

## ELECTRICAL DATA MONITORING SYSTEM USING EMBEDDED SYSTEMS

D.S. Veeranna<sup>1</sup>, Mrs.Ch. Laxmi<sup>2</sup>, Rachakonda Rajesh Kumar<sup>3</sup>, Vankudoth Pavan<sup>4</sup>, Padya Prudhvi<sup>5</sup>

<sup>1,2</sup> Assistant Professor, Department of *ELECTRICAL AND ELECTRONICS ENGINEERING GURU NANAK INSTITUTIONS TECHNICAL CAMPUS*

<sup>3,4,5</sup> UG Scholars, Department of *ELECTRICAL AND ELECTRONICS ENGINEERING GURU NANAK INSTITUTIONS TECHNICAL CAMPUS*

**Abstract:** In recent years, the demand for wireless data acquisition and real-time electrical parameter monitoring in direct current applications has increased. However, traditional setups lack realtime telemetry; one way to improve fault detection is by using Wireless Sensor Networks (WSN), which require embedded architectures. Monitoring systems are required to accurately measure the voltage and current to calculate power. In this Project, the design and implementation of a Bluetooth-enabled embedded system for electrical data acquisition is presented, obtaining a low-latency, high connectivity, scalable, modular, and open architecture system. The tests recorded the instantaneous voltage, current, and environmental data, resulting in highly accurate real-time telemetry and reliable fault alerting mechanism. Notably, the developed embedded system exhibited a robust wireless data transmission rate.

**Keywords:** Embedded Systems, Data Acquisition, Bluetooth Communication, Voltage Sensor, Current Sensor, Raspberry Pi Pico, Wireless Monitoring.

### 1. INTRODUCTION

#### 1.1 GENERAL

The is a system of related computing devices, mechanical and digital machines, objects, people or animals that are provided with unique identifiers and also the potential to transfer data over a network without requiring human-to-human or human-to-computer interaction. Physical items are no longer disconnected from the virtual world, but can be monitored remotely through wireless telemetry. In fact – due to their diminishing size, constantly falling price and declining energy consumption – microcontrollers, communications modules and other electronic components are being increasingly integrated into everyday testing setups. Smart devices. Smartphones. Smart cars. Smart homes.

Smart cities. A smart world. “Smart” embedded nodes play a key role in the DAQ vision, since advanced communication and information technology would have the potential to revolutionize [12]. With the growing presence of Bluetooth and localized wireless access, the evolution toward omnipresent data acquisition and communication networks is already evident [13]. According to recent industrial automation standards, real-time data telemetry will be the fastest-growing requirement for electrical diagnostics, in which embedded sensor nodes are technologically mature. But still there is increase in world’s demand for precision. Adopting automated data acquisition technologies is one advance way of reducing hardware failure. The latest edition of the embedded systems market report now sees wireless telemetry growing 13% more between 2024 and 2030 than it did in last year’s forecast. The share of wireless diagnostics in overall system maintenance will rise from over 23% in 2024 to almost 28% in 2030. Sensor data is widely available throughout the testing environment and can contribute to minimize manual probing. In 90 milliseconds, enough data strikes the microcontroller to provide the entire system's diagnostic needs. Wireless DAQ

entails no physical manual intervention during operation and does not require complex wires. Bluetooth has many benefits like system-friendly deployment, improved operating strategies, like advanced electrical parameter forecasting and enhanced scheduling of maintenance tasks and also investment in additional flexible resources, comprising condition-based resources, data storage, network infrastructure and localized monitoring. The traditional focus on the manual measurement of electricity – a measure of cost for a particular diagnostic technology at the level of a test bench – is no longer sufficient. About a million sensor nodes were installed every day around the world last year. Wireless DAQ leads providing almost 40% of global diagnostic equipment capacity growth over the medium-term. Finally, in analyzing the likely evolution of electricity and condition monitoring sectors – testing, industry and research – it explores the prime role wireless telemetry could play in the long-term future of diagnostic systems. Applications of the monitoring system are in the lab emulators, ground mounted sensors, smart cities, Smart villages, Micro grids and localized power nodes. Consumer Products like automated testing systems; localized home lighting systems; smart lanterns; smart pumps; rapid mobile

chargers; electrical cookers; LED smart torch; RO plants; smart fans, smart Inverters, etc. can be monitor through this project. Commercial Products like automated traffic signals, smart road studs/blinkers are also to be monitor through the proposed system. India, where frequent power fluctuations are very common. Due to which it is important to use embedded data acquisition. By monitoring the electrical forecast, households and testing facilities using DC power can time their load utilization during good grid conditions.

