

IOT-BASED SOLAR-PIEZO HYBRID ENERGY GENRATING SYSTEM

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ABSTRACT - The demand for energy is increasing continuously. This is happening because environmental issues and we are running out of energy sources like coal and petroleum. So people are getting more invested in renewable power solutions.

This proposed system is, about creating a system that uses the Internet of Things to generate energy in a way. The system combines energy from panels with energy from vibrations. This makes the power supply more continuous and reliable. We use elements called piezoelectric elements to get energy from vibrations. The main energy source is a solar panel that gives us 12 volts. The energy that is made is sent through some systems that make it work better. A special controller manages it before it goes into a 12 V, 7 Ah rechargeable battery.

An ESP32 microcontroller keeps an eye on the system all the time. It looks at things like how much energy the solar panels are making the voltage from the piezoelectric and how the battery is doing.

The ESP32 microcontroller sends all the information it collects to a cloud-based platform, on the internet so people can check on things from far away look at the data and control the energy system.

Keywords: Hybrid energy generation, Solar photovoltaic system, Piezoelectric generator, Internet of Things, ESP32, Arduino UNO, Smart monitoring.

1.INTRODUCTION

The population is growing fast and this is putting a lot of pressure on the energy we have. We are using a lot of energy for our homes and cities. This is a big problem. Most of the time we make electricity using fossil fuels like coal and gas.. These fuels are running out and they are also very bad for the earth. They make a lot of pollution. This is making the earth get sick. This is why people around the world want to find new ways to make energy that are clean and good, for the earth. Energy solutions that are clean and sustainable are what we need now. When we look at the options for energy that are available today solar power is one option that a lot of people are using. This is because solar power can be used to make a lot of energy and it is good for the environment.. Solar power has some problems. For example it does not work well when the weather is bad. Also solar power only works when the sun is shining during the day. Solar power is still an option, for renewable energy but these problems can limit how well it works. Solar

power is a part of renewable energy and people are still trying to find ways to make solar power better.[1]

We have a problem with systems that work on their own. So people have come up with an idea. Hybrid renewable energy systems. This means we use two kinds of energy together.

One way to do this is to use something called energy generation. This is when we use the movements and forces around us to make electricity. We can find these movements in lots of places like roads, buildings and sidewalks.

The thing is, each piezoelectric device does not make a lot of electricity on its own.. When we use these devices with solar panels we can make more energy overall. This is a thing for hybrid renewable energy systems, like these which combine piezoelectric energy generation and solar generation to make more energy.[2]

The Internet of Things technology is getting better and better. This is helping us to keep an eye on energy systems and control them in a way. Internet of Things technology is using communication and special sensors to collect data. This means we can track energy use all the time access the systems from away and manage them in a better way. Internet of Things technology is really making a difference, in how we manage energy systems.

In this work, an IoT-based solar–piezo hybrid energy generation system is presented by integrating photovoltaic modules, piezoelectric sensors, energy processing circuits, and wireless monitoring systems. The proposed system is intended to supply uninterrupted low-power energy for applications such as mobile charging,

automated lighting systems, and environmental monitoring units. This study highlights the benefits and potential of combining renewable energy generation system with IoT-based system to support sustainable an energy solution.[3][4]

Method	Key Features	Limitation
Solar-only systems	High energy output	Intermittent (daytime only)
Piezoelectric systems	Utilizes vibrations	Low power output
IoT monitoring systems	Real-time tracking	No energy generation
Proposed hybrid system	Continuous+smart monitoring	Requires integration complexity

2.Body of Paper

1.LITERATURE-SURVEY

People are really interested in renewable energy systems because they can make energy more reliable and we do not have to depend on just one source of energy.

Chowdhury et al. Came up with an idea to use solar power for street lights, in cities which can help reduce the amount of energy cities use and make the infrastructure more sustainable.

