Piezo Electric Rainfall Energy Harvester with Proactive Protection Mechanism with Integrated IOT device

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Abstract. The main objective of this paper is to generate solar power and also monitor the power harvested from the rain fall and to protect the energy harvesting device from natural elements. It is done using solar and piezoelectric panels. The energy from solar and piezoelectric panels are stored in a battery. The data regarding the operation of the solar and piezoelectric panel is transmitted via NodeMCU. This data regarding the amount of energy generated and duration of rainfall can then be viewed from anywhere

Keywords: — Piezoelectric, Energy, Solar Panel and Current Sensor

Introduction

Sunlight and rainfall has been harnessed by humans since the advent of civilizations and even before that. While the fossil fuels are the major source of energy today, exponential depletion of the fossil fuels and global warming and other effects caused due to increasing pollution has forced us to look for other non-conventional sources of energy.[1] Though power generation from sunlight proved initially inefficient and costly initially, various techniques have been developed and implemented to generate electric power from solar energy with increased efficiency and economic feasibility to a considerable extent. But solar energy cannot be efficient at all times, as the sunlight is very minimum during rainy days. Hence to generate power at all times we are making use of solar and piezoelectric panels to harness both sunlight and rainfall. Even though number of studies on generating electricity from rainfall, quantity measurement during rainfall and protection of devices are still absence [2].

The implementation and performance analysis of rainfall energy harvesting with the help of an IOT based measuring system along with a piezoelectric transducer to generate power using solar panels is investigated in this paper[3]. The measurement of energy produced from a rain and sunlight is controlled with an IOT-based measuring system. The electrical energy produced by piezoelectric transducer is computed by IOT based measuring system. There is also a mechanism provided to protect the harvester from natural elements and other birds and animals [4].

1. Transduction Principle

When mechanical stress is applied to a piezoelectric material it converts the mechanical stress into electricity [5]. This principle is called as piezoelectric effect. The working principle of piezoelectric effect is based on the fundamental structure of the crystal lattice. In this paper crystal symmetry and their
Piezoelectricity is very closely investigated. Piezoelectric effect is not observed in all types of crystals. Only crystals without center of symmetry exhibit this property. This can be clearly explained with monocrystal and polycrystalline structures. The basic structure of a monocrystalline crystal can be seen in the figure 1. [6] Even when these crystals are split into pieces, the polar axes would lie unidirectional throughout the crystal [6]. This shows that the polar axes all charge carriers exhibit unidirectional characteristics [4].

![Figure 1. Structure of a Monocrystalline crystal.](image)

Piezoelectricity is given by the following expression in terms of electric field, the strain, the electrical induction and the stress.

\[
\begin{align*}
T_p &= \varepsilon^p_{ij} S_j - e_{jk} E_k \\
D_i &= \varepsilon_{ik} S_k + e^k_{ik} F_k
\end{align*}
\]  
(1)

\[
\begin{align*}
\varepsilon_{ij} &\doteq \frac{\delta D_j}{\delta E_i} = \left( \frac{\delta T_j}{\delta E_i} \right)^T \\
d_{ij} &\doteq \frac{\delta D_j}{\delta T_i} = \frac{\delta S_j}{\delta T_i} \\
g_{ij} &\doteq \frac{\delta E_j}{\delta T_i} = \frac{\delta S_j}{\delta D_i} \\
h_{ij} &\doteq \frac{\delta E_j}{\delta S_i} = -\frac{\delta T_j}{\delta D_i}
\end{align*}
\]  
(2)

Related to each other as follows

\[
\begin{align*}
d_{ij} &= e_{ik} g_{kp} \\
e_{ij} &= d_{ik} e_{kp} \\
g_{ij} &= d_{kp} / e_{ik} \\
h_{ij} &= g_{ik} e_{qp}
\end{align*}
\]  
(3)

\[
k^2_{ij} \doteq \frac{W_j^{(electrical)}}{W_q^{(mechanical)}} = \frac{\varepsilon_{ij}^2}{e_{ik}^2 c_{pq}^2} = \frac{\varepsilon_{ij}^2}{e_{ik}^2 c_{pq}^2 + e_{lj}^2}
\]  
(4)
Where, \( k \) is the coupling factor and \( Q \) is known as the quality factor.

