ISSN: 2633-4828 Vol. 5 No.4, December, 2023

International Journal of Applied Engineering & Technology

INTEGRATION OF DISTRIBUTED RENEWABLE ENERGY SOURCES IN DC MICROGRIDS: ENHANCING POWER QUALITY USING ARTIFICIAL NEURAL NETWORKS

Nisarg Swami[1] and Prof. Ghuge Nilam Nimraj[2]

[1]Ph.D. Scholar, Department of Electrical Engineering, University of Technology-Jaipur, Rajasthan

[2]Associate Professor, Department of Electrical Engineering, JSPM's Bhivrabai Sawant Institute of Technology & Research, Wagholi, Pune, Maharashtra

ABSTRACT

In order to improve power quality using artificial neural networks, distributed renewable energy sources within DC microgrids are developed and discussed in detail in this research. Because distributed renewable energy sources (RES) are intermittent, integrating them into DC microgrids presents substantial issues for power quality maintenance. The goal of this study is to better understand how Artificial Neural Networks (ANNs) can be used in DC microgrid systems with different RES outputs to improve power quality. The main goal of the research is to develop and apply ANNs to forecast and reduce harmonic distortion and voltage instability brought on by variations in RES generation. Renewable energy sources (RES), particularly solar and wind, have variable output that can lead to voltage and current issues, which can ultimately create grid instability. The study offers a solid method for stabilizing these variations, which improves a system's efficiency and dependability.

Keywords: AC power distribution grids, distributed renewable energy sources, DC microgrids, artificial neural networks, power quality, stability of grid, etc.

I. INTRODUCTION

"Integration of Distributed Renewable Energy Sources in DC Microgrids Enhancing Power Quality Using Artificial Neural Networks," the implementation of ANNs will address challenges resulting from the intermittent nature of such renewable energy sources as solar and wind, which usually cause significant voltage and current fluctuations that could dangerously destabilize the grid. ANNs integrate historical information with real-time information for numerical predictions and dynamically offset such fluctuations, hence stabilizing voltage levels and enhancing grid reliability and efficiency in general, with DC microgrids gaining more relevance for often complicated needs in smart cities in the current age. Hence, the developed ANN models are expected to provide continuously adaptive responses to patterns of changing conditions to help maintain power quality and ensure resilient urban energy infrastructure [1-2]. The goal of this study is to better understand how Artificial Neural Networks (ANNs) can be used in DC microgrid systems with different RES outputs to improve power quality. The main goal of the research is to develop and apply ANNs to forecast and reduce harmonic distortion and voltage instability brought on by variations in RES generation. In order to optimize voltage regulation and reduce harmonic content, the research employs a methodical approach that includes modelling a DC microgrid system, gathering empirical data on power quality metrics and RES outputs, and creating artificial neural networks (ANNs) trained on historical data. The findings show that artificial neural networks (ANNs) significantly enhance power quality measurements, providing a reliable alternative to conventional techniques [3-4]. The results highlight the potential of artificial neural networks (ANNs) to improve the stability and dependability of DC microgrids that include renewable energy sources, opening the door to future energy systems that are more robust and effective.

The pressing need to slow down climate change and wean ourselves off of fossil fuels is radically changing the global energy scene. A potential remedy in this regard is the incorporation of distributed renewable energy sources (DRES) into microgrids, such as biomass energy, wind turbines, and solar photovoltaic (PV) systems. Direct Current (DC) microgrids are becoming more popular among the many microgrid configurations because of their inherent advantages in efficiency, power quality, and suitability for renewable energy sources. Nevertheless, there are a number of difficulties involved in integrating DRES into DC microgrids, namely with regard to power supply stability and quality [4-5]. Variability in the production of renewable energy sources combined with the bidirectional power flows found in DC microgrids can result in problems including harmonics, transient disturbances, and fluctuations in voltage. These power quality issues endanger delicate electronic loads in addition to undermining the microgrid's dependability and effectiveness. Intelligent management systems and sophisticated control techniques are crucial for overcoming these obstacles. A subclass of artificial intelligence called artificial neural networks, or ANNs, provide a potent tool for improving DC microgrid power quality. Artificial neural networks (ANNs) are highly suitable for real-time control and optimization in dynamic contexts due to their ability to learn and adapt to complicated patterns. This study examines how DRES can be integrated into DC microgrids, with an emphasis on using ANNs to improve power quality [4-5]. This study aims to accomplish three goals: first, it will analyse the power quality problems related to DRES integration in DC microgrids; second, it will create and apply ANN-based control strategies to mitigate these problems; and third, it will simulate and validate the suggested solutions to assess how well they work.

