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DESIGN OF AN OPEN CHANNEL FLUID FLOW SYSTEM FOR PIEZOELECTRIC ENERGY HARVESTING

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Abstract-This paper includes development of the model for piezoelectric energy harvesting system using hydro-dynamism and conversion of the dynamic pressure of water into electrical energy. In this article, a model has been designed to harvest energy by using dynamic pressure of water on a single patch of PVDF (Polyvinylidene fluoride), a piezoelectric material. The flowing water is made to strike on a piezoelectric patch of PVDF for the conversion of kinetic/pressure energy of water into electric potential on the basis of piezo-electric effect.
Keywords: Energy Harvesting, Piezoelectric Patch, Energy Generation, Voltage Doubler circuit, Full-bridge rectifier circuit.

1. INTRODUCTION

Harnessing of energy is the operation of extracting ambient energy from the environment, storing and converting it to a usable form. It is an easy way to generate electricity from the energy which is lost or unused. With the advancement in wireless and portable engineering, energy harvesting is highlighted as the alternatives of the conventional battery. Ultralow power portable electronics and wireless sensors use the conventional batteries as their power sources, but due to short and limited life than that of the device their use is somewhere restricted. Therefore, a set of researches have been done to harvest energy and apply it as a self-power source of portable devices or wireless sensors. The micro energy harvesting technology is capable of producing mW or μW level power. Piezoelectric materials have capability to produce electric power when stressed. This attribute makes them attractive for energy harvesting from ambient vibrations. The vibration sources can be a machine, human movement, wind, rainfall, waves, etc. The research motivation in this field is due to the reduced power requirement of small electronic components. The ultimate goal in this research field is to power such small electronic devices by using the vibrational energy available in their environment. If this can be achieved, the requirement of an external power source as well as the maintenance costs for periodic battery replacement and the chemical waste of conventional batteries can be reduced. In this paper, a model is presented for harnessing of energy using piezoelectric material with fluid flow dynamism.

1.1 Material Selection

In the present study, PVDF (poly-vinylidene fluoride) is used for the purpose of energy harvesting from the dynamic flow of water. As PVDF is highly flexible so it can work against high pressure and forces applied by water, light in weight, high heat resistance, low thermal conductivity, high chemical resistance, good toughness and unaffected by long-time exposure to ultra violet radiations. Because of all these reasons we have used PVDF for the selected purpose. Figure 1 shows the piezoelectric material used for energy harvesting.

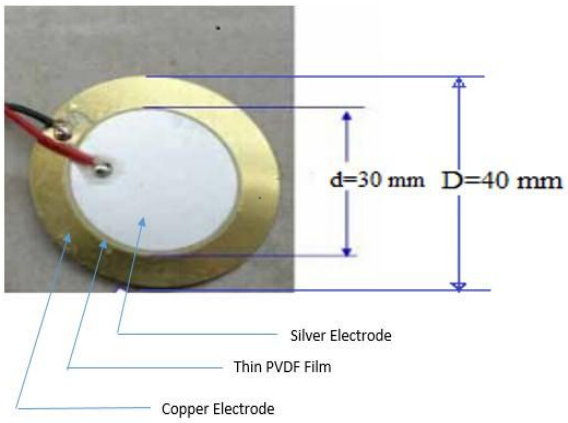

Figure 1 PVDF Piezo-Patch

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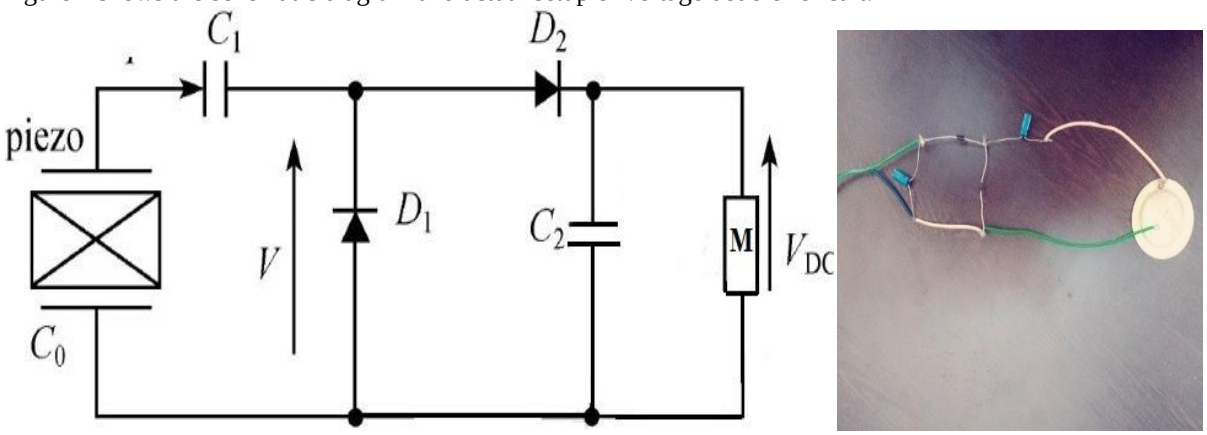
Table 1 shows the basic properties of the PVDF piezo-patch used for energy production.

