



e-ISSN: 2278-8875
p-ISSN: 2320-3765

International Journal of Advanced Research

in Electrical, Electronics and Instrumentation Engineering

Volume 15, Issue 1, January 2026

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.807

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☎ 6381 907 438

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Review Paper Renewable Energy Monitoring System for Microgrid using Novel Model Predictive Control

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ABSTRACT: The growing penetration of renewable energy resources such as solar and wind into modern power systems has significantly increased the need for efficient control and monitoring mechanisms. However, the intermittent and stochastic nature of these renewable sources poses challenges in maintaining voltage stability, frequency regulation, and optimal power flow in microgrid environments. This project presents a Renewable Energy Monitoring System (REMS) for a hybrid solar–wind–battery microgrid, integrated with a Novel Model Predictive Control (MPC) framework. The proposed MPC algorithm predicts the future behavior of the system over a defined horizon and optimizes control actions in real time, ensuring reliable operation under varying renewable and load conditions. The system continuously monitors power generation, storage state, and load demand, providing real-time visibility through a MATLAB/Simulink-based monitoring interface. Simulation studies are carried out in MATLAB/Simulink to evaluate the performance of the proposed system under different operating scenarios. The results demonstrate improved dynamic response, reduced voltage and frequency deviations, and higher renewable energy utilization compared to conventional PID-based and fuzzy logic controllers. The developed MPC-based monitoring system thus offers a comprehensive and intelligent control solution for hybrid renewable microgrids, promoting energy efficiency, stability, and sustainability in modern distributed power systems.

KEYWORDS: Renewable Energy, Microgrid, Model Predictive Control (MPC), MATLAB/Simulink, Hybrid Energy System, Real-Time Monitoring, Energy Management, Solar PV, Wind Turbine, Battery Energy Storage System (BESS).

I. INTRODUCTION

The rapid depletion of fossil fuels and the growing environmental concerns have accelerated the global transition toward renewable energy sources. Among these, solar photovoltaic (PV) and wind energy have emerged as the most promising alternatives due to their sustainability and widespread availability. However, the intermittent and stochastic nature of these resources poses significant challenges to maintaining voltage stability, frequency regulation, and power balance in microgrid environments.

A microgrid is a localized energy system that integrates distributed energy resources (DERs) such as solar PV, wind turbines, and battery energy storage systems (BESS) to supply power to local loads. It can operate in both grid-connected and islanded modes, ensuring flexibility and reliability in power delivery. Effective coordination and control of these heterogeneous resources are essential to ensure system stability and energy efficiency.

Traditional control techniques, such as Proportional–Integral–Derivative (PID) and droop control, are limited in their ability to handle rapid fluctuations in renewable generation and load demand. These methods often rely on static parameters and fail to anticipate future system variations. To address these limitations, advanced predictive and optimization-based control strategies have gained prominence.

Model Predictive Control (MPC) has emerged as a powerful approach capable of forecasting system behavior over a defined prediction horizon and computing optimal control actions while considering system constraints. By integrating



MPC with real-time monitoring and data acquisition, the performance and stability of renewable microgrids can be significantly improved.

This paper presents a Renewable Energy Monitoring System (REMS) for a hybrid solar–wind–battery microgrid integrated with a Novel MPC framework. The proposed system ensures optimal power flow, improved voltage and frequency stability, and enhanced renewable utilization through predictive control and continuous real-time monitoring. The design and implementation are carried out using MATLAB/Simulink, and simulation studies validate the superiority of the proposed approach over conventional PID and fuzzy-based controllers.

The remainder of this paper is organized as follows: Section II presents the literature review and related work. Section III outlines the system design and control methodology. Section IV discusses the simulation results and performance evaluation. Section V concludes the paper with remarks and future research directions.

II. LITERATURE SURVEY

Comprehensive analysis of MPC-based energy strategies for isolated microgrids” (2024) — survey/analysis comparing MPC strategies for active/reactive power dispatch in isolated microgrids; useful as a state-of-the-art baseline and to position your novel MPC against existing MPC flavors and objectives.

Energy Management in a Renewable-Based Microgrid” — MDPI (2024) — presents an EMS for wind + BESS + other DERs with MPPT and converter-level control; includes MATLAB/Simulink implementation details and results you can emulate for PV/wind modeling and comparison. Good practical modeling reference.

