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SMART MONITORING AND CONTROL OF SINGLE-PHASE INDUCTION MOTOR USING IoT

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ABSTRACT :
This project focuses on the smart monitoring and control of a single-phase induction motor using the Internet of Things (IoT) to enhance efficiency, reliability, and remote accessibility. The system employs various sensors to measure key parameters such as temperature, frequency, speed, voltage, current, and power consumption in real time. These values are continuously transmitted to a cloud-based IoT platform (ThingSpeak), enabling users to remotely monitor motor performance. By tracking these parameters, the system helps prevent overheating, overloading, and inefficiencies, ensuring safe and reliable operation. Users can also control motor settings remotely, thus optimizing energy usage and minimizing operational costs. In the event of abnormal conditions, automatic alerts are generated to support preventive maintenance, reduce downtime, and extend the motor's lifespan.
Keywords: IoT, Single-Phase Induction Motor, Smart Control, Remote Monitoring, Energy Efficiency, ThingSpeak, Arduino Uno, Real-Time Data.

INTRODUCTION:

This project aims to develop a smart, IoT-enabled system for the real-time monitoring and control of a single-phase induction motor, addressing key challenges such as energy inefficiency, equipment failures, and lack of remote accessibility. Single-phase induction motors are widely used in domestic, agricultural, and industrial applications due to their simple design and cost-effectiveness. However, traditional systems depend heavily on manual supervision, making it difficult to detect faults, track performance, or ensure safety in real time.To overcome these limitations, the proposed system integrates Internet of Things (IoT) technology with various sensing and control modules. At its core is the Arduino Uno microcontroller, which interfaces with a PZEM module to measure electrical parameters such as voltage, current, power, and frequency. A Hall effect sensor is used to measure the rotational speed (RPM) of the motor, while a temperature sensor (e.g., LM35) continuously monitors motor heat levels.All collected data is displayed on a 16x2 LCD screen and simultaneously transmitted to the ThingSpeak cloud platform via the ESP8266 Wi-Fi module for remote access. The system also includes a relay module that allows the Arduino to automatically turn off the motor if the temperature exceeds a safe threshold (e.g., 40°C), thus preventing overheating and ensuring motor protection.By leveraging IoT, this solution provides real-time monitoring, predictive maintenance, and remote control capabilities, leading to improved energy efficiency, system reliability, and operational safety.

HARDWARE COMPONENTS:

The short introduction of distinct modules used in this undertaking is mentioned below:

REGULATED POWER SUPPLY:

A regulated power supply is an electronic circuit designed to deliver a constant output voltage or

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current, regardless of fluctuations in the input voltage or variations in the connected load. It ensures stable operation of electrical devices and prevents voltage spikes that could damage sensitive components.

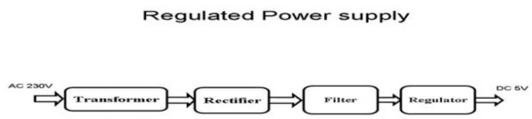

Fig 1: Regulated Power Supply

Components of a Regulated Power Supply:
Transformer: Converts the high-voltage AC supply to a lower voltage as required by the circuit.
Rectifier: Converts AC (alternating current) into pulsating DC (direct current). Common rectifiers include half-wave and full-wave rectifiers.
Filter: Smoothens the pulsating DC by removing ripples using capacitors or inductors, ensuring a steady DC voltage.
Voltage Regulator: Maintains a constant output voltage despite changes in input voltage or load conditions. This can be achieved using:
Linear regulators (e.g., IC 7805 for a fixed +5V output).
Switching regulators (e.g., buck, boost converters for higher efficiency and power-saving applications).

SINGLE-PHASE INDUCTION MOTOR:
Single-phase induction motor is used for IoT-enabled power monitoring and control. It is an AC motor that operates on a single-phase supply and is widely used in industrial and domestic applications.
Since a single-phase motor lacks self-starting capability, a capacitor-start mechanism is used to create a rotating magnetic field for smooth operation. The motor's voltage and current parameters are continuously monitored using sensors, and the data is transmitted to the Blynk app via Wi-Fi for real-time monitoring and remote control.

