applying mechanical motions. Most common natural vibrations are body parts motion such as heart beating, lungs motion, chest expansion and contraction, walking, running which can be converted into electrical energy by using these nanogenretors. In industry, mechanical movements like thrilling and vibrating part of machines surfaces generate energy. The movement, running and jumping of vehicals can be converted into electricity to meet its own requirements of energy. In this way, we can reduce the fuel consumption and can save energy. If we use the piezoelectric generator under the road then due to the vibration and the motion of the vehicles, electiricity can be generated. In short, these MEMS devices can be used as the new source for energy production. Energy produced from these generators may be useful and instantly available for wear able devices. The applications of nano generator schematic are shown in Fig 1.

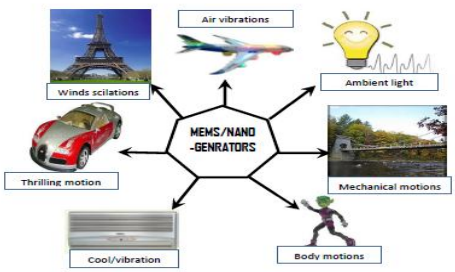

Figure 1 Schematic diagram MEMS based nanogenrator application

Various types of nano generator have been developed by different researcher. Thin film of the ZnO-CuO is deposited by sol-gel method on the silicon substrate and surface was treated at temperatures of 100 -800 ^{o}C. The spin coating techique was used and thickness was increased by increasing the number of coatings. The x-ray diffraction (XRD) technique was used for the surface study [1]. MEMS based nano-generators are popular due to light weight and low cost. The MEMS based nanogenrator devices have been useful in reducing the need for electric wiring, wet and dry chemical batteries or other power sources which are massive and expansive. The piezo nano devices are very effective for energy generation.

The harvesting of energy from such devices is easy and time saving from different aspects. These nanogenrators can produce a power of 1μW only by adjusting the device dimensions 1cm×1cm which is a reasonable amount of energy production at small scale [2]. Nanoelectromechanical system (NEMS) based energy device has produced the energy by applying force and varying the thickness. If the force of the natural vibration would be used in the order of μN and thickness of the device would be in nm range. Then the device could produce the voltage in the range of μV and the current in the range of μA [3]. Fuzzy logic based intelligent system was developed and input parameters were adjusted to get the outputs in a specific range [4]. Highly flexible and efficient piezoelectric based nano device for the energy harvesting was developed. The two modes of the fabrication were used for forward and reversed biased. The sol-gel method for the thin film deposition was used. The device showed better performance [5]. It was reported that the accuracy and unlimited impact of fuzzy logic system for day-to-day life problem showed significant importance [6]. Tang et al. reported a fuzzy logic based system for developing genetic algorithm [7]. MEMS based energy harvester was developed by using the ZnO piezoelectric thin film. Two different strategies like sputtering method and wet chemical method were adopted to fabricate the MEMS device. The results showed that the maximum load frequency, power and voltages were 1300 Hz, 1.25 uW and 2.06 v respectively [8]. Piezoelectric nano materials were used to develop nano devices [9, 10]. Using ZnO thin film deposition on the silicon wafer after coating by the Pt/Ti, the device was developed [11, 12]. Thin film of piezoelectric material was used for the energy harvesting [13]. It was reported that as the length of piezo device was increased, the sress level was also increased [14]. Different computational techniques were reported using fuzzy logic controller [15].

II Simulation

First of all, we select the input and output parameters for the proposed system. The simulation has been performed for MEMS based nanogenrator for the enegy harvesting. Pressure and thickness have been considered as the inputs while voltage and current was considered as out put as shown in Fig. 2.

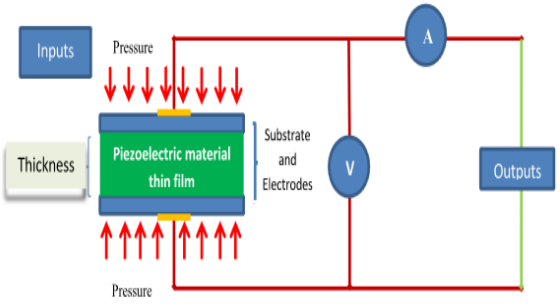

Figure 2 Circuit representation scheme

Schematic of complete system is shown in Fig. 3. Each input and output has been associated by three memebership function and their ranges were defined in order of nano meters.