## **2. Working Methodology**

The working of the system begins with the power supply unit, which converts AC mains voltage into a regulated DC voltage required for the operation of all components. Once powered, the microcontroller initializes and starts reading input signals from the voltage sensor, current sensor, and IR sensor. The voltage sensor measures the electrical potential, while the current sensor detects the current flowing through the load. These analog signals are converted into digital form using the microcontroller's ADC and processed to calculate electrical parameters. The processed data is then displayed on the OLED screen for real-time monitoring. Simultaneously, the microcontroller sends this data to the

Bluetooth module, which wirelessly transmits it to a mobile device, allowing remote access. The system continuously checks for abnormal conditions such as over-voltage, over-current, or environmental disturbances. If any fault is detected, the microcontroller activates the buzzer to alert the user. In addition to monitoring, the system also performs control operations. Based on predefined conditions, the microcontroller sends signals to the ULN2003 driver, which in turn operates the relay. The relay switches the connected load ON or OFF depending on the system status. This integrated approach ensures efficient monitoring, fault detection, wireless communication, and automated control of electrical systems.

## **3. Proposed System**

The proposed system is an embedded-based electrical data monitoring system designed to provide real-time measurement and analysis of electrical parameters such as voltage and current. Unlike traditional systems that rely on manual readings and limited monitoring, this system uses a microcontroller-based architecture integrated with sensors and wireless communication. The system collects data using voltage and current sensors and processes it through a microcontroller. The processed data is displayed on an OLED

screen and also transmitted wirelessly using a Bluetooth module for remote monitoring. Additionally, the system includes fault detection mechanisms such as IR sensors and buzzer alerts to identify abnormal conditions like voltage fluctuations or environmental disturbances. A relay controlled through a driver circuit allows automatic switching of electrical loads, improving safety and efficiency. Overall, the proposed system offers a low-cost, reliable, real-time, and user-friendly solution for electrical monitoring and control.

#### 4. Block diagram

The system starts with the power supply unit, which provides a regulated DC voltage to the microcontroller and all connected components. Once powered, the microcontroller acts as the central unit and continuously receives input signals from the voltage sensor and current sensor. The voltage sensor measures the supply voltage, and the current sensor measures the current flowing through the load. These analog signals are converted into digital values using the internal ADC of the microcontroller and then processed.

After processing, the microcontroller displays the real-time electrical parameters such as voltage and current on the OLED display, allowing the user to monitor the

system locally. At the same time, the processed data is transmitted to external devices through the Bluetooth module, enabling wireless monitoring on a mobile phone or computer.

For control operation, the microcontroller sends signals to the driver circuit, which amplifies the signal and operates the load through switching elements like a relay. Depending on the system conditions or programmed logic, the load can be turned ON or OFF automatically.

Thus, the system performs data acquisition, processing, display, wireless communication, and load control in an integrated manner, ensuring efficient real-time electrical monitoring and management.

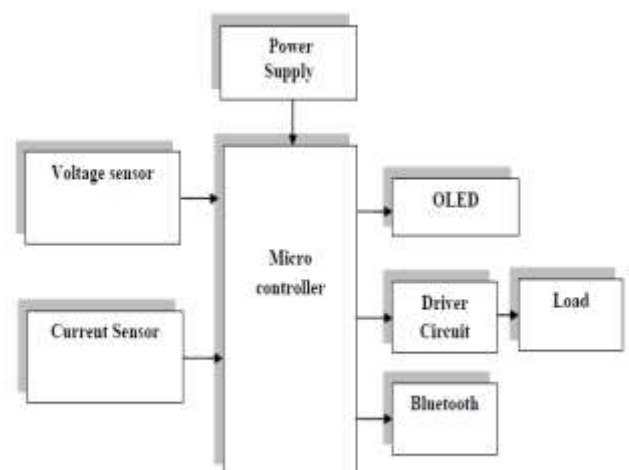


Fig.1 block diagram

#### 5. Hardware Description

### **A. Power Supply Unit**

The power supply unit converts high-voltage AC mains into a stable DC voltage required for the system. Initially, the transformer steps down the 230V AC to a lower AC voltage. This is then converted into pulsating DC using a bridge rectifier. A filter capacitor smooths the ripples present in the output, and finally, a voltage regulator (such as 7805) maintains a constant +5V DC output regardless of input variations. This regulated voltage is supplied to all electronic components to ensure proper and safe operation.

