Energy Management in Hybrid Renewable Energy-Based EV Charging Systems Using PID Controller

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ABSTRACT:
This paper presents an innovative energy management system (EMS) for electric vehicle charging stations (EVCS) that integrates hybrid renewable energy sources, including fuel cells, wind, and solar. The proposed system employs a Proportional-Integral-Derivative (PID) controller to overcome the limitations of traditional artificial neural network (ANN) controllers, ensuring better stability, accuracy, and cost-effectiveness. A 40kW EVCS model is developed in MATLAB Simulink to demonstrate the optimization of power generation, EV power demand, and charging times. The results show significant reductions in charging costs and greenhouse gas emissions, making the system both environmentally and economically sustainable.

KEYWORDS:
Electric Vehicles (EVs), Renewable Energy, Energy Management System (EMS), PID Controller, Hybrid Systems.

INTRODUCTION:
Now a days the electric vehicles (EVs) has implemented the need for efficient and reliable charging infrastructures. With increasing awareness of environmental issues and the advantages of EVs, this growth has led to an increased demand for electric vehicle charging stations (EVCS), which must offer cost-effective, environmentally friendly, and dependable energy solutions to support widespread EV adoption.

Traditional EVCS rely heavily on grid electricity, which is not always sustainable or economical. To address this limitation, hybrid renewable energy-based EVCS have been proposed. To lessen dependency on the grid, cut greenhouse gas emissions, and increase overall system efficiency, Thise systems use fuel cells, wind, and solar energy, among other sustainable energy sources. However, controlling energy flow in the system due to intermittent nature of energy sources the fluctuating power demands of EVs. An effective energy management system (EMS) is crucial to optimize the performance, cost-efficiency, and environmental benefits of hybrid EVCS. Previous studies have explored artificial neural network (ANN) controllers for EMS design. While ANN controllers can simulate various conditions and make real-time decisions, they often suffer from stability issues under certain operational scenarios.

This work suggests an advanced EMS that uses a Proportional-Integral-Derivative (PID) controller rather than an ANN controller in order to overcome these difficulties. The PID controller offers superior stability and accuracy, ensuring efficient power allocation and seamless operation in hybrid renewable systems. A 40kW EVCS model was developed in MATLAB Simulink to evaluate the proposed system.

This study demonstrates how the PID-based EMS optimizes energy flow, reduces charging costs, and stabilizes power generation. Additionally, by integrating renewable energy sources, the system minimizes environmental impact and provides a sustainable, financially attractive solution for EVCS owners.

EXSTING SYSTEM:

The hybrid renewable energy-powered electric vehicle charging station's Energy Management System (EMS) integrates solar systems, fuel cells, and advanced control mechanisms to ensure reliable and efficient operations. The PV system serves as the primary renewable energy source, while the fuel cell provides consistent power when solar energy is insufficient. Key components like Maximum Power Point Tracking (MPPT) and inverters optimize energy extraction and ensure compatibility with grid and charging requirements. At the core, an Artificial Neural Network (ANN) controller processes real-time data to balance power generation, storage, and consumption, enhancing efficiency and sustainability. This comprehensive system maximizes renewable energy use, reduces reliance on fossil fuels, and supports the growing demand for sustainable EV charging infrastructure.

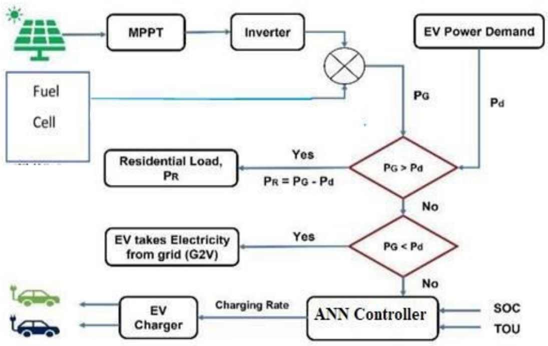

Fig.1. **Existing system**

Artificial Neural Network (ANN):

The Artificial Neural Network (ANN) Controller is a key component in optimizing hybrid energy systems that combine fuel cells and solar cells. It processes real-time data from various system components, including the PV system, MPPT, and inverters, to dynamically adjust operating parameters for efficient energy management. The ANN ensures seamless power sharing between the fuel cell and solar panels, maximizes solar energy harvest, and regulates inverter outputs for reliable energy delivery. Unlike traditional controllers, it adapts to environmental changes and load variations, learning from historical data to enhance performance over time. This makes the ANN controller essential for balancing power generation, storage, and consumption, promoting efficiency, reliability, and sustainability in energy systems.