This integration enhances energy efficiency, fault detection, and operational reliability, making it a smart, IoT-based solution for motor control.

Fig 2: Single-Phase Induction Motor

LCD DISPLAY:
A 16x2 LCD (Liquid Crystal Display) is a widely used alphanumeric display module that can show 16 characters per line across two lines. It is commonly used in embedded systems, automation, and IoT applications due to its low power consumption, simple interface, and efficient data visualization.

Unlike LED or OLED displays, LCDs operate by manipulating liquid crystal molecules to control light transmission, resulting in clear and readable output.

Fig 3: 16x2 LCD Display

Features of 16x2 LCD Display:
Display Format: 16 characters × 2 lines
Character Structure: 5×8 dot matrix per character
Interface: Supports both 4-bit and 8-bit parallel communication
Operating Voltage: Typically 5V DC
Backlight: Optional LED backlight for better visibility
Controller IC: Based on HD44780, which simplifies communication with microcontrollers.

CURRENT AND VOLTAGE MEASURING COIL:
Current and voltage measuring coils are essential components in electrical measurement systems, used to monitor electrical parameters in power systems, metering, and protective relays.
Current Measuring Coil:
Measures current flow based on the magnetic field generated by a conductor.
Types:
Moving Coil: Used for DC current measurements.
Current Transformer (CT): Steps down high AC currents for safe measurement.
Used in ammeters, protective relays, and power monitoring systems.
Voltage Measuring Coil:
Measures voltage levels in a circuit.
Types:
Moving Coil Voltmeter: Used for DC voltage measurements.
Potential Transformer (PT): Steps down high AC voltages for metering and protection.
Used in voltmeters, power meters, and electrical protection systems.
These measuring coils play a vital role in fault detection, power monitoring, and efficient energy management.

Fig 4: Current and voltage measuring coil

PZEM MODULE:

The PZEM module refers to a series of electrical measurement modules used to monitor and measure various power parameters. Manufactured by Peacefair, these modules are widely used in DIY projects, home automation, and industrial applications for real-time monitoring of electrical parameters.

Fig 5: PZEM module

Common Features of PZEM Modules:
Voltage Measurement: Measures the voltage of the connected electrical circuit (e.g., 80–260V AC for PZEM-004T).
Current Measurement: Monitors current using a current transformer (CT), usually capable of handling up to 100A.
Power Measurement: Calculates real-time power (watts).
Temperature Monitoring: When integrated with a temperature sensor (e.g., LM35), it helps monitor the motor's heat levels to prevent overheating.
Frequency Measurement: Measures line frequency (Hz).
Speed Measurement: When used alongside a Hall effect sensor, it enables calculation of the motor's rotational speed (RPM).

ESP8266 WI-FI MODULE:

The ESP8266 is a low-cost, highly integrated Wi-Fi module designed for IoT applications, enabling microcontrollers to connect to Wi-Fi networks and communicate over the internet. It is widely used due to its affordability, compact size, and built-in networking capabilities.

Fig 6: ESP8266 Wi-Fi Module.

KEY FEATURES :

Wi-Fi Connectivity: Supports IEEE 802.11 b/g/n, Wi-Fi Direct, and Soft-AP mode. Microcontroller: Built-in 32-bit Tensilica L106 processor with an 80 MHz clock speed. Communication Protocols: Supports UART, SPI, I2C, PWM, TCP/IP, UDP, and HTTP. Memory: Includes flash memory (typically 4MB) and SRAM for data processing. Power Efficiency: Supports low-power operation, ideal for battery-powered IoT devices.Versatility: Can operate as a standalone microcontroller or as a Wi-Fi module for external controllers like Arduino.

Temperature Sensor:

A temperature sensor is a device used to detect the heat level of a system, ensuring safe and efficient operation by preventing overheating. In induction motor applications, temperature sensors help monitor thermal conditions in real time, enabling automatic shutdown or alerts during abnormal temperature rise. One of the most commonly used sensors for motor monitoring is the LM35 temperature sensor, known for its accuracy and ease of integration with microcontrollers like Arduino. The LM35 plays a critical role in this project by allowing the system to monitor motor heat continuously and automatically switch off the motor using a relay when the temperature exceeds a safe threshold (e.g., 40°C), thus protecting the motor from thermal damage.

