Smart Fan Automation System for Energy Saving in Small Shops

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Abstract— *Energy wastage due to ceiling fans operating in unoccupied small shop environments is a common issue that leads to increased electricity consumption and higher operational costs. This paper presents the design and development of a Smart Fan Automation System that automatically controls fan operation based on human presence. The system utilizes a Passive Infrared (PIR) sensor integrated with an Arduino Nano microcontroller and a relay module to enable automatic switching of the fan. The fan turns ON when motion is detected and switches OFF after a predefined period of inactivity, thereby ensuring efficient energy utilization. A comparative analysis was conducted between conventional manual operation and the proposed automated system. The results indicate that unnecessary fan operation of approximately 2 to 3 hours per day can be reduced to a minimal idle duration of 0.1 to 0.2 hours per day. This leads to a net energy saving of approximately 0.135 to 0.2175 kWh per day, demonstrating a significant improvement in energy efficiency. The system is designed to be simple, cost-effective, and easy to implement, making it highly suitable for small-scale commercial applications. The proposed approach not only reduces energy wastage but also enhances user convenience. Furthermore, the system can be extended with advanced features such as IoT-based monitoring and temperature-based control for improved performance.*

Keywords— Automation, Energy Conservation, PIR Sensor, Smart Fan, Small Shops.

I. INTRODUCTION

Small commercial establishments such as retail shops rely heavily on basic electrical appliances like ceiling fans to maintain ventilation and thermal comfort. In most cases, these appliances are manually operated, which usually results in inefficient usage of energy when fans remain ON even when there are no occupants. This leads to unnecessary energy consumption, increased electricity bills, and reduced operational efficiency. With the world aiming towards sustainable energy and energy conservation, there is an increasing demand for automated systems capable of optimizing energy usage [1], [7].

Sensor-based automation provides an effective solution by enabling appliances to operate as required. Detecting occupancy using sensors such as Passive Infrared (PIR) sensors has gained popularity due to its simplicity, reliability, and cost-effectiveness [4], [9]. Several researchers have proposed smart fan systems using IoT and sensor-based approaches to improve energy efficiency in residential and commercial applications [1], [3].

This work focuses on developing a **Smart Fan Automation System** that automatically controls a fan based on human presence. The system uses a PIR sensor integrated with an Arduino microcontroller to detect occupancy and regulate the fan accordingly. The fan switches ON when motion is detected and turns OFF after a predefined delay when no motion is observed. The proposed system is designed specifically for small shops, considering factors such as low cost, ease of installation, and user convenience. By reducing unnecessary energy usage, the system contributes to efficient energy management and supports sustainable development.

II. MATERIAL AND METHODS

The development of the Smart Fan Automation System was carried out through a systematic approach involving problem analysis, component selection, system design, assembly, and testing.

2.1 Materials

Component	Function
Passive Infrared (PIR) Sensor	Detects human presence by sensing infrared radiation
Arduino Nano Microcontroller	Central control unit processing sensor input
Relay Module	Interfaces low-voltage control circuit with high-voltage fan
Ceiling Fan	Electrical load (70–80W)
Regulated Power Supply	Provides DC voltage to control components
Manual Override Switch	Allows direct user control when needed
Connecting Wires	Establishes electrical connections
Protective Casing	Encloses components for safety

2.2 Why Use It?

In small commercial shop environments, ceiling fans are generally operated manually, which often leads to inefficient energy use. A survey conducted in shops with dimensions ranging from 8 × 10 ft to 12 × 15 ft revealed that a single ceiling fan is typically used for ventilation. During periods of lesser customer presence or temporary absence of the shopkeeper, fans generally remain switched ON, resulting in unnecessary electricity consumption [8].

It was observed that fans continue operating without requirement for approximately 2 to 3 hours per day, causing unnecessary energy wastage. A standard ceiling fan consumes around 70 to 80 W of power, leading to measurable daily energy loss over time.

To overcome this issue, the implementation of an automated control system becomes essential. The use of a PIR sensor enables reliable detection of human presence based on infrared radiation, making it suitable for indoor occupancy sensing [4], [5]. Integration with a microcontroller-based control unit allows real-time processing of sensor inputs and automatic regulation of fan operation. The inclusion of a relay module ensures safe switching of the electrical load [3].

2.3 Market Survey

A detailed market survey was conducted to assess the availability, cost, and practicality of the components. The PIR sensor was found to be economical and reliable. The Arduino Nano offers a compact, low-cost, and easy-to-program platform. The relay module enables safe switching of the high-voltage fan load. The overall system cost was found to be economical, confirming the feasibility of implementing the proposed system without significant financial burden.

