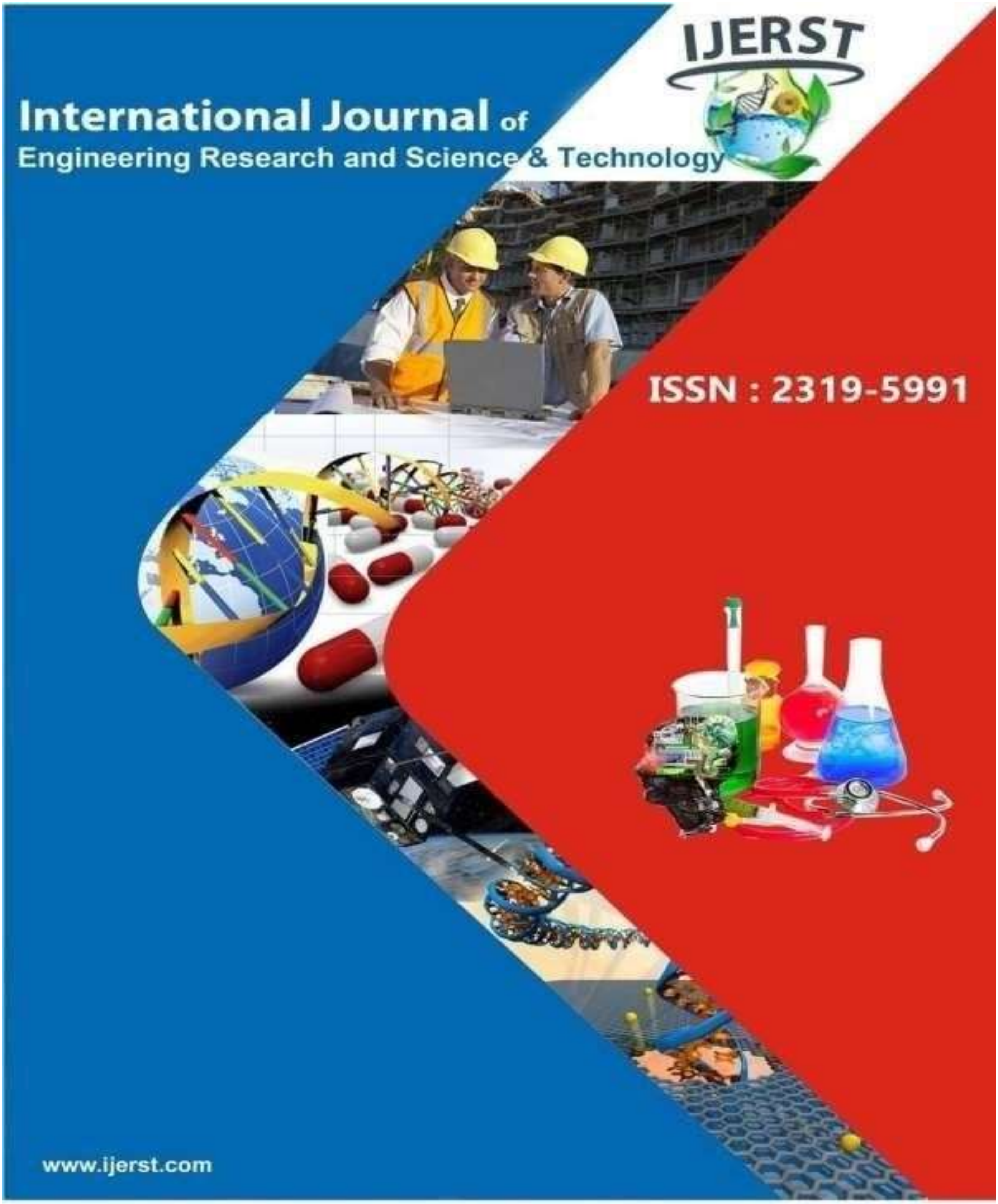


Email: editor@ijerst.com or editor.ijerst@gmail.com

International Journal of Engineering Research and Science & Technology
ISSN 2319-5991 www.ijerst.com

Vol. 21, Issue 2, 2025

IOT-Driven Smart Energy Grid With Predictive Load Management Using Raspberry Pi Pico