PROPERTY	VALUE	UNITS	TEST METHOD
Specific gravity	1.78	-	ASTM D 792
Water Absorption in 24 hours	0.03	%	ASTM D 570
Water Absorption Saturation	0.05	%	ASTM D 570
Flammability	V 0	-	UL 94
Tensile Strength	7,000	Psi	ASTM D 638
Elongation	100	%	ASTM D 638
Modulus	250,000	Psi	ASTM D 638
Rockwell Hardness	M75	-	ASTM D 785
Coefficient of Linear Thermal Expansion	$6.60*10^{-5}$	in/in/°F	ASTM D 696
Dielectric Strength	1600	V/m	ASTM D 149
Volume Resistivity	10^{14}	Ohm-cm	ASTM D 257
Dielectric Constant	8.5	-	ASTM D 150

Table 1: Properties of PVDF material used

1.2 Description Of Smart Electrical Circuit

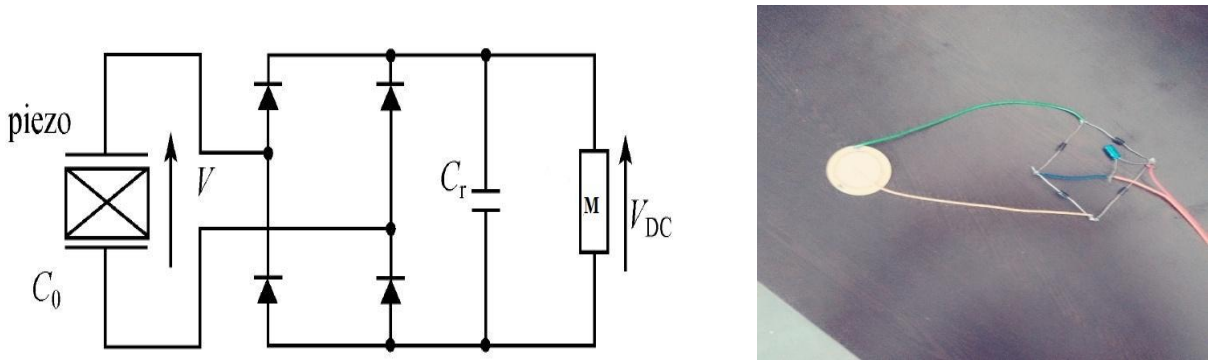
Voltage Doubler Circuit: This is an electronic circuit which charges capacitors from the input voltage and works in such a way that exactly double voltage is produced in the output. The simplest voltage doubler circuits are rectifiers which converts input AC voltage into doubled DC output voltage. The circuit components are two capacitors, two diodes and a multi-meter to measure the output. In the applications where high power is required for a high resistance load this circuit is quite beneficial. Figure 2 shows the schematic diagram and actual setup of voltage doubler circuit.



(a) (b)

Figure 2 (A) Schematic Diagram Of Voltage Doubler Circuit (B) Actual Circuit Of Voltage Doubler Circuit