Real-Time Capable MPC-Based Energy Management of Hybrid Microgrids” — MDPI (2025) — describes an economic MPC (EMPC) framework designed for real-time operation, including computational considerations and hardware-in-the-loop validation; highly relevant for your ‘novel MPC’ real-time monitoring claims.

Economic Model Predictive Control for Microgrid Optimization” (review / technical report, 2023) — in-depth look at EMPC approaches, tradeoffs between economic objectives and tracking, and MPC hierarchies for microgrids; useful for motivating an economic or multi-objective term in your MPC cost function.

Distributed stochastic model predictive control for energy dispatch with distributionally robust optimization(2025) — introduces distributed/stochastic MPC formulations handling uncertainty in renewable forecasts (wind/solar); directly applicable if you plan to incorporate forecast uncertainty and distributed DER coordination.

Distributed model predictive control strategy for microgrid” (2025) — proposes a multi-layer MPC for ESS coordination and frequency regulation in islanded microgrids; shows how decentralized MPC can replace or augment primary layers for current sharing and SOC-aware control. Useful for architecture choices (centralized vs distributed).

Real-Time Energy Management System for a Hybrid Renewable Microgrid” — Wiley / 2024 — practical EMS design with Simulink simulations under variable renewable conditions; includes KPIs (THD, freq/voltage deviation) and controller comparison — handy for your simulation metrics and comparative study (PID/fuzzy vs MPC).

Energy management strategy for a hybrid micro-grid” — Springer (2024) — presents an EMS that optimizes DER dispatch and grid interactions in MATLAB/Simulink; good reference for designing your monitoring dashboard data flows and simulation scenarios.

Integrating MPC, PSO, MILP, and ANN for grid stability and renewable integration” (2025) — a hybrid approach combining MPC with optimization/metaheuristics and ML for stability and HESS coordination; useful if you want to discuss hybrid/augmented MPC or compare against AI-assisted strategies.

Systematic Review and Meta-Analysis of Model Predictive Control applications” — MDPI (2025) — meta-analysis of MPC effectiveness across microgrid functions; supports claims about MPC advantages and exposes common limitations (computational load, model mismatch) that your ‘novel MPC’ should address.

Recent research (2023–2025) shows that Model Predictive Control (MPC) has become the preferred approach for energy management in hybrid renewable microgrids because of its ability to predict future behavior, enforce



constraints, and optimize multi-objective performance. Studies demonstrate MPC's advantages over conventional PID and fuzzy controllers in improving voltage/frequency regulation, reducing power fluctuations, and increasing renewable energy utilization. Developments include economic MPC formulations, stochastic/distributed MPC for uncertainty handling and multi-agent coordination, and real-time capable MPC implementations validated in simulation and hardware-in-the-loop environments.

However, the literature also highlights persistent challenges: high computational complexity of MPC for fast converters, sensitivity to model mismatch and forecast errors, limited scalability in distributed topologies, and sparse integration of monitoring interfaces that bridge predictive optimization with operator-level visualization. Few studies present low-complexity, SOC-aware MPC schemes combined with an integrated real-time monitoring dashboard for hybrid PV-wind-BESS microgrids.

This survey identifies a clear research gap: the need for a **computationally efficient, forecast-robust MPC** that coordinates PV, wind, and battery storage while feeding an intuitive real-time monitoring system. The proposed project — a Renewable Energy Monitoring System for a hybrid microgrid driven by a Novel MPC with adaptive horizon and dynamic weighting — is designed to address these gaps by improving real-time stability, reducing deviation metrics, and enabling transparent system supervision.

III. PROPOSED SYSTEM

The overall design and methodological framework of the proposed **Renewable Energy Monitoring System (REMS)** integrated with a **Novel Model Predictive Control (MPC)** for a hybrid microgrid. The hybrid microgrid combines **solar photovoltaic (PV)** and **wind turbine** systems supported by a **Battery Energy Storage System (BESS)** to ensure uninterrupted power supply and system stability. The design process involves **modeling each subsystem** (PV, wind, and battery) in MATLAB/Simulink, integrating them into a unified microgrid environment, and developing an intelligent **MPC-based control strategy** for optimal energy management. The system also features a **real-time monitoring interface** that visualizes power generation, battery status, and load demand, providing valuable operational insights.

