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DESIGN AND ANALYSIS OF WATER FLOW ENERGY HARVESTING SYSTEM

Saransh Juneja, Shivam Vohra, Souvik Banerjee, Subhranshu Shekhar[1]

Department of Electronics and Communication Engineering, Dr, Akhilesh Das Gupta Institute of Technology and Management, New Delhi-58

Abstract

This study aims to develop a system where the input power comes from self-powered water flow energy harvesting system. This Water flow harvesting system has been designed using a water pump and Pelton wheel turbine, which enables us to transform kinetic energy of the water flow into electrical energy which is further used to power low power electronic devices and sensors. These specialized hydro-systems can operate in a variety of head and flow conditions depending upon the water flow rate. The water flow energy harvesting system and water pressure fluctuation introduced during the testing and the analysis of the project is also used to generate small amount of power. The output produced through the energy harvesting system is predicted to be about 1.87W as per the results achieved which is good enough to run the low power electronic devices.

Keywords: Arduino, Energy Harvesting, Turbine, water

INTRODUCTION

The extraction of energy from non-conventional sources in the environment has received increasing attention over the past decade by researchers studying these alternative energy sources for low power consumption applications. The researchers constantly aim at figuring out recent advancements in the field of energy harvesting. There is a lot of wasted energy in the environment which can be converted to its useful form and showcasing it as a potentially cheap source of power. With the advent growth of technology in the 21st century, we have arrived at a point where many of today's more efficient battery technologies use elements such as lithium, which are often quite rare considering the demand for chemicals for industrial purposes. Today we have to think about how we can manufacture these materials looking at the human needs and, perhaps more importantly, how we can dispose of them at the end of their useful life. The demand for these materials is increasing exponentially with the demand for the materials required to manufacture them. Concerns have been constantly raised about the fate of the planet, not only about how we can fulfil the demand but also about its impact on the world. What the world needs now is a new generation of products that generate their energy from their local environment, rather than relying on conventional batteries. The world needs us to develop products that use energy harvesting as the base for powering low-power electronic devices. We and the world cannot afford not to ignore the subtle demand of this need.

That raises the question of what basically is Energy Harvesting? Energy harvesting could be termed as a process of extracting and converting the ambient energy when it is easily accessible into its usable form such as electrical energy e.g., Wind Energy Harvesting. Energy harvesting is important as it provides an alternative power source for electronic devices where traditional energy sources are not available. This technology, can be extended to devices in the IoT which eliminates network-based energy and conventional batteries, minimizes maintenance costs, eliminates cables and batteries, and is environmentally friendly. Energy generation promotes environmentally friendly technologies that save energy and make this technology indispensable for achieving next-generation smart cities and sustainable society. Previously, solar energy and mechanical energy were two of the most important and only known sources used to produce energy. However, the surge in demand has led to a growing focus on the science that aims to extract energy from various sources such as wind, geothermal, rain, or other natural vibrations. Piezo-electric, thermoelectric are also the techniques that have been used in the past to contribute to the research in this field. The researchers lately introduced such energy harvesting networks that can harvest electromagnetic waves as well as radio waves into electrical energy for power generation The decision about using the harvesting method depends on the location and the application involved. The difference lies in the amount of energy produced with each of the different technique. The table given below depicts the Power Density in different energy harvesting methods.

Table 1 Clearly highlights the comparison of various Energy Harvesting Methods with respect to their Power Densities with their Units. We can also learn about the elements involved in those harvesting techniques.

Energy Harvesting Methods	**Energy Harvesting Elements**	**Power Density**
Solar and Light Energy Harvesting	Photovoltaic solar Panel	1500µW/cm² (Outdoor sunlight 1000W/m²)
Mechanical Energy Harvesting	Wind turbine Vibration piezoelectric Wafer Vibration Electromagnetic vibration electrostatic	3.5mW/cm² 500µW/cm² 4.0µW/cm² 3.8µW/cm²
Thermoelectric Energy Harvesting	Thermoelectric Converter	40µW/cm² 100µW/cm² Temperature difference 5ºC
Electromagnetic Wave Energy Harvesting	RF Harvesting Board	20mW (915MHz Input power 100mW)

Table 1. Comparison of power densities of various Energy Harvesting Techniques.