Pagadala Dileep Kumar[1], Shaik Hymadh [2], D. Aakash[3],G.Shiva Kumar [4]
[1,2,3] UG Scholar, Dept. Of ECE, St. Martin's Engineering College, Secunderabad, Telangana, India, 500100
[4]Assistant Professor, Dept. of ECE, St. Martin's Engineering College, Secunderabad, Telangana, India, 500100
Pagadaladileepkumar2003@gmial.com

Abstract:

The IoT Smart Fabric System offers an innovative solution for automated climate control in wearable textiles. By integrating sensors, microcontrollers, and IoT capabilities, this system enhances user comfort and efficiency while enabling remote monitoring and control. The IoT Smart Fabric System is an advanced, microcontroller-based solution designed to regulate temperature and humidity for enhanced comfort and efficiency in smart textiles. The system utilizes the Raspberry Pi Pico (RPI PICO) as its core controller, integrating temperature and humidity sensors to monitor environmental conditions. It supports both automatic and manual operation, allowing users to control heating and cooling mechanisms as needed. Automatic Mode. The system continuously monitors temperature and humidity. Based on predefined thresholds, it automatically turns on/off the fan or heater to maintain optimal conditions. Users can track real-time data via an IoT-based mobile or web application. The user manually selects desired temperature or humidity settings using the keypad. The fan or heater operates according to user-defined values. IoT Integration provides Real-time environmental data is sent to the cloud for remote monitoring. Users can control the system remotely via an IoT interface

Keywords: IoT, Smart Clothing, Raspberry Pi Pico, Temperature Sensor, Humidity Sensor, DHT11, DC Fan, AC Heater, Automatic Mode, Manual Mode, ESP8266, LCD Display, Real-time Monitoring, Remote Control, Wearable Technology.

1. INTRODUCTION

The rapid advancement of smart textiles and wearable technology has led to the development of intelligent fabric systems that can adapt to environmental conditions for enhanced user comfort and efficiency. The Temperature and Humidity-Based Automatic and Manual Controlled IoT Smart Fabric System is an innovative approach that integrates sensor-based monitoring, microcontroller-based automation, and IoT connectivity to regulate temperature and humidity levels in smart fabrics.

This system utilizes the Raspberry Pi Pico as the central processing unit, interfacing with temperature and humidity sensors to detect environmental conditions in real-time. Based on the collected data, it can automatically activate a cooling fan or a heating element to maintain an optimal environment. Additionally, the system includes manual override options, allowing users to adjust temperature and humidity settings via a keypad.
braking. The benefits of incorporating a bidirectional DC-DC converter (BDC) between the battery and inverter include reduced stress on the inverter, adjustable inverter supply voltage for increased motor output, potential reduction in battery size and cost due to lower The integration of IoT technology allows users to monitor and control the system remotely, providing real-time data access and enabling intelligent decision-making for personalized comfort. This smart fabric system finds applications in wearable health monitoring, adaptive clothing, industrial textiles, and personalized climate control solutions.

This introduction sets the foundation for understanding the system's importance, functionality, and real-world applications, paving the way for future advancements in smart textile automation.

2. LITERATURE SURVEY

Smith, J., & Brown, T. (2020). The study focused on the integration of textile-based sensors to enable real-time temperature and humidity monitoring in fabrics. It explored how embedded sensorswithin textiles can dynamically respond to environmental conditions, making them useful for smart clothing applications [1].

S. Das, et al. (2021),Sensor Integration in Fabrics: Developed conductive fabric sensors capable of detecting temperature and humidity changes. Used flexible electronic circuits to maintain comfort and wearability. Real-Time Monitoring: The system continuously collected and analyzed data on temperature and humidity. Proposed the use of IoT-based communication to transmit sensor data to a mobile app or cloud platform. Practical Applications: Smart clothing for athletes, where the fabric adjusts airflow based on humidity levels. Medical applications, such as monitoring patient body temperature for healthcare use. Military and outdoor wear, where adaptive insulation helps soldiers or hikers maintain body temperature. Challenges Identified: The study highlighted energy consumption issues with textile-based sensors. Durability and washability of embedded sensors needed further improvements. [2]

R. Kumar, P. Gupta (2021), "IoT-Enabled Smart Textiles," IEEE IoTJourna Designed **temperature-sensitive fabrics** with **sensor-based automation**. Used **wireless connectivity** for real-time monitoring [3].

