

# **DESIGN AND FABRICATION OF SMART WORK STATION REAL TIME MONITORING SYSTEM**



**SUBMITTED**

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Engineering

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January 2026

## **Declaration**

We do hereby solemnly declare that the work presented here in this project report has been carried out by us and has not been previously submitted to any University/ Organization for the award of any degree or certificate

We hereby ensure that the works that have been prevented here do not breach any existing copyright.

We further undertake to indemnify the university against any loss or damage arising from a breach of the foregoing obligation.

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## **Certification**

This is to certify that this project entitled “Design and Fabrication of Smart Work Station Real Time Monitoring System” is done by the following students under my direct supervision. This project work has been carried out by them in the laboratories of the Department of mechanical engineering under the faculty of Engineering, Sonargaon University (SU) in partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering.

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## **Acknowledgment**

First, we started in the name of Almighty Allah. This thesis is accomplished under the supervision of **Prof. Md. Mostofa Hossain, Professor & Head**, Department of Mechanical, Sonargaon University. It is a great pleasure to acknowledge our profound gratitude and respect to our supervisor for this consistent guidance, encouragement, helpful suggestions, constructive criticism, and endless patience through the progress of this work. The successful completion of this thesis would not have been possible without his persistent motivation and continuous guidance.

The authors are also grateful to **Prof. Md. Mostofa Hossain**, Head of the Department of Mechanical Engineering and all respect teachers of the Mechanical Engineering Department for their co-operation and significant help in completing the thesis work successfully.

## **Abstract**

With the advancement of Industry 4.0, intelligent monitoring and automation systems have become essential for improving industrial safety, efficiency, and equipment reliability. This project presents a smart Work Station and control system that integrates sensing, automation, and wireless communication technologies to reduce manual intervention and prevent industrial hazards. The main objective is to develop an intelligent Work Station system that ensures secure machine operation, real-time monitoring, and enhanced safety. The proposed system employs RFID technology for authorized machine ON/OFF control and a microcontroller for overall system coordination. Sensors are used to detect fire, gas leakage, motor temperature, and electrical parameters such as voltage, current, and power. A GSM module sends SMS alerts during emergency conditions, while a mobile application provides remote monitoring and control. Automatic shutdown features are implemented to protect machines from overheating and excessive operation. The system operates reliably by providing secure access, continuous monitoring, and instant emergency notifications. It effectively improves safety, reduces energy wastage, and enhances operational efficiency. The developed smart Work Station system offers a cost-effective and scalable solution for modern industrial automation. It significantly enhances equipment protection, worker safety, and overall factory performance.

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## Notation

BCE

Before Common Era

DC

Direct current

# Chapter 1

## Introduction

### 1.1 Introduction

Industrial automation and smart monitoring systems have become essential components of modern manufacturing environments. With the rapid growth of industries, the demand for improved safety, efficient energy management, and reliable machine control has significantly increased. Traditional factory systems often rely on manual operation and limited monitoring, which can lead to equipment damage, energy wastage, and safety hazards. To overcome these limitations, intelligent Work Station solutions are required.

The Work Station System proposed in this project is designed to provide a secure, automated, and real-time monitoring platform for industrial machines. The system integrates RFID-based access control, machine automation, safety monitoring, and remote supervision to enhance overall factory efficiency and safety. By using an ID card-based punching mechanism, only authorized personnel can operate the machine, thereby reducing unauthorized access and operational errors.

Safety is a critical concern in industrial environments. This system continuously monitors hazardous conditions such as fire and gas leakage and immediately generates alerts when abnormal conditions are detected. In emergency situations, an SMS notification is sent to responsible personnel, enabling quick response and minimizing potential damage. Additionally, the system includes motor temperature monitoring, which automatically shuts down the machine if excessive heat is detected, protecting the equipment from overheating and failure.

To support effective energy management, the system measures and displays key electrical parameters including voltage, current, and power in real time. These values are shown both on a local display and on a mobile application, allowing operators to monitor machine performance remotely. Furthermore, the system offers motor speed (RPM) control, enabling precise adjustment of machine operation according to production requirements, either manually or through the mobile app.

Overall, the proposed Work Station System provides a smart, reliable, and scalable solution for industrial automation. By combining safety features, real-time

monitoring, and remote-control capabilities, the system contributes to improved productivity, reduced downtime, and enhanced operational safety in modern factory environments.

## **1.2 Problem Statements**

In many traditional industrial environments, machine operation and monitoring are largely dependent on manual control and limited safety mechanisms. Unauthorized access to machines, lack of real-time monitoring of electrical parameters, and delayed response to hazardous conditions such as fire, gas leakage, and motor overheating often lead to equipment damage, energy wastage, and serious safety risks. Additionally, conventional systems do not provide effective remote monitoring and control, making it difficult for operators to manage machines efficiently and respond promptly to abnormal conditions.

The absence of an integrated system that combines access control, machine automation, safety monitoring, and real-time data visualization results in reduced operational efficiency and increased downtime in factories. Furthermore, manual speed control and the inability to remotely turn machines ON or OFF limit production flexibility and increase human error.

Therefore, there is a need for a smart and automated Work Station System that ensures secure machine access, continuous monitoring of machine health and electrical parameters, early detection of hazardous conditions, and remote control through a mobile application. Such a system can significantly enhance industrial safety, improve energy management, and optimize overall factory operations.

## **1.3 Objective**

The objectives of this project are:

- To develop an intelligent Work station system with RFID (Radio Frequency Identification) -based remote control.
- To ensure safety by automatic shutdown, hazard detection, real-time electrical monitoring, and GSM/mobile-based alerts and visualization.
- To Design and prepare software for monitoring industrial control System.

# **Chapter 2**

## **Literature Review**

### **2.1 Introduction**

The literature review chapter provides an overview of the existing research, technologies, and methodologies related to industrial automation, factory monitoring, and smart control systems. It aims to analyze previous work on machine monitoring, safety mechanisms, electrical parameter measurement, and remote operation, highlighting the advantages, limitations, and gaps in current solutions.

This chapter also examines the applications of RFID-based access control, sensor networks, IoT-based monitoring, and mobile application integration in industrial environments. By studying prior research and industrial practices, the chapter identifies key challenges, best practices, and potential improvements that informed the design and development of the proposed Work Station System.

### **2.2 Literature Review**

The term “Industry 4.0” was initially coined at the Hannover Fair in Germany in 2011. Later, the term was used in different versions in different regions of the world such as “Productivity 4.0”, “Made in China 2025”, and “Society 5.0 (Super-smart society)” [1]. The basic definition of Industry 4.0 is the digital transformation of traditional manufacturing methods with the help of computers and data-based control, monitoring, and management, along with the emergence of new manufacturing methods driven by advancing technology.

Industry 4.0 (I4.0) technologies encompass various components, including the Internet of Things (IoT), big data and analytics, artificial intelligence (AI), cybersecurity (CS), cloud computing (CC), augmented and virtual reality (AR/VR), advanced robotics, digital twin, and additive manufacturing (AM). Among them, AM has the most potential to create new methods and innovate manufacturing processes.

