Newly Manufactured Inverter Testing System

Rupesh Rajesh Ghumare[1], G. B. Polade[2], Darshan Bhausaheb Dhanage[3], Rohit Nandu Jagtap[4]

[1][3][4] B.E Student, [2]Assistant Professor, [1][2][3][4] Department of Electrical Engineering
MET's Institute of Engineering

Abstract— **Inverters are essential devices that convert direct current (DC) into alternating current (AC), enabling the operation of standard electrical appliances. With the growing demand for dependable and energy-efficient power systems, it has become crucial to ensure the quality and performance of newly developed inverters. This paper introduces a microcontroller-based testing setup specifically designed to evaluate single-phase inverters in accordance with Indian electrical standards. The system continuously monitors key output parameters including voltage, current, frequency, power, and power factor under varying load conditions. These parameters are displayed in real time, and any deviation beyond the preset limits triggers an audible alert through a buzzer for immediate fault identification. The inclusion of Bluetooth communication allows for remote monitoring and data logging. This approach not only enhances testing accuracy and efficiency but also offers a reliable framework for improving the performance and safety of inverter systems.**

Keywords— **Inverter testing, microcontroller, performance evaluation, real-time monitoring, voltage, power factor, buzzer alert, automation.**

I. INTRODUCTION

In today's technology-driven environment, ensuring the continuous operation of high-availability systems is a major priority for industries such as data centers, hospitals, and financial institutions. These mission-critical systems demand an uninterrupted power supply to prevent data loss, system downtime, or operational disruptions. Inverters serve as a primary source of backup power during grid failures, ensuring smooth transitions and maintaining system stability in the event of outages.

The effectiveness of an inverter, however, is dependent on its internal circuitry and the condition of the battery bank that powers it. Consistent monitoring of these components is essential to ensure that backup systems are reliable when needed. Conventional monitoring approaches rely on manual inspection or localized monitoring, which often lack real-time responsiveness and scalability. With the advancement of embedded systems and sensor technology, real-time parameter monitoring and fault alerting have become increasingly feasible and efficient.

This paper presents a sensor-based inverter testing and monitoring system designed with a focus on high-availability applications. The system integrates smart sensors at key points within the inverter testing environment to measure crucial electrical parameters such as voltage, current, frequency, power factor, and battery health. These parameters are processed by a microcontroller to detect deviations and generate real-time alerts.

The implementation of such a system supports predictive maintenance, enhances performance evaluation, and minimizes unexpected failures. Additionally, the system enables remote monitoring and report generation, making it a practical solution for both industrial and research use cases.

II. LITERATURE REVIEW

Battery classification and monitoring have evolved beyond conventional methods, with recent research focusing on intelligent systems for enhanced performance and safety. One such approach involved using battery testing equipment to age batteries with different chemistries, leading to the development of a UPS Battery Management System (BMS) based on an ATMEGA microcontroller. This system tracks vital parameters such as State of Charge (SOC), Depth of Discharge (DOD), State of Health (SOH), and battery lifespan using voltage and current sensors on a 12V sealed lead-acid battery.

In electric vehicles (EVs), battery aging significantly impacts performance, making it a key concern. To address this, IoT-enabled monitoring systems are increasingly used to evaluate battery condition and enhance energy efficiency. Additionally, Arduino-powered voltage sensors have been suggested for use in UPS setups, where they can detect voltage

irregularities and activate alarms—offering a solution to the absence of dedicated battery protection in conventional UPS systems.

Safety in lead-acid battery usage, especially in substations, has prompted the design of HVAC control panels using PID-based controllers to manage gas emissions. In renewable energy setups, PV-powered UPS systems with MPPT controllers have been implemented to ensure efficient energy storage and delivery, particularly in remote regions like Adrar. These systems demonstrate the growing need for smart energy solutions that integrate power electronics and environmental monitoring.

Modern BMS solutions play a crucial role in enhancing battery longevity and performance across various applications, from EVs to residential solar systems. Proposed algorithms now estimate battery efficiency based on charging current, duration, and capacity while accounting for aging effects. Precise estimations of State of Charge (SOC) and State of Health (SOH) are crucial for forecasting performance and maintaining battery safety.

Finally, several studies emphasize the importance of robust BMS designs that cover operational modes, system topology, component-level monitoring, fault detection, and compliance with industry standards. Continued research in this domain is vital to support the growing demand for safe, reliable, and sustainable energy storage systems.

III. METHODOLOGY

To evaluate the performance of newly manufactured single-phase inverters, a dedicated testing system was developed using a combination of sensors, microcontroller-based logic, and real-time monitoring components. The setup begins with connecting the inverter to be tested with the system using proper electrical wiring. An AC parameter sensing unit is employed to measure output voltage, current, power, frequency, and power factor. These readings are forwarded to a central microcontroller, which acts as the processing hub of the entire system.