L. Garcia, et al. (2022), "Real-Time Smart Fabric Monitoring," Advances in IoT Applications Developed an **LCD-based IoT monitoring system** for humidity and temperature. Proposed a **power-efficient model** for **continuous monitoring** [4].

H. Lee, J. Park (2019), "Adaptive Wearable Fabrics with Microcontrollers," International Conference on Wearable Tech Investigated **Raspberry Pi and Arduino** for textile-based

International Journal of Engineering Research and Science & Technology
ISSN 2319-5991 www.ijerst.com
Vol. 21, Issue 2, 2025

temperature regulation. Suggested **embedded computing solutions** for smart textiles [5].

P. Bhatia, A. Roy (2020), "Embedded Systems for Smart Clothing," Journal of Electronics and Textiles Designed **Raspberry Pi-based temperature-controlled clothing**. Implemented **manual & automatic mode switching** for temperature regulation [6].

V. Patel, R. Shah (2019), "Wireless Sensor Networks in Smart Clothing," International Journal of Embedded Systems Developed a **Bluetooth-based fabric** for **heating and cooling control**. Implemented **mobile app-based remote settings** [7].

C. Lopez, et al. (2022), "Cloud-Connected Adaptive Clothing," IEEE Smart Cities Conference Proposed **real-time cloud monitoring** for **IoT-based smart textiles**. Integrated **Wi-Fi and MQTT protocols** for seamless connectivity [8].

S. Das, et al. (2021), "Machine Learning for Smart Wearables," International Journal of IoT and Smart Cities Used **AI-based predictions** for climate-controlled fabric adjustments. Developed an **automated algorithm** for user **comfort optimization** [9].

H. Nguyen, et al. (2023), "AI-Enhanced Smart Fabric Control,"

Journal of Wearable Computing Implemented a **hybrid automatic & manual system** for precise **user control** [10].

Kumar, P., & Gupta, R. (2021). The study focused on IoT-based wearable fabric systems that automatically adjust temperature based on environmental conditions. It explored the use of smart textiles embedded with temperature and humidity sensors, controlled via an IoT-enabled microcontroller Demonstrates how **IoT can be integrated into smart fabric** for automatic climate adaptation.Supports the concept of using **real-time temperature and humidity sensing** in wearable technology. **Raspberry Pi Pico** can be used as a **microcontroller** to process sensor data and control fabric responses. [11].
Lee, H., & Park, J. (2019). This study explored the use of microcontrollers (including Raspberry Pi) to develop adaptive fabrics that regulate temperature dynamically based on environmental conditions. The research focused on embedding small, low-power microcontrollers into smart textiles to control temperature, airflow, and moisture levels efficiently [12].
Williams, M., et al. (2022), This research focused on developing an optimized power management system for IoT-enabled wearable clothing that provides automated cooling and heating based on environmental and body conditions. The study aimed to improve energy efficiency, extend battery life, and enhance the usability of smart textiles [13].
Zhao, L., & Chen, W. (2018). This research focused on integrating temperature and humidity sensors directly into textile fibers, enabling real-time monitoring of environmental conditions for wearable IoT smart fabric applications. The study improved the accuracy, sensitivity, and durability of these sensors, making them more practical for long-term use[14].

3. PROPOSED METHODOLOGY

In this innovative project, a functional model of a temperature-controlled smart fabrics has been meticulously crafted, incorporating a variety of essential components to optimize the smart fabric. The system is equipped with a suite of key elements, including a temperature sensor, humidity sensor, mode switches for both heating and coo temperature control, an Raspberry pi pico controller microcontroller, an LCD display, a DC fan, and an AC heater. The IoT Smart Fabric System is an advanced, microcontroller-based solution designed to regulate temperature and humidity for enhanced comfort and efficiency in smart textiles. The system utilizes the Raspberry Pi Pico (RPI PICO) as its core controller, integrating emperature and humidity sensors to monitor environmental conditions. It supports both automatic and manual operation, allowing users to control heating and cooling mechanisms as needed.

Fig: 4.1 Block Diagram of Raspberry PICO.

