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Smart Helmet for Electrical Line Workers

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Abstract*—Electrical line workers are exposed to critical hazards, including high-voltage shocks, accidental falls, and sudden health emergencies which can result in severe injuries or fatalities. Ensuring their safety in real-time is a major challenge for industries such as power distribution, transmission utilities, and construction. This project presents a smart helmet that integrates advanced sensors and IoT-based technology to provide continuous monitoring of worker safety. The helmet is equipped with voltage sensors to detect the presence of live electrical lines, accelerometers and gyroscopes to identify falls or abnormal movements. The system processes sensor data in real-time and, in case of hazardous events, automatically sends alerts along with the worker's GPS location to supervisors via GSM communication. The collected data can also be logged for long-term analysis, enabling predictive maintenance, trend analysis, and safety audits. By enabling instant notification and rapid emergency response, the smart helmet reduces workplace accidents, ensures compliance with industrial safety regulations, lowers compensation and liability costs, and enhances operational efficiency. Furthermore, the system can be scaled to monitor multiple workers simultaneously and integrated with cloud-based platforms for centralized safety management. This IoT-enabled solution represents a practical, scalable, and forward-looking approach to improving occupational safety for high-risk industries, combining real-time hazard detection, health monitoring, and location tracking to create a safer working environment for line workers.

***Keywords*—Smart Helmet, voltage detection, micro controller, GPS &GMS, fault detection.**

I. INTRODUCTION

A. Importance of the Topic

Electrical line workers face constant risk in their daily operations due to exposure to high voltage equipment, elevated work environments, and unpredictable electrical hazards[1]. Even a minor mistake or unexpected equipment failure can lead to serious injuries or fatalities, making safety a critical concern in the power and construction industries. Traditional safety measures such as helmets, gloves, and harnesses provide basic protection but do not actively monitor or prevent hazardous events. With increasing industrialization and complex electrical infrastructure, the need for advanced safety solutions that can provide real-time monitoring and immediate alerts has become more urgent. Protection workers not only ensure their well-being but also reduces operational downtime, liability, and compensation costs for organizations. Industries are now exploring innovative technologies to create smarter and safer working environments that go beyond conventional safety equipment.

B. Problem Statement and Motivation

Electrical line workers are constantly exposed to high-risk environments where accidental contact with live wires, electric shocks, or falls from heights can lead to serious injuries or fatalities[2]. Despite wearing traditional safety helmets, these workers lack an intelligent system that can detect and alert them to potential electrical hazards or accidents in real time. Most existing safety equipment only provides physical protection but fails to monitor environmental and situational risks. There is also a lack of automatic communication and location tracking during emergencies, which delays rescue operations and increases the severity of incidents[3]. Therefore, there is a critical need for a smart, IoT- enabled safety helmet that can continuously monitor working conditions, detect high-voltage presence and accidents, and instantly communicate alerts with real-time location to ensure immediate response and improved worker safety.

C. Proposed Framework

To address the safety challenges faced by electrical line workers, a smart helmet system is proposed using IoT and sensor-based technology. The helmet integrates a voltage sensor and an accelerometer sensor to continuously monitor the worker's environment and physical condition[4]. The voltage sensor detects the presence of high-voltage lines, warning the workers before approaching dangerous zones, while the accelerometer identifies sudden impacts or falls. The sensed data is processes by a microcontroller, which determines if a hazardous situation has occurred. In such cases, the system

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activates GSM and GPS modules to send instant alert messages with the worker's exact location to supervisors or emergency contacts. This real-time communication ensures quick response and assistance. The entire setup operates on a rechargeable battery and is compact, lightweight, and suitable for industrial use. Thus, the proposed solution not only enhances safety but also enables industries to adopt smarter, data driven monitoring for accident prevention and emergency management.