2. Implementation

From the above figure we can see that the power generated from solar and piezoelectric panels are charged using a battery and the charge is controlled using a wifi enabled NodeMCU. A DC motor is used to harness the generated power. Rainfall energy harvesting with the help of IOT based measuring system along with a piezoelectric transducer and their performance is explained in this paper [8].

Though power generation from sunlight proved initially inefficient and costly initially, various techniques have been developed and implemented to generate electric power from solar energy with increased efficiency and economic feasibility to a considerable extent. But solar energy cannot be efficient at all times, as the sunlight is very less during rainy days [9]. Hence to generate power at all times we are making use of solar and piezoelectric panels to harness both sunlight and rainfall. The measurement of energy produced from a rain and sunlight is controlled with an IOT-based measuring system which is pointed towards measuring the actual amount of energy produced by the piezoelectric transducer which is exposed in rainfall at variable durations and the solar panel [10]. The piezoelectric panel being very delicate and sensitive in nature requires safety mechanism to protect it from natural elements such as birds. Hence, an obstacle sensor is used to scare off the birds and animals that go near the energy harvesting device. Further there is an auto open-close mechanism inside which the piezoelectric panel is placed. The rainfall sensor on detecting the rainfall sends signal to the microcontroller. The controller then sends signal to the drive. The driver mechanism which can be controlled in both forward and reverse direction opens the cover so as to expose the piezoelectric panel to the rainfall. Once rain stops the microcontroller again receives signal from the rainfall sensor and makes the drive to cover the piezoelectric panel. This is done to avoid direct exposure of piezoelectric panel to the harsh environment, thereby increasing its lifetime. The plates of the piezoelectric panel are connected in parallel, so as to minimise the voltage drop. [11]
The voltage generated from the piezoelectric panel is impulse in nature due to irregular fall of rain drops. Hence a capacitor is used to store the charge and filter the harmonics, to give out a uniform dc voltage. The power generated from the solar panels undergoes a similar procedure of filter rectifier circuit. Voltage from both the sources is stored in a battery, which can then be used later. The total energy generated can be measured physically across the two terminals of the battery. A diode is used in order to prevent the reverse currents from flowing in the circuit. NodeMCU, a system on chip consisting of Wi-Fi enabled microcontroller ESP8266 is used to control the entire process. It is powered by a 230V-12V step down transformer. The 12V ac supply is rectified before being stepped down to 5V DC to power the controller. The NodeMCU is used here for the purpose of data transmission using IOT.

The voltage generated from the solar and piezoelectric panel is passed through voltage divider circuit before being fed into the controller, for the data regarding the amount of energy stored. [12] But the controller has only one analog pin. So to receive two analogy inputs from the solar and piezoelectric panel, we are using a multiplexer. The duration of the rainfall is calculated using rainfall sensor. This data is also fed to the controller, for efficient tracking of energy generated. [13] All the generated data are then transmitted via wifi using NodeMCU and is displayed in a web page created for the purpose of displaying energy generated. The webpage is created using PHP and program is fed into the NodeMCU in embedded C using arduino software. [14] The screen displays the data about the amount of energy generated from rainfall each time and the cumulative energy generated from the solar and piezoelectric panel and the rainfall duration each time. [15]

3. Software Tools

1. Development Device - PC with Windows 7 OS
2. Target Device - NODE MCU
3. C Variant - Embedded 'C'
4. IDE - Arduino
5. Compiler - Arduino Inbuilt
6. Simulation - Proteus

4. Hardware Tools

1. Oscilloscope - Tektronix DSO
2. Soldering Iron - Soldron 25W
3. Multimeter - Mastech Digital Multimeter

5. Applications

- Rural areas where it is not efficient to bring transmission lines for power supply.
- Tropical and subtropical countries with monsoons.
- For research equipments in dense forests with heavy rainfall.
6. Experimental Setup

The Figure 3 shows the OFF state condition of piezoelectric panel.

![Figure 3.OFF STATE](image)

The Figure 4 shows the ON state condition of piezoelectric panel.