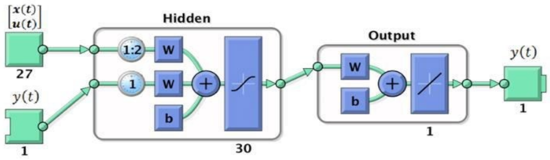

Fig.2. Artificial Neural Network (ANN)

EXSTING METHOD:

This block diagram and Simulink model represent the simulation setup for the existing method, with a focus on the PV Landsman Converter component.

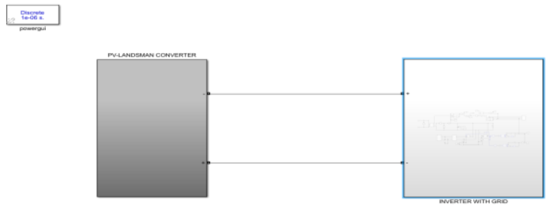

Fig.3. EXISTING METHOD SIMULINK BLOCK DIAGRAM

PV landsman converter:

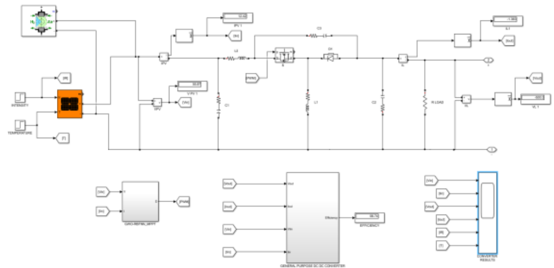

Fig.4. PV Landsman Converter Simulink model

Wave forms (Converter Results):

The waveform results showcase the performance improvements of the proposed method over the existing one, emphasizing better power conversion efficiency, enhanced stability, and other key parameters.

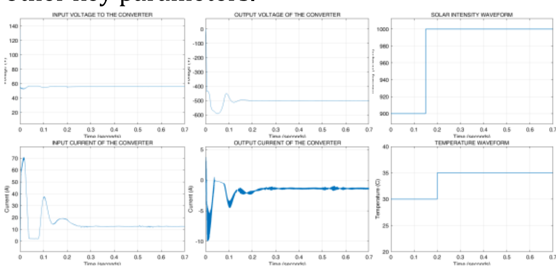

Fig.5. Converter waveforms

Waveforms (DC Voltage):

The detailed waveform results for the PV Landsman Converter demonstrate the quality of *the converted power and improved DC voltage stability achieved with the proposed method.*

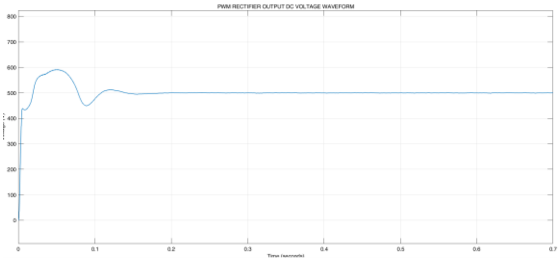

Fig.6. DC Voltage waveform

PROPOSED SYSTERM:

For a hybrid renewable energy-based electric vehicle charging station (EVCS), the suggested Energy Management System (EMS) maximizes the use of renewable energy sources, guarantees dependable charging, and optimizes energy consumption. It combines a fuel cell, wind energy system, and photovoltaic (PV) system. The PV system captures solar energy, the wind system harnesses wind power, and the fuel cell provides reliable electricity through hydrogen-oxygen reactions during low solar or wind availability. A Maximum Power Point Tracking (MPPT) block maximizes efficiency, while an inverter converts DC power to AC for grid and EV charging compatibility. At its core, a Proportional-Integral-Derivative (PID) Controller processes real-time data to balance power generation, storage, and consumption. This integration enhances efficiency, stability, and sustainability, addressing renewable energy and grid challenges for reliable EV charging infrastructure.