Hybrid renewable energy systems are what Ahmed et al. Studied. They found out that the power output can be very unpredictable which is a big problem.[5]

Hybrid renewable energy systems need energy storage units and smart control systems to work properly and consistently which is what Ahmed et al. Said is very important for hybrid renewable energy systems to operate smoothly.

People have shown that it is possible to get energy from movement using materials called piezoelectric materials. Some researchers like Meninger and his team found a way to turn the vibrations that're all around us into energy that we can use. They used devices called piezoelectric transducers to do this and they wanted to use this energy to power small electronic devices. Other people, like Ramadass and Chandrakasan worked on making this process better so they came up with special circuits that help get more energy from the piezoelectric materials and turn it into usable energy.[6]-[8]

The Internet of Things or IoT is being used in ways to make renewable energy systems better. People are looking at how IoT can help us keep an eye on these systems and make sure they are working well. This means we can find problems and fix them from away which makes the whole system work more smoothly.[9]

When we combine kinds of renewable energy with smart monitoring systems it seems like a good way to make power systems that are smart and good for the environment. This is why the proposed research, on Internet of Things and renewable energy systems is important. The Internet of Things and renewable energy systems can really help us make progress in this area.[10]

II. EXISTING SYSTEM

Traditional renewable energy installations usually focus on one energy source, like wind energy, which can make the whole system less reliable. Solar energy is an example. It is used a lot now. The amount of energy it makes depends a lot on the weather. For instance when it is cloudy solar energy systems do not make much energy. At night they do not make any energy at all. During different seasons the amount of energy they make can vary a lot. Renewable energy systems that use vibrations to make energy, like piezoelectric systems have a problem. They can turn the vibrations around us into energy but they usually do not make enough energy to keep things running all the time when they are used alone. Renewable energy systems, like these need to be able to work in different situations to be really useful.

Renewable energy systems have some problems. Many of these systems do not have technology to watch over them. People usually check how well they are working when they are not being used. They might not find problems for a long time. This means they do not work well as they should and it takes more work to keep them running. Renewable energy systems need to be smarter. They need to be connected to the internet so we can watch over them and control them. This will make them work better use energy in a way and we will be able to see how well they are working. We need to make energy systems, like this so they can work really well. Renewable energy systems will be better if they have this kind of technology.

III. PROPOSED-SYSTEM

The system we are talking about uses panels and special devices to make a new kind of

power system that is good for the earth. The solar panels are the source of power for the system. They work really well when the sun is shining. They make a lot of power from the sun. The power from the panels is pretty consistent.

The other part of the system uses devices that can make power from things that move or vibrate like when people walk around and move the ground. These special devices are a part of the system and they help make the system work well. The solar panels and the special devices work together to make a kind of power system that is good, for the earth. These devices are made from a material called lead zirconate titanate or PZT for short and they help make the system work even better by catching the power from these movements.

The voltage from the elements goes back and forth so it needs to be changed into a steady voltage. This is done using a tool called a bridge rectifier. Then the voltage is made smoother using special parts called filtering capacitors.

The energy from the photovoltaic panel and the piezoelectric harvesting unit is sent to a charge controller. The charge controller makes sure the voltage and current levels are okay. It also stops the battery from getting much energy and helps store energy safely in a 12 V 7 Ah LONG Hi-Power rechargeable battery. The charge controller is very important, for the piezoelectric harvesting unit and the photovoltaic panel.

The ESP32 microcontroller is like the brain of the system. It is in charge of watching over everything and collecting data. The ESP32 microcontroller is the part that makes everything work. The voltage sensing circuits are always checking on the module, the

piezoelectric unit and the battery. The ESP32 microcontroller takes the data it collects. Does something with it. It sends the data to a cloud-based IoT platform, such as Blynk or Thing Speak using transmission. The ESP32 microcontroller is really good, at sending this data. This makes it possible to see what is happening in time analyze how well the system is performing and get alerts when something is not working normally with the solar module, piezoelectric unit and battery. The ESP32 microcontroller and the IoT platform work together to make sure the system is working properly.

