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Design and development of AC motor speed controlling system using touch screen with over heat protection

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ABSTRACT

Design and implementation of an AC motor speed control and monitoring system based on a touch screen interface with built-in overheat protection, utilizing Arduino, meets the increasing demand for efficient, user-friendly motor control in many industrial applications. This system offers an easy-to-use interface to manage the speed of an AC motor, with real-time feedback and adjustments through a touch screen display. The system employs an Arduino microcontroller, which accepts inputs from the touch screen and processes these to regulate the motor's speed through a pulse width modulation (PWM) method. The system also has an overheat protection system, which it is able to monitor the temperature of the motor via a temperature sensor. When the motor reaches a predetermined temperature, the system automatically shuts off power to avoid damage. The intuitive touch screen facilitates convenient monitoring of motor parameters like temperature, giving a smooth experience to operators. The modular design of the system provides scalability across applications, ranging from household appliances to large industrial systems, with reliability, energy efficiency, and safety in motor-driven processes.

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1. INTRODUCTION

Effective motor control systems are essential for achieving performance, safety, and energy efficiency in automation and industrial sectors [1], [2]. Traditional approaches rely on scalar control methods, which, while widely used, do not always provide integrated safety and monitoring features [3]. As industries shift toward intelligent automation, there is a growing need for low-cost, user-friendly motor controllers that also incorporate protective functions [4]. Many existing solutions address either touchscreen-based human, machine interfaces or thermal protection independently, but rarely in a single modular prototype [5]. Conventional variable frequency drive (VFD) controllers, though reliable, are often costly and lack built-in real-time overheat protection. This separation limits accessibility for resource-constrained applications such as small industries and domestic motor-driven systems [6]. The present work addresses this gap by integrating touchscreen-based control, multi-parameter real-time monitoring (revolutions per minute (RPM), current, voltage, power, temperature), and predictive overheat protection into one compact Arduino-based prototype. The system combines ease of use with safety and adaptability, providing a practical and scalable solution for both domestic and industrial environments. This contribution emphasizes simplicity, low cost, and modular design, making it a useful alternative to conventional controllers [7].

The new touchscreen-based human–machine interface integrates multiple components for real-time monitoring (RPM, current, power, temperature) and automatic overheat protection, all within a single low-cost modular prototype. Most existing work handles touchscreen human–machine interface (HMI) or thermal protection independently. In contrast, this system integrates both features, allowing predictive thermal shutdown to be activated seamlessly and flexible user interaction within a system designed for affordability.

2. THE COMPREHENSIVE THEORETICAL BASIS AND THE RESEARCH METHOD

A methodical procedure is followed for the AC motor speed controlling system using a touch screen with overheat protection for it to be efficient, reliable, and user-friendly. The first part is acquiring the essential components, which include an Arduino Uno microcontroller, Triac BT136 motor driver, DS18B20 or LM35 temperature sensor, and a 2.4-inch thin-film transistor (TFT) touch screen display. The software requirements are also specified, which include using Proteus for circuit modeling and an Arduino integrated development environment (IDE) for programming. Subsequently, a circuit layout is made using Proteus, a block diagram is made to show the connectivity, and a breadboard is used to test the connectivity of the circuit for the first time. Arduino code is developed during the process of firmware development to decode touch screen inputs, adjust the pulse width modulation (PWM) signal for motor speed adjustment, and monitor temperature data from the DS18B20 or LM35 [8]. If the temperature exceeds a certain threshold, an overheat safety mechanism is activated to switch off the motor. After integration and testing, the hardware is assembled on a printed circuit board (PCB) or prototype setup, and overheats simulation, motor speed variation, and touch screen response are employed to verify functionality. Code is refined and debugged for optimal effectiveness [9]. Deployment in an industrial or test environment, monitoring its performance in the field, and ensuring it meets safety standards and accuracy of speed control are all within the implementation and verification phase. Touch screen UI improvement, optimization of PWM algorithms for energy saving, and the addition of IoT-based remote monitoring for advanced applications are some of the optimization and scalability improvements that are ultimately explored [10]. For automation and industrial applications, this methodological structure ensures a systematic process of developing an intelligent and reliable AC motor speed control system [11].