### **B. Microcontroller (Raspberry Pi Pico)**

The Raspberry Pi Pico acts as the central processing unit of the system. It continuously reads input signals from sensors such as voltage, current, and IR sensors. These signals are processed using its internal CPU and ADC modules. Based on the programmed logic, the microcontroller performs calculations like voltage and current measurement, controls output devices like OLED display, relay, and buzzer, and manages communication with the Bluetooth module. It coordinates the entire operation of the system.

### **C. Voltage Sensor**

The voltage sensor works on the principle of a voltage divider, where high input voltage is scaled down to a safe level. This reduced voltage is then fed into the microcontroller's ADC, which converts the analog signal into digital form. The microcontroller processes this digital value to determine the actual voltage level in the circuit. This allows continuous monitoring of voltage variations and helps in detecting abnormal conditions such as over-voltage.

### **D. Current Sensor**

The current sensor measures the flow of current through the load by converting it into a proportional voltage signal. It may operate either by measuring the voltage drop across a resistor (direct sensing) or by detecting the magnetic field generated by current flow (indirect sensing). The output analog signal is sent to the microcontroller, where it is converted into digital data using ADC. This enables accurate current measurement and helps in calculating power and identifying overload conditions.

### **E. OLED Display**

The OLED display works by emitting light when an electric current passes through organic materials. It communicates with the microcontroller using the I2C protocol. The microcontroller sends processed data such as voltage, current, and system status

to the display. Based on these signals, the OLED updates and shows real-time information clearly without requiring a backlight, making it efficient and easy to read

#### **F. IR Sensor**

The IR sensor operates using infrared light transmission and reception. It consists of an IR transmitter and receiver. The transmitter emits infrared rays, and when these rays hit an object, they are reflected back to the receiver. This reflection causes a change in resistance and voltage at the receiver output. This change is detected and processed by the microcontroller to determine the presence of an object or environmental condition such as dust, triggering necessary actions if required.

#### **G. ULN2003 Driver IC**

The ULN2003 works as a current amplifier and switching device. It receives low-power signals from the microcontroller and amplifies them using internal Darlington transistor pairs. This allows it to drive high-current devices like relays. When the microcontroller sends a HIGH signal, the corresponding transistor in the ULN2003 conducts and allows current to flow to the connected load. It also includes protection diodes to handle inductive loads safely.

#### **H. Relay**

The relay operates as an electrically controlled switch. When a control signal is applied to its coil, it generates a magnetic field that moves the internal contact from normally closed (NC) to normally open (NO) position. This allows the relay to switch ON or OFF high-voltage devices using a low-voltage signal from the microcontroller. When the control signal is removed, the relay returns to its original position using a spring mechanism.

#### **I. Bluetooth Module**

The Bluetooth module enables wireless communication between the system and external devices such as smartphones. It transmits and receives data using radio waves in the 2.4 GHz frequency band. The microcontroller sends processed electrical data to the Bluetooth module, which then wirelessly transmits it to a paired device. This allows users to monitor system parameters remotely without physical connections.

#### **J. Buzzer**

The buzzer works by converting electrical signals into sound. When the microcontroller detects a fault condition such as over-voltage or abnormal readings, it sends a signal to the buzzer. This causes

the buzzer to vibrate and produce an audible alert, notifying the user about the issue.

### K. Load

The load is the electrical device connected to the system for monitoring and control. The current and voltage flowing through the load are measured using sensors. Based on the system conditions, the microcontroller can control the load through a relay, turning it ON or OFF as required. This demonstrates real-time monitoring and control of electrical equipment.