Additive manufacturing (AM) is a technique to produce parts by depositing material layer-by-layer according to the three-dimensional computer model. Compared to traditional subtractive manufacturing methods, AM gets particular attention due to its ability to minimize material waste while producing intricately shaped and multi-

material components. In addition to its advantages in rapid prototyping, AM enables low-batch, customer-centric mass manufacturing by facilitating quick responses to changes in customer requirements. With its numerous benefits, the AM method finds extensive application in diverse industries ranging from aerospace to biomanufacturing.

Although more than a decade has passed since the term Industry 4.0 appeared, the implementation of these technologies has been predominantly carried out by larger companies with the financial resources and expertise required to operate them. However, the characteristics of large companies, such as mass production, complex decision systems, and high levels of automation, suggest that AM may not be the most suitable method for producing parts within their context. On the other hand, previous literature reviews have indicated that AM is a promising I4.0 technology for small and medium-sized enterprises (SMEs) [2,3,4]. However, SMEs struggle to adapt AM and other I4.0 technologies because of insufficient funds and knowledge. Considering that they represent 90% of the companies and provide two out of three jobs, supporting SMEs to resolve their challenges will impact the industry positively [5].

In light of technological opportunities and known challenges, the primary objective of this paper is to analyze ongoing research efforts in the field of AM, specifically focusing on monitoring and control of the systems based on I4.0 technologies. The listed literature will then be examined within the scope of sustainability, cost-effective digital solutions and the applicability of research findings in the industry, particularly SMEs. The main goal is to highlight the relevant monitoring and control systems based on I4.0 technologies to enhance the process efficiency and capacity of AM. Considering the significant presence of SMEs in the industry, this study also includes easily applicable digital solutions that have the potential to contribute to the sustainability of manufacturing processes.

Advanced Sensor Technologies for Industrial Monitoring Systems: Smith, J., Wang, L., and Patel, R. IEEE Transactions on Industrial Electronics, 2019 [6]. This paper explores the development and integration of advanced sensor technologies in industrial monitoring systems. It highlights the advancements in sensor accuracy, durability, and miniaturization. The study emphasizes how these improvements enhance real-time data acquisition and enable more precise monitoring of industrial processes. It

also discusses the application of wireless sensor networks (WSNs) in industrial env, provide insight's into their position, scalability, and impact on operational efficiency.

Machine Learning Applications in Predictive Maintenance: Gupta, S., Kaur, P., and Hernandez, E: Journal of Manufacturing Systems, 2020 [7]. This research focuses on the use of machine learning procedure to predict maintenance needs in industrial settings. By analysis ancient data from many radars, ML models can classify patterns that precede equipment failures. The papers present's several instance trainings where predictive maintenance significantly reduced downtime and maintenance costs. It also covers the challenges of implementing mL in industrial environments, such as data quality and integration with existing systems.

Real-Time Monitoring and Control Using IoT in Industrial Systems: Gupta, S., Kaur, P., and Hernandez, E. International Journal of Advanced Manufacturing Technology, 2018 [8]. This paper examines the role of the IoT in enhancing real-time monitoring and control in industrial systems. It discusses the architecture of IoT-enabled industrial monitoring systems, including the integration of sensors, edge computing, and cloud platforms. The study showcases several industrial applications where IoT has improved monitoring precision, response times, and overall system efficiency. Additionally, it addresses the secure and secrecy worries associate with IoT in industrial contexts.

Enhancing Safety in Industrial Environments Through Monitoring Systems: : Kim, H., Roberts, A., and Martinez, J. Safety Science, 2019 [9] This study focuses on the safety benefits provided by industrial monitoring systems. It reviews various types of hazards that can mitigated through continuous monitoring, such as chemical spills, equipment malfunctions, and environmental conditions. The paper highlights how initial finds of unsafe conditions through monitoring can prevent accidents and protect workers. It also examines regulatory requirements and how monitoring systems help industries comply with safety standards and regulations.

Energy Efficiency Optimization in Industrial Monitoring Systems: Kim, H., Roberts, A., and Martinez, J. Energy Efficiency Journal, 2021 [10]. This research investigated how industry monitoring systems can be leveraged to optimize energy consumption. By continuously tracking energy use and identifying inefficiencies, these systems

can suggest adjustments to reduce waste and improve energy efficiency. The document event Studie demonstrating significant energy savings in various industries, from manufacturing to utilities. It also explores the integration of renewable energy sources and the character of monitoring systems in managing energy distribution and consumption effectively.

# Chapter 3

## Methodology

### 3.1 Introduction

This chapter describes the systematic approach adopted for the design and implementation of the proposed Work Station System. The methodology outlines the overall system architecture, hardware and software integration, data acquisition process, control logic, and communication mechanisms used to achieve secure, safe, and efficient factory operation.

The system is developed by integrating multiple functional modules such as RFID-based access control, machine automation with time-based operation, fire and gas detection, motor temperature protection, and electrical parameter monitoring. Each module is carefully designed to operate both independently and in coordination with other modules to ensure reliable performance under industrial conditions.

