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Smart Energy Harvesting System: Powering Appliances

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ABSTRACT

For security systems to function and ensure ongoing monitoring and threat identification, electricity is essential. However, because vital security elements like CCTV cameras and alarm systems malfunction during power outages, Automated Teller Machines (ATMs) become extremely susceptible to theft. In order to solve this problem, an alternate power source is needed to keep ATMs secure even when there is no grid electricity. Three renewable sources: wind turbines, speed breakers, and footsteps are used in this project to produce electricity. Wind turbines harvest energy from passing cars, and speed breakers and footsteps use piezoelectric sensors to transform mechanical energy into electrical power. Rechargeable batteries are used to store the harvested energy, guaranteeing a steady supply of power. Security features like surveillance cameras, warning lights, and vibration sensors are powered by the stored energy. To discourage criminals, vibration sensors identify attempts at tampering and trigger flashing lights and alarms. Real-time video is simultaneously captured by an ESP32-CAM module and sent to security staff. For a prompt response, the system also notifies authorities via SMS. This initiative offers an economical and environmentally responsible solution for ATM security by leveraging sustainable energy sources, guaranteeing ongoing protection and lowering reliance on traditional powergrid.

Keywords—ATM Security, Piezoelectric Sensors, Speed Breaker Energy Harvesting, Footstep Power Generation, Vibration Sensors, Power Outage Security, Sustainable Energy Solutions, Real-Time Threat Detection, Eco-Friendly Security Technology.

INTRODUCTION

Concerns about the environment, energy availability, and growing electricity prices have made the need for sustainable energy solutions more pressing in the modern world. Essential applications like street lighting and banking security that depend on traditional power sources face a number of difficulties, such as high energy consumption, environmental damage, and power outage susceptibility. Maintaining a steady power supply for public lighting and security systems is essential for both public safety and crime prevention. The goal of this project is to create a system that uses renewable energy to power street lighting and banking security infrastructure. The system offers a dependable and sustainable substitute for conventional electrical grids by utilizing footstep, speed breakers, and wind energy. This strategy not only lowers operating expenses and the carbon footprint, but it also increases energy independence and resilience in critical areas. By integrating wind turbines and energy storage solutions, this system ensures that surveillance cameras, alarm systems, and streetlights continue to operate even during power outages. By switching to renewable energy for security and public lighting, this initiative also contributes to sustainability, energy efficiency, and environmental conservation while ensuring increased safety and security for communities. The project focuses on the design, implementation, and evaluation of renewable energy technologies to assess their feasibility and effectiveness in real-world applications.

RELATED WORK

[1] Research on footstep power generation using piezoelectric materials has shown its potential for security applications. The system converts mechanical energy from footsteps into electricity, making it a viable solution for banking surveillance.
[2] Studies on piezoelectric sensor integration in high- footfall areas demonstrate efficient energy harvesting to power essential security infrastructure, such as CCTV cameras and alarm systems, ensuring uninterrupted surveillance.
[3] The combination of footstep power generation and energy storage systems has been explored to maintain ATM security during power failures, reducing dependency on conventional grid power.
[4] Hybrid energy harvesting approaches, integrating footstep power with renewable sources like solar and wind, have

been studied to enhance the reliability and efficiency of security applications in banking.

[5] Research on IoT-enabled security systems powered by footstep-generated electricity highlights the benefits of smart, sustainable energy solutions in enhancing banking security and promoting environmental sustainability.

METHODOLOGY

This system aims to efficiently capture energy from various renewable sources, namely footsteps, speed breakers, and wind, and convert it into usable power for low-energy appliances. The design and construction of each hardware component play a vital role in ensuring the system functions reliably and efficiently.