### 6. Schematic Diagram

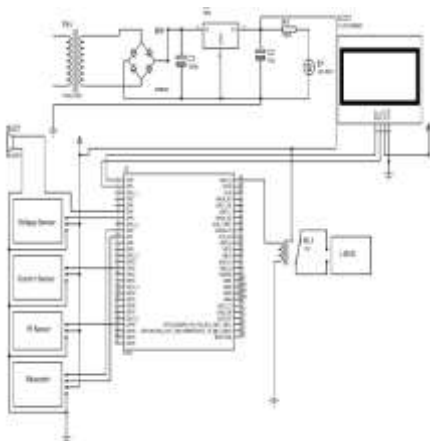


Fig.2: Schematic Diagram

### 7. IMPLEMENTATION RESULTS

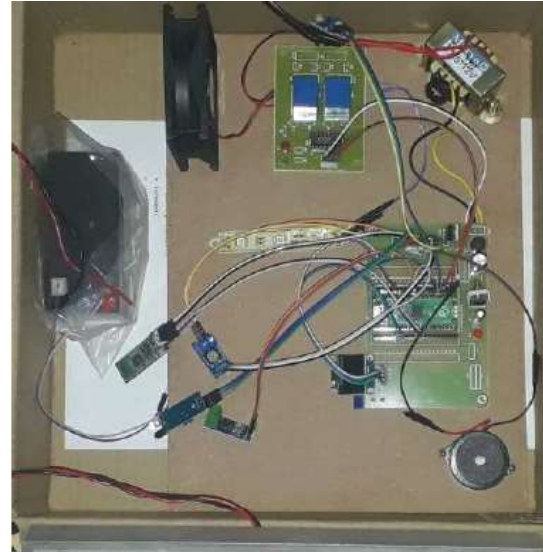


Fig.3: Final output

### WORKING

The "ELECTRICAL DATA MONITORING SYSTEM USING EMBEDDED SYSTEMS Applications" operates on a principle of continuous electrical and environmental monitoring, coupled with automated fault response and remote data transmission, driven by its integrated hardware and software components. The system's operation can be broadly categorized into several key phases: initialization, data acquisition, decision-making, actuation, and communication.

**System Initialization:** Upon power-up or reset, the Raspberry Pi Pico microcontroller executes the `setup()` function of its firmware. During this phase, all necessary hardware components are initialized. This includes configuring

the GPIO pins for the relay control and buzzer as outputs, setting up the ADC (Analog-to-Digital Converter) pins to read the voltage and current sensors, initializing the I2C communication for the OLED display, and establishing serial UART communication for interaction with the HC-05 Bluetooth module. The OLED display provides visual feedback on the initialization status, such as "System Starting..." or "Calibrating Sensors...".

#### **Data Acquisition (Sensor Reading):**

After successful initialization, the system enters its continuous operational loop, defined by the loop() function. At regular intervals, the Raspberry Pi Pico reads the analog outputs from the voltage sensor and current sensor connected to the solar panel output. The raw analog values are processed and mapped to exact Voltage (V) and Current (A) metrics, allowing the microcontroller to calculate realtime Power generation ( $\text{Power} = \text{Voltage} \times \text{Current}$ ). Simultaneously, environmental sensors are polled: the LDR measures sunlight intensity, and the temperature sensor checks the ambient heat. The updated electrical and environmental parameters are immediately displayed on the local OLED screen and printed to the Serial Monitor for local debugging.

#### **Decision-Making (Monitoring Logic):**

Based on the acquired sensor data, the

Pico's firmware applies defined monitoring and safety logic. This logic compares the current electrical levels and environmental conditions against pre-set operational thresholds:

- **Safety Thresholds:** If the voltage spikes too high or drops below a critical minimum (e.g., due to heavy shading or a fault), the system flags a warning condition.
- **Operational Thresholds:** If the temperature exceeds a safe operating limit, or if the power generated is sufficient to drive specific loads, the system determines the appropriate action for the connected relay. This closed-loop monitoring ensures that the solar setup operates within safe parameters and that any inefficiencies or electrical faults are instantly recognized.

**Actuation (Control and Alerts):** Once a decision is made based on the threshold logic, the Raspberry Pi Pico sends control signals to the connected output devices.

- **Load/Cooling Control:** The microcontroller can send a HIGH or LOW signal to the digital pin connected to the relay driver circuit, which can safely switch a connected load or activate a

cooling fan if temperature thresholds are exceeded.

- **Fault Alerts:** If a critical event occurs (such as a sudden drop in current indicating a disconnected wire, or an over-voltage scenario), the microcontroller activates the buzzer to provide a loud, audible alert to the user.
- **Visual Feedback:** The OLED display updates in real-time to reflect the status of the load ("Mode: ON/OFF") and displays any active fault conditions.

#### Communication (Bluetooth

**Integration):** At a set interval, the monitoring system leverages its wireless capabilities for remote data tracking. The HC-05 Bluetooth module facilitates the continuous serial transmission of critical data—including Voltage, Current, Power, Temperature, and Light Intensity—to a paired mobile device. This Bluetooth integration allows users to:

- **Remotely Monitor:** Access real-time data about their solar panel's performance and energy generation directly on their smartphone using a Bluetooth Terminal application.
- **Log Data:** Track the incoming serial data stream to analyze system efficiency over time,

helping to identify peak sunlight hours and overall energy yields.

- **Receive Diagnostics:** Instantly view system status changes or fault codes on their mobile device without needing to physically inspect the local OLED screen.

The continuous cycle of sensing, processing, actuating, and communicating enables the embedded system to maintain a precise energy budget, contributing to safer operation and highly efficient solar power management.