![Figure 4.ON State](image)

Figure 5. In the presence of an obstacle
Output Results

Figure 6. Data Display

7. Conclusion

The implementation of rainfall energy harvesting with the help of a piezoelectric transducer with use of an IOT-based measuring system is done. The measurement of energy produced from a rain and sunlight is controlled with an IOT-based measuring system which is designed in a way so that it will measure the actual amount of electrical energy that is produced by the piezoelectric transducer that is exposed to rainfall of variable durations and the solar panel. There is also a mechanism provided to protect the harvester from natural elements and other birds and animals.

References

[1] Hobecck J. D. & Inman D. J. (2012), “Artificial piezoelectric grass for energy harvesting from turbulence-induced vibration. Smart Material and Structures, Volume 21 105024 doi:10.1088/0964-1726/21/10/105024

[2] Benasciutti D. & Moro L. (2010) “Harvested power and sensitivity analysis of vibrating shoe-mounted piezoelectric cantilevers. Smart Material and Structures” vol. 19 115011 doi:10.1088/0964-1726/19/11/115011

[3] Xiang H. J., Wang J. J., Shi Z. F. & Zhang Z. W. (2013). “Theoretical analysis of piezoelectric energy harvesting from traffic induced deformation of pavements. Smart Materials and Structures Volume 22 (9), doi:10.1088/0964-1726/22/9/095024

[4] Ponnusamy Prem (2020), “A novel cross-connected multilevel inverter topology for higher number of voltage levels with reduced switch count” International Transactions on Electrical Energy Systems 30 4 1 – 18.

[5] J S, Sakthi & Pandarinathan, Sivaraman & Prem, P. & Matheswaran, Alagu. (2020). “Wide Band Gap semiconductor material for electric vehicle charger. Materials Today: Proceedings. April 2020

[6] TAS. Raja, Dr. Jovitha Jerome, R. Senthil Kumar, P.Prem (2011), “Implementation of ZVS Concept in Four Wire Inverter for UPS Fed (Unbalanced) Star Connected Load Journal of Electrical Engineering
[7] Sivaraman P, Sakthi Suriya Raj J S, Matheswaran (2019), “A Renewable Energy Source Integration With Linear And Nonlinear Control Techniques International Journal of Scientific and Technology Research” 8 10 2872 - 2880

[8] Prem P, Jagabar Sathik, Sivaraman P, Matheswaran A, Shady H. E. Abdel Aleem (2019), “A New Asymmetric Dual Source Multilevel Inverter Topology with Reduced Power Switches” Journal of Chinese Institute of Engineers 42 5 460 - 472.

[9] A. Matheswaran C. Ganesh Babu (2017), “Mathematical Modelling and Analysis of Solar PV Based Modified Quadratic Boost Converter for Extraction of Maximum Power” International Journal Applied Mathematics 11 5 1389 – 1397.

[10] A.Matheswaran, C.Ganesh Babu, R.Sumith (2014), “Design and Analysis of Adaptive Hysteresis Controller for Shunt Active Filter with Pq Control Strategy” International Journal of Applied Engineering Research (IJAER) 9 24 27557 - 27568

[11] Prem Ponnusamy, Suresh Velliangiri, Jagabar Sathik Mohammed Ali A (2020), “Hybrid Switched Capacitor Multi-Level Inverter with High Voltage Gain and Self-Voltage Balancing Ability Electric Power Components and Systems” 1 1 – 15.

[12] P Sivaraman, and P Prem (2017)“PR Controller Design and Stability Analysis of Single Stage T-Source Inverter Based Solar PV System” Journal of Chinese Institute of Engineers 40 3 235 – 245.

[13] Van den Ende D. A., van de Wiel H. J., Groen W. A. & van der Zwaag S. (2012). “Direct strain energy harvesting in automobile tires using piezoelectric PZT–polymer composites Smart Materials and Structures” Volume 21

[14] Prem P,Sivaraman P, Dhafer Almakhles,P. Sanjeevikumar,Zbigniew Leonowicz, Matheswaran A,Jagabar Sathik M (2020) “A New Multilevel Inverter Topology with Reduced Power Components for Domestic Solar PV Applications” IEEE Access 10.1109/ACCESS.2020.3030721

[15] Prem P, Bharanikumar R (2018) A New Multilevel Inverter Topology To Integrate Wind-Solar Hybrid System Without A Common DC Bus Journal of Electrical Engineering, Romania 18 2 1 – 8.