II. HARDWARE SPECIFICATIONS

A.ESP8266

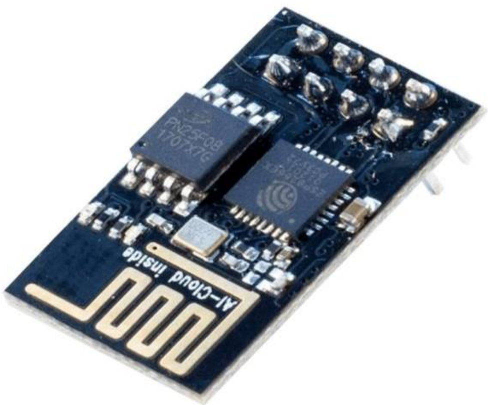

Fig 2.1 : ESP8266

ESP-01 WiFi module is developed by Ai-thinker Team. Core processor ESP8266 in smaller sizes of the module encapsulates Tensilica L106 integrates ultra low power 32-bit bit MCU micro, with the 16 16-bit short mode. Clock speed support 80MHz, 160MHz, supports the RTOS, integrated Wi-Fi MAC/BB/ RF/PA/LNA, /BB/RF/PA/LNA, on on-board antenna.ESP8266 is high integration wireless SOCs, designed for space and power[5]. It provides unsurpassed ability to embed Wi-Fi capabilities within other systems, or to function as a standalone application, with the lowest cost, and minimal space requirement.

B. VOLTAGE SENSOR

Fig 2.2: Voltage sensor

A voltage sensor is an electronic component that measures the voltage of an electrical system and coverts it into a readable value, usually in the form of an Analog or Digital signal. These sensors are crucial for monitoring and controlling systems where voltage levels need to be precisely measured, such as in over voltage levels need to be precisely measured, such as in over voltage and under voltage protection system. In Arduino based projects, voltage sensors help interface the Analog world with digital controllers, like the Arduino microcontroller, allowing it to read the voltage and make decisions based on predefined thresholds.

The ZMPT101B sensor works by converting the AC voltage sensor module that is designed to measure alternating current voltage levels, making it an essential component for various applications, especially in Arduino based projects. This sensor is known for its simplicity, accuracy, and safety features, which makes it a popular choice in over voltage and under voltage protection system, power monitoring and energy management applications. The module can measure

AC voltages typically in the range of 0V to 250V AC, making it suitable for monitoring household and industrial power supplies.

The ZMPT101B sensor works by converting the AC voltage into the proportional Analog output voltage, typically ranging from 0V to 5V, which can then be read by micro controller such as an Arduino. The output is easy to interpret and can be scaled according to the voltage being measured. One standout ZMPT101B is its built in isolation, which ensures that the high voltage AC side of the circuit is electrically isolated from the low voltage Arduino, offering a high level of safety. This isolation is typically achieved using an optocoupler, preventing dangerous voltage spikes from reaching the Arduino and other sensitive components in the circuit.

C.MEMS SENSOR and MMA 7260 Q

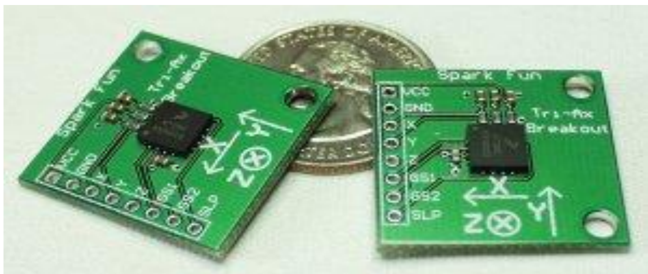

Fig 2.3 : MEMS Sensor

The MMA7260Q is 3-axis accelerometer .An accelerometer measures acceleration (change in speed) of anything that it's mounted on. Single axis accelerometers measure acceleration in only one direction. Dual-axis accelerometers are the most common measure acceleration in two directions, perpendicular to each other. Three-axis accelerometers measure acceleration in three directions.

Accelerometers are very handy for measuring the orientation of an object relative to the earth, because gravity causes all objects to accelerate towards the earth. A two-axis accelerometer can be used to measure how level an object is.

(This would be a good place to fill in equations to calculate a body's angle from the X and Y accelerations on the body).

With a three-axis accelerometer, you can measure an object's acceleration in every direction.

International Journal of Engineering Research & Technology (IJERT)
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Vol. 14 Issue 11, November 2025

D. GPS MODULE

Fig 2.4 : GPS Module

The global position satellite system(GPS) has revolutionized navigation and position location. It is now essential in the aircrafts surveying and in ship navigation also. The GPS system originally called NAVSTAR was developed as a military navigation system for guiding missiles, ships, and aircraft to their targets[6]. GPS satellite transmits L-band signals that are modulated by several codes. The coarse acquisition code was made available to the public and the p code allows authorized persons to achieve high accuracy nearer than 3m. This was not used by the UN authorized persons. It provides reliable positioning, navigation, and timing services to worldwide users on a continuous basis in all weather, day and night, anywhere on or near the earth which has an unobstructed view of four or more GPS satellites.