II. LITERATURE REVIEW

Distributed Renewable Energy Resources in DC Microgrids

Compared to AC microgrids, DC microgrids are more efficient and need less work to integrate with renewable energy sources, which is why they have attracted a lot of interest recently. Lasseter (2011) claims that by using DC power directly in microgrids, several power conversions are not necessary, which lowers energy losses and boosts total system efficiency. Energy storage devices like batteries and supercapacitors, as well as renewable energy sources like solar PV and wind turbines, which naturally produce DC power, are especially well suited for integration with DC microgrids. There are advantages and disadvantages of integrating DRES into DC microgrids. By offering decentralized power generation, DRES can improve the sustainability and resilience of microgrids, lowering dependency on centralized power plants and boosting energy security. However, sustaining a steady and high-quality power supply in DC microgrids is severely hampered by the intermittent and unpredictable nature of renewable energy sources. In DC microgrids, power quality is a major concern, especially when integrating DRES. Voltage swings, harmonic distortions, and transient disturbances are common power quality problems that can negatively impact delicate electronic loads and lower power supply reliability. Traditional control techniques are frequently unable to handle the complicated dynamics and rapidly changing conditions in DC microgrids with high renewable energy penetration, according to research by Karimi-Ghartemani and Iravani (2004).

AI-Based Challenges and Solutions: Direct current microgrids play a crucial role in integrating distributed renewable energy sources (RESs) into remote areas, such as solar and wind power. However, the inherent variability of RESs presents challenges to grid stability and reliability. Artificial intelligence (AI), particularly artificial neural networks (ANNs), can significantly address these issues by optimizing grid operations and enhancing predictive control mechanisms [4].

AI-Powered Power Quality Management: Power quality is essential for the efficiency and reliability of microgrids. ANNs improve power quality by predicting and mitigating issues like voltage variations and harmonic distortions. By learning from historical data, ANNs can anticipate potential disruptions and adjust control strategies accordingly [5].

In DC microgrids, artificial neural networks, or ANNs, have shown promise as a way to improve power quality. Artificial neural networks (ANNs) are highly suitable for real-time control and optimization applications because they can learn from past data and adapt to new patterns. Research conducted in 2018 by Abou El-Ela and colleagues shows that artificial neural networks (ANNs) can forecast and alleviate power quality issues by dynamically altering control settings in response to changes in the microgrid environment. Numerous investigations have looked into the use of ANNs in microgrid control. For example, Alkaff et al. (2016) significantly increased the stability and efficiency of the system by using an ANN-based control technique for managing energy flow in a hybrid AC/DC microgrid. Similar to this, Yang et al. (2017) improved voltage stability and decreased harmonic distortions in a DC microgrid by implementing an ANN controller for voltage regulation.

These investigations highlight ANNs' capacity to deal with the particular difficulties presented by DRES integration in DC microgrids [5-6]. Maintaining power quality in DC microgrids is made more difficult by the introduction of DRES. However, because of ANNs' capacity for adaptive learning and their ability to react instantly to changing circumstances, its use presents a viable remedy. Even though this sector has made great strides, more study is required to confirm these methods in real-world situations and look into possible synergies with other cutting-edge technology. Future research can help create DC microgrids that are more reliable and effective by tackling these issues, which will speed up the shift to sustainable energy sources.