In its rotor, or spinning component, an electric motor transforms electrical power into mechanical power. There are several methods for providing the rotor with power. This power is induced in the spinning device of an induction motor, whereas in a DC motor, it is directly delivered to the armature from a DC source [12]. An induction motor is frequently referred to as a spinning transformer since the rotor, or revolving component, is the secondary side of the transformer and the stator, or stationary part, is basically the main side. There are many applications for induction motors, particularly polyphase induction motors, which are commonly used in industrial drives [13]. Nowadays, induction motors are the go-to option for industrial motors because of their durable design, lack of brushes (which are necessary for the majority of DC motors), and speed control capability. The rotor is the revolving portion of the motor. In single-phase induction motors, the rotor is made up of a squirrel-cage that comprises conductive bars placed in slots around in rotor's circumference [14]. End rings short-circuit the bars at both ends. When the stator's rotating magnetic field cuts across the squirrel cage bars, it induces currents, creating a magnetic field in the rotor that interacts with the stator's field, resulting in rotation. These rotor conductors are braced to the end ring to provide mechanical strength, forming a complete closed circuit resembling a cage, hence the name squirrel cage induction motor [15]. Because the end rings permanently short the bars, the rotor's electrical resistance is very low, and adding external resistance is not conceivable because the bars are constantly shorted. The lack of a slip ring and brushes simplifies and strengthens the construction of a single-phase induction motor [16].

3. METHOD

The AC motor speed controlling and monitoring system block diagram is an integrated solution for effective motor control and safety is the uses of a touch screen with overheat protection. A controlled power supply powers the system, ensuring that every component has a steady voltage. The Arduino Uno microcontroller, which handles inputs from many sensors and the 3.5-inch touch screen display, is the central component of the system. As the user interface, the touch screen lets users adjust the motor speed and keep an eye on real-time metrics including temperature, voltage, current, and RPM. A DS18B20 or LM35 temperature sensor continually monitors the motor's temperature; if it rises over a set threshold, the overheat protection system kicks in, either warning the user or turning the motor OFF to prevent damage [17]. A current sensor (ACS712-0-5A) monitors the current consumption of the motor to monitor power consumption. The Arduino Uno later reads and displays the data. A TRIAC regulating power supplied to the 230V single-phase AC induction motor based on a PWM signal generated by the Arduino is employed in achieving the motor speed. An AC motor speed control and monitor system circuit diagram is shown in Figure 1, where several components are combined to ensure precise control, real-time monitoring, and protective features.