E. IR SENSOR

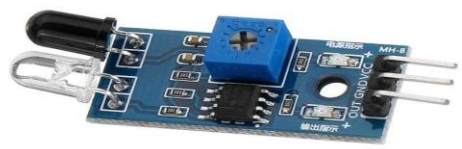

Fig 2.5 : IR Sensor

It has a reasonably narrow detection area which can be increased using the dual version. Range can also be increased by increasing the power to the IR LEDs or adding more IR LEDs[7]. The photo below shows my test setup with some IR LED's as a light source and two phototransistors in parallel for the receiver. You could use one of each but I wanted to spread them out to cover a wider area. This setup works like a First LDR but with IR. It has a range of about 10-15cm with my hand as the object being detected.

WORKING OF INFRADED COMMUNICATION

By using thus project we can design infraded based application easily. The entire circuit consists of two sections named as

1. Transmitter section
2. Receiver section

F. BATTERY

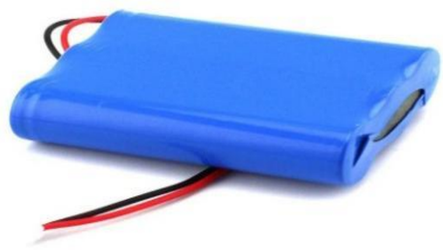

Fig 2.6 : Lithium Ion Battery

The power supply section consists of a rechargeable lithium-ion battery rated between 7.4V and 12V, depending on circuit requirements. A voltage regulator module (LM2596 or AMS1117) is used to provide a stable 5V and 3.3V output for the ESP32 and other sensors. The battery offers sufficient capacity to power the system continuously for 6–8 hours. The design also includes a charging port for easy recharging, ensuring uninterrupted usage during long working hours. Power efficiency is enhanced through ESP32's sleep modes, reducing energy consumption during idle periods.

III. WORKING

When the smart helmet system is powered ON, the ESP32 microcontroller initializes all connected modules, including the voltage sensor, accelerometer, GPS, Once initialized, the ESP8266 continuously reads data from the sensors in real time[8]. The system starts in monitoring mode, where it actively checks for electrical hazards and worker movements without interrupting normal operation. The sensing layer, consisting of the voltage and accelerometer sensors, collects environmental and motion data which is then sent to the ESP8266 for processing and analysis.

The voltage sensor continuously scans the surrounding area to detect the presence of high-voltage electrical fields. When the worker approaches a live electrical line or equipment, the sensor detects a rise in voltage intensity. The analog signal generated by the sensor is converted into a digital value through the ESP8266's ADC (Analog-to-Digital Converter). The microcontroller then compares this voltage value with a predefined safety threshold. If the detected voltage is within a safe limit, the system continues normal operation. However, if it exceeds the set limit, it is identified as a dangerous condition, and the ESP8266 immediately prepares to trigger an alert. Simultaneously, the accelerometer sensor (MPU6050) monitors the worker's body posture and movement. It sends continuous readings of acceleration and angular velocity to the ESP32. Under normal conditions, the sensor data fluctuates smoothly as the worker moves, bends, or climbs. In case of a sudden fall or impact, the accelerometer registers a sharp acceleration spike followed by a period of stillness. The ESP8266 recognizes this pattern as a fall event. To avoid false alarms, the system verifies the reading over a short interval

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Vol. 14 Issue 11, November 2025

before confirming it as an actual fall[9]. Once verified, the system activates the emergency alert sequence.

When either a high-voltage presence or fall event is detected, the communication phase begins. The ESP8266 first retrieves the worker's live location from the GPS module (NEO-6M). The GPS module communicates with the ESP8266 through UART and provides latitude and longitude coordinates with good accuracy. These coordinates represent the exact position of the worker at the time of the incident. After acquiring the location data, the ESP32 formats an emergency message containing the event type (such as "High Voltage Detected" or "Worker Fell"), along with the GPS coordinates.

The smart helmet operates by continuously observing the surrounding conditions and the worker's activity through its built-in processing unit. The system analyzes real-time inputs to identify any unusual or potentially unsafe situations during electrical line work. Once an abnormal condition is detected, the helmet immediately activates its alert mechanism to warn the worker and prompt them to take necessary precautionary actions. At the same time, the internal unit can communicate essential information to the monitoring platform for further assessment. All functions run automatically without requiring manual control, ensuring that the safety mechanism remains active at all times. In this way, the helmet provides uninterrupted protection and enhances on-site safety for electrical line workers.

