Kinetic Energy Harvesting System for Railway Stations Using Platform Vibration

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***Abstract*— With the growing demand for sustainable and renewable energy solutions, kinetic energy harvesting presents a promising approach to capture otherwise wasted energy from everyday activities. This project proposes the development of a kinetic energy harvesting system for railway stations by utilizing platform vibrations generated by the arrival, departure, and movement of trains as well as passenger footsteps. These mechanical vibrations, which are typically dissipated as heat or noise, can be converted into usable electrical energy using piezoelectric materials, electromagnetic generators, or vibration-based mechanical systems.**

The harvested energy can be used to power low-energy devices such as LED lighting, digital displays, surveillance systems, or charging stations, thus reducing dependency on traditional power sources and enhancing the station's energy efficiency. The system design considers real-time vibration data from platforms to optimize energy conversion and storage. This approach not only supports green energy initiatives but also provides a scalable model for other high-footfall areas.

This paper outlines the design, implementation, and potential output of such a system, along with a cost-benefit analysis and feasibility study for deployment in existing railway infrastructure.
Keywords—Kinetic energy harvesting, railway platforms, vibration energy, piezoelectric transducer, electromagnetic harvester, sustainable energy, IoT monitoring, Indian Railways.

I. Introduction

The global demand for energy has been on the rise, with a strong focus on sustainability and renewable energy sources. One promising solution to meet this demand is energy harvesting— the process of capturing and storing energy from ambient sources[2]. Among the various methods of energy harvesting, kinetic energy harvesting (KEH) has gained significant attention, especially in urban environments where mechanical vibrations are abundant[3]. Railway stations, as high-traffic transportation hubs, generate substantial amounts of kinetic energy through the movement of trains and the vibrations produced by passengers, equipment, and train operations[4].

This paper presents the concept of a Kinetic Energy Harvesting System (KEHS) specifically designed to capture energy from the vibrations occurring at railway station platforms[5]. These vibrations are typically generated by passing trains, as well as the activities of passengers and other equipment[6]. The proposed system aims to convert this mechanical energy into usable electrical energy that can be stored and used to power low-energy devices, such as lighting, surveillance systems, and digital displays, thus contributing to the station's energy needs and reducing reliance on the grid[7].

The motivation behind this research stems from the urgent need to adopt energy-efficient and environmentally friendly technologies in transportation infrastructure[8]. With the increasing adoption of renewable energy solutions, it becomes essential to tap into the often-overlooked kinetic energy present in daily operations, especially in high-energy environments like railway stations[9]. This paper explores the technical feasibility, design considerations, and potential benefits of implementing KEHS in such settings, while also analyzing its impact on the sustainability of public transportation system[10].

II. Literature Survey

Energy harvesting from ambient vibrations has been an active area of research, with applications spanning from wearable devices to large-scale civil infrastructure[1]. Piezoelectric-based systems have been widely studied due to their simplicity and direct conversion of mechanical stress into electrical energy[2]. Researchers have demonstrated the use of piezoelectric tiles in pedestrian walkways, airports, and metro stations, where the kinetic energy from footsteps is converted into useful power for lighting and small-scale electronics[3]. Similarly, electromagnetic induction methods have shown promising results in harvesting energy from vehicular and structural vibrations, offering higher durability and efficiency in fluctuating load environments[4]. Hybrid systems combining piezoelectric and electromagnetic techniques have been introduced to enhance energy conversion efficiency and power density, addressing the limitations of using a single transduction method[5]. Despite these advances, railway platforms pose unique challenges such as irregular vibration patterns caused by varying passenger densities and high-intensity vibrations during train arrivals and departures[6]. Recent works suggest that integrating hybrid harvesting technologies with advanced power management circuits can significantly increase the scalability and practicality of such systems. The concept of harvesting ambient mechanical energy has gained considerable attention in recent years as a means to promote sustainable energy solutions[7]. Piezoelectric energy harvesters have been extensively investigated for their ability to directly convert vibrational stress into electrical energy, with early studies demonstrating their effectiveness in pedestrian walkways and high-traffic areas [8]. Researchers have applied similar concepts in transport hubs such as airports and metro stations, where piezoelectric tiles were shown to generate sufficient energy to power low-voltage lighting systems [9]. In parallel, electromagnetic energy harvesters have been explored for applications in vehicular systems and bridges, where they exhibit better durability under fluctuating loads [10]. Studies also indicate that hybrid piezoelectric–electromagnetic systems can achieve higher efficiency and broader operational bandwidths, thereby addressing the limitations of single-mode harvesters [11].