III. METHODOLOGY

Control Strategies for Hybrid DC Microgrids:

Maintaining a stable and efficient energy flow in hybrid DC microgrids, which combine various renewable sources and storage systems, is complex. ANN-based control strategies dynamically manage energy distribution from different sources, ensuring optimal operation under varying load and generation conditions [6]. A number of distributed renewable energy sources (DRES), including wind turbines and solar photovoltaic (PV) panels, are included in the DC microgrid system that is being studied. Energy storage devices (ESS) such as supercapacitors and batteries are also incorporated into the microgrid to control power fluctuations and guarantee a steady power supply. To show off the system's adaptability and durability, the microgrid is built to run in both islanded and grid-connected modes. Power quality monitoring devices that detect voltage, current, frequency, and harmonics are installed in the microgrid. To offer thorough data on power quality across the microgrid, these devices are positioned strategically at different sites [5-6].

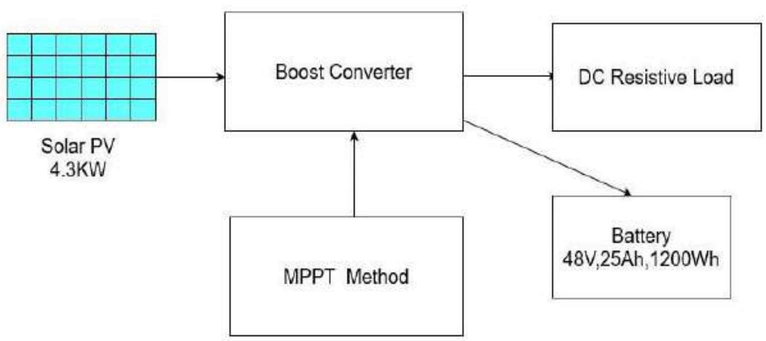


Fig.1- Block diagram of single Source Microgrid system

Table -1 Solar PV component description

Parameter Name	Value
Solar Power	6.3KW
Parallel String	15
Series String	2
Voc (Open circuit voltage)	36.3V
Isc (Short Circuit current)	7.84A
Vmp (Maximum Voltage)	29V
Imp (Current at Maximum power point)	7.35A

Table-2 Boost converter parameter

Parameter Name	Value
Capacitor (C1)	6.67e-05F
Capacitor (C2)	5.72e-05F
DC load resistance	25Ω
Inductor (L)	4.90e-03H

Calculation of Boost converter

Input data

1 string voltage 30V series string is 2

So**,** V_{in} **= 30×2= 60V** Input voltage

1 string current 7A & 15 string connected in parallel

So, I_{in} **=15×7=105A** Input Current

P_{in} =Vin×Iin= 6.3KW Input Power

f_s=25KHz=Switching frequency

Output data

V_{out}=140V

I_{out}=14A

Load resistance:

$$R_L=\frac{V_{out}}{I_{out}} \quad (1)$$

Duty cycle:

$$D=1-\left(\frac{V_{in}}{V_{out}}\right) = 1-(60/140) = 1-0.428=0.572 \quad (2)$$

Ripple Voltage in input **(ΔV_{in})**

$$\Delta V_{in}=20\% \text{ of } V_{in} \quad (3)$$

$$\Delta V_{out}=20\% \text{ of } V_{out} \quad (4)$$

Capacitor (C_1):

$$C_1=\frac{I_{in}\times D}{f_s\times\Delta V_{in}} \quad (5)$$

$$C_2=\frac{I_{out}\times D}{f_s\times\Delta V_{out}} \quad (6)$$

Ripple Current (ΔI_{out})

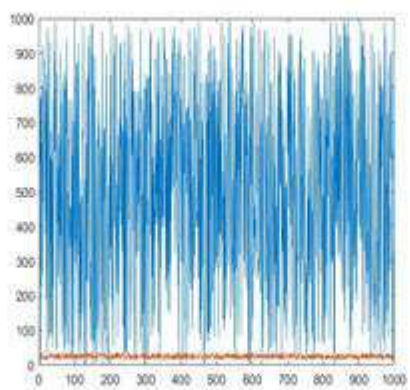
$$\Delta I_{out}= 10\% \text{ of } I_{out} \quad (7)$$