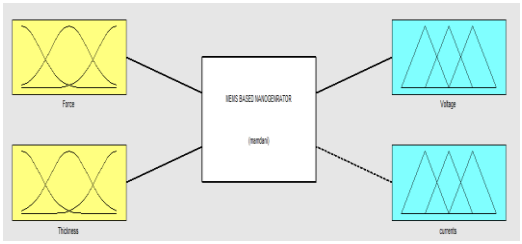

Figure 3 Fuzzy logic nanogenerator

The inputs and outputs vaues of nanogenerator were defined in fuzzy logic inference system. Each of input and output has been given three membership functions with specific ranges. The range of the limits for MF_1 is 0-50 and $MF_2$is 0-100 and while the MF_3 is from 50-100 as shown in Table 1.

Table 1 Ranges in percentage

MFs	%Range	Force	Thickness	Voltage	Current
MF_1	0-50	L	L	L	L
MF_2	0-100	M	M	M	M
MF_3	50-100	H	H	H	H

L = LOW, M = MEDIUM, H= HIGH

Fig. 4 and Fig. 5 show the input membership function and Fig. 6 and Fig. 7 show the output membership function.

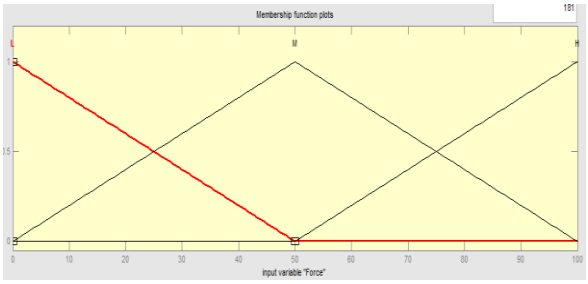

Figure 4 Input membership function plot for force

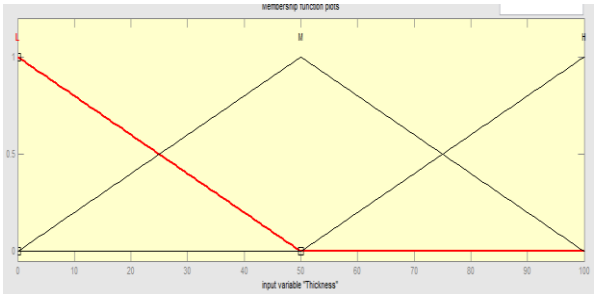

Figure 5 Input membership function plot for thickness

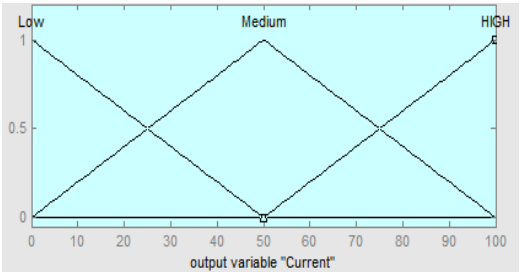

Figure 6 Output membership function plot for current

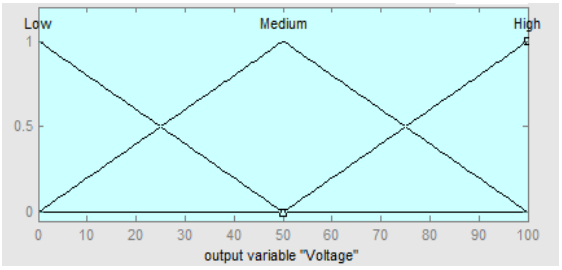

Figure 7 Output membership function plot for voltage

Fig. 4 is the graph between the degrees of memebership function and the force exerted on the FL nanogenrator. This shows the membership function of the input "Force" and its distribution in the different sections. The range of the first overlapping unit is 0 -50 which is called negative region or Region I. The second overlapped region is of range 0 -100 and 50 -100 is called Region 2. These distributions are same for all inputs and the outputs. On the basis of possible combinations of the physical inputs and outputs parameters different rules have been established for the better performance and accurate simulation results. The rules involve the simple If and Then statement and the AND logic. The 3D simulated results in surface viewer are shown in Fig. 8 and Fig. 9.