Fig 7: Temperature Sensor

Features of LM35 Temperature Sensor:
Operating Voltage: 3.3V to 5V
Temperature Range: –55°C to +125°C
Accuracy: ±0.5°C at +25°C
Output Type: Analog output, linear with temperature (10 mV/°C)
Interface: Can be directly interfaced with analog input pins of Arduino
Response Time: Fast response for real-time temperature monitoring

Speed Sensor:
A speed sensor is a device used to measure the rotational speed (RPM) of a motor or rotating object. In the context of induction motor monitoring, it plays a crucial role in real-time performance tracking and fault detection. Speed sensors work on various principles such as magnetic, optical, or Hall effect, converting the rotational motion into a corresponding electrical signal.
The Hall Effect sensor is commonly used in motor-based applications due to its accuracy, reliability, and ease of interfacing with microcontrollers like Arduino.

Fig 8: Quadrature Speed and Direction Sensor.

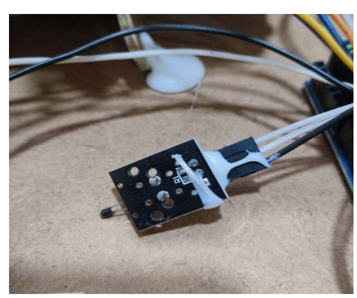

Fig 9: Speed Sensor

Features of Hall Effect Speed Sensor:

Operating Voltage: 3V to 5V
Working Principle: Detects magnetic field changes caused by a rotating magnet
Output Signal: Digital pulses representing rotational speed
Interface: Can be connected to digital I/O pins of Arduino for pulse counting
Applications: Used in automotive systems, industrial motors, and motion control equipment

RELAY MODULE:
A relay module is an electromechanical switching device that allows a low-power microcontroller to control high-voltage or high-current electrical loads such as motors, lights, or home appliances. It works by using an electromagnetic coil to open or close the circuit, effectively isolating the control side (Arduino or microcontroller) from the high-voltage side. Relays are a crucial part of automation and safety systems, allowing devices to be switched on or off based on sensor readings or programmed logic.
In induction motor control, a relay acts as a protective and control element, enabling the system to disconnect the motor in abnormal conditions like overheating or overloading.

Fig 10: 5V Relay Module

Features of Relay Module:
Operating Voltage: 5V DC
Control Signal: Can be activated using digital output from Arduino
Switching Capacity: Typically supports up to 10A at 250V AC or 10A at 30V DC
Electrical Isolation: Built-in optocoupler for safe separation between control and load sides
Indicator: On-board LED indicator shows the relay's switching status
Form Factor: Compact module design for easy integration in embedded and IoT systems

SOFTWARE REQUIREMENTS:
Arduino Uno:
The Arduino Uno is a widely used microcontroller board based on the ATmega328P chip, designed for embedded systems, IoT applications, and real-time automation. It is known for its simplicity, versatility, and open-source architecture, making it ideal for prototyping and development. The board features digital and analog input/output (I/O) pins, allowing seamless integration with sensors, actuators, displays, and other electronic components. It is programmed using the Arduino IDE, which is based on a simplified version of C++, ensuring ease of use for developers and engineers.
Key Features and Components:
Microcontroller: ATmega328P, 8-bit, operating at 16 MHz.

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Input/Output (I/O) Pins:
14 digital I/O pins (6 support PWM output).
6 analog input pins for sensor integration.
Power Supply Options: Operates via USB, external power adapter, or battery (7-12V).
USB Interface: Facilitates programming and serial communication with a computer.
Reset Button: Allows manual resetting of the microcontroller.

