International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 12 Issue: 02 | Feb 2025 www.irjet.net p-ISSN: 2395-0072

SMART BATTERY TEMPERATURE MANAGEMENT SYSTEM WITH ALERT SYSTEM USING IOT

Miss. Mrunali H. Bansode[1], Prof. Mallad H. Mallikarjun [2], Prof. Patil V. Jagannath [3]

[1]Research Scholar at Fabtech Technical Campus, College of Engineering and Research, Sangola, Maharashtra, India.
[2]H.O.D. & Assistant Professor Electrical Dept., Fabtech Technical Campus, College of Engineering and Research, Sangola, Maharashtra, India.
[3]Assistant Professor Electrical Dept., Fabtech Technical Campus, College of Engineering and Research, Sangola, Maharashtra, India.

Abstract - *In this study, the increasing use of lithium-ion batteries in various applications demands efficient thermal management to ensure safety and longevity. This project introduces an IoT-based battery temperature management system utilizing an ESP32 microcontroller to monitor and regulate temperature. A temperature sensor detects overheating, triggering a water-cooled mechanism via a relay-controlled pump to dissipate heat effectively. Additionally, a voltage sensor provides insights into battery health, while a smoke sensor detects potential hazards. Real-time data is transmitted to the Blynk IoT platform, enabling remote monitoring and instant alerts. This system enhances battery safety, efficiency, and lifespan, making it ideal for applications like consumer electronics and electric vehicles.*

Key Words: Battery Management System (BMS), IoT-based Monitoring, Lithium-ion Battery Safety, Thermal Management, Real-time Temperature Monitoring, Energy Storage Safety, Blynk App.

1. INTRODUCTION

Lithium-ion batteries are essential in modern technology, powering everything from smartphones and laptops to electric vehicles and medical devices. Their high energy density, lightweight design, and rechargeability make them ideal for various applications. However, extreme temperatures can significantly impact their efficiency, lifespan, and safety. Cold temperatures reduce power output, while excessive heat accelerates battery degradation. In severe cases, overheating can lead to thermal runaway, a dangerous condition where the battery's temperature rises uncontrollably, potentially causing fire hazards due to the release of flammable electrolytes. To mitigate these risks, an IoT-based battery temperature management system provides an intelligent solution. This system, built around the ESP32 microcontroller, continuously monitors battery temperature using sensors and takes proactive cooling measures when necessary. If the battery overheats, the system activates a water-cooled mechanism that efficiently dissipates excess heat. Additionally, real-time data on temperature and voltage is transmitted to a cloud-based platform like Blynk IoT, allowing users to remotely track battery health through a mobile app. In case of extreme overheating or potential hazards like smoke detection, instant alerts are sent to users, enabling prompt action. By integrating real-time monitoring, automated cooling, and remote alerts, this smart battery management system enhances both the safety and lifespan of lithium-ion batteries. This innovation is especially valuable in electric vehicles, renewable energy storage, industrial applications, and consumer electronics, ensuring optimal battery performance and reducing risks associated with overheating.

1.1 Aim & Objective

to develop a robust IoT-based system using an ESP32 microcontroller and a closed-loop water cooling mechanism to monitor and regulate the temperature of a battery pack, ensuring optimal performance, longevity, and real-time remote monitoring via the Blynk IoT platform.

1. Continuously monitor battery temperature using a high-accuracy temperature sensor.
2. Display temperature and voltage readings on a user-friendly Blynk app interface.
3. Employ a water-cooling system, activated by a relay-controlled water pump, to maintain optimal battery temperature.
4. Trigger alerts via the Blynk app if the battery temperature exceeds a predefined threshold, indicating potential overheating.
5. Optionally, integrate a smoke sensor to provide an additional layer of safety by sending alerts in case of smoke detection, potentially signifying a battery thermal runaway event.
6. Utilize a lithium-ion battery for its inherent safety characteristics, long lifespan, and thermal stability.

2. Literature Review

The literature review highlights the critical role of IoT-based Battery Management Systems (BMS) in enhancing the safety, efficiency, and lifespan of lithium-ion batteries, particularly in

electric vehicles (EVs) and energy storage systems. Studies emphasize real-time monitoring of key parameters like temperature, voltage, and state of charge (SoC) using platforms like Blynk and MQTT, enabling remote accessibility and automation. Various cooling techniques, including water-cooling systems, have been explored to prevent overheating and degradation. Additionally, balancing mechanisms and safety features such as fire and smoke detection further improve battery reliability. The integration of ESP32, Arduino, and Raspberry Pi enhances decision-making, making IoT-enabled BMS solutions crucial for optimizing battery performance and longevity.

