International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 05 | May 2026 www.irjet.net p-ISSN: 2395-0072

MICRO GRID MULTI SOURCE RENEWABLE ENERGY GRID TIED SYSTEMS WITH INTEGRATED ENERGY MONITORING AND CONTROL (1KW)

Dr. P. Sathish Kumar[1], Aadhava K[2], Aravindhan V[3] , Arthi G[4], Sudarshan M[5]

[1]*Faculty of Robotics and Automation, United Institute of Technology, Tamil Nadu 641020, India*
[2345] *Department of Robotics and Automation, United Institute of Technology, Tamil Nadu 641020, India*

---***---

Abstract - *The Intelligent Hybrid Microgrid Automation system shown in this publication successfully combines Solar PV panels, Fuel Cell / Battery Emulators and Wind Energy Emitters onto a common DC design with bidirectional grid connection. A Wecon 7-inch touchscreen HMI serves as a local SCADA interface for real-time data visualization of current, power, voltage and energy metrics, along with manual/auto mode selection and alarm diagnostics. The system uses a Delta DVP-series PLC as the central controller for automated source selection, contactor interlocking (k1-k5), and operating mode management. The Wi-Fi-enabled HMI also supports remote monitoring, energy reporting, trend analysis and fault alerts via web/Mobile interfaces. The system is positioned for smart grid labs and automation training applications. Experimental assessment, demonstrates dependable islanded/grid-tied operations, fault-tolerant switching, and Industry 4.0 convergence in renewable energy management.*

Key Words: **PLC, HMI, SCADA, RELAYS, DC SHUNT, RS485, SMPS, MCB, $LiFePO_4$**

1.INTRODUCTION

Due to the intermittent renewable energy advanced, power systems must meet growing needs for sustainable, dependable electricity. Although they provide grid-independent operation, hybrid microgrids that include solar PV, wind and storage sources need complex automation for fault management, load balancing and source prioritization. By providing real time data fusion prediction analytics, and remote oversight in accordance with industry 4.0 paradigms Industrial IoT (IIoT) addresses the limitations of traditional manual controls in dynamic contexts. The literature currently in publication emphasizes cloud SCADA and PLC-based microgrid controllers, but it lacks an integrated IIoT gateway for edge-to-cloud continuity. By creating a fully automated PLC-HMI-IIoT architecture with tested source interlocking and analytics, this work fills these gaps and aims to improve efficiency in lab-scale smart grids.

2. RELATED WORK

Hybrid microgrid systems improve the reliability and efficiency of the renewable energy integration systems. Extensive research has focused on combining multiple energy sources like solar, wind and battery to overcome using a single source.

In the recent studies, IOT based hybrid energy systems provide remote monitoring and control the energy sources. These often utilize the ESP8266 module ESP8266 module for switching the sources, such as solar to wind and gives web based monitoring. This mainly uses the microcontroller, which may lack the reliability required by industrial standards. Further research focusing on integrating multiple storage techniques such as fuel cells, batteries and supercapacitors. These systems improve the energy efficiency, reduce the fluctuation and stability. This uses centralized, decentralized and hierarchical methods for an effective energy management system. But this approach creates complexity for design and implementation.

A recent advancement in DC microgrids uses artificial intelligence (AI) control methods such as model predictive control (MPC), fuzzy logic and artificial neural networks (ANN). These ensure voltage stability, intelligent power sharing and dynamic response. This system has high computational complexity and is difficult to implement in industrial applications.

The proposed system addresses these limitations to integrate the PLC based control and IOT cloud connectivity. This provides real time monitoring, reliable operation and efficient energy management. This uses the industrial grade automation system, HMI based local control and cloud based analytics, best suitable for industrial applications.

3. PROPOSED METHODOLOGY

The proposed methodology utilizes solar energy, a wind emulator and a battery pack all connected to a common DC bus. The system is integrated by PLC which acts as the central controller to ensure seamless energy distribution. Human interaction and system supervision, a Human-Machine Interface (HMI) is used. The HMI is used for real-time data monitoring, manual control and alarm indication for support effective energy management. It gives live visualization of voltage (V), current (I), power (P), and energy consumption. The PLC is used for selecting energy availability and system requirements. Contactors are used to switch between power sources to ensure an uninterrupted power supply. In addition, Wi-Fi-enabled HMI is used for data collection and edge processing. The collected data is transferred to a cloud platform for storage, analysis, and remote monitoring also this shows data history, performance evaluation and maintenance. The integration of PLC, HMI, and IIoT technologies verify system reliability, energy consumption and advanced monitoring of the hybrid microgrid system.