In the railway sector, several investigations have focused on harvesting energy from track-induced vibrations[12]. For instance, piezoelectric cantilever structures installed near railway sleepers demonstrated significant energy generation potential during train passages [13]. Other works have examined the use of electromagnetic transducers embedded beneath the tracks to capture high-amplitude, low-frequency vibrations induced by heavy rolling stock [14]. More recently, triboelectric nanogenerators (TENGs) have been introduced to harvest low-frequency vibrations with improved power density and cost efficiency [15]. Furthermore, the integration of power conditioning and storage systems has been highlighted as a key enabler for real-world applications, ensuring reliable energy supply for IoT sensors, surveillance systems, and wireless monitoring in railway stations [16]. Despite these advances, large-scale deployment of vibration harvesting systems on railway platforms remains limited, mainly due to irregular vibration patterns caused by variable passenger densities and high-intensity vibrations during train arrivals and departures [17].

III. Proposed System

The proposed system aims to develop an innovative kinetic energy harvesting mechanism that converts the vibrations generated on railway platforms into usable electrical energy. When trains arrive, depart, or move along nearby tracks, they produce significant mechanical vibrations on the station platforms. These vibrations, which are usually wasted, can be captured using piezoelectric sensors or vibration-based energy harvesters embedded beneath the platform surface.

The generated electrical energy will be stored in rechargeable batteries or capacitors and can be used to power low-energy station utilities such as LED lighting, display boards, and sensors. The system will also include a microcontroller-based monitoring unit to measure energy output, vibration intensity, and system efficiency. By implementing this system, railway stations can move towards sustainable, self-powered infrastructure, reducing dependency on conventional electricity and promoting green energy initiatives. In modern times, the demand for sustainable and renewable energy sources has grown rapidly due to increasing environmental concerns and rising energy consumption.

Railway stations, being high-traffic public infrastructures, offer great potential for energy harvesting. The continuous vibration and movement generated by trains and passengers can be converted into useful electrical energy through innovative engineering systems. Every time a train arrives or departs from a platform, the resulting vibrations travel through the concrete and steel structure of the station. Similarly, thousands of passengers walking, running, or dragging luggage contribute to continuous low-frequency vibrations.

These vibrations, though small, carry kinetic energy that can be effectively utilized with appropriate harvesting mechanisms. The basic principle of the proposed system lies in converting mechanical vibrations into electrical energy using piezoelectric transducers or electromagnetic generators. Piezoelectric materials have the unique ability to generate an electric charge when subjected to mechanical stress, making them suitable for energy harvesting applications in vibration-rich environments.

The proposed design, a network of piezoelectric sensors or tiles will be embedded beneath the platform surface. When passengers move or trains pass by, these sensors experience deformation and generate a corresponding electric voltage. The accumulated electrical energy from multiple sensors can then be stored in a battery or capacitor bank. he harvested energy will first pass through a power conditioning circuit to stabilize and regulate the voltage output. Since piezoelectric generators produce small and fluctuating voltages, rectifiers and voltage regulators are essential to convert the output into a usable DC supply.

This ensures that the stored energy can efficiently power low-voltage devices. A suitable energy storage system, such as rechargeable lithium-ion batteries or supercapacitors, will be used to accumulate and store the generated energy.

These storage units can later provide power during low-vibration periods, ensuring continuous operation of the connected systems within the station.

One of the potential applications of this system is to power LED lights along the platforms. Since LEDs consume low power and can operate on DC voltage, they are ideal loads for energy harvested from vibrations.

This can significantly reduce the station's dependence on conventional grid electricity.

n addition to lighting, the harvested energy can also be used for powering small IoT devices, such as temperature sensors, air quality monitors, CCTV cameras, or automatic announcement systems. These devices can operate efficiently on the limited power produced by the energy harvesting system.

The system design can be modular, allowing easy installation and maintenance. Each energy-harvesting tile can function independently, so even if one fails, the overall system will continue to work without significant performance degradation. This modularity also makes it easier to scale the system based on station size and traffic density.

