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PV Wind Battery Based DC Microgrid with Neural Network MPPT

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Abstract:- This Research presents a novel approach to enhancing the performance and efficiency of a PV-wind-battery-based DC microgrid through the integration of a neural network maximum power point tracking (MPPT) system. The proposed system aims to optimize energy harvesting from photovoltaic (PV) panels and wind turbines while efficiently managing energy storage in batteries. By employing neural network algorithms, the MPPT system adapts to varying environmental conditions and load demands, thereby maximizing energy extraction and system stability. Two important RE (Renewable Energy) power sources—photovoltaic cells and wind energy systems—are examined in this technical study under a range of meteorological conditions. Initially, a state-of-the-art intelligent controller system was developed to help monitor the peak power point. For RES, an MPPT (maximum power point tracking) controller is necessary since weather patterns are unpredictable. The purpose of this work is to provide novel ways for power generation using solar and wind energy that are based on MPPT and IDNN (enhanced deep neural network). The integration of a hybrid PV/WES system into microgrids, or MGs, has the potential to lower THD values and enhance power quality. The simulation findings validated that the suggested IDNN system outperforms the current approach in various operating scenarios, as seen by decreased mean square error (MSE) rates, total harmonic distortion (THD), and computational complexity.

Keywords: PV wind, battery, dc microgrid, neural network, MPPT

1. INTRODUCTION

It is now more important than ever to include renewable energy sources into power systems in order to solve the issues of climate change and energy sustainability [1]. Systems for wind and photovoltaic (PV) energy generation are important players in the production of renewable energy since they provide plentiful and clean power sources. The sporadic nature of these resources, however, makes it difficult to integrate them successfully into traditional grids [2]. Microgrids, which provide localized and decentralized power generation, distribution, and administration, have emerged as a possible answer to these problems [3]. DC microgrids have attracted a lot of interest lately because of their built-in benefits, which include improved efficiency, easier control, and seamless integration of renewable energy sources [4]. Furthermore, the growing use of DC loads in a variety of applications, such as data centers, electric cars, and LED lighting, highlights the importance and promise of DC microgrids [5]. Establishing robust and independent DC microgrids that can handle a range of energy requirements is made possible by integrating several renewable energy sources, such as solar and wind power, with energy storage systems (ESS), such as batteries [6].

The effective use of Maximum Power Point Tracking (MPPT) algorithms is a crucial component in microgrid performance optimization for PV and wind energy systems [7]. By ensuring that renewable energy systems run at their optimum power output in a variety of environmental situations, MPPT algorithms maximize the efficiency of energy harvesting [8]. Although they have been used extensively, traditional MPPT techniques like Perturb and Observe (P&O) and Incremental Conductance (IncCond) have drawbacks including oscillations, a sluggish reaction to

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changing conditions, and a vulnerability to local optima [9]. In order to overcome these constraints and improve the efficiency of PV-wind-battery-powered DC microgrids, new control methods like machine learning (ML) and artificial intelligence (AI) have attracted a lot of attention [10]. An advanced nonlinear relationship between input data (such solar irradiance, wind speed, and battery state of charge) and output variables (like power output) can be learned via neural networks, a subset of machine learning techniques. The microgrid system can adjust dynamically to changing load demands and environmental circumstances by utilizing neural network-based MPPT algorithms, which enhances overall energy harvesting efficiency and system stability. This research provides a thorough analysis of the planning, execution, and performance assessment of a neural network-based MPPT system integrated with a photovoltaic-wind-battery DC microgrid. The robustness and effectiveness of the suggested technique are evaluated under several operating conditions and load profiles through simulation studies and experimental validation. By providing insights into the real-world application of neural network-based MPPT for improved energy management in DC microgrids, the research findings advance the state-of-the-art in renewable energy integration and microgrid control.