The new system combines energy sources and it has a smart way to monitor everything. This hybrid system helps to keep the power on all the time. It also makes the system stronger and able to deal with problems. The system is really smart. It helps to make the most of renewable energy sources like solar and wind power. The hybrid system is a thing, for renewable energy harvesting applications. It makes energy harvesting better and more efficient.

IV. SYSTEM ARCHITECTURE AND BLOCK DIAGRAM DESCRIPTION

The system architecture is made up of four parts:

- * The system architecture has a main components

The system architecture includes four major subsystems:

This means the system architecture has four main subsystems that work together

The system architecture is divided into four major subsystems.

1. Energy Harvesting Unit – solar panel and piezoelectric modules.

2. Power Conditioning and Storage Unit – rectifier, filter, charge controller, battery, Arduino UNO and Transformer.

3. Sensing and Control Unit – voltage sensors, current sensors and ESP32 microcontroller.

4. IoT Monitoring Unit – Wi-Fi connectivity and cloud dashboard.

The solar panel converts incident sunlight into DC electrical energy. Piezoelectric elements generate alternating voltage when subjected to vibrations. After rectification and regulation, the combined power is stored in the battery. The ESP32 continuously acquires sensor data and transmits it to the IoT platform, enabling remote monitoring and system diagnostics..

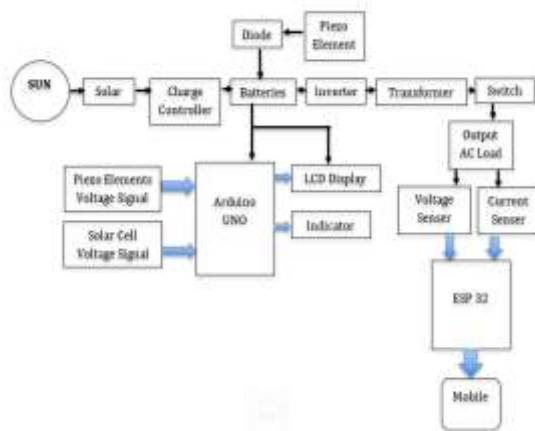


Fig 1- Block Diagram

V. HARDWARE COMPONENTS

- **Solar Panel:** The main renewable energy source is a 12 V photovoltaic module.
- **Piezoelectric components:** PZT-based sensors with a resonance frequency of around

3 kHz, a rated voltage of at least 30 V, and a capacitance of 30 to 50 nF.

- **Battery:** 12 V, 7 Ah rechargeable battery.
- **Microcontroller:** Arduino UNO and ESP32 with integrated Wi-Fi for Internet of Things communication.
- **Charge Controller:** Prevents deep discharge and overcharging of the battery.
- **Voltage sensors:** Used to track battery, piezo, and solar voltages. Diodes, capacitors, resistors, connections, PCBs, and breadboards are examples of supporting components.
- **Current Sensor:** This thing is used to see how much current is coming out. It measures the current that is being produced by something. The Current Sensor is really good, at doing this job. It helps us know what is going on with the Current Sensor and the current it is measuring.
- **Transformer:** It is used to step up power and inductance from 1.1 H to 100 H

VI. METHODOLOGY

1. **Requirement analysis:** determining the needs for low-power hybrid renewable applications.
2. **Component Selection:** Choosing the battery, ESP32, piezo elements, solar panel, and sensors.
3. **Circuit design:** creating circuits for sensing, control, and rectification.
4. **IoT Programming:** The Arduino IDE is used to program the ESP32 and Arduino Nano for data collection and Wi-Fi connectivity.
5. **Hardware Integration:** Subsystem connections and module assembly.
6. **Testing:** Evaluation of performance in different vibration and sunshine conditions.
7. **Analysis:** System stability, monitoring precision, and power contribution observation.



