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Automated Entry Door Powered by Waste-to-Electricity Generation

Sharvari Shinde[1], Vedika Ambadkar[1], Ajay Thakare[1,*], Dinesh Malkhede[1]

Abstract

Waste-to-energy technologies are currently under scrutiny due to the rising demand for sustainable energy solutions. This paper discusses the design and implementation of an automated entry door system powered by waste-to- electricity technology. The system integrates renewable energy generation from organic and inorganic waste with an efficient automated door mechanism, providing a sustainable and eco-friendly solution for energy utilization in modern infrastructure. The waste-to-electricity module converts biodegradable waste into biogas or employs thermoelectric processes to harness energy from waste combustion. The suggested solution addresses waste management issues while drastically lowering reliance on electricity derived from fossil fuels by using waste as a renewable energy source. This strategy enhances energy sustainability, lessens pollution in the environment, and makes effective use of waste resources that are readily available locally. Additionally, the potential for creative uses of waste-to-energy technology in public and commercial buildings is highlighted by the integration of smart automation with renewable energy generation. All things considered, the system exhibits a sustainable and scalable solution that supports international initiatives for the development of smart infrastructure and the adoption of green energy. This energy would power the automated door system, which senses motion and uses access control with sensors. This solution reduces the reliance on traditional sources of energy, promotes waste management, and brings to the fore the possibilities of integrating renewable energy technologies with smart automation for sustainable development.

Keywords: Automated entry door, waste-to-electricity generation, renewable energy, waste management, energy efficiency, biogas conversion, thermoelectric power, eco-friendly technology

INTRODUCTION

The increasing demand for sustainable energy solutions has driven innovations in harnessing renewable energy from unconventional sources. One promising approach is the conversion of waste into electricity, which not only addresses the global energy crisis but also tackles the critical issue of waste management. The integration of this technology into automated systems can revolutionize the way energy is utilized in everyday applications [1].

This study proposes the idea of an automatic entry door fueled by waste-to-electricity generation, combining sustainability with smart automation. The system exploits energy from both biodegradable and nonbiodegradable waste through conversion processes, such as biogas generation or thermoelectric conversion. The energy powers an automatic entry door that is motion-sensing enabled for a more effective function. This solution reduces dependence on traditional electricity sources and encourages environmental responsibility by exploiting waste as a renewable energy source [2]. The development of such systems has the potential

***Author for Correspondence**
Ajay Thakare
E-mail: ajay.electrical_ioe@bkc.met.edu

[1]Student, MET Institute of Engineering, Adgaon, Nashik, Maharashtra, India

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to merge green energy technologies with intelligent systems, paving the way for more sustainable and energy-efficient infrastructure. The intention behind this study is to highlight the feasibility, benefits, and environmental impacts of this innovative solution [3].

LITERATURE REVIEW

The significance of automation and energy-efficient technologies in improving operational efficiency, safety, and dependability across a variety of infrastructure systems has been thoroughly studied in a number of studies. The potential of automation to minimize human participation, decrease errors, and optimize energy consumption has made it a widely acknowledged essential component of contemporary smart systems. Significant gains in operational safety and efficiency have been shown by research on automated railway gate control systems that use sensors and microcontrollers. In a similar vein, studies on unmanned railroad level crossing systems have demonstrated how well automation can replace manual processes [4]. Without the need for human interaction, these automated systems use a variety of sensors, control units, and communication modules to identify oncoming trains and manage gate operations. Significant decreases in operating delays, human reliance, and the possibility of human error are reported in studies, all the while guaranteeing enhanced safety protocols for both automobile and pedestrian traffic [5]. This degree of automation helps improve system dependability, lower maintenance needs, and steady performance, especially in distant or energy-constrained settings. These results highlight the wider applicability of automation technology in critical infrastructure systems, where energy optimization, operational effectiveness, and safety are crucial. The precision and responsiveness of the system are increased by the use of embedded systems and sensor networks, which enable continuous real-time monitoring and quick automated reactions to changing circumstances [6]. These systems use automated decision-making and real-time sensing to control gate operations, which lowers the chance of accidents and improves energy efficiency through better control mechanisms. Further research on RFID-based automatic door control systems highlights improvements in security and reductions in overall energy consumption. These studies indicate that automated door systems are effective in minimizing human involvement while optimizing energy usage, making them suitable for smart infrastructure applications. Investigations into smart automatic gate control using microcontroller platforms such as Arduino demonstrate the feasibility of real-time automation with low-power consumption [7]. These systems showcase efficient control mechanisms, sensor integration, and adaptability to various operational environments. Additional studies on microcontroller-based automated gate systems discuss existing limitations and propose future enhancements, offering valuable insights into optimizing energy utilization and system performance. Collectively, these studies support the feasibility of integrating automation technologies with renewable energy sources. The findings reinforce the potential of waste-to-electricity-powered automated systems as a sustainable, energy-efficient, and practical solution for modern infrastructure applications [8].