2.4 System Design and Circuit Diagram

The Smart Fan Automation System integrates a PIR motion sensor with an Arduino Nano microcontroller and a relay module. The PIR sensor detects motion by sensing changes in infrared radiation and sends a signal to the Arduino when occupancy is detected.

The Arduino processes the input signal and generates an output to control the relay module. When motion is detected, the relay is activated, and the fan switches ON. In the absence of motion for a predefined duration, the relay is deactivated, turning the fan OFF.

Prior to hardware implementation, the system was validated through digital simulation using Wokwi software, where an LED was used to represent the fan load. The simulation helped validate the circuit logic and ensured proper functioning before hardware implementation [6].

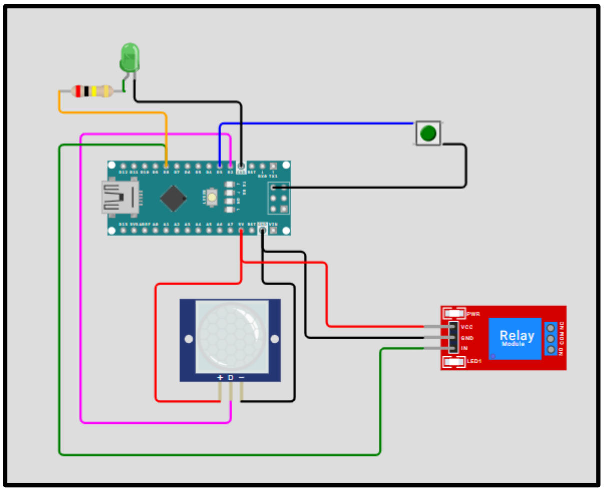

Figure 1: Circuit Diagram of the System

2.5 Assembly

The assembly was carried out by integrating all electronic components into a compact and well-organized setup. The Arduino Nano was positioned for efficient interfacing with the PIR sensor and relay module. The PIR sensor was mounted at a suitable height and orientation to ensure accurate detection.

All electrical connections were established using insulated jumper wires in accordance with the designed circuit diagram. The relay module was connected to the fan load through adequately insulated wiring. A manual override switch was incorporated to provide flexibility. The entire setup was housed within a protective enclosure.

III. RESULTS AND DISCUSSION

To evaluate the effectiveness of the proposed Smart Fan Automation System, a comparative analysis was conducted between fan usage before and after system implementation.

TABLE 1
COMPARATIVE ANALYSIS OF FAN OPERATION

Parameter	Manual Operation	Automated System
Unnecessary operation per day	2–3 hours	0.1–0.2 hours
Daily energy consumption (at 75W)	0.15–0.225 kWh	0.0075–0.015 kWh
Daily energy saving	—	0.135–0.2175 kWh

Based on field observations, it was found that in small shop environments, ceiling fans remained unnecessarily switched ON for approximately 2 to 3 hours per day during temporary absence of occupants. Considering an average power consumption of 75 W, this resulted in a daily energy wastage of approximately 0.15 to 0.225 kWh.

After implementing the proposed system, the unnecessary operating time was significantly reduced, as the fan automatically switches OFF in the absence of human presence. Due to inherent sensor delay and response characteristics, a minimal idle operation of approximately 0.1 to 0.2 hours per day (6–12 minutes) was observed. Consequently, the daily energy consumption decreased to approximately 0.0075 to 0.015 kWh, resulting in a **net energy saving of 0.135 to 0.2175 kWh per day**.

Key Findings:

Finding	Value
Unnecessary operation (manual)	2–3 hours/day
Unnecessary operation (automated)	0.1–0.2 hours/day
Daily energy saving	0.135–0.2175 kWh
Annual energy saving (approx.)	49–79 kWh

The results demonstrate that the proposed system effectively minimizes unnecessary fan usage while maintaining user convenience. The integration of the PIR sensor with a microcontroller-based control unit ensures reliable detection and efficient operation.

IV. CONCLUSION

The Smart Fan Automation System presented in this work offers an effective solution to reduce unnecessary energy consumption in small shop environments. The study identified that conventional manual operation of ceiling fans leads to significant energy wastage during periods of occupant absence.

Key Contributions:

1. Identification of energy wastage (2–3 hours/day of unnecessary fan operation)
2. Development of a low-cost PIR sensor-based automation system
3. Net energy saving of 0.135–0.2175 kWh per day
4. Simple, cost-effective, and easy-to-implement design

The experimental results demonstrate that the system significantly reduces idle running time, leading to substantial energy savings while maintaining user convenience and ease of operation. The use of low-cost, readily available components ensures that the system is economical and suitable for practical implementation in small commercial setups.

Future Work:

- IoT-based remote monitoring and control
- Temperature-dependent fan speed control
- Integration with lighting automation
- Solar-powered operation for off-grid applications

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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