VII. MATHEMATICAL ANALYSIS AND RESEARCH FINDINGS

1. Solar Power Output

Solar panel electrical power:

$$P_s = V_s \times I_s$$

Where:

V_s = Solar voltage

I_s = Solar current

From your IoT dashboard:

$$V_s = 69.2V, \quad I_s \approx 0.97A$$

$$P_s = 69.2 \times 0.97 = 67.12W$$

$$\sim \text{Solar output} \approx 67.2 \text{ W}$$

2. Piezoelectric Energy Generation

Piezo output voltage: $V_p = d_{33} \times F \times t$

Where:

d_{33} = piezoelectric coefficient

F = applied force

t = thickness

Electrical energy from piezo: $E_p = 1/2 CV_p^2$

Typical values: $C = 47nF, \quad V_p = 30V$

$$E_p = \frac{1}{2}(47 \times 10^{-9})(30)^2$$

$$E_p = 21.15 \mu J$$

$\therefore$ This energy increases with multiple footstep impacts.

3. Hybrid Power Equation

Total hybrid power: $P_{total} = P_s + P_p$

Where: $P_p = E_p/t$

Assuming vibration interval $t = 0.5s$:

$$P_p = 42.3 \mu W$$

$$\therefore P_{total} = 67.12 + 0.000042$$

$$P_{total} \approx 67.12W$$

$\therefore$ Solar dominates, piezo supplements during low sunlight.

4. Battery Charging Analysis

Battery energy capacity: $E_b = V_b \times Ah$

$$E_b = 12 \times 7 = 84Wh$$

Charging time:

$$T = E_b/P_{total}$$

$$T = 84/67.12 = 1.25 \text{ hours}$$

$$\therefore \text{Full charge} \approx 1.25 \text{ hours (ideal conditions)}$$

5. System Efficiency

$$\eta = P_{load}/P_{input} \times 100$$

$$\text{Assuming 85\% power conditioning: } \eta = 0.85 \times 100 = 85\%$$

VIII. RESULTS AND DISCUSSION

Our system was really something. It worked well. The photovoltaic module made energy when it was daytime. The photovoltaic module did a job of making energy from daylight.

The piezoelectric elements made electricity when people moved them around.

The piezoelectric elements also did a job of making electricity when they were moved.

The charge controller kept the voltage and current at the levels when the battery was being charged by the photovoltaic module and the piezoelectric elements.

This means the energy from the photovoltaic module and the piezoelectric elements was stored safely and correctly in the battery.

The voltage information from the sensors was sent to the IoT dashboard all the time.

We could see the voltage information from the sensors on the IoT dashboard.

The IoT dashboard was very useful for seeing the voltage information, from the sensors. This shows that the wireless communication was working dependably. The photovoltaic module and the piezoelectric elements were parts of the system and they worked well together. The combined use of solar and piezoelectric sources enhanced overall system availability, demonstrating the practicality of the proposed architecture for low-power smart applications.