A. Block Diagram

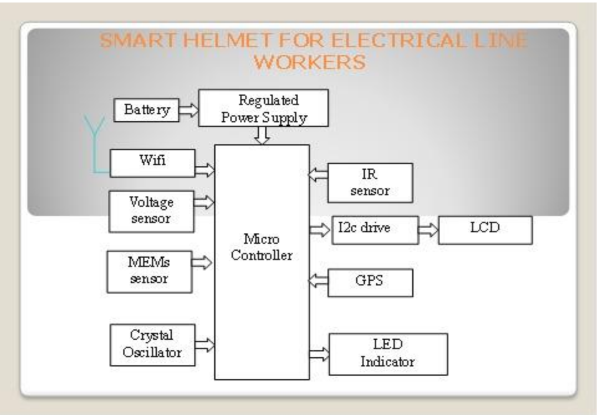

Fig 3.1 : Block Diagram of smart helmet for electrical line workers

B.Code Implementation

```
#include <TinyGPS++.h>
#include <SoftwareSerial.h>
static const uint32_t GPSBaud = 9600;
TinyGPSPlus gps;
SoftwareSerial ss(12, 13);
float l,m;

#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <SoftwareSerial.h>

// LCD setup
LiquidCrystal_I2C lcd(0x27, 16, 2); // I2C address 0x27, 16
columns, 2 rows
#define DEBUG true

void setup() {
 pinMode(2,INPUT);
 // Initialize LCD
 lcd.begin();
 lcd.backlight();
 lcd.setCursor(0, 0);
 lcd.print("SMART HELMET");
 lcd.setCursor(0, 1);
 lcd.print("SYSTEM");
 delay(2000);
 lcd.clear();
 lcd.print("GPS Checking---->");
 ss.begin(115200);
 Serial.begin(9600);       // Start serial communication
 delay(2000);
 Serial.println("AT+CNMI=2,2,0,0,0");
 //get_gps();   // gps config function which run code to check
gps working and fetch gps values
while(l<1)
 {
  while (Serial.available() > 0)
   if (gps.encode(Serial.read()))
    displayInfo();
    delay(100);
 }

 delay(2000);

 lcd.clear();
 lcd.print("GPS OK---->");
 delay(2000);
 lcd.clear();

 lcd.clear();
 lcd.setCursor(0, 0);
 lcd.print("Connecting WiFi");
 delay(2000);
 esp8266Serial("AT+RST\r\n", 5000, DEBUG); // Reset the
ESP8266
 esp8266Serial("AT+CWMODE=1\r\n", 2000, DEBUG); //
Set station mode

esp8266Serial("AT+CWJAP=\"project123\",\"12345678\"\r
\n", 5000, DEBUG); // WiFi credentials

 while (!ss.find("OK")) {}
 String ipResp = esp8266Serial("AT+CIFSR\r\n",
2000,DEBUG);
 int z = ipResp.indexOf("STAIP");
  String ipAddr = ipResp.substring(z+6, z + 22);
   lcd.clear();
   lcd.setCursor(0, 0);
   lcd.print("IP Address:");
   lcd.setCursor(0, 1);
   lcd.print(ipAddr);
   delay(5000);
```

