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Smart Inverter Fault Detection using Artificial Intelligence

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ABSTRACT: The main objective of this project is to implement a smart inverter fault detection system using Artificial Intelligence, aimed at improving the safety, reliability, and efficiency of power systems. Inverter faults, if left undetected, can lead to severe equipment damage and system failures. This project utilizes various sensors to monitor parameters such as voltage, current, and temperature, which are processed through an Arduino-based embedded system. The acquired data is analyzed using a Random Forest machine learning algorithm to accurately detect and classify different types of faults including overvoltage, undervoltage, short circuit, and thermal overload. A key feature of the system is its integration with an IoT platform, allowing real-time monitoring of sensor data and graphical visualization through a dedicated web interface. Fault information is also displayed on an LCD screen and communicated to users via a GSM module for instant alerts. The system prioritizes multiple fault conditions based on severity and ensures timely notifications for maintenance or shutdown procedures. This intelligent fault detection approach not only reduces downtime but also supports proactive maintenance. Future enhancements may include predictive fault analysis and integration with renewable sources like solar to create a more sustainable and adaptive energy management system.

KEYWORDS: Inverter faults, Artificial Intelligence, Random Forest, Arduino, IoT platform, Fault detection, Real-time monitoring, GSM alert system.

I. INTRODUCTION

Inverter systems play a critical role in providing backup power in residential, commercial, and industrial settings. However, these systems are prone to faults such as overvoltage, undervoltage, short circuits, and overheating, which can lead to equipment failure, increased downtime, and safety hazards. This project proposes a smart inverter fault detection system that leverages Artificial Intelligence (AI) and Internet of Things (IoT) technologies to identify and classify such faults in real time.

The growing demand for uninterrupted power supply and the increasing complexity of power systems necessitate intelligent monitoring solutions. Traditional fault detection methods are often manual, time-consuming, and reactive in nature. To overcome these limitations, the proposed system utilizes sensors connected to an Arduino circuit to measure critical parameters like voltage, current, and temperature. These sensor readings are transmitted via a Wi-Fi module to an IoT platform, where users can visualize the data and its corresponding graphs in real time through a web interface.
The collected data is then exported from the IoT platform and fed into a trained Random Forest machine learning model. This model accurately predicts the presence and type of fault, enabling timely intervention and preventive maintenance. The detected faults are also displayed on an LCD module and communicated to users via GSM alerts, ensuring that operators are immediately informed of any issues. This integrated approach enhances the safety, reliability, and intelligence of inverter-based power systems.

II. LITERATURE SURVEY

The increasing demand for uninterrupted power supply in critical infrastructures like hospitals, industries, and data centers has driven the development of intelligent switching and monitoring systems. According to S. M. Imran [1], a microcontroller-based automatic transfer switching system (ATS) is an effective solution for managing alternate power sources such as mains, generators, and inverters. His design employed voltage sensors, relays, and microcontroller logic to ensure seamless power transition without manual intervention.

Amuzuvi and Addo [2] proposed a similar ATS using an 89C52 microcontroller that controls relays, voltage sensing circuitry, and an LCD interface to provide feedback and switching status. Their system demonstrated enhanced performance and faster operation with reduced component count. Keshinro [3] further improved on this concept by designing a low-cost, efficient single-phase automatic transfer switch that minimized power consumption and simplified control circuitry.

With the rise of the Internet of Things (IoT), real-time monitoring and remote control have become integral to power systems. Jamal et al. [5] presented an IoT-based fault detection mechanism for power transformers, utilizing sensors and microcontrollers to send real-time data to an IoT dashboard, enabling preventive actions and enhanced visibility.

Artificial Intelligence (AI) has also emerged as a powerful tool for fault prediction. Chen et al. [4] implemented a Random Forest model for intelligent fault detection in photovoltaic (PV) systems using voltage and current data. Their model demonstrated high accuracy in identifying fault patterns from real-time sensor inputs, supporting the feasibility of AI-powered fault diagnosis in power electronics.

These studies laid the groundwork for our project, which integrates sensor-based data acquisition via Arduino, real-time data transmission to an IoT interface, and intelligent fault prediction using a Random Forest AI model. This approach enhances fault detection accuracy, supports real-time monitoring, and automates the diagnostic process for smart inverters.