Inductor (L): $L=\frac{V_{in}\times D}{f_s\times\Delta I_{out}}$

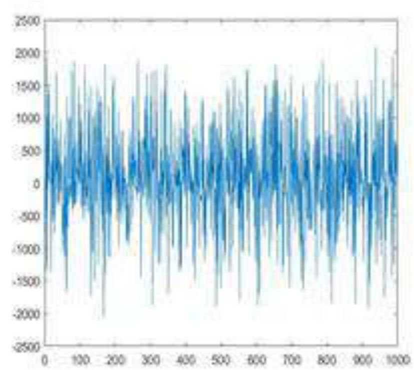
CASE STUDIES AND IMPLEMENTATION:

Practical applications and case studies demonstrate the effectiveness of ANNs in microgrid management. For example, ANNs have been used to integrate solar panels and wind turbines to maximize output while maintaining power quality. These studies show significant improvements in grid stability and efficiency through advanced AI techniques. Integrating RESs into DC microgrids, supported by AI and ANNs, offers a promising solution to the challenges of renewable energy variability and grid stability. By leveraging the predictive and adaptive capabilities of ANNs, microgrid operators can enhance power quality and ensure a reliable power supply, essential for adopting sustainable energy solutions [7,8]. Over a considerable amount of time, data is gathered from the power quality monitoring devices to capture a variety of operational events, such as varying weather, load fluctuations, and fault occurrences. Measurements of voltage levels, current flows, DRES power output, and energy storage systems' charge state are all included in the dataset. Preprocessing is done on the collected data to get rid of noise and anomalies that could skew the results. By scaling the data within a predetermined range, normalization techniques make sure that every input characteristic contributes equally to the ANN training process. The right ANN architecture is chosen; this usually consists of an output layer, many hidden layers, and an input layer. Normalized power quality data is sent to the input layer, and it is processed by the hidden layers using a sequence of weighted connections and activation functions. In order to modify the operational characteristics of the microgrid components, control signals are generated by the output layer. Supervised learning approaches are used to train the ANN, matching the input data with the expected output. Backpropagation is used in the training phase, when the ANN's weights are iteratively changed to minimize the error between the expected and actual outputs. A smaller subset of the dataset is set aside for validation, while the majority is used for training [6-9].

ANN Input and Output data



INPUT DATA



OUTPUT DATA

METHODOLOGY OVERVIEW FOR DC MICROGRIDS USING ARTIFICIAL NEURAL NETWORKS

System Overview: The research has used a flexible, grid-connected micro-grid that can also operate off the main grid. This has been implemented through the coupling of some of the photovoltaic arrays harnessed with MPPT (Maximum Power Point Tracking) to fine-tune energy harvested under varying intensity of sunlight. The system also considers battery storage to effective power management as well as for storage in cases when the produced energy is less than the demand [5-6].

ANN Design: We have developed Artificial Neural Networks to solve power quality issues, such as voltage fluctuation and harmonic distortion. The architecture consists of some input layers to receive data from the microgrid, hidden layers to accomplish processing, and output layers to construct the control signals. Such ANNs are trained with last data about the voltage levels and load demand to output a result which can offer a solution to the problem using back propagation and a feed-forward network to attain accuracy and response in the proposed DC microgrid system [6-7].

Simulation Environment: Our simulations have been using a software platform that emulates the electrical and control systems in the microgrid. We have varied input variables, such as solar irradiance, wind speed, battery status, and load demands, to create a range of operational scenarios. The performance of the ANNs is then assessed within this environment regarding its ability to keep power quality and ensure stable voltages, among other such as outage prevention and energy efficiency [7-8].

Real-Time Control: The trained ANN model is integrated into the microgrid's control system. It processes real-time power quality data and generates control signals to adjust the operation of inverters, converters, and ESS. The primary control actions include voltage regulation, harmonic compensation, and load balancing [8-9].

Adaptive Learning: The ANN model is designed to adapt to changing conditions in the microgrid. It continuously updates its weights based on new data, ensuring that the control strategies remain effective under varying operational scenarios [9-10].

The efficiency of PID controllers and other conventional control techniques is contrasted with that of ANN-based control schemes. Voltage stability, harmonic distortion levels, and disturbance response time are examples of key performance metrics. A software tool like MATLAB/Simulink is used to create a detailed simulation model of the DC microgrid. The physical elements and operating circumstances of the microgrid are replicated in the simulation, enabling comprehensive testing of the ANN-based control techniques.