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 11, November 2025

```
  esp8266Serial("AT+CIPMUX=1\r\n", 2000, DEBUG);
  esp8266Serial("AT+CIPSERVER=1,80\r\n", 2000,
DEBUG);

   lcd.clear();
}

void loop() {

int a=analogRead(A0);
int b=analogRead(A2);
int c=0;
if(a<360 || a>470)
{
  c=1;
}
else if(b<350 || b>460)
{
  c=1;
}
else
{
  c=0;
}
int sensorValue1 = analogRead(A1); // Read A0 pin value
float voltage1 = sensorValue1 * (5.00 / 1023.00) * 6; //
Scaled voltage
voltage1=(voltage1)-2
if(voltage1<=0)
{
  voltage1=0;
}
  if(digitalRead(2)==0)
  {
    String s1="V:"+String(voltage1)+" HEL:OK ";
    String s2="";
    if(c==1)
    {
      s2="ACCIDENT ALERT";
      lcd.clear();
      lcd.print(s1);
      lcd.setCursor(0, 1);
      lcd.print(s2);
      sendESP8266Data(s1+"\n"+s2);
      String
sss="http://maps.google.com/maps?&z=15&mrt=yp&t=k&
q="+String(l, 6)+"+"+String(m, 6);
      sendESP8266Data(sss);
    }
    else
  {
      s2="NO ALERT";
      lcd.clear();
      lcd.print(s1);
      lcd.setCursor(0, 1);
      lcd.print(s2);
      sendESP8266Data(s1+"\n"+s2);

    }
  }
  else
  {
    String s1="V:"+String(voltage1);
    String s2="NO HELMET";
      lcd.clear();
      lcd.print(s1);
      lcd.setCursor(0, 1);
      lcd.print(s2);
      sendESP8266Data(s1+"\n"+s2);
  }

  delay(1000);  // Wait before the next loop
}

String esp8266Serial(String command, const int timeout,
boolean debug) {
  String response = "";
  ss.print(command);
  long int time = millis();
  while ((time + timeout) > millis()) {
    while (ss.available()) {
      char c = ss.read();
      response += c;
    }
  }
  if (debug) {
    Serial.print(response);
  }
  return response;
}

void sendESP8266Data(String message) {
  String cmd = "AT+CIPSEND=0," +
String(message.length() + 2) + "\r\n";
  esp8266Serial(cmd, 1000, DEBUG);
  esp8266Serial(message + "\r\n", 1000, DEBUG);
}


void displayInfo()
{
  if (gps.location.isValid())
  {
    l=gps.location.lat();
    m=gps.location.lng();
  }
  else
  {
 Serial.print(F("INVALID"));
  }

  //Serial.println();
}
```

C. Result

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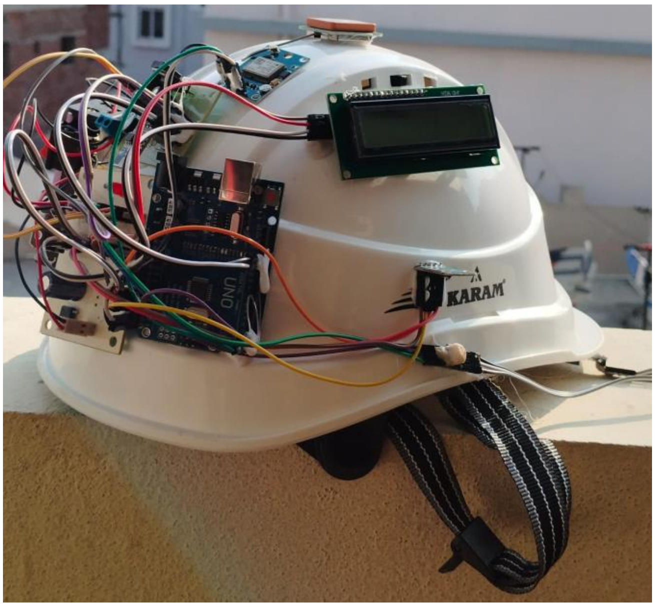

Fig 3.2 : Prototype of smart helmet for electrical line workers

IV.CONCLUSION

The Smart Helmet for Electrical Line Workers effectively enhances worker safety by integrating IoT-based monitoring and hazard detection in a single wearable device. Using sensors, ESP8266, ESP8266 the system ensures real-time detection of high-voltage areas and instant alert transmission with location details. This enables faster response during emergencies and reduces the risk of electrical accidents in industrial environments.

The prototype proved to be reliable, portable, and cost-effective, making it suitable for large-scale implementation in power distribution and construction sectors. Overall, the project demonstrates how modern IoT technology can be used to create smart safety solutions that protect workers and promote a safer industrial ecosystem.

A. Future Scope

The Smart Helmet system can be further enhanced by integrating advanced sensors such as gas sensors for detecting toxic environments and motion sensors for identifying worker fatigue or drowsiness[10]. Cloud storage and AI-based data analytics can be incorporated to predict accident-prone zones and generate safety insights. In the future, the system can also be connected to a mobile or web dashboard for real-time remote monitoring of multiple workers across different sites.

Additionally, solar-powered charging and wireless communication can be introduced to make the helmet more energy-efficient and sustainable. By combining IoT, machine learning, and cloud technology, this smart helmet can evolve into a comprehensive industrial safety solution that ensures maximum protection and operational efficiency for line workers.

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