### 3.2 Block Diagram

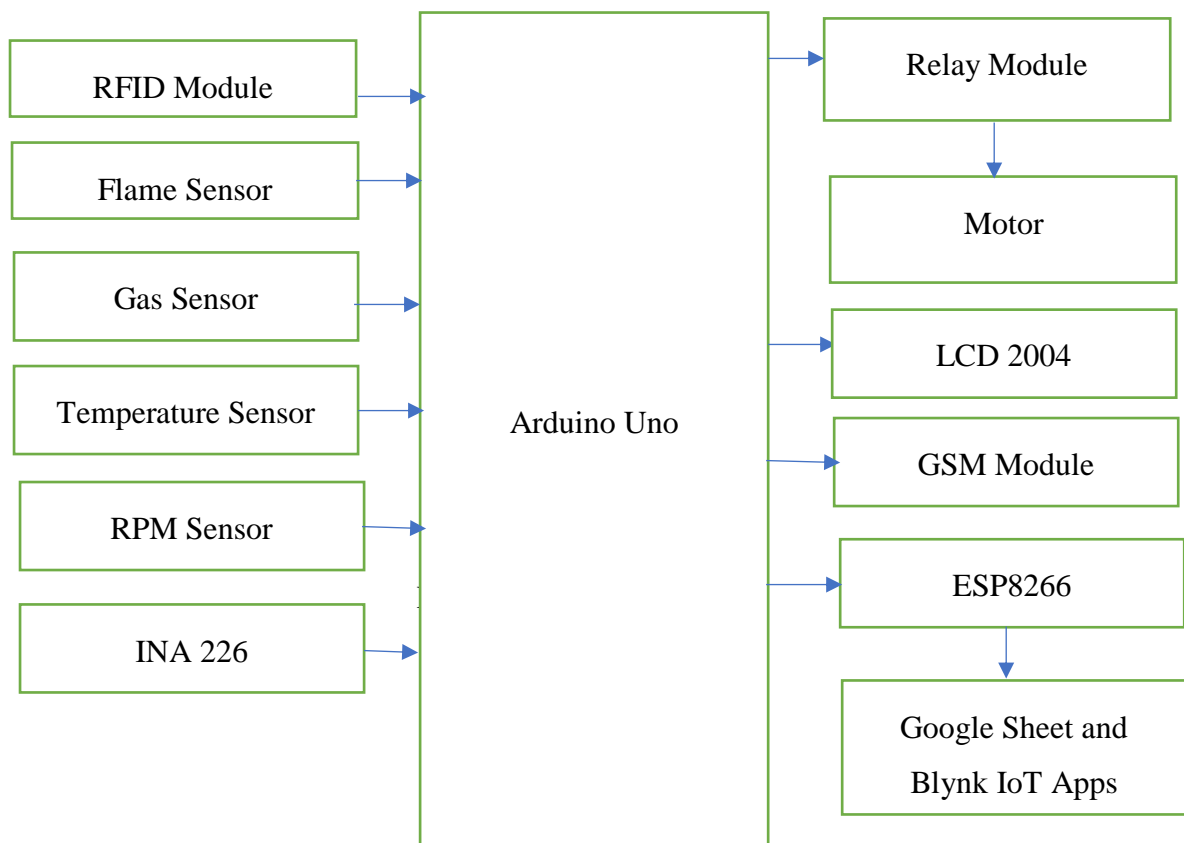


Figure 3.1: Block Diagram

### 3.3 Circuit Diagram

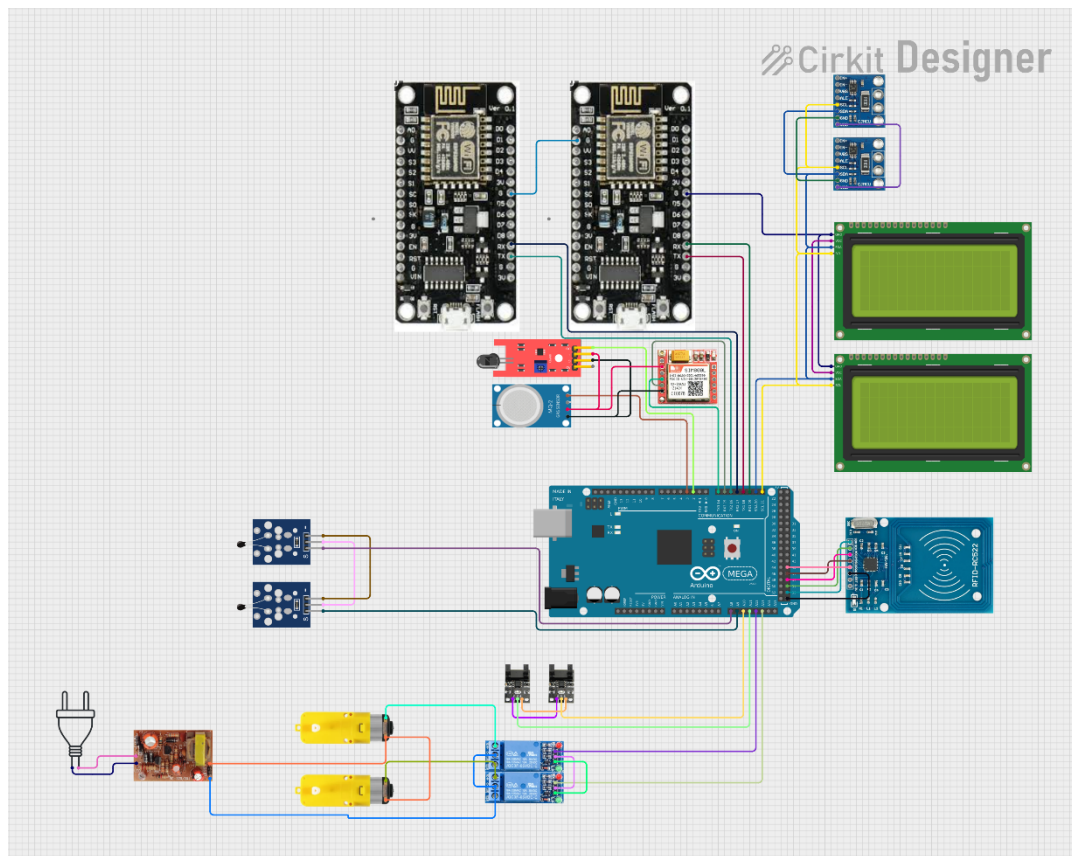


Figure 3.2: Schematic Diagram

As seen in the figure above, the electronic components have been soldered in a prototyping board. The general schema is the following: We utilized one 6V power supply which drives all the components. With this 6-volt provision, we powered the two servos, inductive sensor and the capacitive sensor. Next, we used a step-down converter to convert the 6V to 5V with which we can drive the Arduino via the 5V pin and power the ultrasonic sensor. When soldering one has to be careful and connect all the components to the same ground.

### 3.4 Working Principle

The proposed Work Station System operates by integrating access control, safety monitoring, electrical parameter measurement, and remote control into a single automated platform. The system continuously collects data from various sensors and executes predefined control logic using a central microcontroller.

Initially, the system remains in standby mode. When an authorized user punches a valid RFID ID card, the microcontroller verifies the card information and activates

the machine through a relay or motor driver. The machine starts operating and continues running for a predefined time duration of two minutes. If the same ID card is punched again within this period, the machine is turned OFF manually. Otherwise, after the completion of the set time, the system automatically switches OFF the machine to ensure safety and prevent unnecessary energy consumption.

During operation, the system continuously monitors environmental and machine safety conditions. Fire and gas sensors detect the presence of fire or gas leakage in the factory environment. Upon detecting any hazardous condition, the system immediately triggers an alarm and sends an SMS alert to the authorized personnel using a GSM module, enabling quick emergency response.

Simultaneously, the motor temperature sensor monitors the temperature of the industrial motor. If the temperature exceeds the safe threshold level, the microcontroller automatically shuts down the motor to prevent overheating, mechanical damage, or fire hazards.

The system also measures important electrical parameters such as voltage, current, and power using suitable sensing modules. These parameters are processed and displayed in real time on a local display unit and transmitted to a mobile application through a wireless communication interface. This allows operators to monitor machine performance remotely.

Furthermore, the motor speed control unit enables the adjustment of motor speed by varying the control signal (PWM). The speed can be increased or decreased based on operational requirements, either through physical controls or via the mobile application. The mobile app also provides remote ON/OFF control of the machine, offering flexibility and improved operational efficiency.

### **3.5 Components List**

#### **Hardware Part:**

- Arduino Mega
- RFID Module
- RFID Card
- LCD 2004 With I2C

- Flame Sensor
- Gas Sensor
- GSM
- Temperature Sensor
- Motors
- Step Down Converter
- Relay Module
- Motor Speed Controller
- RPM Sensor
- SMPS

### **Arduino Mega**

In a nutshell, the Arduino Uno is an open-source microcontroller board based on the ATmega2590 microcontroller. Various expansion boards shields, and other circuits can be interfaced with the board's digital and analog input/output pins. A type B USB cable is required to program the board using the Arduino IDE (Integrated Development Environment). It has 54 Digital pins and 16 Analog pins. An external 9-volt battery can be used to power it, or a USB cable can be used. It is also similar to the Arduino Nano and Leonardo. It can be downloaded from the Arduino website and distributed under the Creative Commons Attribution-Share Alike 2.5 license. Various layouts and production files are also available.