III. METHDOLOGY

The system is designed to detect faults in a smart inverter setup by monitoring various electrical parameters in real-time. The core of the system is an Arduino-based microcontroller unit that collects data from energy-monitoring sensors and controls power output to the load using relays. It ensures that if an abnormal condition or electrical fault is detected, the system can isolate the fault and send data to an AI model that predicts possible failure types. This helps in preventing damage to expensive electrical appliances and provides users with an automated monitoring and fault prediction solution.

The motivation behind this work is to enhance the reliability and safety of inverter systems, particularly in smart homes and industrial setups, where electrical disturbances can result in performance degradation or damage to equipment. Using Artificial Intelligence, the system is capable of predicting faults before they occur, adding a layer of intelligence and automation to conventional inverter systems.

A. Working

The **ATmega328 microcontroller** is the main processing unit. It is responsible for reading real-time electrical parameters using the **PZEM-004T** energy metering module, which provides voltage, current, power, and frequency values.

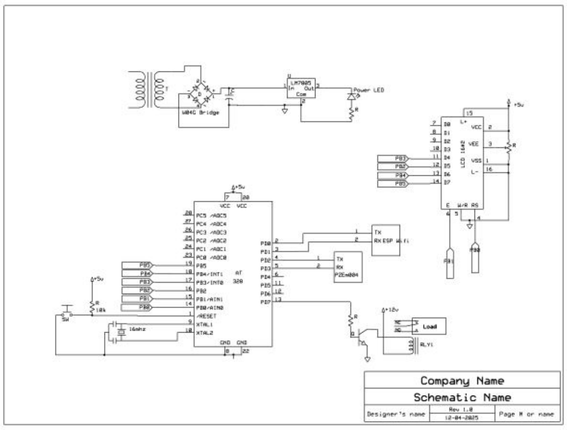
The **ESP8266 Wi-Fi module** is connected to the microcontroller and transmits data to a cloud-based **IoT platform**. This enables remote monitoring of electrical parameters and logging of historical data.
The **relay module** is used to connect or disconnect the load based on the electrical readings. If a fault is detected, the microcontroller cuts off the power supply to protect the load.

The **LCD display** provides live feedback to the user, showing voltage, current, and system status like "Normal", "Overload", or "Fault Detected".

The microcontroller constantly compares the sensed values with predefined threshold limits. For example:
Voltage < 80V or > 260V
Current > 10A
Power Factor < 0.7

If a value crosses a critical threshold, a **relay is triggered** to disconnect the load. Simultaneously, this event is sent to the **cloud dashboard** through the ESP8266.

Periodically, data is exported from the IoT platform and used to train a **Random Forest model**. This model learns from historical patterns and is capable of predicting whether a fault is likely to occur, even before it actually happens.



B. Hardware Description

1. Power Supply:
The system uses a regulated 5V power supply. The input 12V DC is stepped down using an **LM2596 buck converter**, which efficiently converts it to 5V to power the microcontroller, sensors, relays, and Wi-Fi module.

2. ATmega328 Microcontroller:
Acts as the main controller that interfaces with the PZEM004T module, relay, LCD, and Wi-Fi module. It runs the logic to detect faults, control relays, and communicate with the cloud.

3. PZEM004T Energy Monitoring Module:
Used to measure AC parameters like voltage (80–260V), current (0–100A), power, frequency, and power factor. Communicates with the microcontroller via TTL interface.

4. Relay Module:
Provides electrical isolation between the high-voltage load and the low-voltage microcontroller. Controlled by digital signals, it connects or disconnects the power supply to the load during normal or fault conditions.

5. ESP8266 Wi-Fi Module:
Sends real-time data to a cloud IoT platform for live monitoring. It also helps export the collected dataset for AI model training.

6. 16x2 LCD Display:
Displays real-time values of voltage, current, and status messages to the user for quick local feedback.

C. Software and AI Integration

1. The Arduino is programmed using embedded C/C++ to control the system logic and data acquisition process.
2. Collected data is uploaded to the cloud using HTTP or MQTT protocols via the ESP8266 module.
3. The dataset is then downloaded and pre-processed in **Jupyter Notebook**, an open-source Python-based environment widely used for data science and machine learning tasks.
4. A **Random Forest classifier** is trained using this historical sensor data. The model is capable of classifying the system’s operational state into categories such as "Normal", "Warning", or "Fault".
5. Once trained, the model can generate predictions based on new incoming data, providing early warnings and aiding in preventive maintenance of the inverter system.