2. REVIEW OF LITREATURE

Ab-BelKhair et al. (2020) Examine how deep neural network (DNN) controllers can be used to improve power quality in hybrid PV/wind systems that use smart inverters. The study focuses on using cutting-edge control techniques to enhance the performance of renewable energy systems [11]. Through the use of DNN controllers and smart inverters, the authors hope to reduce power quality problems like harmonics and voltage variations. The study offers insightful information about how AI-based control methods may improve the stability and dependability of hybrid renewable energy systems.

Akpolat et al. (2021) Examine how to use artificial neural networks (ANNs) and model predictive control (MPC) to stabilize DC microgrids dynamically. The study looks into how ANN-MPC methods might be used to enhance DC microgrid performance and stability in a range of operating environments [12]. The authors want to maximize energy management and improve system resilience through the use of ANN models and predictive control techniques. By providing prospective answers for resolving dynamic stability issues, the research aids in the development of sophisticated control approaches for DC microgrid systems.

Albarakati et al. (2021) provide a study on the application of artificial intelligence (AI) methods to real-time energy management for DC microgrids [13]. The goal of the research is to create AI-based algorithms for DC microgrid systems that are effective at defect detection, load balancing, and energy scheduling. To improve DC microgrid operations' autonomy and dependability, the authors want to incorporate AI approaches including machine learning and optimization algorithms. The study shows how intelligent control and decision-making in DC microgrid environments may be facilitated by AI-driven energy management systems, opening the door to more sustainable and effective energy distr*ibution architectures.*

Boualem et al. (2022) give an Elman neural network-based power management plan for a grid-connected solar, wind, and battery hybrid system. The goal of the study is to manage power generation from various renewable energy sources and energy storage in batteries in an efficient manner to maximize the performance of the hybrid system [14]. Through the use of an Elman neural network, the suggested approach adjusts to fluctuating load demands and environmental circumstances, improving the stability and efficiency of the system. By providing insights into the use of neural networks to optimize the performance of hybrid energy systems, the research advances intelligent power management strategies for grid-connected renewable energy systems.

*Chandrasekaran et al. (2022***)** suggest a dynamic Maximum Power Point Tracking (MPPT) controller for a wind power conversion system with energy management capabilities [15]. The research aims to improve wind energy conversion systems' performance and efficiency by precisely tracking the maximum power point in a variety of wind conditions. By utilizing a cascade neural network structure, the suggested MPPT controller adjusts to changes in wind speed and turbine characteristics, guaranteeing optimal energy harvesting. The research also makes a valuable contribution to the development of advanced control strategies for wind power systems.

3. PROPOSED METHODOLOGY

An IDNN calculation is proposed as a power control method in this paper. An IDNN for a crossover wind/PV/battery-based MG climate, a MG model, a framework PV-battery framework, power and recurrence deviations in the MG, load recurrence the executives in the MG, and the assessment of results are completely remembered for the proposed work.

3.1 Microgrid Model

An MG comprises common freestanding energy sources, loads, power converters, storage devices, and control systems. The suggested secondary storages served as the primary backup power sources and kept the DC bus voltages in a typical freestanding DC MG within threshold limits. Sensors and filter circuits utilized to generate measurement signals were included in the measurements (denoted by M). These signals were used by controllers to create their own signals. PV, wind, and battery-based hybrid energy systems are shown in Figure 1.

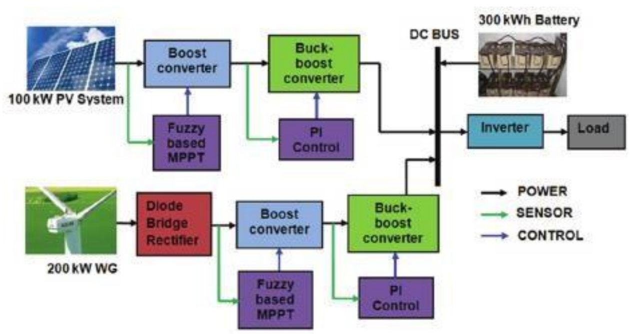

Figure 1: battery-/wind-/photovoltaic-based hybrid energy system.