Figure 3.3: Arduino Mega

This initial release of the Arduino Software was given the name "Mega" for its Italian meaning. Arduino Uno was the first of a series of USB-based Arduino boards, and the Arduino IDE and Uno together were the first releases of Arduino software. A bootloader is already preprogrammed into the ATmega328, allowing programmers to upload new code without an external hardware programmer. It is the first board not to include the FTDI USB-to-serial driver chip while using the STK500 protocol as its communication protocol. The USB-to-serial converter uses the Atmega16U2 (Atmega8U2 up to version R2) as an analog input.

**Specifications:**

**Operative Voltage:** 5V and 3.3V

**Input Voltage:** 5-12V (5V model) and 3.3-12V (3.3V model)

**Digital I/O Pins:** 54 Pins (16 are PWM output pins)

**Analog Input Pins:** 16 pins

**DC Current per I/O Pin:** 40 mA

**Flash Memory:** 32 kB (0.5 kB is taken by bootloader)

**SRAM:** 2 Kbytes

**EEPROM:** 1 Kbytes

**Clock Speed:** 16 MHz (5V model) and 8 MHz (3.3V model)

**Table 3.1: ARDUINO Mega Configuration**

Pin Group	Pin Name	Description
POWER SOURCE	VCC, GND, and RAW	VCC- Linked to +5V or +3.3V GND- Linked to Ground RAW- Linked to Unfettered power supply 5+V to +12V
Communication INTERFACE	UART Interface (RXD, TXD) SPI Interface (MOSI, MISO, SCK, SS ) TWI Interface(SDA, SCL)	UART (Universal Asynchronous Receiver Transmitter) Interface can be used to program PRO MINI SPI (Serial Peripheral Interface) Interface can be used to program PRO MINI TWI (Two Wire Interface) Interface can be used to attach peripherals.
INPUT-OUTPUT PINS	PD0 to PD7 (8 pins of PORTD) PB0 to PB5 (6 pins of PORTB) PC0 to PC6 (7 pins of PORTC) ADC6 and ADC7 (2 extra pins)	They oblige various dedications, but they can be classified as data I/O pins.

ANALOG to DIGITAL CONVERTER	ADC0, ADC1, ADC2,...ADC7	They can be used for analog input and feature 10-bit resolution.
PWM	OC0A,OC0B,OC1A,OC1B,OC2A ,OC2B	It delivers PWM outputs and 8-bit tenacity.
RESET	RESET	Resets the controller.
EXTERNAL INTERRUPTS	T0 and T1	Hardware interrupts are provided by these two pins.
ANALOG COMPARATOR	AIN0 and AIN1	An internal comparator connects these two pins.

### Step Down Converter

The DC/DC step-down voltage regulator is capable to convert voltage between 3.2V and 40V into a smaller voltage between 1.25V and 35V. It is capable of driving a 3A load.

We have adjusted this step-down converter for our requirements, respectively the 6V from the power supply has been converted to 5V which feeds the Arduino Uno; this has been done via the potentiometer for voltage adjustment.



Figure 3.4: LM2596

#### Specifications:

- Input voltage: 3.2V - 40VDC
- Output voltage: 1.25V - 35VDC
- Max. output Current: 3A

- Dimensions: 43mm x 21mm x 14mm(l) x (w) x (h)
- Weight: 12 g

### RFID Module



Figure 3.5: RFID Module

The RC522 is a low-cost, highly popular RFID (Radio Frequency Identification) module used for contactless communication between a microcontroller (like Arduino, Raspberry Pi, ESP32) and RFID tags/cards. It operates at 13.56 MHz and is capable of reading/writing data from compatible RFID cards or tags.

#### Key Features

- Operating Frequency: 13.56 MHz (High Frequency, HF)
- Communication Interface: SPI, I<sup>2</sup>C, UART (commonly SPI with Arduino)
- Power Supply: 3.3V DC (direct connection to 3.3V pin recommended)
- Read Distance: Typically, 2–5 cm (depending on antenna size and tag)
- Compatible Cards: ISO/IEC 14443A standard cards and tags
- Compact Size: Small and lightweight, ideal for embedded projects

#### Working Principle

- The RC522 generates an electromagnetic field to detect nearby RFID tags.
- When a tag enters the field, it receives energy from the module's field and responds with its unique ID.
- The module processes the tag's data and communicates it to the microcontroller via SPI/I<sup>2</sup>C.
- Using the microcontroller, actions can be triggered, like unlocking a door, logging attendance, or turning on a device.

## LCD 2004



Figure 3.6: LCD 2004

The LCD 2004 is a 20x4 character LCD display, which means it can display 20 characters per line and has 4 lines. It is widely used in microcontroller-based projects for displaying text, numbers, and basic symbols.

- Display Size: 20 characters × 4 lines (20×4)
- Controller: HD44780 or compatible
- Interface: Parallel (4-bit or 8-bit) and can be used with I<sup>2</sup>C adapter
- Operating Voltage: 5V DC
- Backlight: LED backlight for better visibility
- Character Set: 5x8 dots per character, supports custom characters
- Low Power Consumption: Ideal for embedded systems

### Pin Configuration (Standard 16-pin Module)

- VSS: Ground
- VDD: +5V Power Supply
- VO: Contrast adjustment (via potentiometer)
- RS: Register Select (Command/Data)
- RW: Read/Write Select (usually connected to GND for write-only)
- E: Enable Pin 7–14. D0–D7: Data Pins (for 8-bit mode; D4–D7 used in 4-bit mode)
- A (LED+): Backlight +5V

- K (LED-): Backlight GND

## Flame Sensor

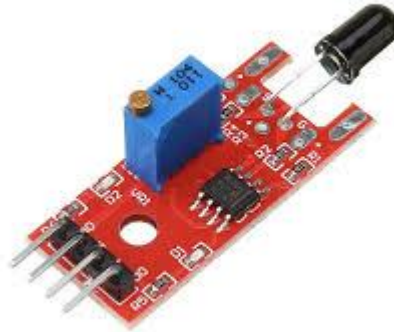


Figure 3.7: Flame Sensor

A Flame Sensor is an electronic sensor designed to detect fire or flame in its environment. It is widely used in fire alarm systems, safety devices, and robotics projects for detecting the presence of fire.

- Detection Range: Typically, 760 nm to 1100 nm (near-infrared, matches flame emission spectrum)
- Output Type: Digital (HIGH/LOW) and Analog (optional, depending on module)
- Operating Voltage: 3.3V – 5V DC
- Detection Distance: Usually up to 100 cm, depending on flame size and sensor sensitivity
- Signal Pins: VCC, GND, DO (Digital Output), AO (Analog Output for some versions)

### Working Principle

- The sensor has a photodiode or infrared receiver that detects light in the flame spectrum (around 760–1100 nm).
- When the sensor detects a flame, it generates an electrical signal.
  - Digital Output: Goes HIGH or LOW depending on detection.
  - Analog Output: Provides a voltage proportional to flame intensity.