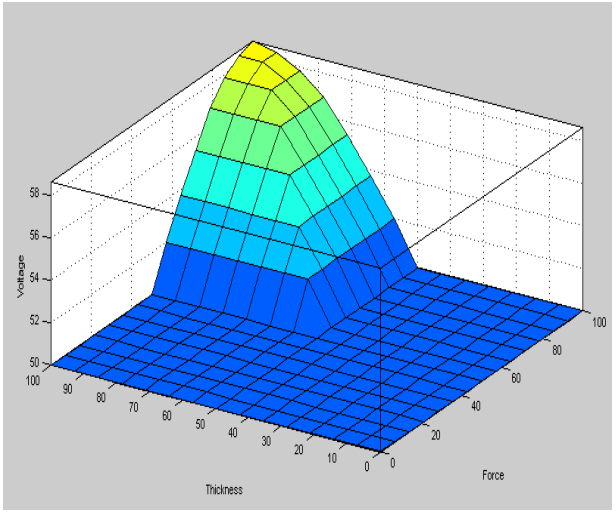

Figure 8 Graphical representation of collective behaviour of thickness verses force and output voltage

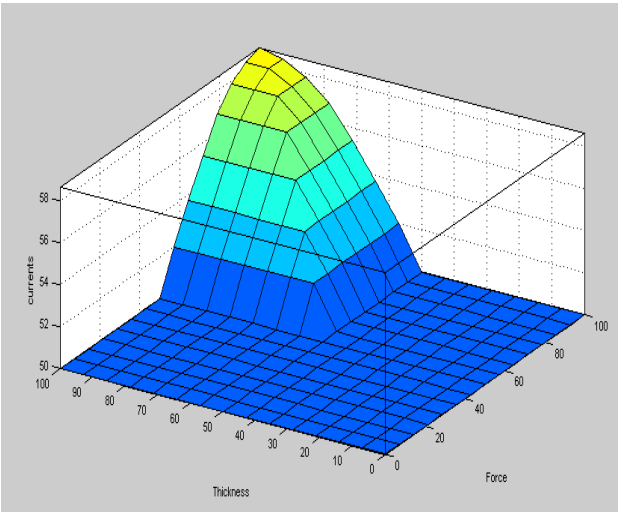

Figure 9 Graphical representation of collective behaviour of thickness verses force and output current

This graph shows that when specific values of applied force on the device has been increased then the output value of the voltages also increases by keeping the thickness and area constant. From the 3D graph, it is observed that if we increase the force or pressure on the piezo thin film upto an extent, then the compression increases directly. Hence, by more expansion and compression of the piezo thin film, more voltage can be produced. In the same way if we increase the thickness of the material thin film at a certain extent by maintaing it into the nano-range, the resulting output voltage will also increase directly with applied force or pressure.

III Design Algorithm

An algorithm of fuzzy logic system for the nanogenerator has been desined for the energy harvesting. Fig. 10 represents the collective behavior of adjusted inputs and outputs for proper solution of algorithm. The yellow areas represent the inputs like force and thickness while the blue areas represent the outputs like voltage and current.