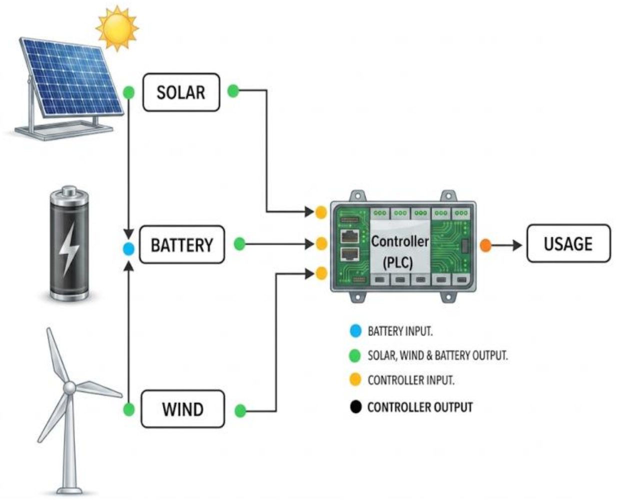

Fig -1: Controller Output

4. SYSTEM MODEL

This hybrid microgrid integrates multisource energy platforms such as solar PV, wind emulators and battery packs ($LiFePO_4$). Which these are all connected to a common 96 V DC bus architectureSolar energy is the primary energy source; a wind emulator serves as the secondary source during solar intermittency. The battery pack is used to store the excess energy and then serves as a backup energy source.

The system consists of three layers, which are power, control and monitoring. The power layer and all energy sources are interfaced through the common DC busbar and the control layer electromechanical contactors (k1-k5), which facilitate safe and secure source switching. Protection mechanisms such as surge protection devices, miniature circuit breakers and shunt based current sensing ensure safety. The control layer is implemented using the Delta DVP series with a programmable logic controller (PLC), which executes real-time decision-making for source selection, load management and fault handling. The monitoring layer, which includes the Wecon 7-inch human machine interface (HMI) for local supervision, also has RS 485 Modbus communication and a LoRa/IIoT gateway for remote monitoring.
This system follows a hierarchical power flow strategy in which solar energy is prioritized, followed by wind energy and batteries. The primary function of the common DC bus is to act as a central node for integrating all energy sources to ensure stable voltage regulation and efficient power distribution to the load. The overall power balance of a system determined the combined contribution of solar, wind and battery.

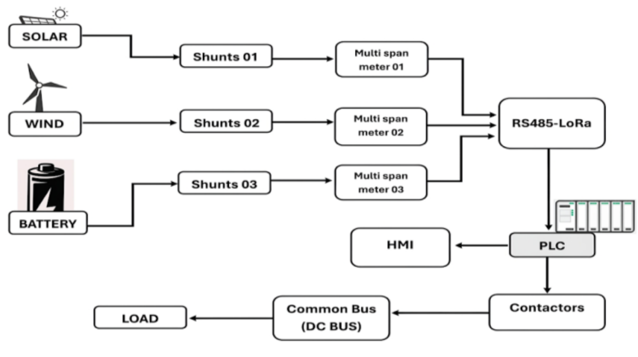

Fig -2: Functional Architecture Diagram

5. METHODOLOGY

Fig -3: HMI software

Fig -4: Hybrid Energy Management Trainer Experimental Model and Setup

Fig -5: Wind Emulator

Fig -6: Solar PV

Fig -7: PLC software

6. ALGORITHM

The algorithm of the hybrid microgrid system implements the PLC logic sequence to ensure the seamless operation and system reliability. This operation begins with system initialization for all communication interfaces, including PLC, HMI and IIOT modules; these are all verified and activated. From this phase all contactors are reset to a safe state and system diagnostics are performed.

Following system initialization, the system continuously collects the real-time data, such as voltage, current and power, from the sensors and meters. From these functions, the PLC evaluates the source availability and its condition. A priority-based decision-making process is executed; solar energy is selected as the primary whenever it is available. In case output is insufficient, the system switches wind source automatically. If both sources are insufficient, the battery engages, and if all local sources are unavailable, the system transitions to grid-tied mode. For safe operation, interlocking logic is implemented to connect only one source to the DC bus at a time to prevent back-feeding and also short circuits. Time delays are incorporated to avoid rapid switches from one source to another. This also includes the load management function to maintain the DC bus voltage for balancing generation and demand. In case of overcurrent, overvoltage, or communication failure, the PLC initiates the fault handling procedure, which is to disconnect the sources, activate the alarm and transition the system to safe operation.