- This signal can be read by a microcontroller (Arduino, Raspberry Pi, ESP32) to trigger an action

## MQ 2



Figure 3.8: MQ 2

The MQ-2 is a widely used gas and smoke sensor designed to detect flammable gases and smoke in the air. It is commonly used in gas leakage detection, fire alarm systems, and safety monitoring projects. The sensor is easy to interface with microcontrollers such as Arduino, ESP8266, ESP32, and Raspberry Pi.

### Gases Detected

- LPG
- Propane
- Methane
- Hydrogen
- Smoke
- Alcohol vapors

### Working Principle

- The MQ-2 contains a tin dioxide ( $\text{SnO}_2$ ) sensing element whose resistance changes in the presence of combustible gases.
- When gas concentration increases, the sensor resistance decreases.
- This change is converted into an analog voltage at the AO pin.

- The digital output (DO) changes state when gas concentration crosses the preset threshold.
- A microcontroller reads the output and triggers alarms, displays data, or activates safety systems.

## Temperature Sensor

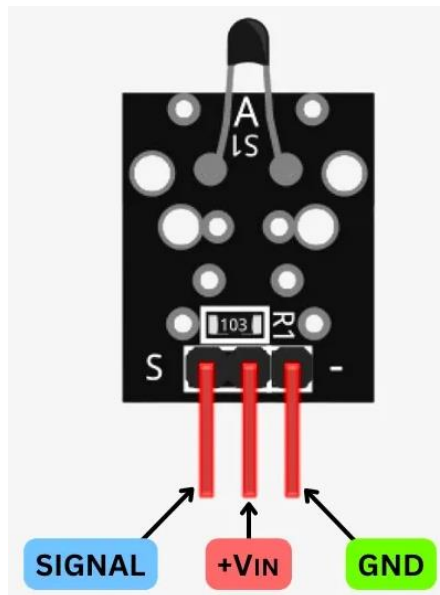


Figure 3.9: Temperature Sensor

A Temperature Sensor is an electronic device used to measure the temperature of an environment, object, or system and convert it into an electrical signal. It is widely used in industrial control systems, weather stations, medical devices, and microcontroller-based projects.

- Operating Voltage: 3.3V – 5V (depends on sensor type)
- Output Type: Analog or Digital
- Measurement Range: Varies by sensor (e.g.,  $-55^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$ )
- Accuracy: From  $\pm 0.5^{\circ}\text{C}$  to  $\pm 2^{\circ}\text{C}$  depending on model
- Fast Response Time.

The sensor changes its electrical property (voltage, resistance, or digital data) according to temperature. This change is processed by a microcontroller or signal

conditioning circuit. The measured temperature can be displayed on an LCD, sent to the cloud, or used to control devices like fans, heaters, or alarms.

## Relay Module



Figure 3.10: Relay Module

A Relay Module is an electrically operated switch that allows a low-voltage control signal from a microcontroller (such as Arduino, ESP32, or Raspberry Pi) to control high-voltage or high-current devices safely. It provides electrical isolation between the control circuit and the load.

- Operating Voltage: 5V / 12V (depending on module type)
- Control Signal: Digital HIGH/LOW from microcontroller
- Switching Capacity: Typically, up to 10A at 250V AC or 30V DC
- Relay Type: SPDT (Single Pole Double Throw)
- Isolation: Optocoupler or transistor-based isolation (on most modules)
- Indicator LED: Shows relay ON/OFF status.
- A digital signal is applied to the IN pin.
- The relay coil is energized through a driver circuit.
- This creates a magnetic field that switches the contact between NO and NC.
- The connected load (lamp, motor, fan, etc.) turns ON or OFF accordingly.
- Electrical isolation ensures safety of the low-voltage control circuit.

## Motor Speed Controller



Figure 3.11: Motor Speed Controller

A Motor Speed Controller (10A) is an electronic device used to control the speed of DC motors by regulating the voltage or duty cycle supplied to the motor. It is commonly used in robotics, automation systems, DIY electronics, and motor control projects. The 10A rating means it can safely handle motor currents up to 10 amperes.

- Current Rating: Up to 10A continuous
- Operating Voltage: Typically, 6V – 30V DC (varies by model)
- Control Method: PWM (Pulse Width Modulation)
- Efficiency: High efficiency with low heat loss
- Speed Adjustment: On-board potentiometer or external PWM signal
- Compact Design: Suitable for embedded projects

## INA219

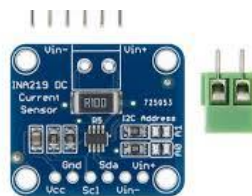


Figure 3.12: INA 219

The INA219 is a high-side current and voltage sensor used to measure DC current, bus voltage, and power in electronic circuits. It communicates using the I<sup>2</sup>C protocol,

making it ideal for use with Arduino, ESP32, ESP8266, Raspberry Pi, and other microcontrollers.

- Supply Voltage: 3.0V – 5.5V
- Bus Voltage Measurement: 0 – 26V
- Current Measurement: Depends on shunt resistor (commonly  $\pm 3.2\text{A}$ )
- Power Measurement: Calculated internally
- Interface: I<sup>2</sup>C
- Current: up to 12-bit
- Voltage: up to 12-bit
- High-Side Measurement: Measures current without disturbing ground
  
- The INA219 measures the voltage drop across a shunt resistor placed in series with the load.
- Using Ohm's Law, it calculates the current flowing through the circuit.
- It also measures the bus voltage directly.
- Power is computed internally using:
  - $Power = Voltage \times Current$
- The measured values are sent to the microcontroller via I<sup>2</sup>C.

The INA219 is a powerful and accurate sensor for monitoring electrical parameters in embedded systems. Its ability to measure current, voltage, and power simultaneously makes it ideal for energy monitoring and protection applications.

### RPM Sensor



Figure 3.13: RPM Sensor

An RPM (Revolutions Per Minute) Sensor is a device used to measure the rotational speed of a rotating object such as a motor shaft, wheel, or fan. It is widely used in motor control, automation systems, robotics, and industrial monitoring applications.

- Operating Voltage: 3.3V – 5V (varies by sensor)
- Output Type: Digital pulse output
- Measurement Range: From few RPM to several thousand RPM
- Non-contact Measurement: No mechanical wear
- Fast Response Time

#### Working Principle

1. A marker (reflective tape or magnet) is attached to the rotating shaft.
2. Each rotation produces a pulse detected by the sensor.
3. The microcontroller counts the number of pulses in a fixed time interval.
4. RPM is calculated using:

$$RPM = \frac{\text{Pulses per minute}}{\text{Pulses per revolution}}$$

5. The measured RPM can be displayed or used for speed control.

#### ESP8266



Figure 3.14: ESP8266

The ESP8266 is a low-cost Wi-Fi-enabled microcontroller module developed by Espressif Systems. It allows electronic devices and microcontroller-based systems to connect to the internet and communicate wirelessly, making it a popular choice for IoT (Internet of Things) applications.