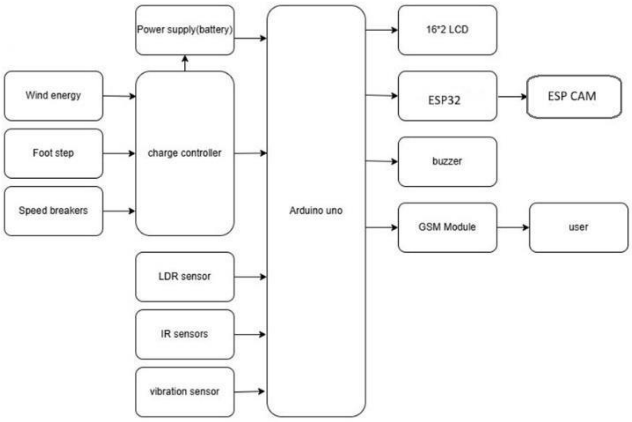

Figure 1 Block Diagram

A. Piezoelectric Sensor

When mechanical stress, such as pressure, vibration, or force, is applied, a piezoelectric sensor produces an electrical charge. It works on the basis of the piezoelectric effect, which states that when some materials (such as quartz or PZT ceramics) are deformed, an electric charge is produced. Piezoelectric sensors will be utilized in your energy-harvesting security system for theft detection and electricity generation. An array of nine piezoelectric sensors per plate will be incorporated into the floor to generate electricity by converting the mechanical pressure of footsteps. To ensure a backup power source for ATM security during power outages, this energy, which was initially in AC form, will be rectified to DC using a bridge rectifier circuit before being stored in a battery or supercapacitor.

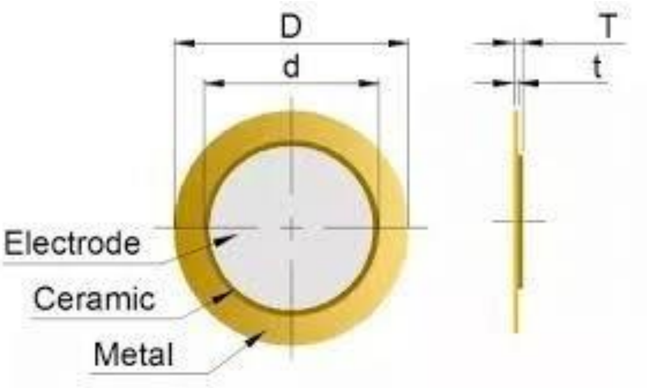

Figure 2 Piezo Electric Sensor

B. Power Generation

If each step generates 0.5 millivolts (mV) per sensor, and you have 9 sensors per plate, then the total voltage per step for one plate is:

$$0.5\text{mV} \times 9 = 4.5\text{mV}$$

Voltage per step per plate = 4.5 mV Target voltage = 24V

1V = 1000 mV, so 24V = 24,000 mV

$$\textit{Steps required} = \frac{24{,}000\text{mV}}{4.5\text{m.V per step}}$$

So, approximately 5,334 steps are required to reach 24V using a single plate.

C. Additional Power Sources

Two more sources of power Wind turbines and speed breakers are combined to improve energy production for ATM security during blackouts. Using a mechanical-to- electrical conversion mechanism, like a roller mechanism, the speed breaker system transforms a vehicle's kinetic energy into electrical energy. The downward force created when cars cross the speed breaker moves a mechanical assembly that is connected to a generator, which powers a gear mechanism to produce electricity. A battery is then used to store the generated power for use in ATM security operations at a later time. The wind turbine system, on the other hand, captures wind energy from highways where air currents are created by moving cars. When placed in strategic locations, these turbines use a generator to transform wind energy into electrical power. Sources' voltage and current, guaranteeing a consistent supply for the ATM security system. This includes supplying electricity for alert systems, vibration sensors, and surveillance cameras, improving security even in the event of a power outage. The charge controller also aids in controlling energy input variations, guaranteeing that the system functions effectively in a variety of scenarios.