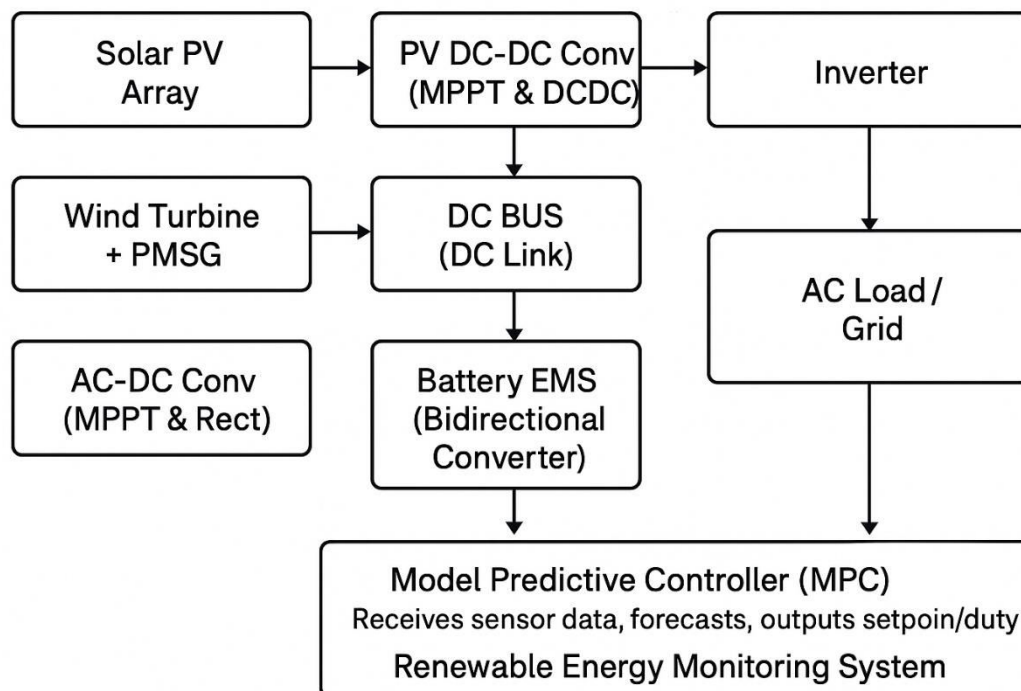


Fig.1. Proposed System



The proposed hybrid renewable microgrid consists of three primary energy sources and a monitoring-control unit:

1. Solar PV Subsystem – Converts solar irradiance into DC power using a PV array with a DC–DC boost converter controlled by an MPPT (Maximum Power Point Tracking) algorithm.
2. Wind Energy Subsystem – Utilizes a Permanent Magnet Synchronous Generator (PMSG) driven by a wind turbine, connected through an AC–DC converter for power regulation.
3. Battery Energy Storage System (BESS) – Stores excess energy during high generation periods and supplies power during low renewable availability.
4. Model Predictive Control (MPC) Unit – Predicts future system states and optimizes control actions dynamically to maintain stability and efficiency.
5. Renewable Energy Monitoring System (REMS) – Provides real-time visualization of energy flow, SOC (State of Charge), voltage, frequency, and load status.

IV. CONCLUSION

The present work titled “Renewable Energy Monitoring System for Microgrid using Novel Model Predictive Control (MPC)” focuses on the development of an intelligent, efficient, and reliable control framework for a hybrid renewable microgrid. The system integrates solar photovoltaic (PV) and wind energy systems with a Battery Energy Storage System (BESS) to ensure continuous power supply and improved system stability.

Through MATLAB/Simulink modeling, the hybrid microgrid has been simulated to analyze its performance under varying environmental and load conditions. A Novel Model Predictive Control algorithm was designed to predict future system behavior, optimize control actions, and handle constraints in real time. The MPC’s predictive capability ensures better adaptation to fluctuations in solar irradiance and wind speed, maintaining a stable DC-link voltage and minimizing frequency deviations in the AC side.

The project also implemented a Renewable Energy Monitoring System (REMS), offering real-time visualization of power generation, load demand, and battery SOC. This enhances system transparency and allows operators to monitor performance, making it a complete supervisory control and monitoring solution for renewable microgrids.