Fig 11: Aruduino Uno

Working of Arduino Uno:
Programming and Code Execution
Programs are written using the Arduino IDE and uploaded via USB.
The microcontroller executes the code stored in its flash memory, enabling interaction with external devices.
Input and Output Operations
Reads digital (HIGH/LOW) and analog (0-1023) signals from sensors.
Controls actuators like LEDs, motors, and relays based on programmed logic.
Real-Time Processing
Continuously loops through the code, making it suitable for automation and IoT applications.
Supports PWM (Pulse Width Modulation) for precise control of connected devices.

ARDUINO UNO CODE:
```
#include <PZEM004Tv30.h>
PZEM004Tv30 pzem(11, 12);
#include <LiquidCrystal.h>
LiquidCrystal lcd(8, 3, 4, 5, 6, 7);
#define relay 9
#define VIBRATION_PIN 2
// Function prototype
void vibrationInterrupt();
volatile int vibrationCount = 0;
void setup() {
  pinMode(VIBRATION_PIN, INPUT);
  attachInterrupt(digitalPinToInterrupt(VIBRATION_PIN), vibrationInterrupt, RISING); // Trigger
on rising edge
  lcd.begin(16, 2);
  lcd.setCursor(0, 0);
  lcd.print("Welcome To The  ");
```

```
 lcd.setCursor(0, 1);
 lcd.print("Project        ");
 delay(2000);
 lcd.clear();
 digitalWrite(relay, HIGH);
}

void loop() {
 int t = analogRead(A0);
 int rpm = vibrationCount * 60;  // Multiply by 60 to convert to RPM
 float frequency = rpm / 60.0;  // Convert RPM to Hz (frequency)
 vibrationCount = 0;
 float v = pzem.voltage();
 if (!isnan(v)) {
  lcd.setCursor(0, 0);
  lcd.print(v);
  lcd.print(" ");
 } else {
  v = 0;
  lcd.setCursor(0, 0);
  lcd.print(v);
  lcd.print(" ");
 }

 float c = pzem.current();
 if (!isnan(c)) {
  lcd.print(c);
  lcd.print(" ");
 } else {
  c = 0;
  lcd.print(c);
  lcd.print(" ");
 }
 float p = pzem.power();
 if (!isnan(p)) {
  lcd.print(p);
  lcd.print(" ");
 } else {
  p = 0;
  lcd.print(p);
  lcd.print(" ");
 }
 float f = pzem.frequency();
 if (!isnan(f)) {
  lcd.setCursor(0, 1);
  lcd.print(f);
  lcd.print(" ");
 } else {
  f = 0;
```

```
    lcd.setCursor(0, 1);
    lcd.print(f);
    lcd.print(" ");
  }
  lcd.setCursor(6, 1);
  lcd.print(t);
  lcd.print(" ");
  lcd.print(rpm);
  lcd.print("      ");
  if (t > 40) {
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("High Temperature");
    digitalWrite(relay, LOW);
  } else {
    digitalWrite(relay, HIGH);
  }
  Serial.print(v);
  Serial.print(",");
  Serial.print(c);
  Serial.print(",");
  Serial.print(p);
  Serial.print(",");
  Serial.print(f);
  Serial.print(",");
  Serial.print(t);
  Serial.print(",");
  Serial.println(rpm);
  delay(1000);
}
// Interrupt function for vibration sensor
void vibrationInterrupt() {
  vibrationCount++; // Increment vibration count when vibration is detected
}
```

RESULTS:

The proposed IoT-enabled power monitoring and control system for a single-phase induction motor was successfully designed, implemented, and tested. The system monitored real-time parameters including voltage, current, power, frequency, temperature, and motor speed (RPM). These values were displayed locally on a 16x2 LCD and transmitted wirelessly to the ThingSpeak cloud platform via the ESP8266 Wi-Fi module, enabling remote monitoring and control.

The system demonstrated high reliability, fast response, and user-friendly operation, making it a cost-effective and scalable solution for both industrial and domestic motor applications. It also laid a strong foundation for further enhancements such as predictive maintenance and advanced data analytics.

Key observations from the experiment include:

Key observations from the experimental setup include:

Accurate real-time monitoring of electrical parameters using the PZEM module.