Power balances in systems are maintained by the standalone DC MG's overall system. Equation (1) applies to the conditions for net power shortages or availabilities in MG.

$$\Delta \boldsymbol{i}_{diff} = \boldsymbol{i}_s - \boldsymbol{i}_l \qquad \textbf{[1]}$$

where Δ represents the net instantaneous current deficits or availabilities of the system; is denotes the sum of the currents supplied to the DC buses by all energy sources; and iL denotes the total currents extracted from the DC buses by all MG loads. Currents and iL are calculated using equations (2) and (3) in the following way.

$$\{\boldsymbol{i}_s = \sum_{K=1}^{P} \boldsymbol{i}_{ESK} \qquad \textbf{[2]}$$

$$\{\boldsymbol{i}_l = \sum_{k=1}^{Q} \boldsymbol{i}_{Esk} \qquad \textbf{[3]}$$

where iLk represents currents drawn from DC buses by kth loads and k = 1, 2,... and iESk represents currents supplied to DC buses by the kth energy sources. It indicates an MG power deficit when ESDs discharge power for balancing when $\Delta idiff$ is not positive. Conversely, an MG with a positive $\Delta idiff$ indicates the availability of additional power that is used to charge ESDs.

3.2 Grid PV-Battery System

This study looked at a reliable RES for homes built with PV panels and lead-acid battery banks for energy storage Electric networks connected to the system made it possible for energy to move across systems. PV-producing systems and battery banks were connected using PEMS (predictive EMS) controllers. Circuit breakers, which are safety devices, can be used to manually switch between utility grids and PEMS controllers, which are essential safety elements. This chip also controlled battery bank charging and discharging at the greatest level SOC for PV systems.

Wind and battery mode: This mode was initiated when the wind converter achieved its greatest receptive power potential and the purpose in like manner coupling (PCC) voltage surpassed the most extreme limit. Battery voltage the executives mode was locked in to supply dynamic receptive power support.

Power and frequency variations in microgrids: Apart from an unregulated renewable energy source (RES), other sources like fuel cells, diesel engine generators (DEGs), and aqua electrolysers can be fully managed. The fuel that drives FCs is hydrogen, which is created by AE using variations in wind energy. In the MG cars, the FCs and DEGs served as actuators. To keep fluctuating frequencies within the permitted range, control signals from the PI controllers adjusted power injunctions between the diesel generators and fuel cells.

3.3 Load Frequency Control in MG

It is feasible to analyze minute changes in signal recurrence and their impacts on directed sources by utilizing the first-request move capability model to portray all the power sources. Wind turbine generators were taken care of assessed wind profiles, and the generators produced the power that the wind turbine advertised. Along these lines, the sun powered PV model utilized an expected profile of irradiance to make sun-oriented power.

The appropriated energy assets are utilized normally to accomplish essential control whenever this has started in the MG, and this is straightforwardly connected with framework dormancy. Chief control measures are carried out promptly following aggravations to restrict high recurrence wavering rates. Optional controls manage powers from extra sources notwithstanding essential controls to reestablish frequencies. The MG is put through a stage interference to break down the heap recurrence conduct and the reactions of other-directed sources to evaluate the regulator reaction.

4. RESULTS AND DISCUSSION

The framework being scrutinized was reproduced utilizing MATLAB and various functional circumstances. The reproductions' results were shown. The receptive power utilized by the MG's customer load was around 220 kVR, demonstrating the absolute power created by the crossover PV/WES framework. To direct the examination, the MG framework's voltage and current were by and large held consistent comparable to the lattice incorporated mixture PV/WES nonlinear power sources' waveforms. Despite the fact that the half breed PV/wind generators in this recommended thought produced in excess of 40 kW of power, controlling power at power-age stations as per buyer requests stays the principal issue. This study's essential goal was to lessen THD values at PCC and further develop power quality.