1) Arduino IDE (Programming):
Arduino is a prototype platform (open-source) based on an easy-to-use hardware and software. It consists of a circuit board, which can be programed (referred to as a microcontroller) and a ready-made software called Arduino IDE

(Integrated Development Environment), which is used to write and upload the computer code to the physical board. The key features are:

Arduino boards are able to read analog or digital input signals from different sensors and turn it into an output such as activating a motor, turning LED on/off, connect to the cloud and many other actions.

You can control your board functions by sending a set of instructions to the microcontroller on the board via Arduino IDE (referred to as uploading software).

Unlike most previous programmable circuit boards, Arduino does not need an extra piece of hardware (called a programmer) in order to load a new code onto the board. You can simply use a USB cable.

Additionally, the Arduino IDE uses a simplified version to of C++, making it easier to learn to program.
Finally, Arduino provides standard form factor that breaks the functions of the microcontroller into a more accessible package

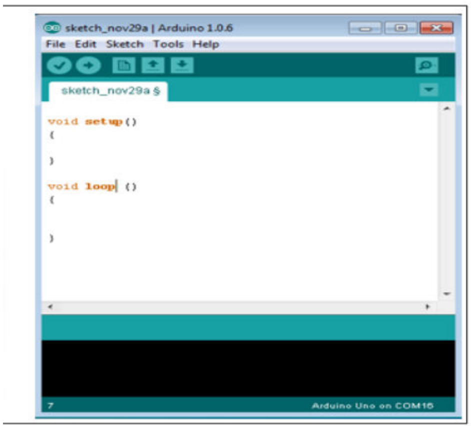


Fig.1 Arduino Software

To create a new project, select File --> New

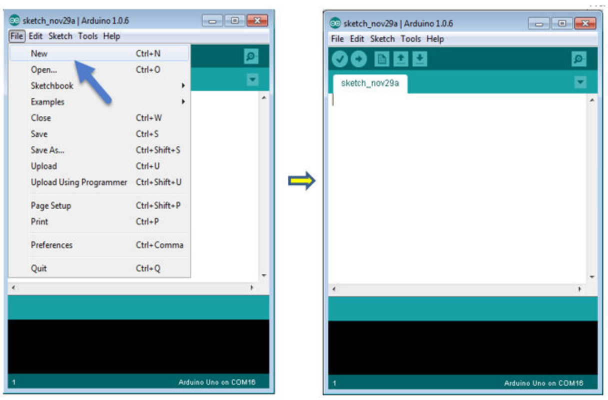


Fig.2 Arduino Software Setup

2) Proteus :

The PROTEUS Environment:

Proteus PIC Bundle is the complete solution for developing, testing and virtually prototyping your embedded system designs based around the Microchip Technologies TM series of microcontroller. This software allows you to perform schematic capture and to simulate the circuits you design. A demonstration on the use of PROTEUS will be given to you on this lab session, after that; you are encouraged to learn to use the software interactively.

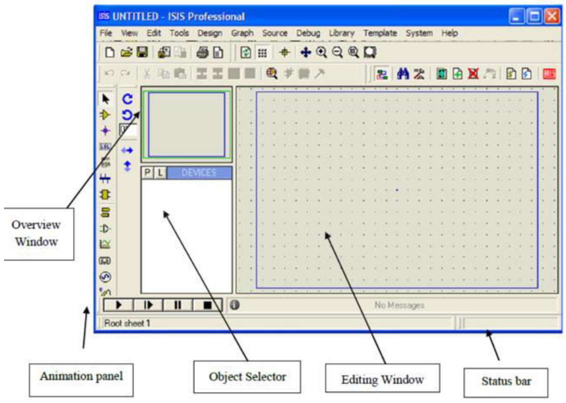


Fig.3 Express PCB

Express PCB :
Design of a PCB using layout software from ExpressPCB, which is freeware available at www.expresspcb.com. Before beginning you should make sure your computer has both ExpressPCB and ExpressSCH, if not than you should download the software. Before beginning the PCB process, you should come up with the initial design, build it and test it on a breadboard, fix any errors, and determine specific components. It is also useful to have datasheets and dimensions for all of the "special" components such as transistors, ICs, sensors, actuators, etc., on hand. Entering the Schematic into ExpressSCH

1. Open ExpressSCH to create a fresh schematic. The first time you start ExpressSCH you will get a dialog box with a link to a quick start guide for ExpressSCH. This can be useful if you want to get a general overview for the tool.
Once you are ready to start, close the dialog box to view the empty schematic.