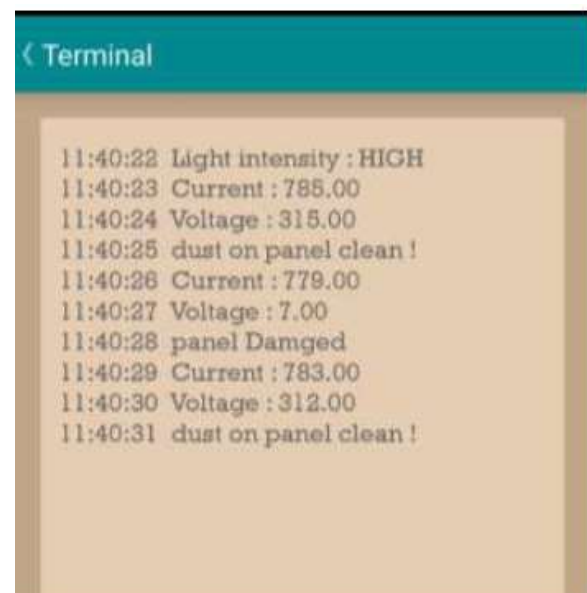


Fig.4: Final output Showing on serial Bluetooth terminal

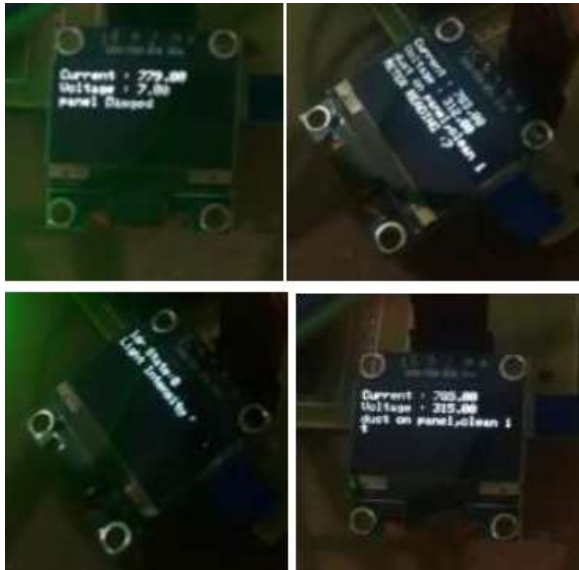


Fig.5: and also showing on OLED display

## 8. CONCLUSION

Implementing embedded data acquisition technologies is one recommended way of reducing system hardware failures. Because of frequent power fluctuations it is important to use realtime telemetry and monitoring it. Monitoring guides the user in analysis of precise electrical usage. This DAQ system is cost effective. The data transmission rate is about 95%. This enables the efficient use of local diagnostics. Thus it is reducing the undetected issues. This project can be further enhanced, by using the results of this current project, i.e. the monitoring values obtained are helpful in predicting the future values of the parameters considered. The data logged via Bluetooth can also be analyzed using the MatLab. The CSV file from the serial is taken for analysis in R. The web application can be

developed for interaction with the end user; the user can also predict faults of the future events. In the same way we can go for android application also. During the prediction two or more models can be used for same dataset, to find the accuracy of each model.

## REFERENCES

- 1.Purusothaman S.R.R. and Dhiwaakar et al., 2013. "Implementation of Anrduino-based multiagent system for rural Indian microgrids." IEEE Innovative Smart Grid Technologies- Asia (ISGT Asia). IEEE, 2013.
- 2.Kabalci, Ersan, Gorgun A. and Kabalci Y., 2013. "Design and implementation of a renewable energy monitoring system." Power Engineering, Energy and Electrical Drives (POWERENG), Fourth International Conference on. IEEE, 2013.
- 3.Jiju K. et. al., 2014. "Development of Android based on-line monitoring and control system for Renewable Energy Sources." Computer, Communications, and Control Technology (I4CT), International Conference on. IEEE, 2014.
- 4.Yoshihiro G. et. al., 2007. "Integrated management and remote monitoring system for telecommunications power plants with fully DC-powered center equipment." INTELEC 07- 29th

International Telecommunications Energy  
Conference. IEEE, 2007.

5. Alexander S. and Galkin I., 2013. "Case  
study on using non-intrusive load  
monitoring system with renewable energy  
sources in intelligent grid applications."  
International Conference/Workshop  
Compatibility And Power Electronics.

6. Mayamiko N., Zennaro M. and Bagula  
A., 2011. "SM 2: Solar monitoring system  
in Malawi." Kaleidoscope: The Fully  
Networked Human?-Innovations for  
Future Networks and Services (K-2011),  
Proceedings of ITU. IEEE, 2011.