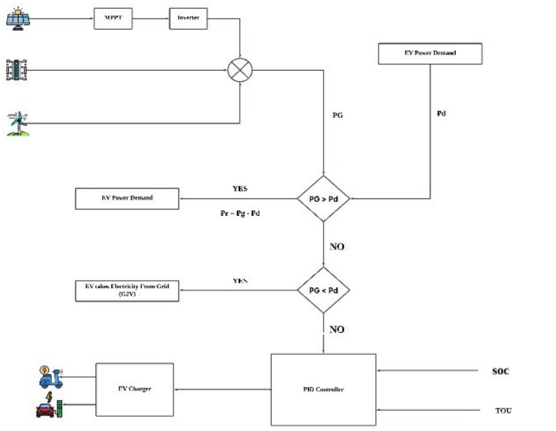

Fig.7. Proposed system block diagram

Proportional-Integral-Derivative Controller:

Proportional-Integral-Derivative controllers have been widely used in various engineering applications due to their simplicity, stability, and robustness. Unlike ANN controllers, PID controllers provide a more deterministic and stable approach to managing energy flow in dynamic systems. demonstrated the effectiveness of PID controllers in stabilizing power generation and meeting demand in renewable energy systems. Their research underscores the potential of PID controllers to improve the reliability and efficiency of hybrid renewable EVCS.

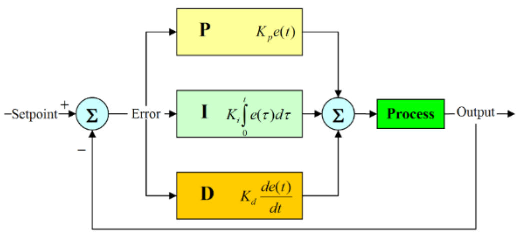

Fig.8. PID CONTROLLER

Proposed Method:

his block diagram illustrates the simulation setup for the proposed method, similar to the existing one, with a focus on the PV Landsman Converter component.

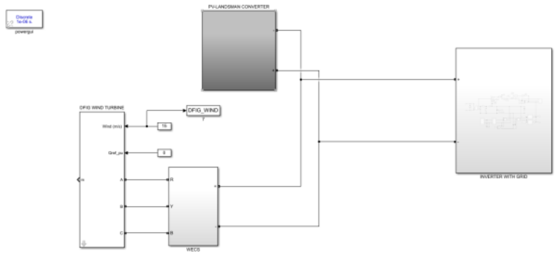

Fig.9. Proposed system Simulink Block diagram

PV landsman converter:

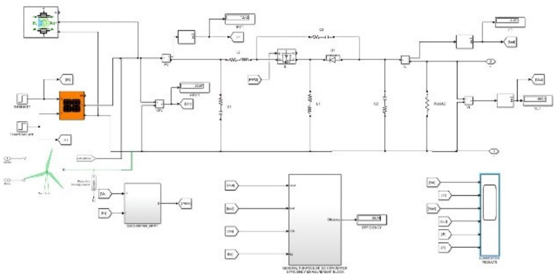

Fig.10. Landsman Converter Simulink model

Wave forms (Converter Results):

The waveform findings show how the suggested approach outperforms the current one in terms of performance, emphasizing improved stability, higher power conversion efficiency, and other crucial-factors.

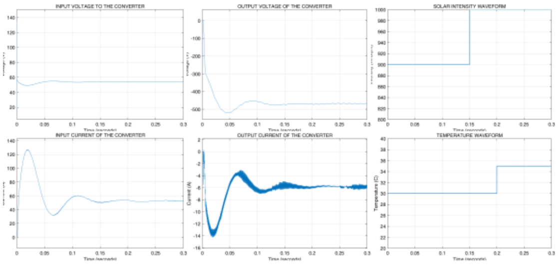

Fig.11. Converter waveforms

Inverter with grid:

The simulation diagram highlights the interaction between the inverter and the grid, while waveform results demonstrate improved grid parameter regulation and compatibility achieved with the proposed method.

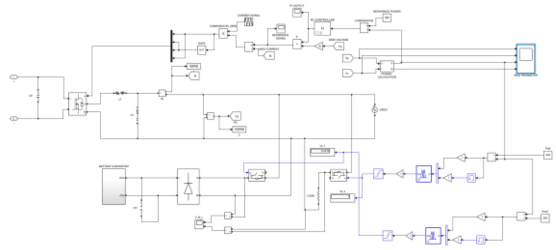

Fig.12. Inverter with grid Simulink model

Waveforms (Grid Parameter):

The waveform results for grid parameters highlight the improved stability and compatibility of the inverter's output with grid requirements achieved by the proposed method.