Contributions of researchers are presented as follows,

Rohan Nandi, Abhishek Verma, Kunal Dr. H.P Singh (2023) [1] The study examined a Battery Management System (BMS) for an electric bike and explored ways to improve its quality and reliability. It focused on understanding the battery management system, its applications, and incorporating new safety and cooling features to enhance its robustness and dependability.

Samyak Nagrale, Ankit Waghmare, Tanmay Sahare, Achal Nagwanshi, Ishika Sakhale, Dr. Jyoti Sathe (2023) [2] The case study examined the growth of electric vehicles in recent years due to their zero emissions of harmful gases and efficient energy usage. However, the performance of an electric vehicle depends on its Battery Management System (BMS). The goal of this paper is to design an Arduino-based BMS to monitor and control the charging and discharging processes of the battery. The BMS tracks the state of charge, temperature, and voltage of each cell in the battery pack. It utilizes various sensors and indicators to provide information about battery life and performance. The proposed BMS can enhance the performance and lifespan of the battery pack, making electric vehicles a more reliable and efficient mode of transportation.

Akanksha Chouhan, Akshay Deshmukh, Sandesh Somware, Ujjain Jori(2021) [3] The case study designed a smart building automation system using Arduino and Arduino software for programming. The system supports various sensors and their functionalities while maintaining a practical and cost-effective configuration. The design and implementation of a Building Management System (BMS) contribute to the development of various green projects, utilizing advanced technology to create a superior living and working space. This system helps reduce human effort by automating key functions. The key features of our project include gate opening and closing via an RFID module, common area lighting control, door operation using a keypad, and fire detection with alerts sent to the main system. All hardware sensors and Arduino components are integrated into an optimized demonstration model to test the system and present its functionality in real time. With this model, the smart BMS environment is effectively visualized, making its functions easy to understand. The BMS is a reliable circuit that automates and controls various integrated systems, enhancing efficiency and convenience.

Ashutosh Patel, Shriparno Dey, Akshat Ashish Choudhury, Harris B. Mathews [4] the case study examined the use of Li-ion batteries in electric vehicles and energy storage due to their low self-discharge rate, long cycle life, high energy density, and wide operating temperature range. To ensure safety and proper management of Li-ion battery packs, a Battery Management System (BMS) is required. The balancing process is crucial for maintaining battery lifespan and protecting battery cells in a series connection. Passive balancing is commonly used in BMS due to its cost-effectiveness and simplicity. It utilizes passive components such as resistors or diodes to discharge excess charge from the battery. A BMS is designed using hardware components such as resistors, diodes, transistors, and LEDs. In this study, a MOSFET is used for switching voltage to balance the cells, while a diode and resistor help discharge the battery. The experimental platform includes functionalities such as voltage and current measurements, State of Charge (SOC) calculation, cell balancing, and battery charging.

Muhammad Mansab Uzair,Salah Yacoub Al-Kafrawi,Karam Manaf Al-Janadi,Ibrahim Abdulrahman Al-Bulushi [5] The case study designed an Internet of Things (IoT)-based Building Management System (BMS) for monitoring, control, and energy management in buildings, aiming to optimize energy utilization efficiently. Existing systems primarily focus on monitoring various parameters but offer limited control and automation functions. Additionally, they lack automatic decision-making, advanced safety management, and resource tracking capabilities. In contrast, the proposed system provides a comprehensive solution for monitoring, controlling, and making automatic decisions regarding various environmental and electrical parameters in buildings—such as temperature, humidity, dust levels, and voltage—using a low-cost wireless sensor network (WSN). The architecture of the proposed system consists of five layers and incorporates analog sensors connected to Arduino Mega 2560 microcontrollers for data collection, NodeMCU ESP8266 modules for wireless communication, and Raspberry Pi 4 microcomputers for decision-making. It also features a Node-RED dashboard, running locally on the Raspberry Pi 4, to provide a user-friendly interface. Furthermore, the system employs the Message Queuing Telemetry Transport (MQTT) communication protocol over Wi-Fi, relying entirely on local devices within the architecture, eliminating the need for cloud computing services. The proposed system supports two different types of automation, enhancing both efficiency and reliability in building management.