- Wi-Fi Standard: IEEE 802.11 b/g/n
- Operating Voltage: 3.0V – 3.6V (3.3V typical)
- CPU: 32-bit Tensilica LX106
- Clock Speed: Up to 80 MHz (160 MHz optional)
- Flash Memory: External (commonly 4MB)
- GPIO Pins: Digital I/O, PWM, I<sup>2</sup>C, SPI, UART
- ADC: 1 × 10-bit ADC
- Low Power Modes: Deep sleep supported
- The ESP8266 connects to a Wi-Fi network as a station or access point.
- It can send and receive data from the internet or local servers.
- Sensor data is processed internally and transmitted using TCP/IP.
- It can be programmed directly using Arduino IDE or Micro Python.

### **TT Gear Motor**



Figure 3.15: TT Gear Motor

The TT Gear Motor is a small DC geared motor commonly used in robotics and DIY projects, especially in two-wheel and four-wheel robot cars. It consists of a DC motor combined with a plastic gearbox that reduces speed and increases torque.

- Operating Voltage: 3V – 6V DC (commonly 6V)
- Gear Ratio: Typically 1:48 or 1:120 (varies by model)
- Speed: ~200 RPM at 6V (approx.)
- Torque: High torque at low speed
- Shaft Type: Dual-shaft (for wheel + encoder)

- Lightweight and Compact

### Working Principle

1. When DC voltage is applied, the motor shaft starts rotating.
2. The gearbox reduces the motor's high speed.
3. Reduced speed results in increased torque at the output shaft.
4. This makes the motor suitable for moving robot wheels smoothly.

### 3.6 Instrument Cost Analysis

Table 3.2: Cost analysis of instruments

Serial No	Components	Price
01	Arduino Mega	1800
02	RFID Module	330
03	LCD 2004 With I2C	1100
04	Flame Sensor	85
05	Gas Sensor	135
06	GSM	550
07	Temperature Sensor	240
08	Relay Module	140
09	Motor Speed Controller	900
10	INA 226	800
11	PVC Board	400
12	RPM Sensor	200

13	ESP8266	600
14	LM2596	300
15	TT Gear motor	140
16	SMPS	1000
17	Switch	10
18	Wire and Others	1000
	Total=	9730 BDT

## Chapter 4

### Results & Discussion

#### 4.1 Introduction

In this chapter presents the results obtained from the design, implementation, and testing of the proposed Work StationSystem. The performance of the system is analyzed to evaluate its effectiveness in achieving the defined objectives, including secure machine control, safety monitoring, real-time data acquisition, and remote operation.

The analysis focuses on the behavior of individual system modules such as RFID-based access control, time-based machine operation, fire and gas detection, motor temperature protection, and electrical parameter monitoring. Experimental results are examined to verify the accuracy, reliability, and response time of the system under normal and abnormal operating conditions.

Additionally, the results obtained from motor speed (RPM) control and mobile application-based monitoring and control are analyzed to assess system stability, communication reliability, and user responsiveness. Comparative observations are also discussed to demonstrate how the proposed system improves safety, energy efficiency, and operational flexibility compared to traditional Work Stationmethods.

#### 4.2 Project Picture

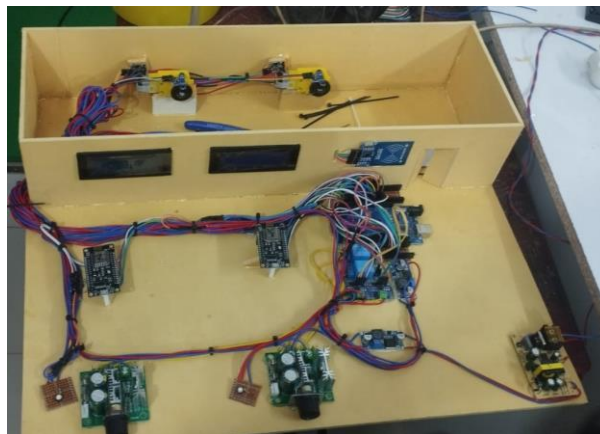


Figure 4.1: Project Picture

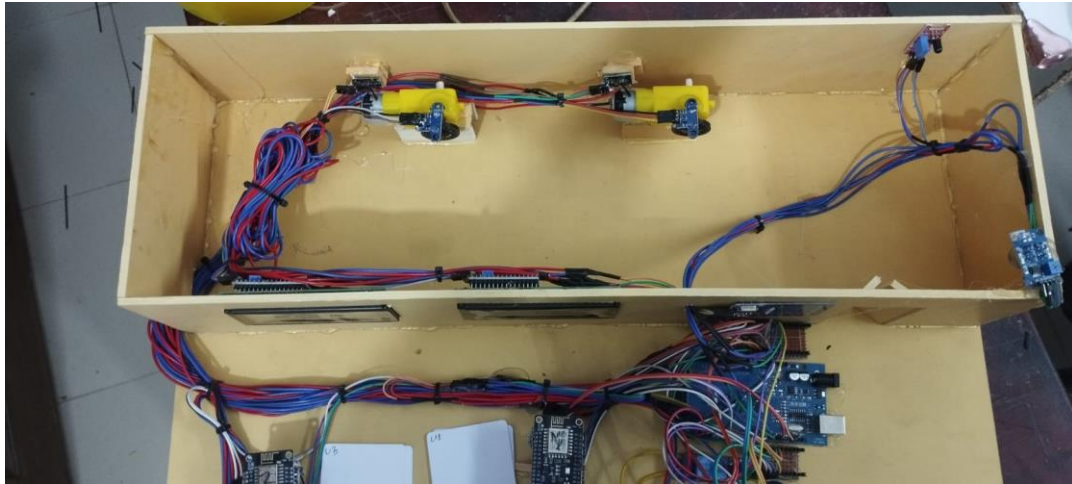


Figure 4.2: Motor Setup Room

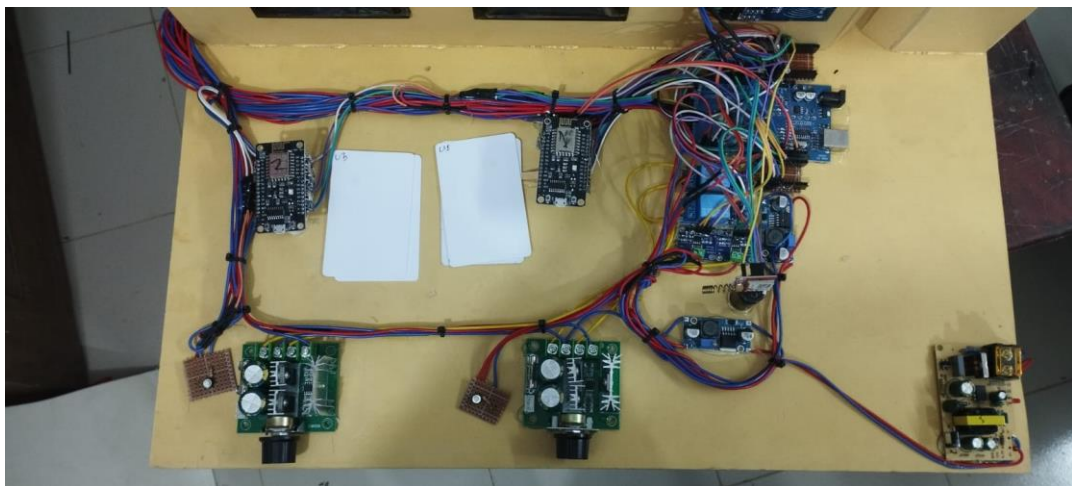


Figure 4.3: Circuit Setup of project

### 4.3 Result

Machine-1 ☆ 📁 ☁

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	B	C	D	E
Date				
Time				
ID				
Status				
	12-Jan-2026	03:47:14 PM	40-8C-D2-61	IN
	12-Jan-2026	03:47:34 PM	40-8C-D2-61	OUT