Condition (4) represents how the MSE is utilized to measurably gauge normal squared contrasts among assessed and genuine qualities, or normal squared mistakes, while assessing unseen factors.

$$\boldsymbol{MSE = 1 \backslash n \sum_{i=1}^{n} (\gamma_i - \gamma_i)^2} \qquad \textbf{[4]}$$

When sample counts are represented by n, observed values are implied by Yi, and anticipated values are denoted by $Y\hat{\imath}$. Figure 1 below compares and analyses, in terms of MSEs, popular methodologies and the suggested methodology. The approaches are listed along the x-axis, while the MSE values are displayed along the y-axis.For this specific setting, the suggested IDNN approach produces lower MSEs than the method incorporating the DNN algorithm. Therefore, it can be inferred from the proposed IDNN results that it enhances the performance of hybrid energy systems.

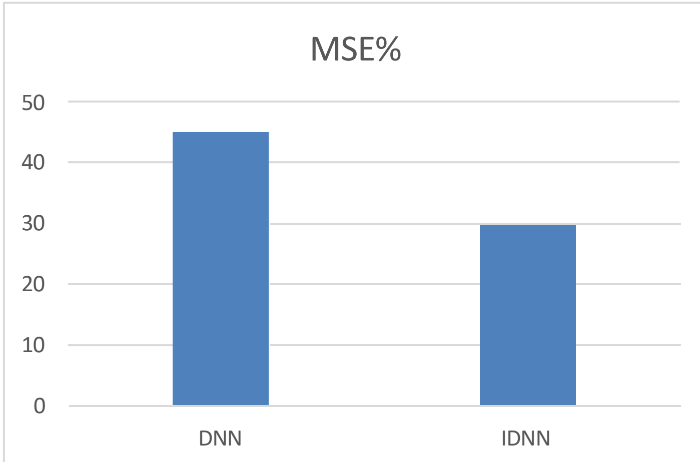

Figure 1: MSC

The underneath Figure 2 shows the THD near examination between the normally utilized and proposed strategies. Plotting the methodologies along the x-hub and posting the THD values along the y-pivot. While the proposed IDNN strategy yields diminished THD values for the predefined PV current framework configuration, approaches, for example, the DNN calculation yield more noteworthy THD values. The outcomes show the capability of the proposed IDNN to upgrade the presentation of the half and half energy framework.

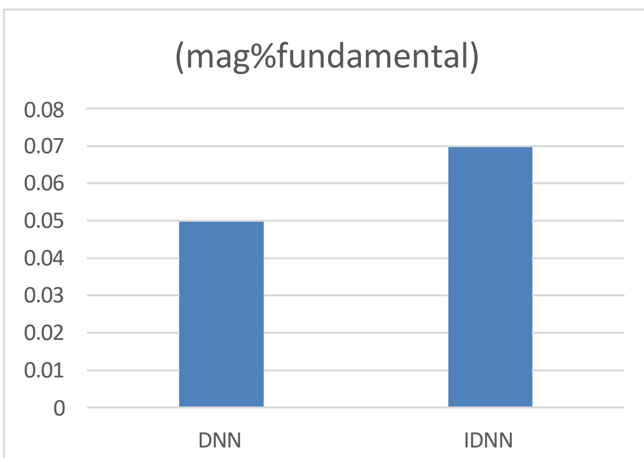

Figure 2: THD readings for the PV current setup.

The near investigation of the proposed and available procedures as far as THD values is displayed in Figure 3. The strategies are displayed along the x-pivot, and the THD values are recorded along the y-hub. While the proposed IDNN calculation yields lower THD values for the given setting as far as wind voltage, a well known technique, for example, the DNN calculation yields more noteworthy THD values. Hence, it tends to be gathered from the result that the half and half energy framework's exhibition can be upgraded by the proposed IDNN.