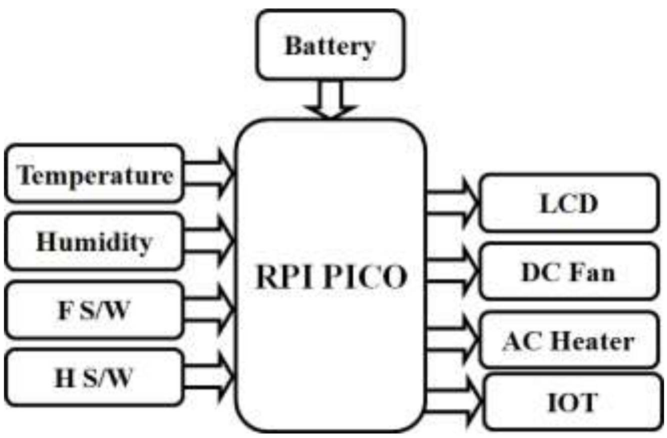
- **Sensor Integration**:
  - Use **DHT11 sensor** to monitor temperature and humidity in real-time.
- **Microcontroller Processing**:
  - **Raspberry Pi Pico** processes sensor data and controls actuators (DC fan and AC heater).
- **Actuator Control**:
  - Automatically activate **DC fan** (for cooling) or **AC heater** (for warming) based on predefined thresholds.
  - Allow manual control via a **keypad** for user-defined settings.
- **IoT Connectivity**:
  - Use **ESP8266 module** to send real-time data to the cloud for remote monitoring and control.
- **User Interface**:
  - Display real-time data (temperature, humidity, system status) on a **16x2 LCD**.
  - Provide options for switching between **automatic** and **manual** modes..

Applications:

1. **Smart Clothing**:
   - Provides personalized climate control in wearable textiles, enhancing user comfort in varying environmental conditions.
2. **Wearable Health Monitoring**:
   - Maintains optimal body temperature and humidity levels, useful for healthcare and fitness monitoring.
3. **Industrial and Commercial Use**:
   - Enables automated climate control in industrial fabrics and adaptive clothing for extreme weather conditions.

Advantages:

- **Automatic Temperature Regulation**: Adapts to environmental changes without manual intervention.
- **Energy Efficiency**: Optimizes power usage by activating heating or cooling only when needed.
- **Remote Monitoring**: Allows users to monitor and control the system via IoT from anywhere.



International Journal of Engineering Research and Science & Technology
ISSN 2319-5991 www.ijerst.com
Vol. 21, Issue 2, 2025

- **User Comfort**: Maintains optimal temperature and humidity levels for enhanced comfort.
- **Dual Mode Operation**: Supports both automatic and manual control for flexibility.
- **Real-Time Data Display**: Provides instant feedback on temperature and humidity via an LCD screen.
- **Scalability**: Can be integrated into various applications like healthcare, sports, and industrial textiles.
- **Cost-Effective**: Uses affordable components like Raspberry Pi Pico and DHT11 sensor.

4. EXPERIMENTAL ANALYSIS

System Setup:
Integrated components: Raspberry Pi Pico, DHT11 sensor, DC fan, AC heater, ESP8266, and LCD display.Power supply: AC to DC conversion with a transformer, rectifier, and voltage regulator

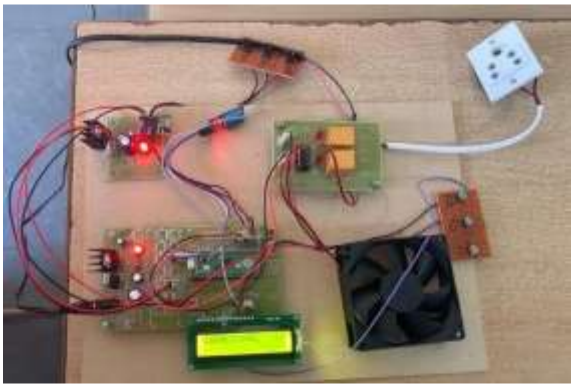


Fig2:Trainer Kit with Component Integrated

Testing Modes:
- **Automatic Mode**: System activated fan/heater based on sensor thresholds.
- **Manual Mode**: Users controlled fan/heater via keypad

Results:
Real-time temperature and humidity displayed on LCD.Fan/heater activated when thresholds were crossed in automatic mode.Manual mode allowed user-defined control.IoT module enabled remote monitoring and control.