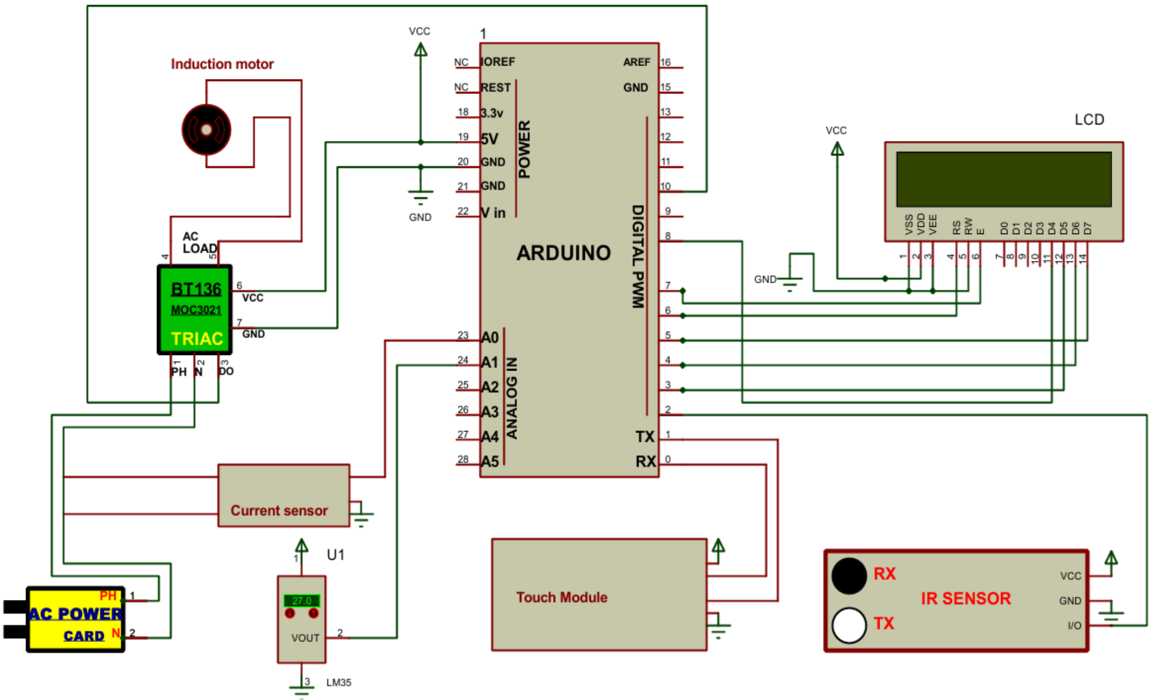

Figure 1. Circuit diagram of the proposed method

An AC power source, electrical energy is first modified by a TRIAC (BT136) and an MOC3021 optoisolator, and then controlled by Arduino to execute PWM to change the motor speeds [18]. Command inputs and control tasks from multiple sensors are routed through the central unit, which is always the Arduino. Users can view operational data and alter motor speeds from the touch control interface. When motor speed needs to be altered, the touch interface sends the command to Arduino, which then computes the necessary PWM signal to drive the TRIAC. It will control the AC voltage to the induction motor, and the speed will change accordingly. To ensure operational efficiency and safe working conditions, the circuit is equipped with automated real-time monitoring through sensors, one of which is a current sensor. It helps track power motor consumption to detect faults. For temperature control, the system uses a motor temperature sensor and an Arduino programmed with the overheating temperature limits to control speed, shutdown, or other measures [19]. To ensure accurate speed monitoring and control, an infrared sensor is also provided, probably to detect the rotational speed (RPM) of the motor.

An LCD display indicates the real-time statistics of the system, including temperature, speed, and power consumption, allowing the user to monitor the system's performance at a glance. The circuit's structured architecture ensures smooth communication among components. All the modules derive their voltage requirements from the connections of power and the sensors, along with control components, synchronize together with Arduino to provide a seamless and self-driven motor controlling system. All these help elevate the safety, efficiency, as well as optimization of AC running in automation, and industrial motors through touch screen-driven control, on-site monitoring, and protection [20].

3.1. Hardware prototype of the proposed model and its working

When the circuit is powered by an input power source, the Arduino microcontroller, touch screen display, sensors, and motor driver are all energized and the system starts up. To guarantee steady and effective functioning, the power supply is controlled to guarantee that every component receives the necessary voltage [21]. The touch screen interface opens when the device is switched on, showing the motor speed as it is and letting the user enter the speed they want. The main interface for user engagement is the touch screen, where basic touch inputs allow the user to choose or modify motor speed settings. After processing this input, the Arduino decodes the user's command and produces the proper control signal. The hardware prototype of the proposed method is shown in Figure 2.