LITERATURE REVIEW

From H F Liew et al 2021 [1], In this water pipeline system consists of two Arduino and two LCD screen used in the system to display different parameters from the source. The first Arduino and LCD is work as screen to collect and display data from the hydroelectric generator. Then the second Arduino and LCD screen is used to collect and display data from the water flow sensor. At the same time, power generated from the hydroelectric generator will directly function as to light up a LED bulb. Also, parameters measured which are included current, voltage and power from the generator will be displayed on the LCD screen with an Arduino Uno board as the processor. From the source, water will flow through the water flow sensor to measure the water flow rate. Water flow rate will also be displayed on the LCD screen with an Arduino Uno as the processor. Finally, with the ESP8266 Wi-Fi module as the processor, all the parameters obtained should be displayed on the web-server for the monitoring system purposes. As the water flow rate increased, the voltage generated by the generator also increased. The voltage varies constantly from water flow rate range 3 - 12 L/min but at range 12 - 15 L/min, voltage experienced raise and increase constantly at range 15 - 20 L/min. The result present that water flow rate is controlled by controlling the water pipe faucet with 3 L/min recorded as the minimum water flow rate and 20 L/min recorded as the maximum water flow rate by the water flow sensor. When output current produced from the system increasing from 23 mA as the minimum value and 107 mA as the maximum value are recorded.

In 2015, Casini [2], The internal and external systems of the in-pipe hydropower system are separated into two primary groups and two main portions. In internal system the runner is totally inside the pipe section and only the generator sticks out from the pipe have the merit of minimal size, making it more useful for smaller applications, but not limit itself. The output of this project varies from 5-10 Watt to 100 KW for more energy-required applications, which to provide self-powered water metering or monitoring systems. On the other hand, external system where a secondary pipe that covers the main pipe contains a runner which do not depend upon the size of the pipe and allows much greater flexibility.

Ye and Soga in 2012 [3] suggested that want to monitor water distribution systems within the facility trade within the field of energy harvest. thanks to harvest renewable energy from a water or environmental distribution system would be a gorgeous possibility, water sensors are put in into areas wherever power provide is lacking and downsides difficulties replacement of batteries or drawback restricted lifetime. The water distribution systems into energy harvest systems square measure analyzed, compared and modelled victimization simulation knowledge and real knowledge [1, 2]. The results of this analysis introduced by hydrothermal energy harvesters and water pressure fluctuations is probably going to produce range in mW of power. Overall, this works reportable that on the likelihood of energy harvest in a very water distribution system from hydraulic energy in bypass water pipes, thermal energy in water-air gradient, and mechanical energy in water pressure fluctuations.

This research work deals with the water flow energy harvesting system using water flow through a dual pressure pump to replicate a natural water flow, which helps measure various electrical parameters such as DC Current, DC Voltage, AC Voltage using Arduino platform and generates energy for intelligent measurement applications. This research also highlights some prime ideas for enhancing the amount of energy produced by water flow energy harvesting system, which is dependent upon the power output, water pressure which varies with the output of Pressure pump used. The project work generates power output which is good enough to operate low power devices such as sensors controlled using Arduino software. Furthermore, the application can be extended across locations closer to the arches based on the water flow rate through which various experimental configurations can be experienced.

METHODOLOGY ADOPTED

A system to generate hydroelectric power from water is designed using Arduino Uno as the core of processor to obtain all the data and parameters required and display it onto the LCD screen for monitoring parameter as well as use Bluetooth for measuring Temperature and Humidity data. In this energy harvesting prototype, the system consists of Two Arduino and one LCD screens that are used in the system to display various parameters from the source. The project starts with the use of a 24v dc pump to create the necessary pressure required for the Pelton wheel to rotate. This pressurized water jet strikes the runner of the Pelton wheel turbine which is connected to an alternator which converts this rotational mechanical energy to electrical energy in form of alternating current (A.C), this A.C is then passed through full bridge rectifier with a 2200uf capacitor to obtain a smooth D.C output. This D.C output is then used to power an Arduino uno directly and charge a 7.5-volt battery pack simultaneously. The first Arduino is connected to a voltage sensor and a lcd, the voltage sensor is a voltage divider consisting of two resistors of 30k***Ω*** and 7.5k***Ω*** i.e., a 5:1 voltage divider, the data form the voltage sensor is then displayed over the lcd with an Arduino board as the processor. The 7.5-volt battery pack is a combination of 6 cells of 1.25V each connected in series to give a total of 7.5v output voltage. The battery pack is getting charged from the D.C supply provided from the rectifier and is also powering a second Arduino simultaneously. This second Arduino is connected to a DHT-11 sensor and a HC-05 Bluetooth module. The DHT-11 sensor is used to measure the humidity and temperature, DHT-11 sensor consists of a capacitive humidity sensing element and a thermistor for sensing temperature. The moisture sensor capacitor contains two electrodes between which a moisture-retaining substrate is located as a dielectric material. The Capacitance value changes in accordance with the change in humidity levels. The IC measures, processes these changed resistance values and changes them into digital form. The temperature sensor uses principle of a Negative Temperature coefficient thermistor, which in term can lead to resistance value decrease with temperature increase. To get a larger resistance value even for the smallest change in temperature the data from this sensor is sent to the Bluetooth module by the second Arduino, this Bluetooth module which uses the 2.45GHz frequency band. The data transfer rate may be varied up to 1Mbps and is in the range of 10 meters. then sends the temp and humidity data to the phone connected through this Bluetooth.