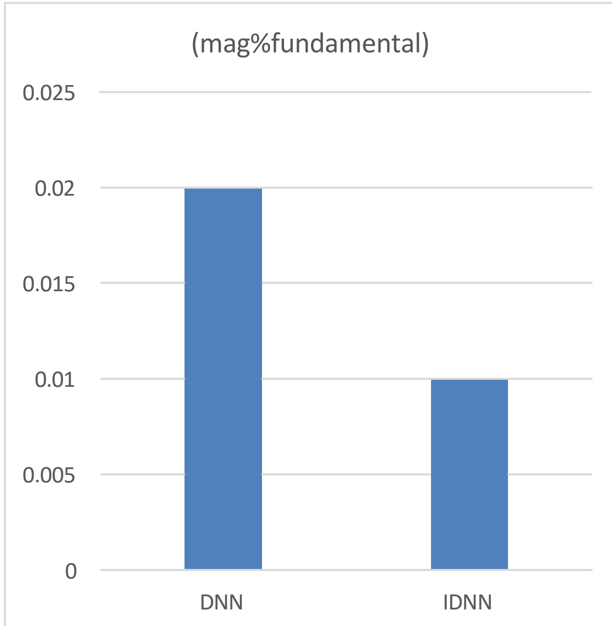

Figure 3: Wind voltage THD values.

Execution time: On the off chance that the recommended calculation is finished in a more limited measure of time, the framework is productive.

The assessment of the execution seasons of the recommended strategy and the broadly utilized methods is shown in Figure 4 beneath. The x-pivot addresses methods, and the y-hub addresses execution lengths. For the given PV/wind/battery-based framework, the proposed IDNN strategy had a more limited execution time than the ongoing DNN method. Thusly, the result recommends that the proposed IDNN can upgrade execution.

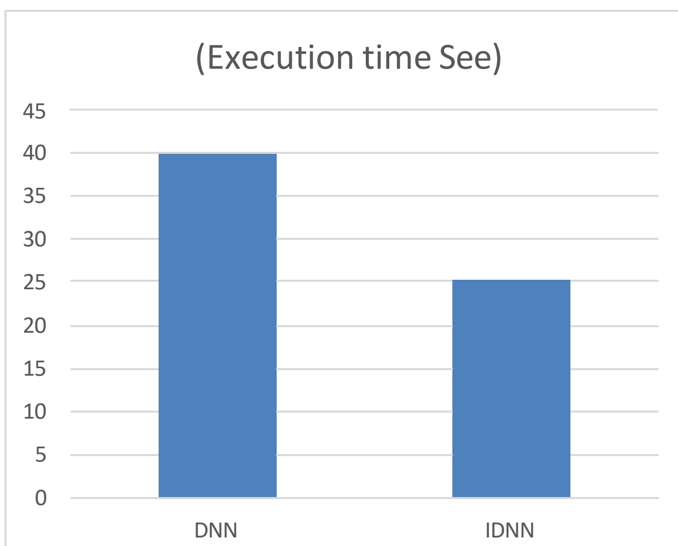

Figure 4: Execution time

5. CONCLUSION

The exhibited gains in power control, power quality, energy management, and computational efficiency of the proposed IDNN algorithm illustrate its robustness as an optimization solution for hybrid energy systems in microgrid situations. The IDNN algorithm maximizes the use of renewable resources while ensuring grid stability by efficiently balancing power from various sources, including wind, photovoltaic, and battery-based systems. It reduces grid disruptions and improves overall system reliability with sophisticated control methods like reactive power support and load frequency management. Its greater computational efficiency as seen by its lower execution durations in comparison to traditional methodologies further increases its usefulness. Overall, the IDNN algorithm presents itself as a viable strategy for promoting the integration of renewable energy sources and streamlining the shift to environmentally friendly microgrid operations.

6. FUTURE SCOPE

The future scope involves applying neural network maximum power point tracking (MPPT) methods to improve the PV-Wind-Battery based DC microgrid. This is refining the neural network-based maximum power point tracking (MPPT) algorithms to increase the accuracy and efficiency of electricity generation from wind and solar sources. Furthermore, grid stability and energy management can be improved by using sophisticated control algorithms that make use of neural networks to regulate the dynamic interactions between renewable energy sources and storage systems. Furthermore, proactive decision-making and adaptive operation in response to shifting environmental circumstances and energy demands can be made possible by investigating fresh ways for integrating predictive analytics and machine learning algorithms into the microgrid control framework.