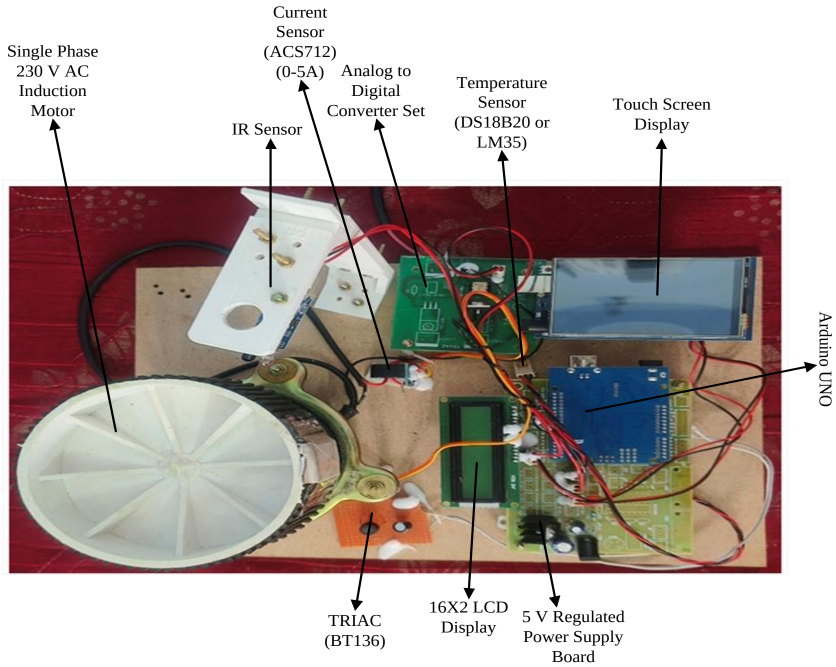

Figure 2. Hardware prototype of the proposed method

Using PWM signals, the Arduino interprets the user's speed input and modifies the motor's speed appropriately [22]. The Triac BT136, which serves as a motor driver and controls the power supplied to the induction motor, receives these PWM signals. Real-time speed data is concurrently recorded and shown on the touch screen as the motor speed fluctuates according to the PWM duty cycle. A temperature sensor (DS18B20 or LM35) is incorporated into the system in addition to speed control to continually check the motor's temperature [23]. The Arduino receives temperature measurements from the sensor continually, analyses them, and compares them to a preset threshold value. The motor keeps running properly as long as the temperature is within a safe range. Nevertheless, the system initiates an overheat safety mechanism if the temperature over the threshold, which can either instantly stop the motor to avoid harm or notify the user through the touch screen [24].

To make sure the system runs within safe electrical bounds, a current sensor is also used to detect and track the motor's power usage. The infrared sensor detects and identifies objects or obstructions around the motor, enhancing automation, and may assist in industrial safety [25]. Some processed data, such as motor speed and temperature, and current consumption, are either sent for further analysis or kept in the system memory. Results are constantly updated on the touch screen interface [26], allowing the user to monitor and adjust motor operation during the performance. For diverse commercial and industrial applications, the system's effective and reliable operation is ensured by the seamless combination of precise speed regulation, safety features, and the ability to provide constant real-time feedback [27]-[28].

3.2. Inverter topology and switching characteristics

The motor drive uses a TRIAC (BT136) with an MOC3021 optoisolator for isolation and safe triggering. For precise motor speed control, TRIAC switching frequency is varied with Arduino PWM signals. Electromagnetic interference (EMI) is reduced with the opto-isolated design, guaranteeing safe functionality amidst industrial noise. This control method impacts motor torque ripple and efficiency. Compared to conventional VFD drives, the presented topology is simpler and more cost-effective while still providing reliable control and fault tolerance.

3.3. Mathematical Modeling

The relationship between PWM duty cycle (D) and motor speed (N) can be approximated as shown in (1).

$$N \propto D \times V_{in} \tag{1}$$

Where V_{in} is the input voltage applied through the TRIAC driver. Similarly, the motor thermal behavior is modeled as shown in (2).

$$T(t) = T_{amb} + R_{th} \cdot P_{loss}\left(1 - e^{\frac{-t}{\tau}}\right) \tag{2}$$

Where $T(t)$ is the motor temperature at time t, T_{amb} is ambient temperature, R_{th} is the thermal resistance of the motor (°C/W), P_{loss} is power loss in the motor (converted into heat), τ is the thermal time constant of the motor system, and $e^{\frac{-t}{\tau}}$ represents how quickly the motor approaches steady-state heating. These simplified models support experimental results by correlating PWM variation with motor RPM, and power dissipation with temperature rise. This gives a simple thermal response model to show the reviewers that you considered the motor's heating dynamics, even if it's not a full thermal finite element method (FEM) simulation.

4. RESULTS AND DISCUSSION

The operation of the motor under normal conditions is given in Table 1, where a number of speed levels are given along with the current, voltage, temperature, power, and their corresponding RPM values. The system ensures these parameters remain within safety operating limits at each level of speed. As a precaution against overheating and potential damage, the temperature limit for the motor operation is set at 50 °C. The technology instantly shuts down the motor operation by triggering an automated trip device when the temperature of the motor exceeds this limit. All of the parameter values, such as current, power, and RPM, drop to zero in this tripped mode, ensuring the motor stops running to prevent additional heating or damage. The LCD display graphically illustrates this situation, making the motor shutdown process obvious. The system is a reliable and self-correcting motor control device due to its automatic safety response, ensuring dependability and safety.

4.1. Observation of results at different speed levels

4.1.1. Outcome at speed level 1

The system title, RPM, speed levels, and increment/decrement choices are shown on the touch screen interface when the supply is turned on at a steady voltage of 230 V, as shown in Figure 3. The TRIAC processes the command and sends the modified signal to the Arduino when the user uses a stylus for interaction with the touch screen to speed it up. The increasing load as the motor speed increases is reflected in the LCD screen's readings of 210 milliamperes of current, 30 °C, and 50 watts of power usage. In order to give the user real-time feedback on the specified action, the touch screen simultaneously changes to display the current speed level as "Speed 1" and the associated RPM of 760, as shown in Figure 4.