SYSTEM OVERVIEW

Design and Construction of an Automatic Door

The main goal was to utilize the electrical energy produced by the waste-to-energy system to power the automated door. The system must manage energy storage, control, and distribution to ensure the efficient operation of the door without relying on the grid, as shown in Figure 1. To accomplish this, the system was built to effectively handle energy distribution, regulation, and storage, guaranteeing a steady and uninterrupted power supply for the functioning of the automated door. Waste conversion operations provide electrical energy, which is then stored in appropriate energy storage units and adjusted to meet the voltage and current requirements of the actuation and control components [9]. The system is also responsible for intelligent power management, which guarantees the best possible energy use while avoiding power outages and system inefficiencies. Reliable and autonomous door functioning is made possible by the system's integration of energy control and distribution mechanisms with the automation unit, even in situations where energy is limited.

Overall, the design prioritizes operational dependability, energy efficiency, and sustainability to enable an automated infrastructure independent of the electrical grid. It is responsible for ensuring that energy is stored, regulated, and distributed effectively to automate the door mechanism [10].

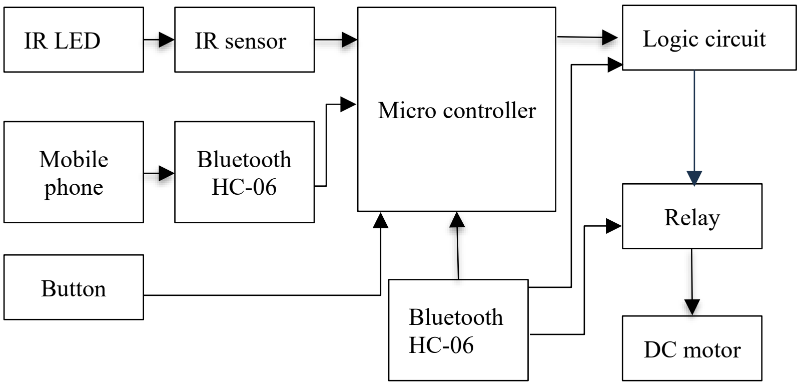

Figure 1. Block diagram of an automatic door system.

Key Components of the System

Battery storage system: A critical component that stores the energy produced by thermoelectric generators (TEGs). The energy is stored for later use to ensure the continuous operation of the automated door, even when waste-to-energy generation is not active. Both the control circuitry and the mechanical actuation of the door are supported by the safe accumulation, retention, and delivery of energy at the necessary voltage and current levels by the storage system. Proper energy storage avoids power fluctuations, increases overall reliability, and strengthens system stability. The automatic door mechanism can operate independently by integrating an effective battery storage system, which makes the entire solution feasible, sustainable, and independent of real-time waste-to-energy generation.

Power control and distribution system: A network that manages the distribution of stored energy to the automated gate sensors, motors, and control systems.

Automated door mechanism: The actual door mechanism that includes:

1. Motors/actuators open and close the door.
2. Sensors that detect the presence of people or objects to trigger the door movement.
3. Control units to process inputs and control the movement of the door.
4. *Energy management system (EMS):* This system ensures optimal energy use and balances the power needs of the door with the available stored energy.

Process Flow

Here is the step-by-step process for utilizing the energy generated by the waste-to-energy system to operate the automated door.

Step 1: Energy Storage in Batteries

Battery type: Select batteries that can handle the power output of the waste-to-energy system. Common choices include lithium-ion or lead-acid batteries, depending on the system size and cost considerations.

Energy storage calculation

- *Energy generated per day:* 3.33 kWh (from Group 1). Energy consumption of the automated door: 0.3 kWh per day (calculated in the previous section).
- *Energy storage required:* At least 1–2 days of energy reserve is recommended for continuous operation; therefore, the storage system should ideally hold 0.6-0.8 kWh per day.

Step 2: Power Distribution to Automated Door

Inverter/Power supply unit (PSU): The stored DC power (from batteries) may need to be converted into AC power for the door actuator and other systems. An inverter or DC-to-DC converter may be required based on the system configuration. Power Distribution Control: The power distribution unit (PDU) ensures that the energy from the batteries is directed towards the door components in real time. This system will prioritize powering critical systems, such as motors and sensors. Regulates energy flow to prevent overloading.