REFERENCES

[1] Chettibi, N., Mellit, A., Sulligoi, G., & Pavan, A. M. (2016). Adaptive neural network-based control of a hybrid AC/DC microgrid. IEEE Transactions on Smart Grid, 9(3), 1667-1679.

[2] Jasim, A. M., Jasim, B. H., Neagu, B. C., & Alhasnawi, B. N. (2022). Coordination control of a hybrid AC/DC smart microgrid with online fault detection, diagnostics, and localization using artificial neural networks. Electronics, 12(1), 187.

[3] Mahjoub, S., Chrifi-Alaoui, L., Drid, S., & Derbel, N. (2023). Control and implementation of an energy management strategy for a PV–wind–battery microgrid based on an intelligent prediction algorithm of energy production. Energies, 16(4), 1883.

[4] Prakasam, M. M. A., Karuppaiyen, M., & Siddan, G. (2023). A Photovoltaic (PV)-Wind Hybrid Energy System Using an Improved Deep Neural Network (IDNN)-Based Voltage Source Controller for a Microgrid Environment. Engineering Proceedings, 59(1), 30.

[5] Ranjan, R., Prince, S. K., Parasamulu, B., & Panda, G. (2019). A Control Scheme for Wind and Battery System Operation in DC Microgrid. In GRIDTECH 2019.

[6] Sharma, S., Chauhan, B. K., & Saxena, N. K. (2023). Artificial neural network grid-connected MPPT-based techniques for hybrid PV-WIND with battery energy storage system. Journal of The Institution of Engineers (India): Series B, 104(6), 1217-1226.

[7] Sharma, S., Chauhan, B. K., & Saxena, N. K. (2023). Artificial neural network grid-connected MPPT-based techniques for hybrid PV-WIND with battery energy storage system. Journal of The Institution of Engineers (India): Series B, 104(6), 1217-1226.

[8] Singh, P., & Lather, J. S. (2020). Dynamic power management and control for low voltage DC microgrid with hybrid energy storage system using hybrid bat search algorithm and artificial neural network. Journal of Energy Storage, 32, 101974.

[9] Subramanian, V., Indragandhi, V., Kuppusamy, R., & Teekaraman, Y. (2021). Modeling and analysis of PV system with fuzzy logic MPPT technique for a DC microgrid under variable atmospheric conditions. Electronics, 10(20), 2541.

[10] Vasantharaj, S., Indragandhi, V., Subramaniyaswamy, V., Teekaraman, Y., Kuppusamy, R., & Nikolovski, S. (2021). Efficient Control of DC Microgrid with Hybrid PV—Fuel Cell and Energy Storage Systems. Energies, 14(11), 3234.

[11] Ab-BelKhair, A., Rahebi, J., & Abdulhamed Mohamed Nureddin, A. (2020). A study of deep neural network controller-based power quality improvement of hybrid PV/Wind systems by using smart inverter. International Journal of Photoenergy, 2020, 1-22.

[12] Akpolat, A. N., Habibi, M. R., Baghaee, H. R., Dursun, E., Kuzucuoğlu, A. E., Yang, Y., ... & Blaabjerg, F. (2021). Dynamic stabilization of dc microgrids using ann-based model predictive control. IEEE Transactions on Energy Conversion, 37(2), 999-1010.

[13] Albarakati, A. J., Boujoudar, Y., Azeroual, M., Jabeur, R., Aljarbouh, A., El Moussaoui, H., ... & Ouaaline, N. (2021). Real-time energy management for DC microgrids using artificial intelligence. Energies, 14(17), 5307.

[14] Boualem, S., Kraa, O., Benmeddour, M., Kermadi, M., Maamir, M., & Cherif, H. (2022). Power management strategy based on Elman neural network for grid-connected photovoltaic-wind-battery hybrid system. Computers and Electrical Engineering, 99, 107823.

[15] Chandrasekaran, K., Mohanty, M., Golla, M., Venkadesan, A., & Simon, S. P. (2022). Dynamic MPPT controller using cascade neural network for a wind power conversion system with energy management. IETE Journal of Research, 68(5), 3316-3330.