Figure 4.4: Machine 1 Employee IN and Out data Stored System in Google Sheet

Machine-2 ☆ 📁 ☁️ ⌛ 🗨️

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Date	Time	ID	Status
12-Jan-2026	03:47:00 PM	61-EB-AC-17	IN
12-Jan-2026	03:47:41 PM	61-EB-AC-17	OUT

Figure 4.5: Machine 2 Employee IN and Out data Stored System in Google Sheet



Figure 4.6: Machine 1, Motor Status Control and Monitoring

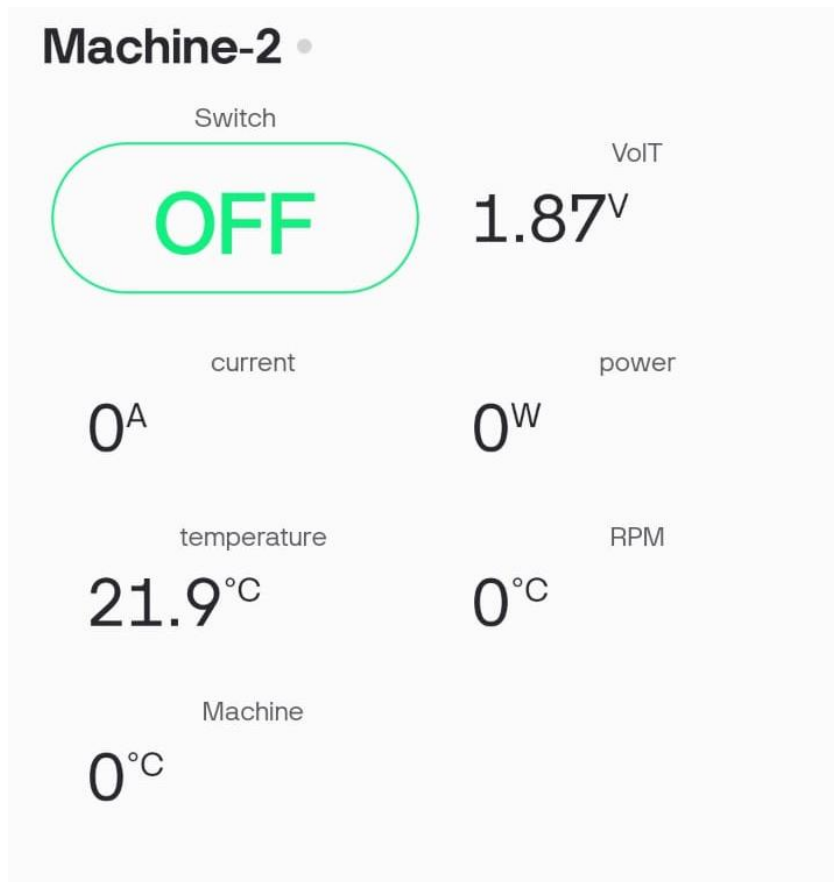


Figure 4.7: Machine 2, Motor Status Control and Monitoring

### Electrical Load and Power Consumption Calculation

The proposed Work StationSystem operates using a 12V DC SMPS as the main power source. The total current required by the system, including the industrial motor and control electronics, is 2A.

#### Power Calculation

The electrical power consumed by the system is calculated using the formula:

$$P=V \times I$$

Where:

$$V=12V \text{ (Supply Voltage)}$$

$$I=2A \text{ (Load Current)}$$

$$P=12 \times 2=24W$$

Therefore, the total electrical power consumed by the system is 24 Watts.

## Energy Consumption

The energy consumed by the system in one hour is calculated as:

$$\text{Energy} = \text{Power} \times \text{Time}$$

$$\text{Energy} = 24 \times 1 = 24\text{Wh}$$

This means the system consumes 24 Watt-hours (Wh) of energy when it runs continuously for one hour.

## Energy Consumption per Operating Cycle

In this project, the machine operates for 2 minutes after each authorized RFID card punch.

$$\text{Time} = \frac{2}{60} = 0.033 \text{ hours}$$

$$\text{Energy} = 24 \times 0.033 = 0.8\text{Wh}$$

Thus, each machine operation cycle consumes approximately 0.8 Wh of energy, which makes the system energy-efficient and suitable for continuous industrial operation.

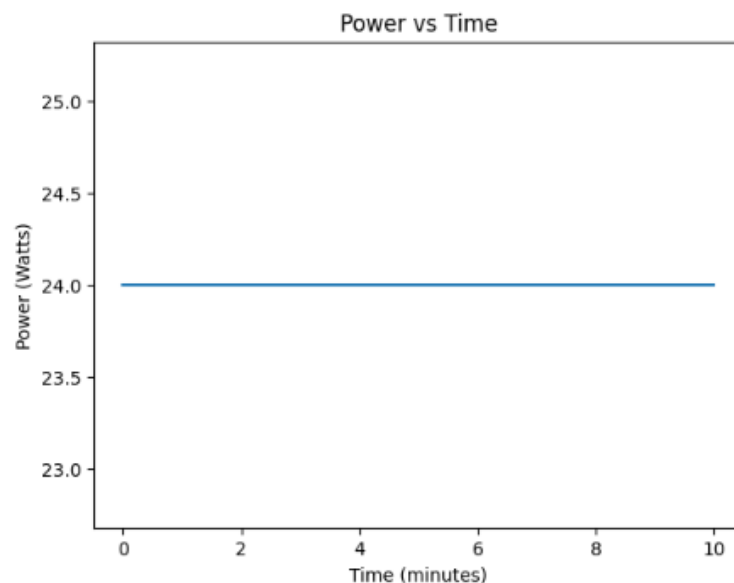


Figure 4.8: Time vs Power Graph

The Power vs Time graph shows a constant power consumption of 24 W, indicating stable operation of the system when powered by a 12V, 2A SMPS.