Khaligh, S. Mishra, and L. Xu (2021) [6] The case study examined an IoT-based Battery Management System (BMS) for electric vehicles (EVs). It highlights the importance of monitoring temperature, voltage, and current to ensure optimal battery performance and safety.

S. S. Patil, S. S. Bhongale, V. V. Wankhede, and P. P. Patil (2017) [7] The case study examined an IoT-based Battery Management System (BMS) that monitors battery voltage, current, temperature, and state of health (SoH). It emphasizes the role of IoT in enhancing battery safety and extending its lifespan.

M. S. Hashmi, S. R. Bhat, and M. A. Rashid (2019) [8] The case study developed an IoT-based battery monitoring system for EVs, focusing on key parameters such as voltage, current, and temperature. It highlights the system's user-friendliness and the enhanced remote data accessibility enabled by IoT.

A. A. Neha, R. P. Saini (2021) [9] The case study examined various thermal management techniques for lithium-ion batteries, including phase change materials, heat pipes, and liquid cooling. It emphasizes the importance of maintaining optimal battery temperatures to prevent degradation and ensure safety.

H. Yang, Y. Jia (2020) [10] The case study examined an IoT-based Battery Management System (BMS) designed for electric vehicles, featuring real-time monitoring of battery parameters such as temperature, voltage, and current. The system utilizes ESP32 microcontrollers and Blynk for remote data access and control.

M. G. Prakash, S. Venkatesan (2021) [11] The case study designed a smart battery management system using IoT technologies, incorporating sensors for temperature and voltage monitoring. It employs a water-cooling mechanism activated by a relay and controlled via an IoT platform.

R. K. Singh, P. Kumar [12] The case study explored the integration of IoT in the thermal management of lithium-ion batteries, utilizing various sensors and a cooling system controlled by a microcontroller. It focuses on improving battery safety and performance through real-time monitoring.

3. Problem Statement

Lithium-ion batteries, while offering high energy density, are susceptible to performance degradation and safety hazards at extreme temperatures. When a battery overheats, it can lead to:

- **Reduced Capacity and Lifespan:** High temperatures accelerate chemical reactions within the battery, causing faster capacity loss and shortening its overall life.
- **Thermal Runaway:** In extreme cases, overheating can trigger a chain reaction where the battery releases heat, further increasing its internal temperature, potentially leading to a fire or explosion.
- **Safety Concerns:** Overheated batteries pose a significant safety risk, especially in applications where they are used in close proximity to people and property

3.2 Gap Identification :

Below are few gaps we found in existing system

Automatic Pump Flow Regulation:

- Implement pulse-width modulation (PWM) to control the water pump's speed, adjusting cooling based on temperature variations.

Data Logging and Prediction:

- Store historical temperature data in the cloud platform or local storage for analysis.
- Utilize machine learning to predict potential battery overheats and initiate preventive actions.

Battery Health Monitoring:

- Track voltage and temperature trends to estimate battery health over time.
- Implement algorithms to identify potential battery degradation and suggest maintenance or replacement.

Security:

Use secure authentication and encryption mechanisms for communication between the ESP32, cloud platform and Blynk app.

4. METHODOLOGY

4.1 Hardware Assembly:

- Connect the temperature sensor to an analog input pin of the ESP32
- Build a voltage divider circuit or use a dedicated voltage sensor to measure battery voltage and connect it to another analog input pin
- Interface the water pump driver with a GPIO pin of the ESP32 to manage the pump's operation. Connect the pump driver's output to the pump's power supply.
- (Optional) Connect the smoke sensor to a digital input pin for smoke detection.
- Securely mount the temperature sensor near the battery to accurately capture its thermal state. Consider thermal paste for optimal contact.

- **Crucially, ensure proper water circulation around the battery by creating a closed-loop cooling system:**
    - Use tubing suitable for the water flow rate and temperature range.
    - Design inlets and outlets for efficient water flow.
    - Consider a reservoir for the water to prevent constant refilling.
    - Power the ESP32 using a suitable power supply.

4.2 Software Development :-

- **ESP32 IDE Setup:**

Install the Arduino IDE (https://www.arduino.cc/en/software) and add the ESP32 board package following the official guide (https://docs.espressif.com/projects/esp-idf/en/stable/esp32/get-started/index.html).