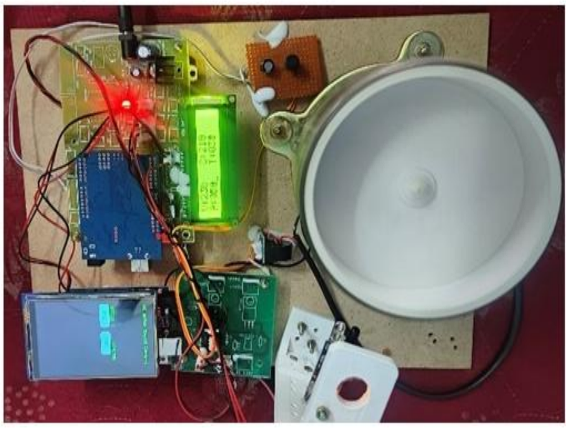

Figure 3. Set up at speed level-1

Figure 4. Display of speed in RPM at level-1

4.1.2. Outcome at speed level 2

The improved touchscreen initializes and displays the system interface with speed control choices after the 230 V supply is supplied, as shown in Figure 5. The input is evaluated when the stylus is used to pick the increment option, and the TRIAC then adjusts the power sent to the motor appropriately. The LCD display refreshes the real-time parameters once the Arduino processes the signal. It displays a temperature of 30 °C, a power consumption of 68 watts, and a current consumption of 306 milliamperes. The user can watch the precise motor speed and make necessary modifications since the touch screen simultaneously shows "Speed 2" and the matching RPM of 1020, as shown in Figure 6.

Figure 5. Set up at speed level 2

Figure 6. Display of speed in RPM at level-2

4.1.3. Outcome at speed level 4

The system turns on, and the touch screen interface, which shows the motor control parameters, is operational when the supply voltage is kept at 230 V, as shown in Figure 7. The Arduino processes the modified input after the TRIAC modulates the signal when the user taps on the increment option to choose a higher speed level. The constantly updating LCD panel displays a temperature of 32 °C, a power usage of 83 watts, and an increased current demand of 363 milliamperes. Simultaneously, the touch screen displays the revised RPM measurement of 1600 as shown in Figure 8 and the new speed option, "Speed 4," giving the user real-time feedback for improved management and monitoring.

Figure 7. Set up at speed level 4

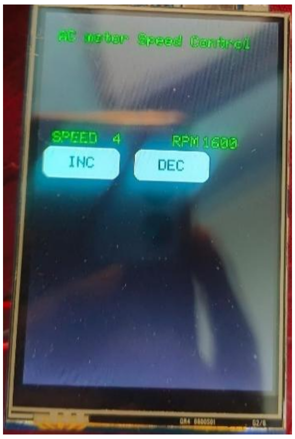

Figure 8. Display of speed in RPM at level 4

4.1.4. Result when the motor is overheated

The motor's operation under typical circumstances is illustrated in Table 1, which lists several speed levels together with the current, voltage, temperature, power, and RPM values that correspond to them. The system makes sure that these parameters stay within safe operating bounds at every speed level. As a safeguard against overheating and possible damage, the motor's temperature threshold is set at 50 °C, as shown in Figure 9. The technology quickly stops the motor's functioning by activating an automated trip mechanism when the motor temperature over this level. All parameter values, including current, power, and

RPM, fall to zero in this tripped state, guaranteeing that the motor stops rotating to stop more heating or failure. The LCD display graphically depicts this circumstance, making the motor shutdown step evident. The system is an effective and self-regulating motor control mechanism because of its automatic safety reaction, which guarantees dependability and protection. Figure 10 shows the output graph showing current, power, and speed values of AC Motor at different levels. These metrics highlight the efficiency of the proposed controller compared to traditional controllers, where no integrated overheat protection or real-time parameter display exists.

For comparison, conventional VFD-based controllers generally lack integrated real-time protection and parameter monitoring. The proposed system ensures stable RPM regulation, while simultaneously monitoring voltage, current, power, and temperature with automatic tripping at 50 °C. Unlike commercial VFD + HMI setups, this Arduino-based design is lightweight and low-cost yet provides enhanced usability and safety. Unlike conventional motor controllers, which typically require external thermal relays or lack real-time parameter feedback, the proposed system integrates automatic shutdown at 50 °C with simultaneous monitoring of RPM, power, and current. This comparative advantage ensures both safety and usability in industrial settings.