IV. SIMULATION AND RESULT DISCUSSION

This is proposed system is Solar PV DC microgrid with single battery system, here without MPPT system will implement so, battery charging current and power are fed to DC bus so, without MPPT get high oscillation and less efficiency. Solar generated power is fed to battery system for charging purpose.

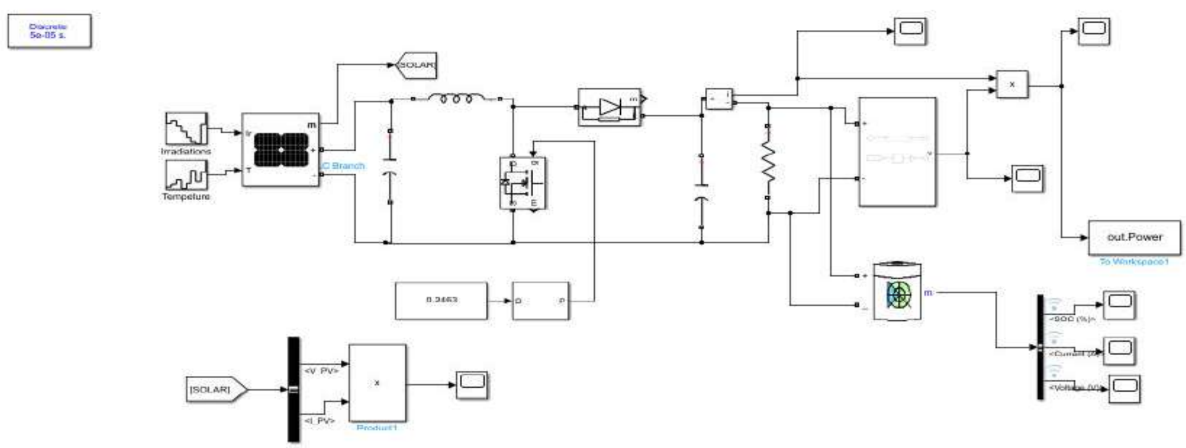


Fig.1- DC microgrid system without MPPT

DC Microgrid are made by different source and load so here load taken is battery and source is only is Solar PV. Solar PV generation is supplied to DC load here DC load is Battery and Battery have current power oscillation is high.

PV Array Power: Compare Scenarios with and without MPPT.