- **Blynk Library Integration:**

Include the Blynk library in your Arduino project and configure your Blynk account with a unique authentication token.

- **Sensor Reading and Calibration:**

Read temperature and voltage sensor values using relevant functions (e.g., analogRead()). Apply calibration factors if needed for accurate readings.

- **Water Pump Control Algorithm:**

Implement a control logic based on temperature readings. For example:

- If temperature < safe threshold (e.g., 35°C): Turn off pump.
- If temperature > safe threshold and < critical threshold (e.g., 40°C): Turn on pump at a lower duty cycle (e.g., 50%) for partial cooling.
- If temperature > critical threshold (e.g., 45°C): Turn on pump at full duty cycle (100%) for maximum cooling.
- Consider hysteresis to prevent rapid on/off switching of the pump:
- Define a lower threshold (e.g., 33°C) to turn the pump off after cooling.

- **Smoke Detection and Alerting:**

(Optional) If smoke is detected, send an immediate alert notification to the Blynk app.

- **Data Visualization on Blynk App:**
    - Create virtual gauges or charts in the Blynk app to display battery temperature and voltage readings in real-time.
    - Implement visual or audible alerts for overheating and smoke detection.

1. **Blynk App Configuration:**
    - Create a new project in the Blynk app and enter your authentication token from the ESP32 code.
    - Add appropriate widgets (gauges, charts, buttons, notifications) to visualize sensor data and control actions.
2. **Testing and Deployment:**
    - Thoroughly test the system by simulating different temperature scenarios and verifying pump activation/deactivation, sensor readings, and Blynk app functionality.
    - Ensure system safety by double-checking connections and water flow.
    - Once satisfied, deploy the system in.

4.3 Working Principle :

1. **Sensor Data Acquisition:** The ESP32 periodically reads data from the temperature and voltage sensors.
2. **Temperature Control Logic:** The ESP32 implements a control algorithm to determine if the battery temperature exceeds a pre-defined threshold (e.g., 45°C).
3. **Water Pump Control:** If the temperature is above the threshold:
    - The ESP32 activates the relay, turning on the water pump.
    - The water pump circulates coolant through the tubes, drawing heat away from the battery.
4. **Overheating Alert:** If the temperature reaches a critical level (e.g., 55°C):
    - The ESP32 sends an immediate alert notification to the Blynk app, indicating potential thermal runaway.
    - (Optional) The ESP32 can also trigger an audible alarm or shut down the system for safety.
5. **Blynk App Interface:** The Blynk app displays real-time data:
    - Battery temperature
    - Battery voltage
    - Alert notifications (if triggered)
    - Optionally, the app can allow manual control of the water pump for user intervention