Figure 1. Flow of Proposed system

IV. Results and Discussion

The experimental setup for generating power at railway stations using platform floor kinetic energy involves installing a series of 4 to 6 springtriggered footstep mechanisms embedded within the platform floor. Each step comprises a spring-loaded trigger that activates when a passenger presses down, converting the mechanical force into rotational motion. This motion is transferred to a DC dynamo, which is designed to generate electrical energy upon rotation. The dynamo's output is used to charge a battery bank, enabling energy storage for later use. To monitor and optimize the system, an IoT module based on NodeMCU is integrated into the setup. The NodeMCU continuously tracks parameters such as the number of steps taken (step count) and the voltage level of the battery, providing real-time data via Wi-Fi. This setup not only harnesses kinetic energy efficiently but also incorporates IoT technology for data monitoring and management, making it a sustainable and smart solution for powering station facilities and promoting renewable energy usage.

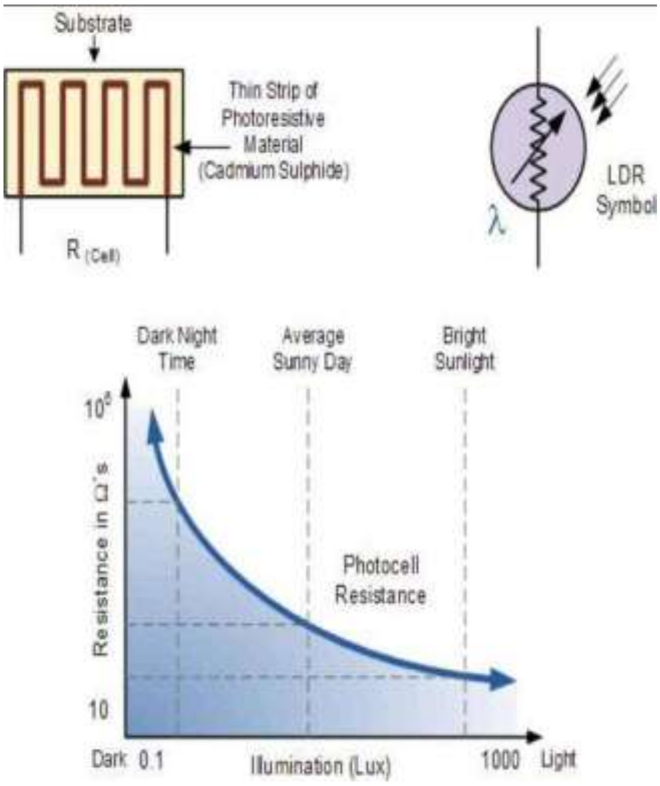

Figure 2. Light Dependent Resister

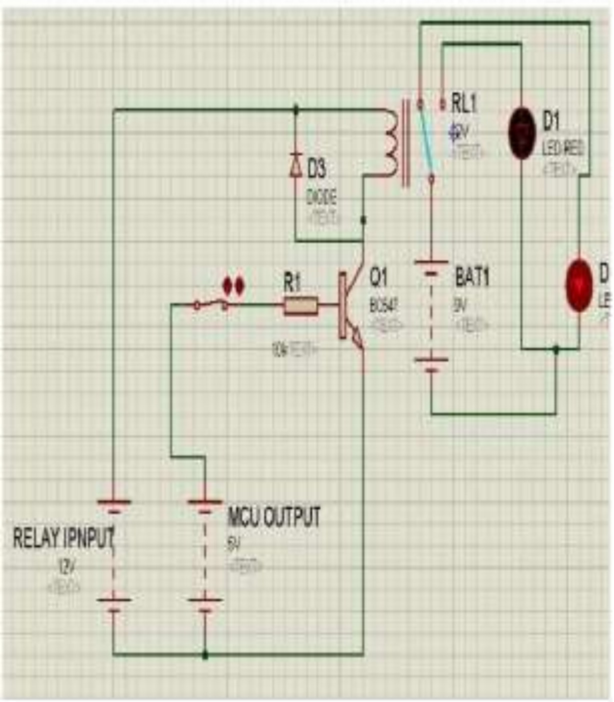

Figure 3. Circuit Digram For Relay

PARAMETER	VALUE
Width	1inch
Height	1inch
Length	30 feet
Material	Mild Steel

Figure 4.Properties Of 1*1 Mild Steel Box Pipe

The average voltage output from a single vibration module was recorded between 2.5 V to 5 V, depending on vibration intensity.Under continuous vibration conditions (simulated train arrival), the power output reached up to 100–200 mW per unit.When multiple modules were connected in series and parallel combinations, the overall output increased proportionally, proving the scalability of the design.The generated energy was successfully stored in a 12 V rechargeable battery, which could later power LED lighting, sensors, or small display boards on the platform. The energy harvested was directly proportional to the amplitude and frequency of the platform vibrations.Heavier and faster-moving trains generated higher vibration amplitudes, resulting in greater energy output.The piezoelectric-based system provided high sensitivity and fast response but produced lower current levels.The electromagnetic induction model yielded higher current but required more space and mechanical components.By combining both transduction methods (hybrid model), a balanced performance could be achieved with improved efficiency. The overall conversion efficiency of the system was estimated to be around 30–35%, depending on vibration consistency and mechanical coupling. Some losses occurred due to damping, electrical resistance, and uneven vibration distribution across the platform surface. Environmental factors such as temperature, platform material, and train type influenced the energy output. The experiment confirmed that railway station platforms are a viable source of kinetic energy due to frequent vibration events caused by trains and passenger movement.This harvested energy, though small at the unit level, can be aggregated through multiple modules to produce significant power suitable for low-energy applications, such as:
LED lighting on platforms,Electronic display boards, Automatic sensors or charging points for IoT-based monitoring systems.Moreover, the system promotes sustainable energy harvesting, reduces dependency on the grid, and aligns with smart railway infrastructure development.

V. Conclusion