Figure 3 Charge Controller

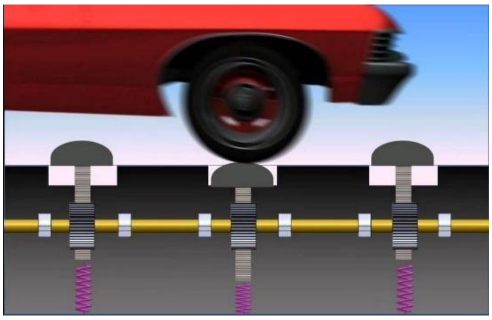

Figure 4 Speed Breakers

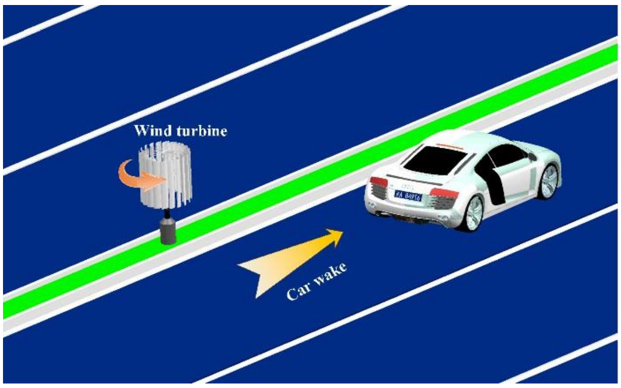

Figure 5 Wind Turbine on Highway

D. Charge Controller

An essential part of the energy-harvesting security system is a charge controller, which makes sure that power is efficiently regulated from the wind turbines, speed breakers, and piezoelectric floor to the battery. By regulating the flow of electricity, it avoids problems like deep discharging, overcharging, and short circuits that could shorten battery life and compromise system dependability. The charge controller optimizes power storage and distribution by stabilizing the energy

E. Powering Appliances

Often used for interactive projects, Arduino is an open- source electronics platform that offers development boards based on microcontrollers, such as the Arduino Uno, Mega, and Nano. An IR sensor uses an IR LED and a photodiode to detect infrared light, primarily for proximity and obstacle detection. Automatic lighting systems use the Light

Dependent Resistor (LDR) sensor, which adjusts resistance according to light intensity. Vibration sensors, which are frequently used in security alarms and machine monitoring, detect mechanical movements. Mobile communication is made possible by GSM modules, like the SIM800L and SIM900A, which use AT commands via UART to transmit data, make calls, and send SMS. With an ESP32 microcontroller and a camera, the ESP32-CAM is a small module that supports Bluetooth and Wi-Fi for uses like remote surveillance and video streaming in Internet of Things projects.

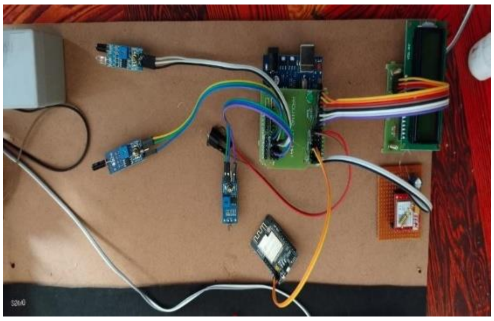

Figure 6 Integrating Sensor to Arduino

RESULT ANALYSIS

Real-time powering of ATM security components was accomplished by the system. When several sources were combined, energy harvesting efficiency increased. Tests of reliability under various circumstances revealed steady power generation. By lowering dependency on traditional electricity, the system offers a self-sufficient security solution.
Key Findings:

Overall power availability is increased when wind, speed breaker, and piezoelectric energy are combined. Even in low-energy situations, the energy output is adequate to operate security equipment. For other vital infrastructures, such as train stations and smart cities, the system is flexible and scalable.