To simulate different load conditions, a relay mechanism is used to control the connection between the inverter and a load bank. The relay is activated and deactivated by the microcontroller based on the programmed test sequence. The system continuously compares the measured values against predefined threshold limits, also known as setpoints. These setpoints are configurable and help in determining whether the inverter meets the required performance standards.

The system displays real-time readings on an LCD screen, giving the user instant visual feedback. If any of the parameters cross the acceptable limit, a buzzer is activated immediately to alert the operator. In addition to this, the system features Bluetooth connectivity, which can be used to transmit test data wirelessly to external devices for further analysis.

Efficiency is a critical part of the testing process. It is calculated by comparing the inverter's input power (DC) and its output power (AC). This ratio helps evaluate the inverter's energy conversion efficiency. The gathered test data can be saved for future evaluation and analysis. This helps in reviewing the inverter's long-term performance and supports quality control through trend analysis and reporting tools.

To ensure reliable power to the entire test circuit, a regulated power supply is used. This ensures that the microcontroller and its peripherals receive stable voltage during operation. The AC sensor is calibrated to maintain accuracy under varying conditions, and software filters are implemented to eliminate noise from the measurements. The microcontroller software is programmed using embedded C, allowing it to handle multiple tasks such as data acquisition, parameter calculation, display management, and decision-making for alarms or switching. Safety precautions, including proper insulation, short-circuit protection, and overload monitoring, are also part of the system design.

Furthermore, the system can be enhanced with data logging functionality, where test results can be stored in non-volatile memory or transmitted to a computer for generating performance reports. This makes the setup useful not only for production-level testing but also for research, development, and academic purposes.

IV. SYSTEM DESIGN

A. Block Diagram
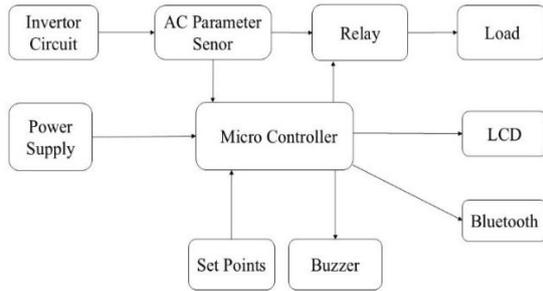
- **Inverter Circuit**

This is the core unit being evaluated. It converts DC input into AC output, which is analyzed for performance and stability by the testing setup.

- **Power Supply**

This module provides the required power to the overall system, enabling operation of sensors, controllers, indicators, and other electronic components.

- **AC Parameter Sensor**

This module is designed to monitor key AC parameters such as voltage, current, frequency, and power. The collected data is sent to the controller for processing and decision-making.

- **Microcontroller Unit**

The microcontroller serves as the main control unit responsible for managing the system's operations. It receives input data from the sensors, compares it with predefined setpoints, and executes logic to trigger relays, alarms, or display outputs.

- **Set Point Input**

Push buttons or similar interfaces are used to input threshold values for acceptable inverter performance. These values serve as references for evaluating test results.

- **Buzzer Indicator**

An audio alert system (buzzer) is integrated to notify users of abnormalities or when a test is completed, ensuring quick fault detection.

- **Relay Circuit**

The relay is used to connect or disconnect the load during testing. It simulates real-time load conditions and also acts as a safety mechanism to isolate faulty components.

- **LCD Module**

An LCD display is used to present real-time readings and status updates, offering the user clear visibility of test parameters and outcomes.
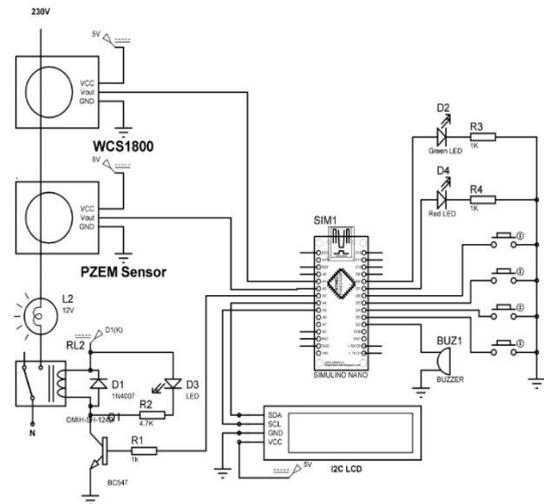
- **Load**

A dummy or artificial load is used during testing to simulate real operational conditions and evaluate the inverter's behaviour under different stress levels.

- **Bluetooth Module**

A Bluetooth communication module is included to enable wireless data transmission to mobile devices or computers for extended monitoring and logging.

B. Circuit Diagrma:

C. Components

a. Arduino Nano

Based on the ATmega328P (for most models), the Arduino Nano is a small, low-cost input, with pins that are well-open and available as known sources of resources. and microcontroller operating the popular board voltage board with for and has engineers building frequency 22 and is input/output hobbyists developing 5V pins, because small and 6 of embedded 16MHz of its systems respectively. the compact and This are sizes, prototyping analog simplicity ideas and the large board can be used easily, particularly by Arduino's well-connected IDE suited to (Integrated for many Development applications sensors, Environment) actuators, which have and allows communication the limited modules.