RESULTS

The main idea was to improve the efficiency of the energy harvester through the designing of a DC-to-DC Converter by using 555 timer and MOSFET as the switching device. The trade-off between voltage and current has been an integral improvement in the energy harvester prototype since the low current, low voltage or both have been an issue with the energy harvesters for a long time now. Essential power management is important for various applications. The DC Voltage before using the Converter was 20V which was reduced to 17V in order to increase the DC current for extending the range of sensors that could be powered using the power available from the energy harvester and furthermore increasing the efficiency of the energy harvester prototype designed in this research. The voltage fluctuations were reduced at the output and on LCD screen giving constant display for displaying the excess voltage obtained after powering the Arduino boards, voltage sensor.

In **Table 2** Following Electrical Quantities were measured to analyse the energy performance of the water flow energy harvesting system and compare the results with the ones achieved through the researches done before and see how the system prototype is better than others. The Values displayed in the table listed below are the Peak Values.

Electrical Quantities	Before Amplification	After Amplification
AC Voltage	8.4V	8.6V
Dc Voltage	20V	17V
DC Current	90mA	110mA
DC Power	1.8W	1.87W
Energy	0.440kWh	0.317kWh

Table 2 Electrical Parameters Obtained

Time(minutes)	Voltage Capacity
0-2	3.8V(50%)
2-3	5.6V(75%)
3-4	6.86V(91%)
4-5	7.04V(94%)
5-6	7.20(96%)

Table 3 Charging Phase Analysis

Table 3 showcases the charging phase analysis of the rechargeable battery pack that is charged through the power obtained from the prototype of the energy harvesting system. The table contains the data of the time taken to charge the 7.5 V battery pack. The maximum capacity of the battery pack is 7.5V. The 2nd column of the table contains the battery voltage achieved and the percentage of the total capacity of the battery. Firstly the stop watch is set at a timer of 2 minutes and the voltage capacity is measures. As observed the battery is charged to 3.8V in 2 minutes which is approximately 50% of the total capacity. In the next 1 minute the capacity exceeds to 75% of the total capacity. This is quite obvious keeping in mind the battery when at lower voltage charges at a rapid rate at first and then the charging rate slows down as its difficult to move the ions inside the cell due to the temperature and potential.

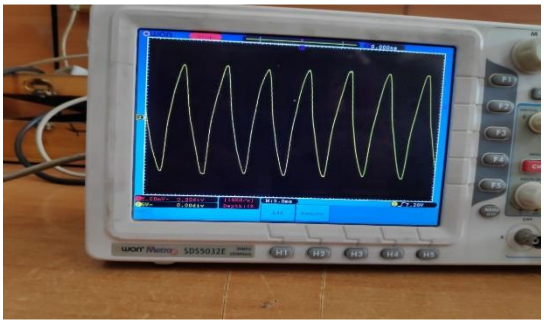

Fig 1 AC Voltage Plot

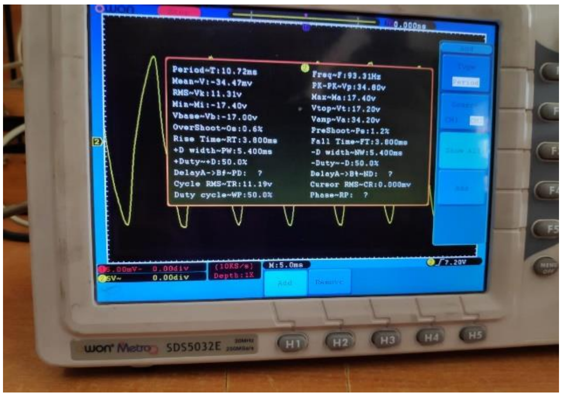

Fig 2 Voltage Plot Specifications

Figure 1 shows the voltage plots obtained for taking into account the performance of the energy harvester designed. The Graphs were plotted using DSO (Digital Storage Oscilloscope) for the analysis of the performance of our prototype.

Figure 2 shows the enlistment of the Plot specifications such as RMS Value, frequency, Peak overshoot value, rise time, fall time, time period and various other specifications which gives us a better understanding of the voltage plot.