Continuous measurement of temperature using the LM35 sensor, allowing for thermal protection.

Reliable detection of motor speed (RPM) using a Hall effect sensor.

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Seamless wireless data transmission to ThingSpeak, enabling cloud-based visualization.
Remote motor control using ThingSpeak, including automatic shutdown via relay when unsafe conditions such as overheating were detected.
Enhanced energy efficiency through real-time analysis and user awareness.
Effective early fault detection, minimizing the risk of damage and reducing maintenance needs.

THING SPEAK DATA:

_id	field1	field2	field3	field4	field5	field6
1	233.2	0.38	86.4	49.9	34	1590
2	232.2	0.38	87.2	50	34	1620
3	234.5	0.38	87.6	50	33	1590
4	235.7	0.38	87.8	50	36	1590
5	233.5	0.38	88	50	37	1620
6	236.4	0.29	68.7	50	42	1788
7	230.2	0.38	88.2	50	35	1620

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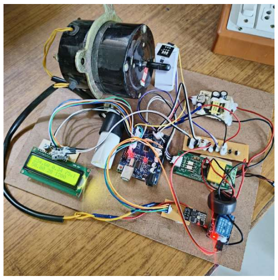
PROTOTYPE PICTURES:



CONCLUSION:

The IoT-enabled power monitoring and control system for a single-phase induction motor successfully integrates **sensor-based automation, real-time data acquisition**, and **wireless communication** to provide a smart and reliable solution for motor management. The system utilizes components such as the **Arduino Uno**, **PZEM module**, **LM35 temperature sensor**, **Hall effect speed sensor**, **ESP8266 Wi-Fi module**, and the **ThingSpeak cloud platform** to monitor parameters including **voltage, current, power, frequency, temperature**, and **motor speed (RPM)**. Real-time data is displayed on an LCD screen and simultaneously transmitted to the cloud, allowing users to access and control the motor remotely. The use of a relay module ensures automatic shutdown in the event of unsafe operating conditions, such as overheating, enhancing safety and preventing motor damage. This system not only improves **energy efficiency** and **operational reliability**, but also supports **preventive maintenance** by generating alerts during abnormal conditions. Its **low cost, scalability, and ease of deployment** make it highly suitable for both **industrial and domestic applications**, where real-time monitoring and control of electrical loads are critical for safe and efficient operation.

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REFERENCES:

1. R. Kumar Bindal, I. Kaur, *Comparative Analysis of Different Controlling Techniques Using Direct Torque Control on Induction Motor*, 2016 International Conference on Next Generation Computing Technologies, IEEE.
2. K. Zeb, S. A. Khan, R. Verma, *IoT-Based Smart Monitoring and Control System for Induction Motors*, 2020 International Conference on Power, Energy, and Smart Grid, IEEE.
3. P. Srinivas, N. Ramesh, B. V. Narsimha Rao, *Wireless Monitoring and Control of Induction Motors Using IoT*, International Journal of Electrical and Electronics Engineering Research, Vol. 8, No. 2, 2019.
4. R. Kumar, R. Gupta, *ThingSpeak-Based IoT Monitoring System for Power Consumption in Induction Motors*, International Conference on Electrical and Electronics Engineering, Springer, 2021.
5. V. Rajesh, S. Chakraborty, *Real-Time Power Monitoring and Control of Single-Phase Motors Using IoT*, International Journal of Smart Systems and Technologies, Vol. 6, No. 1, 2022.
6. S. Deshpande, P. Patil, *Arduino-Based Real-Time Monitoring of Electrical Parameters in Induction Motors*, Proceedings of the National Conference on Emerging Trends in Electrical Engineering, 2020.
7. M. Venkatesh, R. Raghavendra, *Design and Implementation of IoT-Based Motor Control System Using ESP8266*, International Journal of Innovations in Electrical Engineering, Vol. 5, No. 3, 2019.
8. T. Prakash, K. Harish, *A Review on IoT Applications for Smart Industrial Motor Control*, Indian Journal of Science and Technology, Vol. 14, No. 7, 2021.