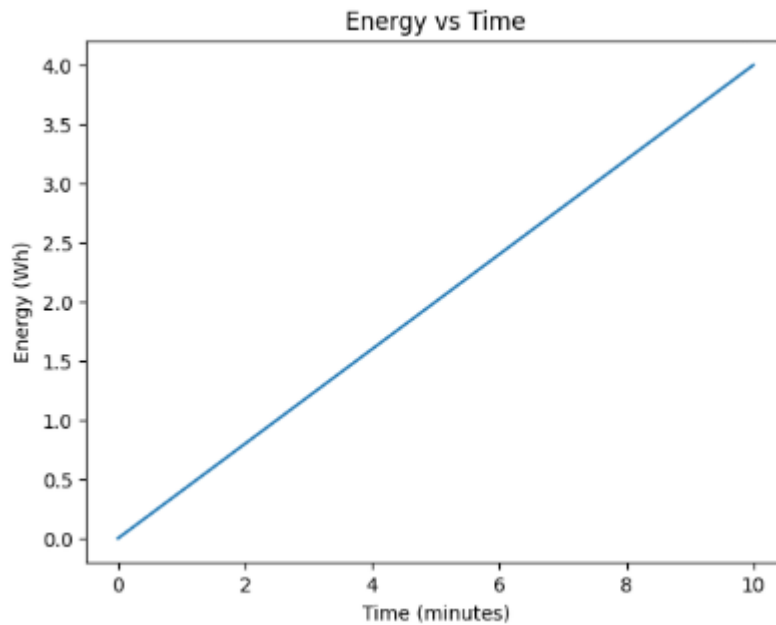


Figure 4.9: Time vs Energy Graph

The Energy vs Time graph shows a linear increase, indicating that the system consumes energy proportionally with time at a constant power of 24 W

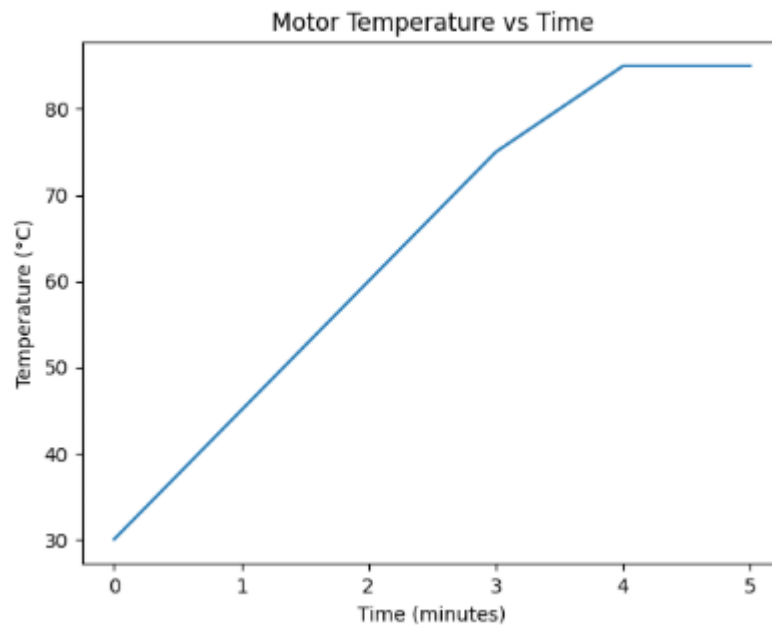


Figure 4.10: Motor Temperature vs Time Graph

The Motor Temperature vs Time graph shows a gradual rise in temperature during operation. When the temperature reaches the preset safety limit of 85°C, the system automatically turns OFF the motor to prevent overheating and damage.

#### **4.4 Advantages**

- Secure machine operation using RFID ID cards
- Automatic machine shutdown after set time
- Fire & gas alerts with SMS notification
- Motor over-temperature protection
- Real-time monitoring of voltage, current, and power
- Remote ON/OFF control via mobile app
- Motor speed (RPM) control
- Improved energy efficiency
- Quick emergency response
- Scalable and modular system design

#### **4.5 Limitation**

- System depends on power supply and network connectivity
- Initial setup and hardware installation can be costly
- RFID-based control requires authorized cards; lost cards may cause inconvenience
- Sensors may require periodic calibration for accuracy
- Mobile app control depends on stable internet connection
- Limited to predefined operating time unless manually overridden
- May not cover all types of industrial hazards without additional sensors

#### **4.6 Application**

- Smart factory and industrial automation
- Real-time machine monitoring and control
- Energy-efficient industrial operations
- Industrial safety management (fire, gas, motor protection)
- Remote monitoring via mobile application
- Production process optimization
- Training and demonstration for industrial IoT projects

#### **4.7 Discussion**

The experimental results of the proposed Work StationSystem demonstrate that the system successfully meets its intended objectives of secure machine control, real-time monitoring, and enhanced industrial safety. The integration of multiple sensing

and control modules enables reliable operation under both normal and abnormal factory conditions. The RFID-based access control mechanism effectively restricts unauthorized machine usage. During testing, the machine responded accurately to valid ID card punching by turning ON and OFF as expected. The implementation of a time-based automatic shutdown after two minutes proved effective in reducing unnecessary machine operation and energy consumption, while also enhancing operational safety. The fire and gas detection system showed prompt and reliable response during simulated hazardous conditions. Upon detection of fire or gas leakage, the system immediately triggered alerts and successfully sent SMS notifications through the GSM module. This rapid response capability is crucial for minimizing damage and ensuring personnel safety in industrial environments. The motor temperature protection mechanism performed efficiently by continuously monitoring the motor temperature. When the temperature exceeded the predefined threshold, the system automatically shut down the motor, preventing overheating and potential equipment failure. This feature significantly improves machine reliability and reduces maintenance risks.

Electrical parameter monitoring, including voltage, current, and power, provided stable and accurate real-time readings. These values were correctly displayed on both the local display unit and the mobile application, enabling effective remote supervision. The availability of live electrical data allows operators to make informed decisions regarding machine performance and energy usage. The motor speed (RPM) control functionality demonstrated smooth and responsive operation. Speed variations were accurately achieved through PWM control, and remote speed adjustment via the mobile application worked reliably with minimal delay. The app-based remote ON/OFF control further enhanced system flexibility and ease of operation.

# Chapter 5

## Conclusion

### 5.1 Conclusion

The proposed Work Station System successfully demonstrates the integration of automated machine control, safety monitoring, real-time electrical parameter observation, and remote operation through a mobile application. By implementing RFID-based access control, the system ensures that only authorized personnel can operate the machines, enhance security and reduce human error. Safety features such as fire and gas detection along with motor temperature protection effectively minimize potential hazards, ensuring both equipment and personnel safety. Real-time monitoring of voltage, current, and power, coupled with motor speed (RPM) control, improves operational efficiency and energy management. The mobile application interface provides convenient remote control and monitoring, offering flexibility in industrial operations. Overall, this system enhances productivity, reduces downtime, ensures safety, and provides a scalable solution for modern smart factories. The project confirms that integrating automation, IoT, and safety mechanisms into a single platform significantly improves industrial management and operational reliability.

### 5.2 Future Work

- Integration of more sensors such as vibration, humidity, or dust detection for comprehensive factory monitoring.
- Implementation of AI-based predictive maintenance to anticipate machine failures before they occur.
- Expansion of cloud-based data storage and analytics for long-term performance evaluation.
- Addition of voice control or gesture-based control for more intuitive machine operation.
- Integration with industrial SCADA systems for large-scale automation and centralized monitoring.
- Implementation of real-time video monitoring for enhanced security and safety.
- Enhancement of energy management features to optimize power consumption further.
- Development of multi-user access hierarchy for better control and security in large factories.

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## **APPENDIX**