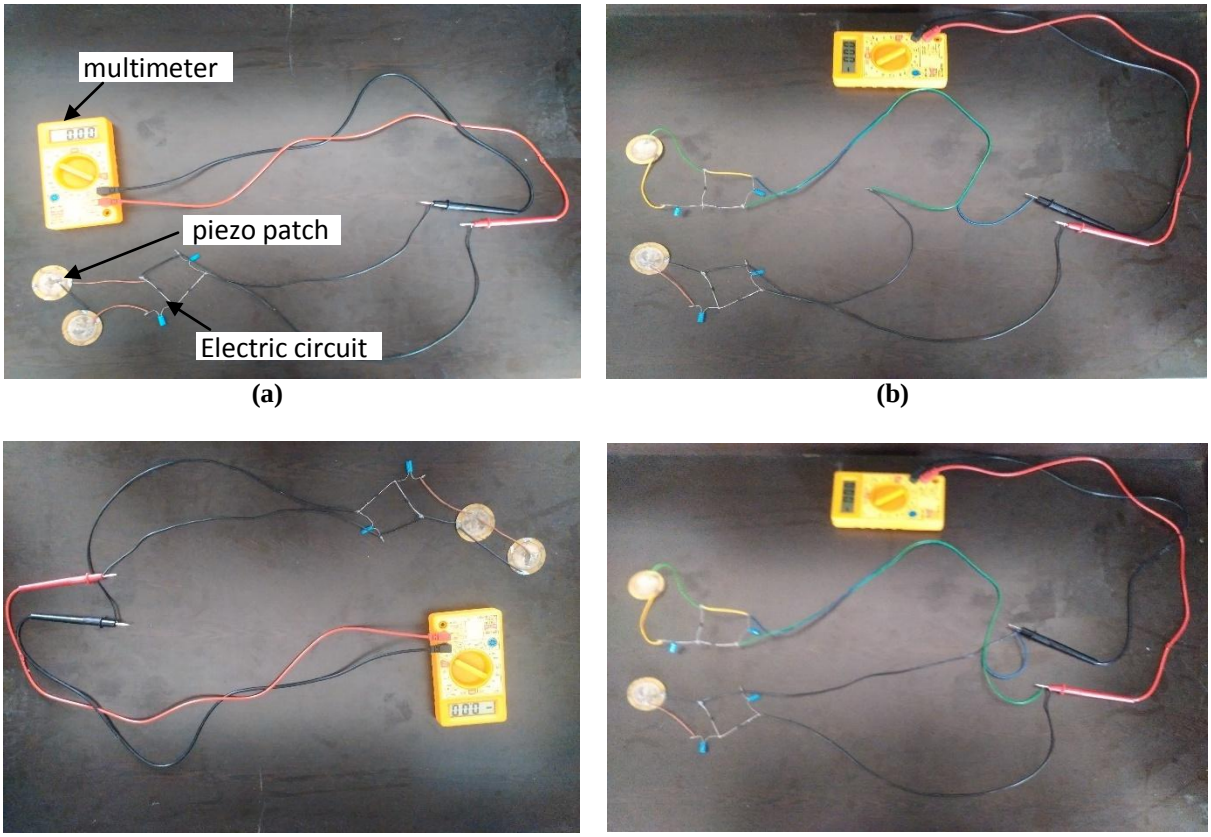
Full Bridge Rectifier Circuit: This converts the complete AC input waveform into constant polarity DC and gives a higher average output voltage. The circuit components are two diodes and a center tapped transformer, or four diodes in bridge configuration and an AC source. Figure 3 shows the schematic diagram and actual setup of full bridge rectifier circuit.



(a) (b)

Figure 3 (A) Schematic Diagram Of Full Bridge Rectifier Circuit (B) Actual Circuit Of Full Bridge Rectifier Circuit

Figure 4 shows the component used and four different configurations of piezoelectric patch and voltage doubler circuit which are used to harvest energy from hydraulic dynamism.