4.4 Block Diagram :

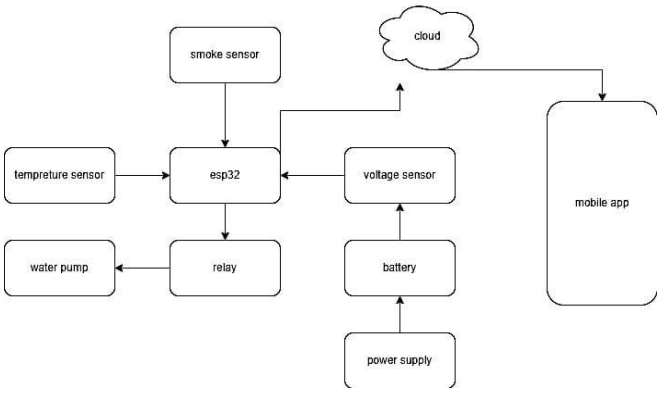

Figure 4.1: Block Diagram of Proposed System

4.5 Technical Specifications:

1. **ESP32 Microcontroller**
   - **Description**: A powerful microcontroller with built-in Wi-Fi and Bluetooth.
   - **Specification**:
     - Dual-core 32-bit CPU
     - 2.4 GHz Wi-Fi
     - Bluetooth 4.2
     - Operating Voltage: 3.3V
2. **DS18B20 Temperature Sensor**
   - **Description**: A digital temperature sensor used to monitor the battery temperature.
   - **Specification**:
     - Temperature Range: -55°C to +125°C
     - Accuracy: ±0.5°C
     - Operating Voltage: 3.0V to 5.5V
3. **Voltage Sensor (e.g., Voltage Divider Circuit)**
   - **Description**: A simple voltage divider to measure the battery voltage.
   - **Specification**:
     - Input Voltage: Up to 25V
     - Output Voltage: 0-3.3V (to match ESP32 ADC input)
4. **Water Pump**
   - **Description**: A small submersible water pump to circulate water around the battery.
   - **Specification**:
     - Operating Voltage: 5V or 12V
     - Flow Rate: Variable (e.g., 240 L/H for a small pump)
5. **Relay Module**
   - **Description**: Used to control the water pump.
   - **Specification**:
     - Operating Voltage: 3.3V or 5V (depending on the module)
     - Current Rating: 10A at 250V AC or 10A at 30V DC
6. **MQ-2 Smoke Sensor**
   - **Description**: A sensor to detect smoke or gases that may indicate overheating or combustion.
   - **Specification**:
     - Detection Range: LPG, Smoke, Alcohol, Propane, Hydrogen, Methane, CO
     - Operating Voltage: 5V
7. **Lithium-Ion Battery**
   - **Description**: The battery being monitored and managed.
   - **Specification**:
     - Voltage: 3.7V to 4.2V (typical for a single cell)
     - Capacity: Varies (e.g., 2000mAh to 4000mAh)
8. **Water Tubing**
   - **Description**: Tubes to circulate water around the battery for cooling.
   - **Specification**:
     - Material: Silicone or PVC
     - Diameter: Suitable for the water pump's flow rate
9. **Blynk App**
   - **Description**: An IoT platform for real-time monitoring and alerts.
   - **Specification**:
     - Compatible with iOS and Android
     - Requires Blynk Library for ESP32.

5. RESULTS

5.1 Enhanced Battery Life:

By maintaining optimal temperature, the battery's lifespan and performance are extended. This is because high temperatures can accelerate degradation processes within the battery cells, leading to reduced capacity and increased risk of failure. By preventing excessive heat buildup, the system helps to preserve the battery's health and prolong its service life.

5.2 Improved Safety:

Early detection of overheating or fire hazards prevents potential accidents. The system's continuous monitoring and alert capabilities enable prompt intervention in case of abnormal conditions. This reduces the risk of thermal runaway, a dangerous condition that can lead to fires and explosions.

5.3 Remote Monitoring:

Real-time data and alerts enable proactive maintenance and troubleshooting. By remotely monitoring the battery's temperature and voltage, users can identify potential issues early on and take corrective actions. This minimizes downtime and reduces the likelihood of unexpected failures.

5.4 Cost-Effective Solution:

The system provides a cost-effective way to manage battery temperature and ensure safety. Compared to traditional cooling methods, the water-based cooling system is relatively inexpensive to implement and maintain. Additionally, the IoT-based monitoring and control capabilities allow for efficient resource utilization and minimize energy consumption

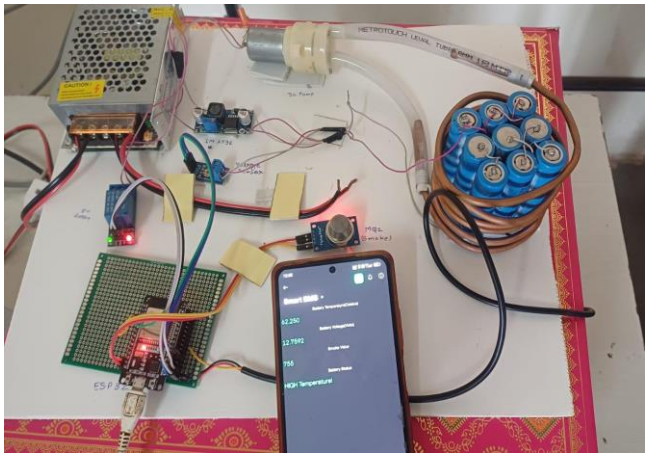

Figure 5.1: Working Model

6. CONCLUSIONS

An IoT-based battery temperature management system employing an ESP32 and Blynk offers a proactive and efficient solution for maintaining optimal battery health and safety. This system provides real-time monitoring, automated cooling control, and timely alerts, making it a valuable tool for applications that rely on lithium-ion batteries. By keeping battery temperatures within a safe range, this system can significantly extend battery lifespan, reduce maintenance costs, and enhance the overall reliability and safety of battery-powered systems.