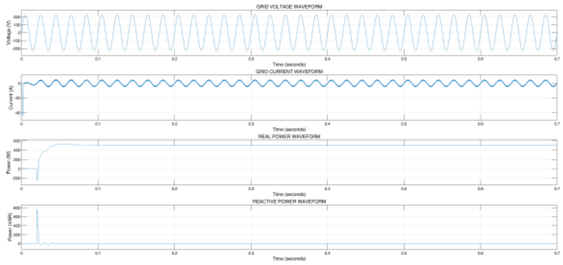

Fig.13. Grid parameter waveforms

WIND ENERGY CONVERSION SYSTEM:

The simulation model for the Wind Energy Conversion System (WECS) is presented, accompanied by waveform results highlighting the performance improvements achieved through the proposed method.

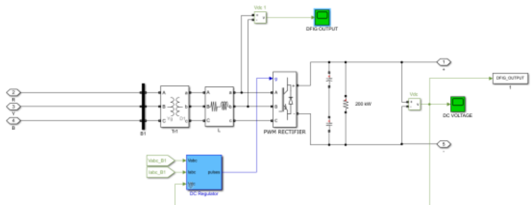

Fig.14. WECS Simulink model

WECS Results:

The simulation model of WECS is presented, with waveform results showcasing performance improvements from the proposed method, including enhanced efficiency and better voltage regulation

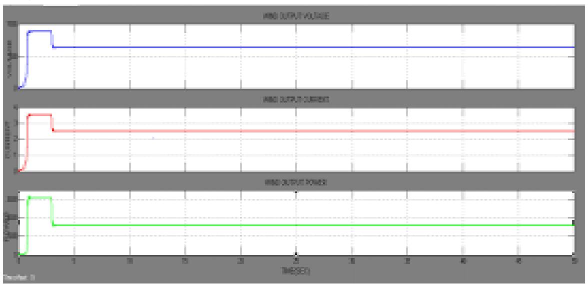

Fig.15. WECS results

Battery Converter:

The simulation model for the battery converter is presented, along with waveform results showing performance improvements achieved by the proposed method, including enhanced charging/discharging efficiency and better voltage regulation.

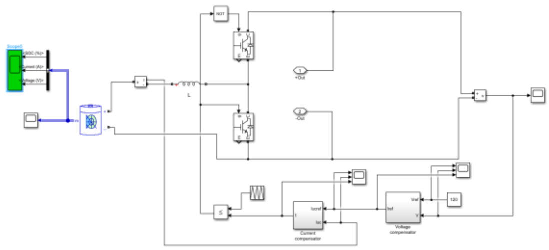

Fig.16. Battery Converter Simulink model

Battery Converter Results:

The simulation model for the battery converter is shown, with waveform results highlighting performance improvements from the proposed method, such as better charging/discharging efficiency and improved voltage regulation.

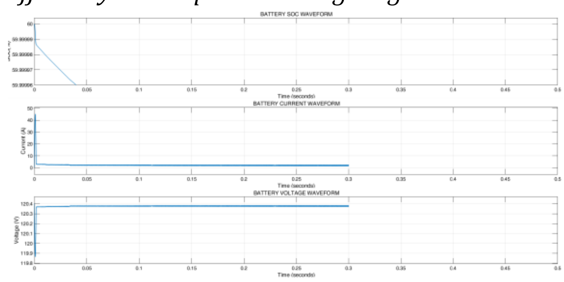

Fig.17. Battery Converter results

CONCLUSION:

The design and development of a hybrid renewable energy-based electric vehicle charging station (EVCS) that combines fuel cells, wind, and solar power is presented in this paper.

A Proportional-Integral-Derivative (PID) controller written in MATLAB Simulink is used by an advanced energy management system (EMS) to balance dynamic EV charging demands, optimize energy flow, and guarantee stability. Simulation results highlight key benefits, including cost efficiency through reduced reliance on grid electricity, stability under fluctuating renewable energy and EV demand, environmental sustainability via reduced greenhouse gas emissions, and scalability for diverse applications. The proposed hybrid EVCS offers a practical, eco-friendly solution to meet the growing need for efficient, sustainable transportation infrastructure.

FUTURE EXPAND:

This project's future scope encompasses a number of crucial sectors for development and growth, the system smarter by predicting energy demand and adjusting charging schedules. Improving battery capacity could also increase efficiency. Exploring hybrid fuel cell and battery systems might improve overall energy use, and expanding the EMS to handle more charging stations could make the system more scalable.

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