Step 3: Energy Management System

An EMS ensures that the available energy is managed efficiently. The system monitors battery charge levels, regulates power usage, and ensures that the automated door operates optimally without exceeding the available energy. Functionality of EMS: Battery Monitoring: Track charge levels and control charging cycles to extend battery life. Energy Optimization: Ensure that non-critical systems are powered down when the battery charge is low and adjust power distribution based on energy availability.

Feedback mechanism: The system monitors real-time power usage and adjusts the energy supply to ensure the uninterrupted operation of the automated door.

Step 4: Automated Door Operation Sensors

Sensors detect the presence of people or objects near the door, triggering the opening or closing mechanism.

Common types of sensors used in automated doors include infrared sensors, motion detectors, and ultrasonic sensors.

- *Control unit:* The control unit processes the signals from the sensors and sends commands to the door actuator to open or close the door. It will also interface with the power distribution system to manage power requirements.
- *Actuator (motor):* The actuator (typically a motor) uses electrical energy to move the door. The power requirement of the motor depends on the weight and size of the door and the frequency of use.
- *Motor power consumption:* Typically, a small-to medium-sized door motor consumes 50–200 W per cycle; however, the system will operate based on the average consumption, considering the energy storage constraints.

Step 5: Powering Sensors and Control Unit

Low-power consumption: The sensors and control units have relatively low-power consumption, typically in the range of 5–20 W, depending on the sensor type. These components operate continuously in low-power mode, activating the motor only when necessary.

Calculations and Power Requirements

The power requirements for each component were determined to calculate the daily energy consumption of the automated door motor.

Assume the motor uses 150 W for each cycle.

If the door opens and closes 10 times per day, the total energy used by the motor is

Energy used by motor per day = 150 W×10 cycles = 1500 W-hours = 1.5 kWh/day

Sensors and Control Unit

Assume an average consumption of 0.1 kWh/day for sensors and control electronics.

Total energy consumption per day: The energy required for the motor + sensors/control = 1.5 kWh/day + 0.1 kWh/day = 1.6 kWh/day.

Given that the system generates 3.33 kWh/day (from waste-to-energy generation), it can easily cover the 1.6 kWh/day required for door operation, with additional energy available for storage or potential use in other low-power systems.

RESULT

The proposed automated door system, powered by waste-to-electricity technology, demonstrates significant feasibility and efficiency in terms of sustainable energy utilization. The system effectively harnessed energy from waste, generating an impressive 3.33 kWh per day. This surpasses the total daily energy consumption of 1.6 kWh, which includes the power requirements for the motor, sensors, and control units. As a result, the system produces an excess of 1.73 kWh daily, which can be stored or utilized for auxiliary applications, thereby enhancing its overall energy efficiency and reliability.

A critical component in ensuring uninterrupted operation is the battery storage system. This feature provides a backup power supply during periods of low energy generation, preventing operational delays. Additionally, the EMS plays a crucial role in optimizing energy usage. It regulates power distribution, ensures efficient utilization, and minimizes energy wastage, thereby improving the overall performance and sustainability of the system.

The door mechanism was designed to operate efficiently, with sensors and motors consuming an average of 150 W per cycle. Over the course of a day, the motor's energy usage totaled approximately 1.5 kWh, indicating an optimized power consumption strategy. This ensures that the system remains functional while minimizing energy expenditure.

In addition to operational efficiency, the system offers substantial environmental and economic benefits. Converting waste into electricity actively contributes to waste management solutions, reduces landfill accumulation, and promotes sustainable disposal practices. Furthermore, it decreases reliance on nonrenewable energy sources, leading to a reduction in carbon emissions and supporting the global transition towards cleaner energy alternatives.

By incorporating energy-efficient automation, this system aligns with the vision of smart, sustainable infrastructure. This presents an innovative and eco-friendly solution suitable for modern applications, particularly in urban settings, where energy conservation and waste reduction are priorities. The integration of renewable energy with automated technology not only enhances efficiency but also fosters a greener and more sustainable future for smart buildings and intelligent transportation systems.

CONCLUSION

The automated entry door system powered by waste-to-electricity technology demonstrates a practical and sustainable solution for integrating renewable energy with smart automation. By utilizing energy derived from waste, the system effectively reduces dependency on traditional power sources while addressing the critical issue of waste disposal. The system design, which incorporates components such as battery storage, power control, and an EMS, ensures reliable operation, efficient energy utilization, and environmental responsibility.

This solution not only meets the energy demands of automated doors but also provides a scalable and eco-friendly approach to modern infrastructure needs. This highlights the potential of renewable energy in everyday applications, offering a way to reduce carbon footprints while promoting sustainable development.

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