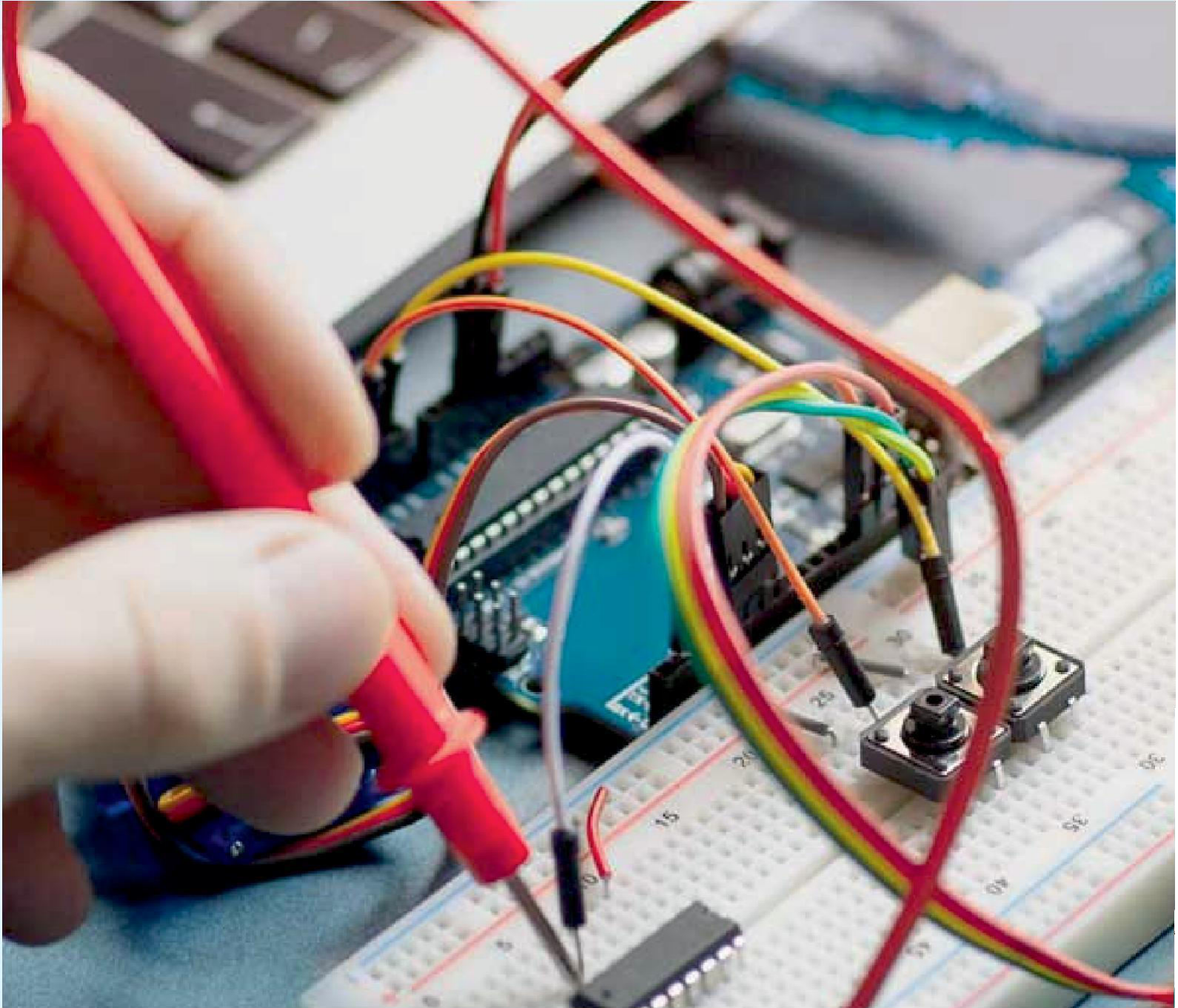
Simulation studies confirm that the proposed MPC-based control system outperforms conventional control techniques (PID and fuzzy logic) by delivering: Faster dynamic response and better transient stability, Reduced total harmonic distortion (THD), Enhanced renewable energy utilization efficiency, and Optimal battery charge/discharge management. Hence, the proposed system effectively contributes toward the design of smart, sustainable, and autonomous energy networks, aligning with global trends in renewable integration and smart grid development.

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