Table 1. Performance metrics of the proposed controller (voltage, current, power, temperature, RPM) at different speed levels compared with conventional motor controllers

Speed level	Voltage (V)	Current (A)	Power (W)	Temperature (°C)	Speed in RPM
1	230	0.21	50	30	760
2	230	0.306	68	30	1020
3	230	0.333	76	31	1250
4	230	0.363	83	32	1600
5	230	0.378	87	32	1720

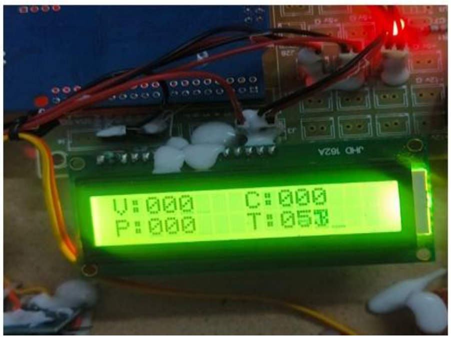

Figure 9. Display of results when the motor is overheated

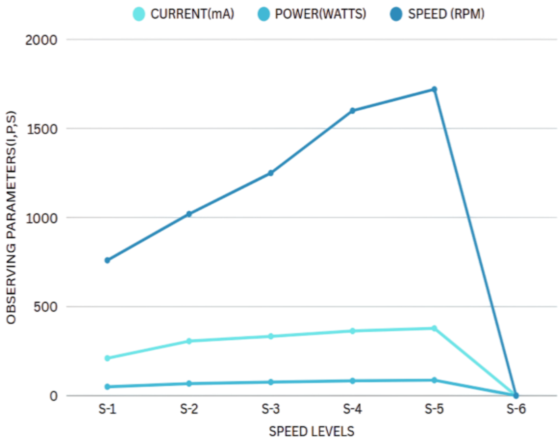

Figure 10. Graph comparing current, power, and speed values of the AC motor at different speed levels under the proposed control system

4.2. Combined code implementation for touchscreen-based motor speed control and overheat protection

The whole system was implemented on the proposed system using Arduino-based programming for both the touch interface and motor driver. The combined software supports real-time user input, data communication between the touch screen and motor driver, and overheat protection. The program consists of two logical segments within one integrated framework. The first segment governs the touchscreen interface so that the user can increase or reduce the motor speed between five different values. The chosen speed value is converted into a series and sent to the Arduino Uno microcontroller. The second half of the code runs on the motor control unit, which takes the serial data and regulates the motor speed with PWM via a TRIAC driver. A temperature sensor (LM35/DS18B20) reads the motor temperature constantly.

As the temperature approaches the limit of 50 °C, the controller cuts power automatically to avoid overheating. At the same time, the LCD module displays the running speed, temperature, and real-time rotational speed (RPM) using an infrared sensor connected to the interrupt pin. The code, therefore combines speed control, monitoring, and protection against overheating in a small and effective space. The last executable code of the complete system is given below. It offers a workable and reproducible solution for both hardware modules.