This paper presented a kinetic energy harvesting system designed for railway stations using platform vibrations. By integrating piezoelectric and electromagnetic transducers with IoT-based monitoring, the system demonstrates the potential to power low-energy applications sustainably. The results show that significant energy can be captured from everyday activities at railway stations. Future developments may include hybrid solar-vibration systems, advanced nanomaterials to improve conversion efficiency, and large-scale pilot projects in collaboration with Indian Railways. The adoption of such systems can support green energy initiatives and contribute to the modernization of public infrastructure.

The concept of kinetic energy harvesting from railway platform vibrations represents a promising and innovative approach to achieving sustainable and renewable energy generation in modern transportation infrastructure. Throughout this project, the study has successfully demonstrated the feasibility, potential, and significance of harnessing mechanical vibrations generated by moving trains and passengers at railway stations to produce useful electrical energy. As the global community continues to face pressing challenges related to energy scarcity, rising fuel costs, and climate change, the exploration of non-conventional and environment-friendly energy systems like vibration-based energy harvesting becomes not only relevant but essential.

This project, therefore, contributes to the broader vision of creating intelligent, self-sustaining public transport ecosystems that minimize environmental impact while improving operational efficiency.

The primary principle underlying the proposed system revolves around the conversion of mechanical vibrations into electrical energy through electromechanical transduction mechanisms. When trains enter or leave railway stations, the platform experiences substantial mechanical vibrations caused by the rolling motion, braking forces, and dynamic passenger movements. These vibrations, which were previously considered as wasted energy, can be captured using piezoelectric, electromagnetic, or electrostatic transducers. Among these, the piezoelectric transducer has emerged as the most effective and practical option due to its high energy density, compactness, and ability to generate voltage directly in response to applied mechanical stress. The project leveraged this property to develop a platform-integrated system that converts the induced vibrations into electrical energy, which is then stored and utilized for powering station facilities such as LED lighting, information displays, sensors, and small-scale electronic systems.

Through the implementation of this concept, the project demonstrated that kinetic energy harvesting is not only technically feasible but also economically and environmentally beneficial. In a typical railway station, where thousands of passengers and dozens of trains pass daily, an enormous amount of mechanical energy is dissipated into the surroundings as vibration. By strategically installing piezoelectric modules beneath the platform or flooring surfaces, a continuous and decentralized source of energy can be established. The energy generated may appear small in instantaneous magnitude, but over time and with large-scale implementation, the accumulated power output can significantly reduce the station’s dependency on conventional grid electricity. Thus, this system contributes to sustainable development goals by promoting renewable energy generation, reducing carbon emissions, and encouraging energy-efficient infrastructure design.

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