The programmer powers Arduino to and Nano writes, space is compile requirement programmed and

because upload it code is small and with communication minimal protocols effort. like UART, I2C, is SPI usually so powered up to assist in USB system connection integration or in a various battery and it supports applications. In this project, Arduino Nano serves as the central working unit for data storage, control, and communication with other devices. Its versatility and simplicity make it a reliable solution for embedded systems and automation work in engineering applications.

b. *PZEM-004T Sensor*

The PZEM-004T multi-function AC power monitor is frequently used in projects focused on monitoring and analyzing electrical energy consumption. It can measure four key electrical parameters: voltage, current, power, and energy. This compact module is well-suited for monitoring single-phase AC (RMS) voltage, current, and power. It also integrates smoothly with Arduino and similar platforms through available code libraries.

Function

- Tracks important electrical parameters like voltage, current, active power, and energy consumption.
- Includes an overload alert feature, where the display flashes and a buzzer sound if power exceeds a set threshold.
- Enables users to define a specific power threshold to activate an alarm.
- Features an energy reset function that can be activated by a dedicated button.
- Preserves energy data even when power is lost.
- Equipped with a bright red digital display showing voltage, current, power, and energy readings.
- Supports serial communication via a built-in TTL interface, enabling data exchange and parameter configuration with various devices through pin connections.

c. LCD Display

This 16x2 LCD display module, featuring an I2C interface, provides a high-quality 2-line, 16-character display with built-in contrast control and backlighting. It simplifies the setup process, particularly for beginners using Arduino, by removing the need for complex driver circuits. This minimizes the use of I/O pins on the Arduino, simplifying firmware development, further supported by the extensive availability of compatible Arduino libraries. As a result, it is an excellent option for those looking to integrate a reliable and easy-to-use display solution with minimal setup.

d. Relay Module

A relay is an electrically controlled switch used to power low-power signals through circuits while, at the same time, giving complete electrical isolation between the control and the controlled circuits. While standard relays switch the circuit with an electromagnet mechanically, there are also solid-state relays that utilize semiconductor devices in place of the electromagnetic switch, helping to eschew some of the mechanical elements and providing reliability and speed.

There are a variety of applications for relays. Their first applications were in long-distance telegraph systems, where they increased the power of incoming signals and retransmitted them over other circuits.

e. Hall Current Sensor

Functional Description:

The Winson WCS1800 current sensor provides an affordable and precise method for measuring DC and AC currents in various industrial, commercial, and communication applications. Its unique design allows for seamless integration into existing setups without the need to alter the original system, making it ideal for a variety of applications such as motor control, load detection, over-current fault identification, and intelligent power management systems.

The WCS1800 incorporates a precise Hall effect sensor IC with built-in temperature compensation, housed in a 9.0mm through-hole configuration. Users can pass their system's own electrical wiring through this hole to measure the current, allowing system designers to monitor any current flow without making modifications to the original system layout. As current flows through the hole, it generates a magnetic field detected by the Hall sensor, which then converts it into a proportional voltage.

The sensor's conductive path terminals are electrically separated from the sensor leads, allowing the WCS1800 to be used in applications requiring electrical isolation, without the need for costly opto-isolators or other isolation techniques, thereby helping to keep system costs low.

Features
- The 9.0mm diameter conductor through-hole provides an output voltage that is proportional to both AC and DC currents, with a wide current sensing range from 0 to 35 A at 5V.
- High sensitivity 72mV/A
- Wide operating voltage range 3.0~12 V.
- Low operating current 3mA
- Isolation voltage 4000V
- Ratio metric output from supply voltage
- 23K Hz Bandwidth
- Two bronze rods are provided for convenient soldering onto the PCB.

D. ADVANTAGES
- Real-time system parameter tracking
- Improved battery health and longevity
- Enhanced inverter performance
- Early detection of faults or irregularities
- Increased overall system efficiency

E. APPLICATIONS
- Inverter systems used in commercial and industrial facilities
- Public electric vehicle (EV) charging stations
- Battery chargers in EV service centers
- Monitoring systems in energy storage solutions

V. CONLUSION

The conclusion implementation of a Sensor-based Inverter Monitoring System for high-availability environments offers significant benefits, including preventing unexpected downtime and minimizing the risk of data loss. By continuously tracking inverter performance and sending real-time alerts, the system reduces the need for on-site maintenance, making it ideal for large-scale data centers and critical infrastructure. This study focused on ensuring the reliable performance of inverters and batteries, with potential future developments integrating IOT for better management of key factors like voltage, current, and power. Remote monitoring capabilities, enabled by IOT, will allow IT administrators to easily access critical information and improve the overall performance and safety of inverter systems.

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