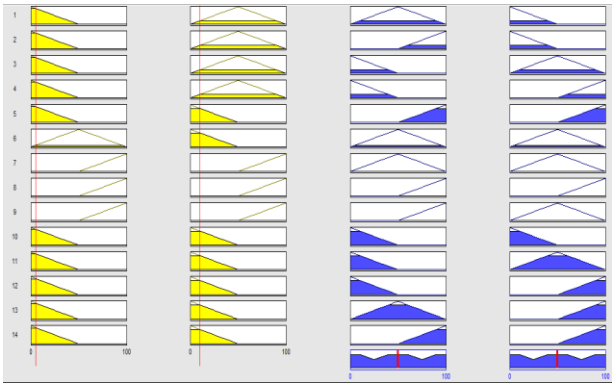

Figure 10 Collective representations of all possible rules of assigned inputs and its respective outputs

For calculation the values of parameters are: Force = 5.42, Thickness = 10.2, Voltage = 50. The value of the force in simulation is (5.42 μN) that lies in Region 1 as shown in Fig. 11. The related membership functions are Low (L) and Medium (M) as indicated in the Region I.
The MF_1 and MF_2 for these values are:

MF_1 = (50 - 5.42)/50 = 0.892
MF_2 = 1 - mf_1 = 1- (0.892) = 0.108

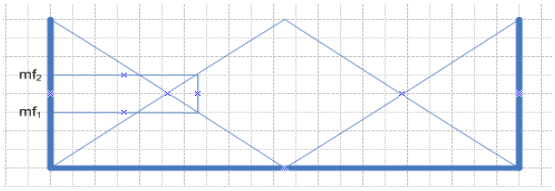

Figure 11 Graph showing the values of the membership functions MF_1 and MF_2 for the pressure

Similarly, the thickness of the thin film is (10.22 nm) that lies in the Region 1 as shown in Fig. 12. Membership functions of the Region 1 are Low (L) and Medium (M). The MF_3 and MF_4 for these values are:

MF_3 = (50 - 10.20)/50 = 0.796
MF_4 = 1 - MF_3 =1- 0.80 = 0.204

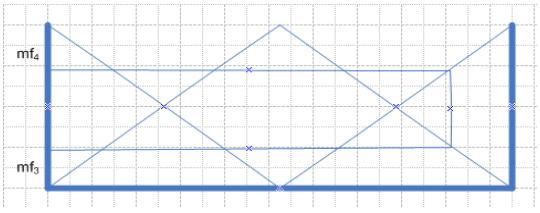

Figure 12 Graph showing the values of the membership functions MF_3 and MF_4 for the thickness

The suitable rules for the high performance of the nanogenrator are selected for calculation of design algorithm. The input parameters like Force = 5.42 and Thickness =10.22 have been used for calculation. The value of input parameter force F= 5.42 lies in Region 1. The inputs like force and thickness, voltage and singleton values are shown in Table 2.

Table 2 Selected rules

	SELECTED RULES			
Rules	Force	Thickness	Voltage	Singleton Value
R_1	L	L	M	0.5
R_2	L	M	M	0.5
R_3	M	L	M	0.5
R_4	M	M	H	1

The value of membership functions for force is MF_1 = 0.892 and MF_2 = 0.108.

A. Voltages and Current Calculation by using the Mamdani's Formula

Mamdani formula is used for calculation of output under the following conditions. The input value of force, F = 5.42 lies in Region I and value of thickness is T = 10.22. The calculated values for Membership functions are: MF_1 = 0.892, MF_2 = 0.108, MF_3 = 0.796 and MF_4 = 0.204. Singleton values for calculation are 0.5 for Medium (M) and 1 for high (H). Hence, I_i x Σ S_i = 0.846, Σri = 1.692.

[ΣIi × Si / ΣIi] = 0.846/ 1.692 = 0.51

Simulated value by MATLAb = 0.50

Mamdanis formula value = 0.510

Differenc = 0.510 - 0.50 = 0.010

The percentage error in output voltage is only 1% which is very small. Similarly, the value of current has been calculated as 50μA and has lesser error as for voltage. Thus the presented simulation for nano generator is accomplished well.

IV Conclusion

Here, the fuzzy logic based analysis of nano generator for the energy harvesting has been presented. The values of inputs like force and thickness are 5.42 μN and 10.42 nm respectively. Three membership functions are used for each input and each output. The output voltage and current have the values of 50μV and 50μA respectively. The fuzzy inference system works according to the defined rules. Results were analysed by the surface viewer. AND logic was used for simulation. The presented nanogenerator controller has 1% error and can be used for harvesting the energy.

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