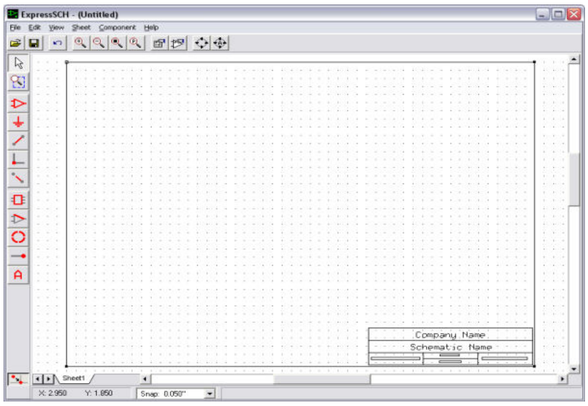


Fig.4 Express PCB Setup

Creating the Layout in ExpressPCB
When doing the layout, it is particularly useful to have the actual components and/or in front of you, along with a ruler or set of callipers (the ruler and callipers are unnecessary for this tutorial).

1. Open ExpressPCB. When you first open the program, a dialog box appears with links to the Quick Start Guide and a PCB Design Tips file. If you have time, both of these links can be instructive. Once you're ready to continue, hit OK to go to a new file.

2. Under "File" select "New file." Choose the 2-layer board, with Default via '0.056" round via with 0.029" hole'. Change both default clearances for the filled planes to 0.05 (the maximum allowed). Hit OK and again OK on the warning that appears in the next window. The yellow line on the screen shows the boundary for the PCB. The default boundary is 3.8 x 2.5 inches, which matches the express PCB mini-board service. This demo will use the entire board—**however for our class project you should only use half the board (1.9" x 2.5") so that we can double up designs**. Also, be aware that no copper (pads or traces) can be placed closer than 0.025" to the perimeter of the board.

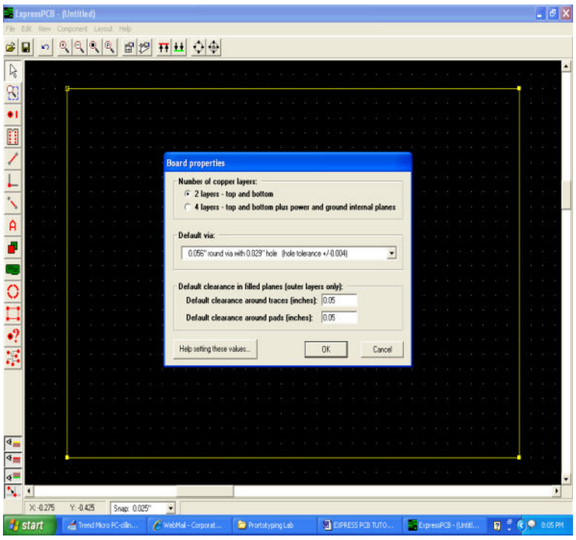


Fig.5 Express PC Board setup

3.AT mega328 Microcontroller:

Fig.3 Microcontroller AT Mega 328

4.Regulator LM2596 DC-DC Buck Converter:

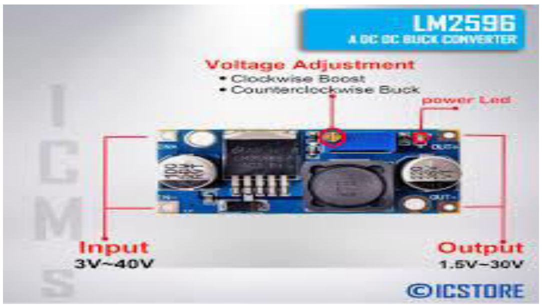


Fig.4 Regulator (LM2596)

The **LM2596** is a **DC-DC buck converter** module, which means it steps down higher DC voltage to a lower voltage. It's based on the **LM2596 switching regulator IC**, designed to provide high-efficiency voltage conversion with minimal heat generation. This module is widely used in projects that require a stable, adjustable DC output.