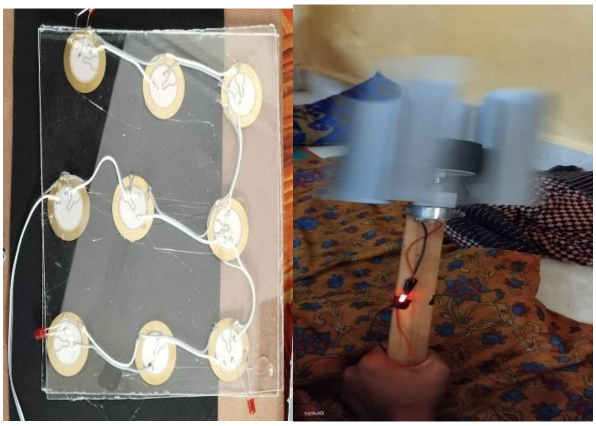

Figure 7 Power Genaration

The performance of the project's three different renewable energy sources—wind turbines, speed breakers, and piezo tiles—was assessed based on their voltage output. The piezo tiles only generated 0.55 mV, a very low output, when tested with a weight of 60 kg, or roughly the weight of a human. This implies that for practical use, several tiles or an effective energy storage system would be required. The speed breakers produced a noticeably higher voltage of 0.5 V when tested with a vehicle of average weight, making them a more practical energy source for collection and storage. The wind turbine was the most effective of the three sources. It produced the highest voltage output when tested at a typical vehicle-induced wind speed of 50 km/h.

Your project's outcomes show how renewable energy generation and ATM security can be successfully integrated. With the help of speed breakers, wind, and footsteps, the system efficiently produces power that can be stored and used to run appliances. With vibration, infrared, and LDR sensors to identify unwanted activity, the ATM security system works effectively.

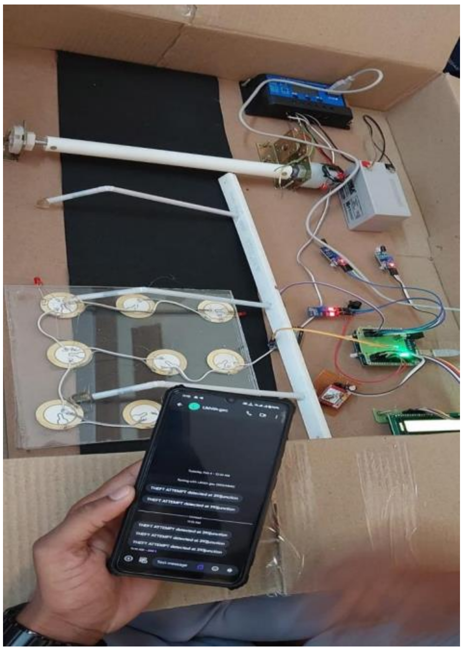

Figure 8 Final Results

The GSM module's real-time alerts verify that theft attempts are correctly detected and reported. By taking live pictures or videos of possible threats, an ESP32- CAM adds an additional degree of surveillance and improves security. The system is a useful, creative, and all-encompassing Internet of Things solution because it combines power generation, security monitoring, and image capture.

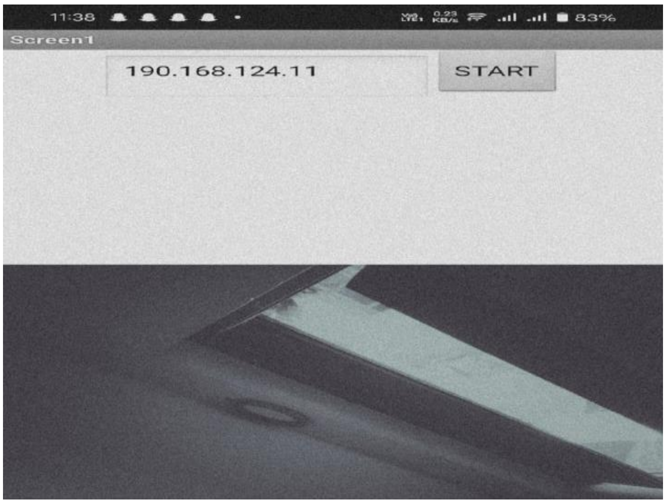

Figure 9 ESP 32 cam for surveillance

APPLICATIONS

- ATM Security Systems
- Street Lighting
- Public Transport Infrastructure
- Schools and Colleges
- CCTV Surveillance
- Smart Traffic Managemen

CONCIUSION

Incorporating renewable power into banking security and street lighting presents a cost-saving, green solution through the generation of footsteps, wind, and other sources. Though there is an initial outlay and maintenance expense, it guarantees independence from energy and backup power, with less carbon emission. The project contributes to railway station and public space sustainability through reduced energy consumption, cost saving, and the encouragement of green culture.

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