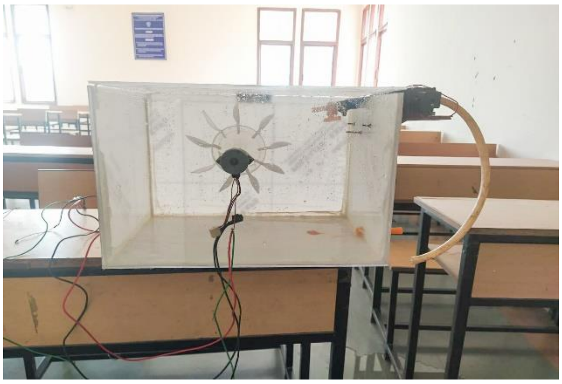

Fig 3 Front View of the Energy Harvester Prototype

The **figure 3** above depicts the setup of the Energy Harvester Prototype

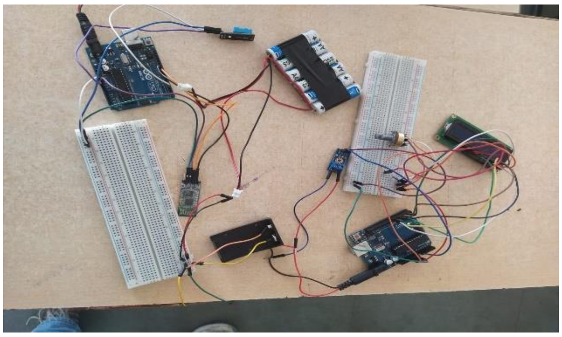

Fig 4 Sensors Used in the Project

Figure 4 showcases the various sensors used for the application of the project such as DHT-11 Temp and Humidity sensor, Bluetooth HC-05 Module, Voltage sensor (Vcc<25V), lcd module

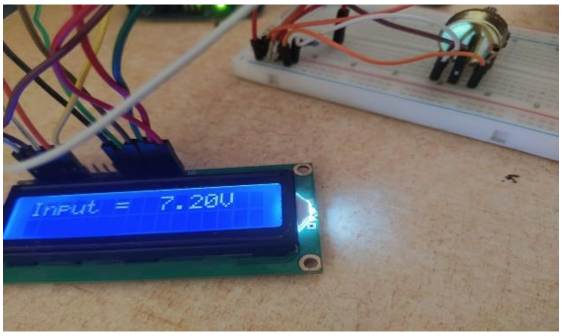

Fig 5 Excess Voltage Displayed on LCD Screen

Figure 5 depicts the voltage sensor setup for displaying the excess output voltage after powering the deployed sensors and Arduino Board for their applications.

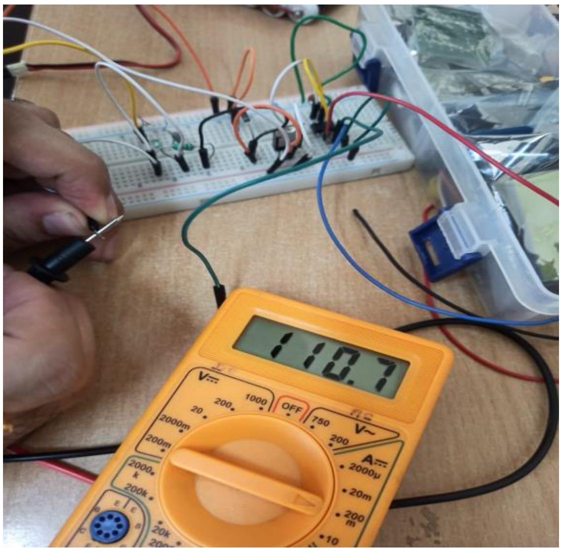

Fig. 6 Maximum Current measured using PMC circuit

Figure 6 Displays the DC Current measured using the Multimeter after the DC-DC Conversion.

CONCLUSION

This research focuses on energy harvesters' core operation, dominance, and analysis. The most straightforward way to turn out energy is to use water flow. Instead, the output power supplied by the system is low in comparison to the capabilities of the instrumentality used in the system. The system, on the other hand, relied on a large-scale electrical generator to provide the highest voltage (24V DC). This project, which uses water as its primary source of energy, is able to create an energy collection system that is both clean and promising in terms of supply. It is being used to replace generators to generate energy since it has numerous advantages and is simple to deploy because it provides useful data and change period measurement for users, and it can be accessed at any time and from any location. Another improvement that will be made to the project in the future is the use of a larger electrical generator to get more power, Because the generator used in this project will only produce a maximum output voltage of 16 volts, the power will be limited and will not be able to support a heavier load. Finally, using the battery as a direct connection to the Arduino's capability for this purpose may result in other concerns such as the requirement for regular battery replacement and the possibility of electrical shocks as a result of water leaks. As a result, with a few recommendations and alternatives, the system may be built and improved in a safer setting.

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