The system transmits the data to the cloud platform via a wireless communication module. This is used for real-time monitoring, data storage and predictive maintenance.

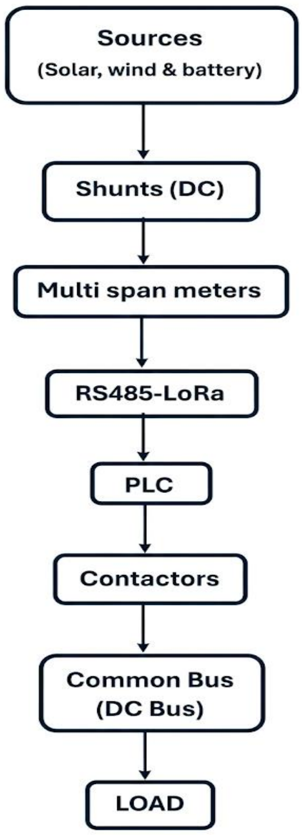

Fig -8: Data Acquisition and Control Logic Flow

7. RESULT AND DISCUSSION

A. EXPERIMENTAL CONFIGURATION

The setup for the experiment consists of:

1. Solar panel with an output of about 17.96V
2. Emulator for wind energy (12-24V rectified output)
3. System of batteries (96V DC)
4. MFM meters and current shunts
5. LoRA convertor PLC with RS485 communication network (Delta DVP series utilizing WPLSoft)
6. Wi-Fi - enabled HMI (Wecon touchscreen)
7. IIOT for cloud integration
8. 1kW VFD motor drive as the load
9. To replicate a real-time hybrid microgrid system, every component is connected.

B. OUTCOMES

The system showed:

1. Successful automated source synchronization and switching.
2. DC bus output voltage stability (96V)
3. Precise real-time voltage and current monitoring
4. Efficient remote monitoring with an IIOT cloud platform
5. Modbus and RS485 technologies for dependable communication
6. By dynamically choosing the most efficient source, the PLC-based logic guaranteed a steady power supply.

C. DISCUSSION

The findings show that the suggested system:

1. Increase energy dependability by integrating several sources
2. Uses Automation to do away with human intervention
3. Improves management and monitoring using cloud and HMI systems
4. Allows for scalability in smart grid and industrial applications.Nevertheless, restrictions consist of:
5. reliance on stable communication
6. The initial cost of setting up industrial components Future enhancement cloud consists of:
7. Prediction energy management using AI
8. Real-time weather forecasting integration
9. Extension to more expansive grid systems.

8. CONCLUSION

An IIOT-based hybrid microgrid automation system that combines industrial automation technology with renewable energy sources is presented in this study. Cloud-based analytics, real-time monitoring, and automatic source selection are all successfully accomplished by the system.

The application shows a workable fix for:

1. Labs for smart grids
2. Training in industrial automation
3. Systems for managing renewable energy
4. All things considered, the project shows how PLC, IIoT, and renewable energy systems may be combined for effective and intelligent power control.

ACKNOWLEDGEMENT

The authors express their sincere gratitude to Dr. P. Sathish Kumar, Associate Professor in the Department of Robotics and Automation at United Institute of Technology, Coimbatore, for his valuable guidance and support throughout this project. We also thank Sara Controls and Automation for their technical support and resources.

REFERENCES

[1] Dongran Song, Asifa Yousaf, Javeria Noor, Yuan Cao, Mi Dong, Jian Yang, Rizk M. Rizk-Allah, M. H. Elkholy, and M. Talaat, "ANN-based Model Predictive Control for Hybrid Energy Storage Systems in DC Microgrid," Protection and Control of Modern Power Systems, vol. 10, Jul. 4, 2025.

[2] Adekanmi Miracle Adeyinka, Oladapo Christopher Esan, Ahmed Olanrewaju Ijaola and Peter Kayode Farayibi, "Advancements in hybrid energy storage systems for enhancing renewable energy-to-grid integration", Adeyinka et al. Sustainable Energy Research, 2024.

[3] T. Raveendran, M. Padmavathi, and J. Chandramohan, "Hybrid Energy Storage with IOT System," International Journal of Engineering Inventions, vol. 12, Oct. 2023.