The ability to remotely monitor and control the system through the Blynk app allows for greater user convenience and facilitates preventative maintenance strategies. For instance, users can receive alerts when battery temperatures start to rise outside of normal operating ranges, enabling them to take corrective actions before a critical thermal event occurs. Additionally, the system's data logging capabilities can provide valuable insights into battery health trends over time, allowing for proactive maintenance scheduling and battery replacement planning.

Furthermore, the scalability of this IoT-based system makes it suitable for a wide range of applications. By adjusting the number and configuration of temperature sensors, water pump capacity, and cooling loops, the system can be adapted to accommodate battery packs of various sizes and power requirements. This flexibility makes it ideal for applications ranging from portable electronics and electric vehicles to large-scale energy storage systems in renewable energy installations and grid balancing operations.

REFERENCES

[1] Rohan Nandi, Abhishek Verma, Kunal Dr. H.P Singh "Design of Battery Management System (Bms) Of An Electric Bike" Volume:05,Issue:04,April-2023.

[2] Samyak Nagrale, Ankit Waghmare, Tanmay Sahare , Achal Nagwanshi , Ishika Sakhale , Dr. Jyoti Sathe "Arduino Based Battery Management System For Electric Vehicles" Vol-9 Issue-2 2023.

[3] Akanksha Chouhan, Akshay Deshmukh, Sandesh Somware, Ujjain Jori "IoT based Smart Building Management System using Arduino" Volume: 08 Issue: 04 | Apr 2021 www.irjet.net.

[4] Ashutosh Patel , Shriparno Dey , Akshat Ashish Choudhury , Harris B. Mathews "Battery Management System using Passive Elements and Arduino" International Journal of Science and Research (IJSR) ISSN: 2319-7064 SJIF (2019): 7.583.

[5] Muhammad Mansab Uzair, Salah Yacoub Al-Kafrawi, Karam Manaf Al-Janadi, Ibrahim Abdulrahman Al-Bulushi "A Low-Cost IoT Based Buildings Management System (BMS) Using Arduino Mega 2560 And Raspberry Pi 4 For Smart Monitoring and Automation".

[6] M. Naguib, P. Kollmeyer, and A. Emadi, "Lithium-ion battery pack robust state of charge estimation, cell inconsistency, and balancing: Review," IEEE Access, vol. 9, pp. 50 570–50 582, 2021.

[7] K. Rumpf, M. Naumann, and A. Jossen, " Experimental investigation of parametric cell-to-cell variation and correlation based on 1100 commercial lithium-ion cells," J. Energy Storage, vol. 14, pp. 224–243, 2017.

[8] A. Farjah and T. Ghanbari, "Early ageing detection of battery cells in battery management system," Electron. Lett., vol. 56, no. 12, pp. 616–619, 2020. [Online]. Available: https://ietresearch.onlinelibrary.wiley.com/doi/abs/10.1049/el.2019.3944.

[9] A. A. Neha, R. P. Saini, "Thermal management of lithium-ion batteries: A review," Renewable and Sustainable Energy Reviews, 2021.

[10] H. Yang, Y. Jia, "IoT-based Battery Management System for Electric Vehicles," IEEE Access, 2020.

[11] M. G. Prakash, S. Venkatesan, "An IoT-enabled Smart Battery Management System for Electric Vehicles," Journal of Power Sources, 2021.

[12] R. K. Singh, P. Kumar, "IoT-enabled Thermal Management of Lithium-ion Batteries," International Journal of Energy Research, 2023.

BIOGRAPHIES

Miss. Mrunali H. Bansode

B.E. (Electrical), M.Tech (Electrical Engineering)(Pursuing) Research Scholar at Fabtech Technical Campus, College of Engineering and Research, Sangola, Maharashtra, India and Faculty of N. B. Navale Sinhgad College of Engineering, Solapur, Maharashtra, India.

Prof. Mallad H. Mallikarjun

Working as Head of Department & Assistant Professor Electrical Engineering, Fabtech Technical Campus, College of Engineering and Research, Sangola, Maharashtra, India. Having experience of more than 15 years in teaching .

Prof. Patil V. Jagannath

Working as Assistant Professor in Electrical Engineering, Fabtech Technical Campus, College of Engineering and Research, Sangola, Maharashtra, India. Having experience of more than 15 years in teaching.