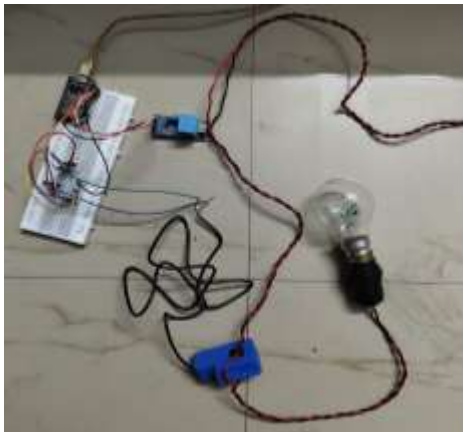


Fig 1- Sensing Module



Fig2- Blynk Output

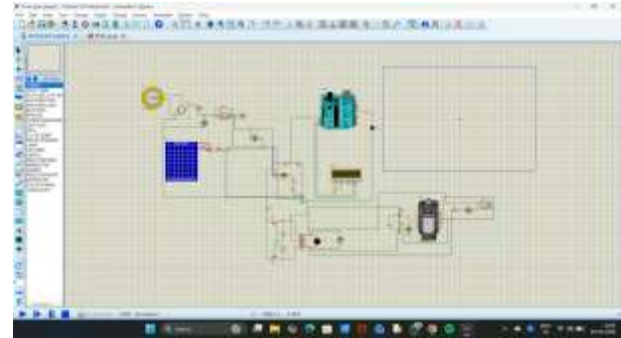


Fig 3- Circuit Diagram on Proteus

IX. APPLICATIONS

- Smart street lighting
- IoT-based sensor networks
- energy harvesting from public infrastructure and walkways
- remote environmental monitoring stations
- smart city and campus automation systems

X. LIMITAIONS

1. **Low Output from Piezoelectric Unit-** Piezoelectric sensors generate very small power (μW range) Only effective when continuous vibrations/footsteps are present.
2. **Dependence on Solar Energy-** The system still needs solar energy to work. This means it does not work well on cloudy days or at night. It also does not work well in different seasons when the sun is not out as much.
3. **Energy Loss in Circuit Components-** Some of the power gets lost in the parts of the system. This happens in the bridge rectifier, capacitors and charge controller.

All of these losses add up. Make the system less efficient.

4. **Limited Power Capacity-** Our system is suitable only for Mobile charging, Small IoT devices, Low-power loads.

3.CONCLUSION

The Internet of Things or IoT based solar and piezo hybrid power generation system is a way to get energy in a way that is good for the earth and always works. This Internet of Things or IoT based solar and piezo hybrid power generation system combines making power from the sun with getting energy from piezo things. This shows that we can use kinds of energy together so we have power when we need it. Sometimes the sun is not. We cannot use just the sun, for energy. The Internet of Things or IoT based solar and piezo hybrid power generation system is better because it uses energy in a way. It helps things like IoT nodes and devices that monitor the environment and parts of smart infrastructure work all the time. The IoT based solar and piezo hybrid power generation system is very useful, for things that do not use a lot of power.

The Internet of Things or IoT is really cool when you use it with cloud platforms like Blynk or Thing Speak. This combination makes it possible to supervise systems in a way and access them from anywhere.

You can keep an eye on things like voltage levels and battery status all the time. This helps you find problems early make decisions

about energy and improve performance without having to be there in person.

IoT is very important, for energy systems. These systems rely on using data to make decisions and being able to manage things from a distance.

The project is really cool from an engineering point of view. It shows how well power electronics and embedded systems and software development can work together. They used ESP32 or Node MCU microcontrollers. Added some sensing and charge management circuits. This makes the design very flexible and easy to add to.

So in the future we can add things to the system like different ways to get energy from the environment or better ways to manage power. We can also add analytics to predict how much energy we will need. This is what makes the project so great. The system can be made bigger and better with ideas, like maximum power point tracking.

The system is really important for more than its technical features. It is also very useful for education and for society as a whole. The system is a tool for students and researchers who are learning about renewable energy and IoT-based solutions. These students and researchers can use the system to get some hands-on experience with renewable energy and IoT-based solutions.

In some places people do not have access to a power grid like in areas or places that have been hit by disasters. The system can be very helpful, in these areas. In these places the system can help with communication and monitoring which're really important. The system can also be used in cities, where it can be put into infrastructure to use the energy that is already around us and reduce our need for regular power sources. Hybrid renewable

energy systems, like this one can make a difference.

The new system does what it is supposed to do. It helps make energy use better for the planet. It also helps make energy smarter. We started with an idea. Made a working model. This means we can keep working on it and make it even better. We can also use it in the world with other systems that are connected to the internet. The hybrid renewable energy solutions and the internet connected systems will work together. The hybrid renewable energy solutions will be used in the world.

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