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5.LCD 16*2:

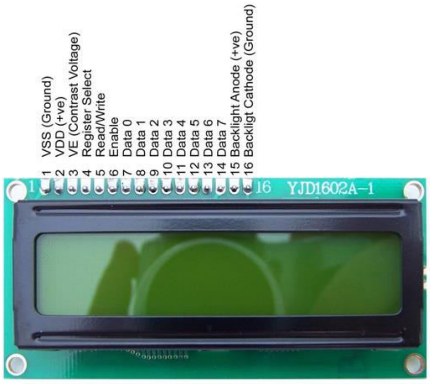

Fig.5 LCD 16*2

The **16x2 LCD Display** is a popular display unit in embedded systems and electronics projects. It is used to display alphanumeric characters and basic symbols. This display contains two internal byte wise resisters, One for the commands (RS=0) and second for character to be displayed (RS=1). It also contains a user programmed RAM area (the character RAM) that can be programmed to generate any desired character that can form using a dot matrix. To distinguish between these two data areas, the hex command byte 80H will be used to signify that display RAM address 00H is chosen. Port 1 is used to furnish the command or data byte, and ports 3.2 to 3.4 furnish register select and read/write levels. The display takes varying amounts of time to accomplish the functions. LCD bit 7 is monitored for a logic high (Busy) to ensure the display is not overwritten.

6.ESP8266-01 Module:

Fig.6 ESP8266-01 Module

Operating Modes

The ESP8266-01 can operate in several modes, determined by the configuration of the GPIO0 and GPIO2 pins during startup:

Station Mode (STA): Connects to an existing Wi-Fi network as a client, like a phone or laptop. The ESP8266 can then send or receive data over the network.

Soft Access Point Mode (AP): The ESP8266 creates its own Wi-Fi network, allowing other devices to connect to it directly.

Station + AP Mode: The module can operate as both an access point and a station simultaneously.

Deep Sleep Mode: Used in power-saving applications, this mode drastically reduces the power consumption of the ESP8266.

7.Relay:

Fig. 7 Relay

A **relay module** is an electronic device that allows low-power circuits to control high-power circuits safely. It is commonly used to control high-voltage devices (like appliances, motors, and lights) using a low-voltage control signal from a microcontroller or a sensor. Relay modules are integral to projects in home automation, industrial control systems, and many other applications. A relay operates like an electrically controlled switch. It allows the control of an electrical circuit by opening or closing contacts in a circuit using an electromagnet.

8.PZEM004 module

The PZEM-004T AC communication module, the module is mainly used for measuring AC voltage, current, active power, frequency, power factor and active energy, the module is without display function, the data is read through the TTL interface.

REFERENCES

[1] S. M. Imran, “A Microcontroller-Based Automatic Transfer Switching System for a Standby Electric Generator,” International Journal of Engineering Research and Applications, vol. 6, no. 3, pp. 25–29, 2016. [Online]. Available: https://www.academia.edu/32008213

[2] C. K. Amuzuvi and E. Addo, “A Microcontroller-Based Automatic Transfer Switching System,” Ghana Mining Journal, vol. 15, no. 1, pp. 85–92, 2015.

[3] K. K. Keshinro, “Design and Construction of a Low-Cost Automatic Single-Phase Transfer Switch,” FUOYE Journal of Engineering and Technology, vol. 5, no. 1, pp. 45–50, 2016.

[4] Z. C. Chen, F. Han, L. Wu, and J. Yu, “Random Forest Based Intelligent Fault Diagnosis for PV Arrays Using Array Voltage and String Currents,” Energy Conversion and Management, vol. 179, pp. 75–84, Jan. 2019.

[5] H. Jamal et al., “IoT-Based Fault Detection and Protection of Power Transformer in the Smart Grid,” Smart Cities, vol. 3, no. 1, pp. 89–102, 2020.

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