(a) **(b)**

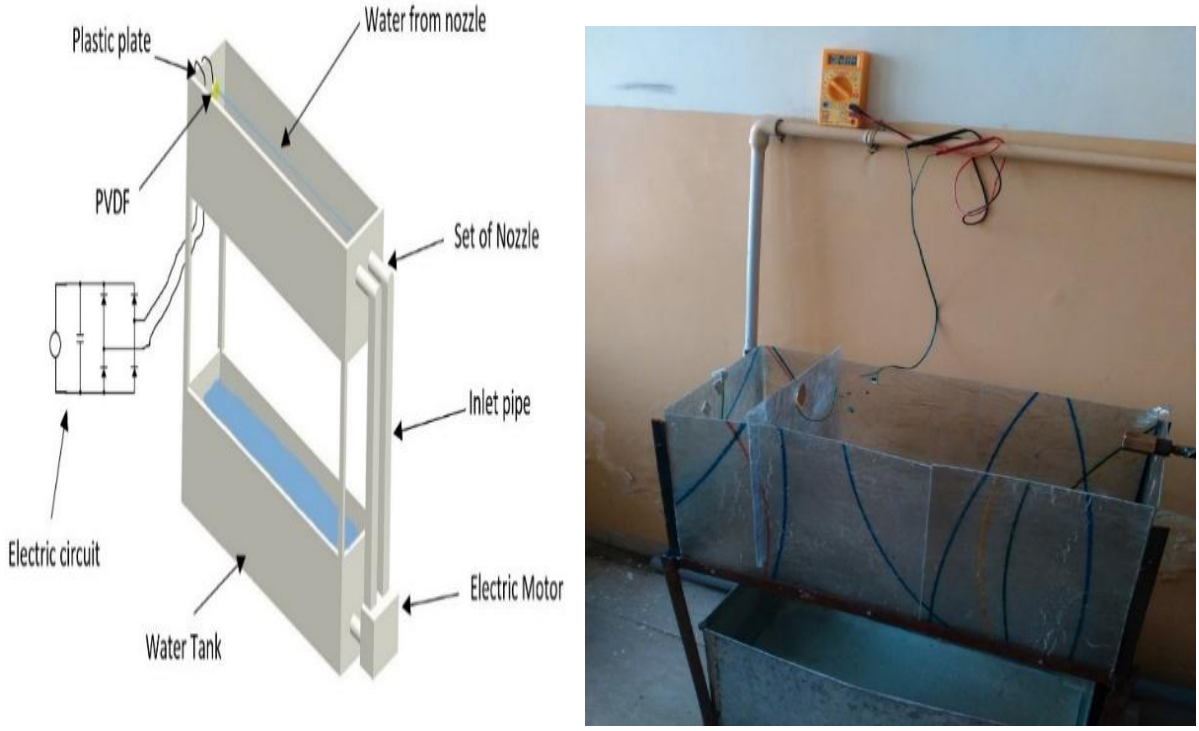
(c) **(d)**

Figure 4 (A) Series Connection Of Two Piezo Patches (B) Series Connection Of Two Circuits (C) Parallel Connection Of Two Piezo Patches (D) Parallel Connection Of Two Circuits

1.3. Description Of The Model:

The proposed mechanical model is composed of a water tank, a set of nozzle to increase the velocity of fluid, pipe to circulate the water flow, PVDF patches mounted on a plate and voltage doubler circuit to generate output terminal voltage. The model can be used where the water supply is continuous such as river, lakes, bridges, waterfall, etc. In case, if water is present in limited quantity then a reservoir tank can be used to store the water and a pump can be used for recirculation of the water.

Figure 5 shows the schematic diagram and working model of energy harvesting system and figure 6 shows the components of energy harvesting system like diode, set of nozzles, capacitor etc.



(a) (b)

Figure: 5 (A) Schematic Diagram, (B) Experimental Model Of Apparatus

Figure: 6 Components Of Energy Harvesting System

Here, the water tank is used to store as well as supply the water. An electric motor is used to recirculate the water. Piezoelectric patch is mounted on a perforated sheet and is allowed to place in flowing water. The flowing water strikes on the piezo-patch which directly converts the vibration energy of flowing water into electrical energy on the basis of piezoelectric effect. The electric circuit is used to store the extracted energy.

2. DISCUSSION

Every bit we have seen different methods of energy conversion which can be utilized to harvest energy from ambient vibrations. Every method has both advantages and disadvantages together and also their use is limited to a particular case of ambient condition. The solar system is applicable only for converting energy coming from the Sun into a useable form of energy. In electromagnetic system the coil arrangement is comparatively sound and makes it hard to move quickly, which results in the difficult operation to generate a high frequency response. Electrostatic system requires some initial voltage to excite the system. Among all of these we can see that piezoelectric energy generation is quite beneficial than others as it is more reliable than other system and can be applied under wide range of excitation. Also the power requirement for initiation is very low or negligible as compared to others and piezoelectric materials can be easily integrated with other systems. Thus we see that piezoelectric materials can be used effectively to harvest energy as compared to other harvesting systems. Also

piezoelectric materials have a large no of applications, though power output is low but can be increased by using suitable parameters. So, purpose of the paper is to present a piezoelectric energy harvesting model using PVDF-piezo material with hydro dynamism to extract maximum energy.

3. CONCLUSIONS

1. An effective and efficient model has been developed for piezoelectric energy harvesting using hydro-dynamism to convert the dynamic pressure of water into electrical energy.
2. The generated output can be controlled upto 12 V by using IC-7804 for battery charging purpose.
3. This is a cost effective and environment friendly model.
4. This system can be incorporated at the end of the flaps of boats to provide electric energy to power small devices like mobile, bulb etc.
5. The model presented here can be used to generate power from the water, which is wasted from homes, industries, power plants etc.
6. The model can be used near canal to supply electricity to the street lights.
7. The model can likewise be used where water quantity is fixed and the water recirculation is done by utilizing a water pump.

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