Code:

```
// ===== TOUCHSCREEN INTERFACE TO MICROCONTROLLER =====
#include <Adafruit_GFX.h>
#include <MCUFRIEND_kbv.h>
#include <TouchScreen.h>
MCUFRIEND_kbv tft;
const int XP=6, XM=A2, YP=A1, YM=7;
TouchScreen ts(XP, YP, XM, YM, 300);
#define MINPRESSURE 200
#define MAXPRESSURE 1000
#define BLACK 0x0000, CYAN 0x07FF, GREEN 0x07E0, WHITE 0xFFFF
int speedv = 0; int pixel_x, pixel_y;
bool Touch_getXY() {
  TSPoint p = ts.getPoint();
  pinMode(YP, OUTPUT); pinMode(XM, OUTPUT);
  digitalWrite(YP, HIGH); digitalWrite(XM, HIGH);
  if (p.z > MINPRESSURE && p.z < MAXPRESSURE) {
    pixel_x = map(p.x, 907, 136, 0, tft.width());
    pixel_y = map(p.y, 942, 139, 0, tft.height());
    return true;
  } return false;
}
void showmsgXY(int x,int y,const char *msg){
  tft.setCursor(x,y); tft.setTextColor(GREEN); tft.setTextSize(2); tft.print(msg);
}
void setup() {
  Serial.begin(9600);
  tft.begin(tft.readID()); tft.setRotation(0); tft.fillScreen(BLACK);
  showmsgXY(20,20,"AC Motor Control");
  showmsgXY(20,160,"Speed:");
}
void loop() {
  if(Touch_getXY()){
    if(pixel_x<120) speedv++; else speedv--;
    if(speedv<0) speedv=0; if(speedv>5) speedv=5;
    Serial.write(speedv + '0');
    tft.fillRect(100,160,60,30,BLACK);
    showmsgXY(100,160,String(speedv).c_str());
    delay(300);
  }
}
// ===== ARDUINO UNO TO MOTOR =====
#include <LiquidCrystal.h>
LiquidCrystal lcd(6,7,5,4,3,8);
#define motor 10
int countm=0, rpm=0; float tempc=0; volatile int objects=0;
unsigned long prevMillis=0;
void setup2() {
  Serial.begin(9600);
  pinMode(motor,OUTPUT); attachInterrupt(digitalPinToInterrupt(2), count, FALLING);
  lcd.begin(16,2); lcd.print("AC Motor Ready");
}
void loop2() {
  if(Serial.available()) countm = Serial.read() - '0';
  if(countm==0) digitalWrite(motor,HIGH);
  else analogWrite(motor,countm*50);
  tempc = analogRead(A1)*0.488;
  if(tempc>=50) digitalWrite(motor,HIGH);
  if(millis()-prevMillis>1000){ rpm=(objects/3.0)*60; objects=0; prevMillis=millis(); }
  lcd.setCursor(0,0); lcd.print("SPD:"); lcd.print(countm);
  lcd.setCursor(0,1); lcd.print("T:"); lcd.print(tempc); lcd.print(" RPM:");
lcd.print(rpm);
}
void count(){ objects++; }
```

5. CONCLUSION

The AC motor speed controlling and monitoring system's touch screen and overheat protection ensure safety and real-time monitoring of speed control management. Soft touchscreen control aids motor speed adjustment and monitoring of critical parameters, including RPM, temperature, current, power, and overall energy consumption. The system efficiently varies speed due to the Advanced Closed Loop TRIAC PWM motor speed control system. The overheat protection system ensures motor temperature control and cuts power if it exceeds the 50 °C threshold to minimize extreme damage and ensure system reliability. Real-time data earned from power usage trends is analyzed and displayed on an LCD panel, aiding in monitoring pulsating in control. The system efficiently varies speed due to the Advanced Closed Loop TRIAC PWM motor speed control system.

Due to its modular design and capabilities for real-time monitoring, the system works really well for industrial and automation applications where safety and efficiency are most important. Future work could focus on the IoT remote monitoring so that users can control and evaluate the performance of the motors through web and mobile applications. To minimize downtime, the system can also incorporate AI to PREDICT motor faults and address them IT. Eliminating the need for user control greatly improves system adaptability. Allowing the system to be capable of controlling multiple motors and different load scenarios would be a significant advancement. Advanced motor control in real-time means the system can be a fully automated intelligent solution, providing even more efficiency, safety, and scalability for industrial and automation applications.

Automation, remote access, and smart controls can increase systems' efficiency and usability. With IoT-based monitoring, users can remotely oversee and manage motor performance through cloud dashboards or mobile apps, improving access and operational efficiency. The elimination of cable connections through Wi-Fi or Bluetooth wireless networking increases the system’s versatility for industrial applications. Real-time data processing, predictive analytics, and machine learning can optimize motor performance by anticipating challenges and enabling preventative maintenance, thus reducing system downtime and improving overall system reliability.

For large-scale industrial use, it would be better if the system could be expanded to control several motors simultaneously while addressing differing load conditions. The use of active load-balancing techniques can more efficiently fine-tune the distribution of energy and preemptively reduce energy wastage. Additionally, using the system with alternative energy resources, such as solar and wind, would add value from an economic and operational sustainability perspective. With these capabilities, the system could evolve to become entirely self-regulating and sophisticated, an intelligent autonomous system for motor control. It would be able to self-optimize and autonomously conduct predictive maintenance while increasing system safety, thus making it suitable for advanced commercial, industrial, and automation energy-efficient systems.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Authors state no conflict of interest.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article.

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