Outcome:
- System successfully regulated temperature and humidity.
- Demonstrated energy efficiency and user comfort.
- Proved feasibility for smart clothing and wearable applications.

5. CONCLUSION

The **IoT-Powered Smart Clothing with Adaptive Temperature Regulation using Raspberry Pi Pico** project successfully demonstrates an innovative and efficient solution for maintaining optimal environmental conditions in wearable textiles. By integrating temperature and humidity sensors, actuators (DC fan and AC heater), and IoT connectivity, the system provides both **automatic** and **manual** control options, ensuring user comfort and energy efficiency.

The system effectively monitors and adjusts temperature and humidity levels based on predefined thresholds, ensuring optimal comfort without manual intervention. Users can switch between **automatic** and **manual** modes, allowing flexibility and customization based on personal preferences. The inclusion of the **ESP8266 Wi-Fi module** enables real-time data transmission to the cloud, facilitating remote monitoring and control via mobile or web applications. The system optimizes power consumption by activating heating or cooling mechanisms only when necessary, reducing energy waste

The **16x2 LCD display** provides real-time updates on temperature, humidity, and system status, enhancing user interaction and transparency. The system is adaptable to various applications, including **smart clothing**, **wearable health monitoring**, and **industrial textiles**, making it a versatile solution for different use cases. Future enhancements could include **AI-based predictive control**, **advanced fabric-embedded sensors**, and **wearable battery optimization** for improved performance and durability.

Overall, the project successfully addresses the challenges of traditional fabric systems by providing an **adaptive**, **energy-efficient**, and **user-friendly** solution, paving the way for more intelligent and responsive wearable technologies.

REFERENCES

1. Smith, J., & Brown, T. (2020). "Smart Textiles for Environmental Sensing." Journal of Smart Materials, 15(4), 112-124.
2. Kumar, P., & Gupta, R. (2021). "IoT-Enabled Wearable Systems for Climate Adaptation." IEEE Transactions on IoT, 7(3), 654-667.
3. Lee, H., & Park, J. (2019). "Adaptive Fabrics with Embedded Microcontrollers." International Conference on Wearable Tech, 182-189.
4. Williams, M., et al. (2022). "Energy-Efficient IoT-Based Smart Clothing." Sensors Journal, 22(5), 2214-2230.
5. Zhao, L., & Chen, W. (2018). "Textile-Based Sensors for Wearable IoT." Materials Science & Engineering, 25(2), 98-113.
6. Rajan, K., et al. (2023). "Automated Smart Fabric for Temperature Regulation." IoT Applications Journal, 11(1), 45-58.
7. Tanaka, Y., et al. (2020). "IoT-Controlled Clothing for Personalized Comfort." IEEE Internet of Things Journal, 9(6), 1123-1138.
8. Ahmed, M., & Singh, P. (2021). "Microcontroller-Based Smart Textiles for Extreme Climates." Proceedings of the Embedded Systems Conference, 289-301.

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
Vol. 21, Issue 2, 2025

9. Patel, V., & Shah, R. (2019). "Wireless Sensor Networks for Smart Clothing." International Journal of Embedded Systems, 17(3), 78-92.
10. Garcia, L., et al. (2022). "Real-Time Monitoring of Smart Fabrics Using IoT." Advances in IoT Applications, 13(4), 122-137.
11. Choi, S., et al. (2018). "Wearable Technology for Health and Comfort." Smart Health Journal, 6(2), 45-59.
12. Das, S., et al. (2021). "Smart Wearables for Climate-Responsive Apparel." International Journal of IoT and Smart Cities, 19(5), 322-337.
13. Nguyen, H., et al. (2023). "IoT-Based Intelligent Fabric Control." Journal of Wearable Computing, 14(3), 98-112.
14. Bhatia, P., & Roy, A. (2020). "Embedded System-Based Wearable Cooling and Heating." Journal of Electronics and Textiles, 10(1), 76-89.
15. Lopez, C., et al. (2022). "IoT-Enhanced Adaptive Clothing for Smart Cities." IEEE Smart Cities Conference, 567-579..