Fig.2-PV Array Power without MPPT

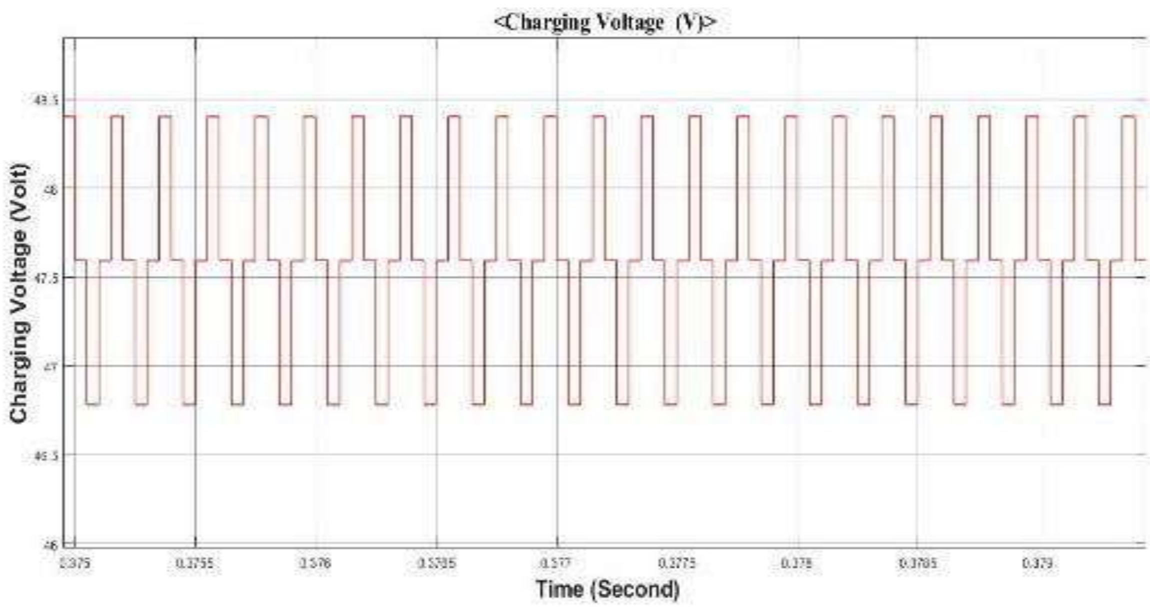


Fig.3- Battery charging voltage without MPPT

SIMULATION RESULTS ON MPPT'S IMPACT IN DC MICROGRIDS

Simulation Results Interpretation:

The simulation was performed under two distinct scenarios to assess the impact of Maximum Power Point Tracking (MPPT) on the performance of photovoltaic (PV) arrays integrated into a DC microgrid. The first scenario lacked MPPT, resulting in the PV array's power output being subject to fluctuations due to varying solar irradiance, leading to suboptimal energy extraction. The second scenario incorporated MPPT, which stabilized and enhanced the power output by consistently operating at the maximum power point regardless of changes in sunlight conditions.

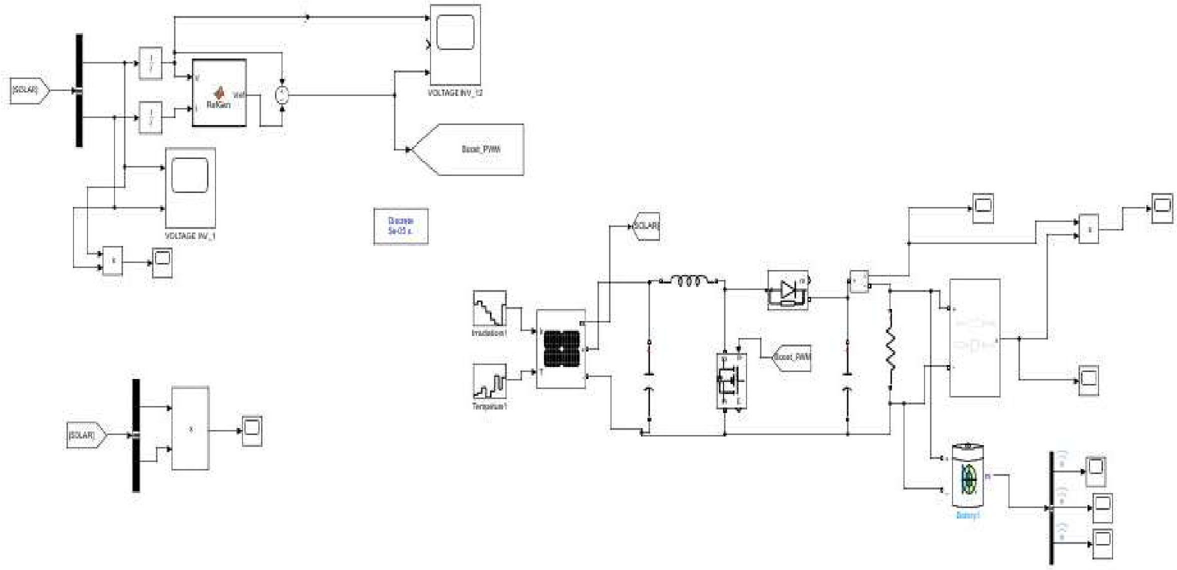


Fig.4- DC Microgrid with MPPT System

Solar PV power fed to DC load with MPPT system reduce fluactuation and osillation so, Battery charging current & Power are constantly charge by solar power and MPPT get highly efficiently charhing current. Irradiation level with change with whole days so, charging level of battery will remove or minimize by this MPPT.

Battery Charging Characteristics: Traditional vs. ANN-Enhanced Methods

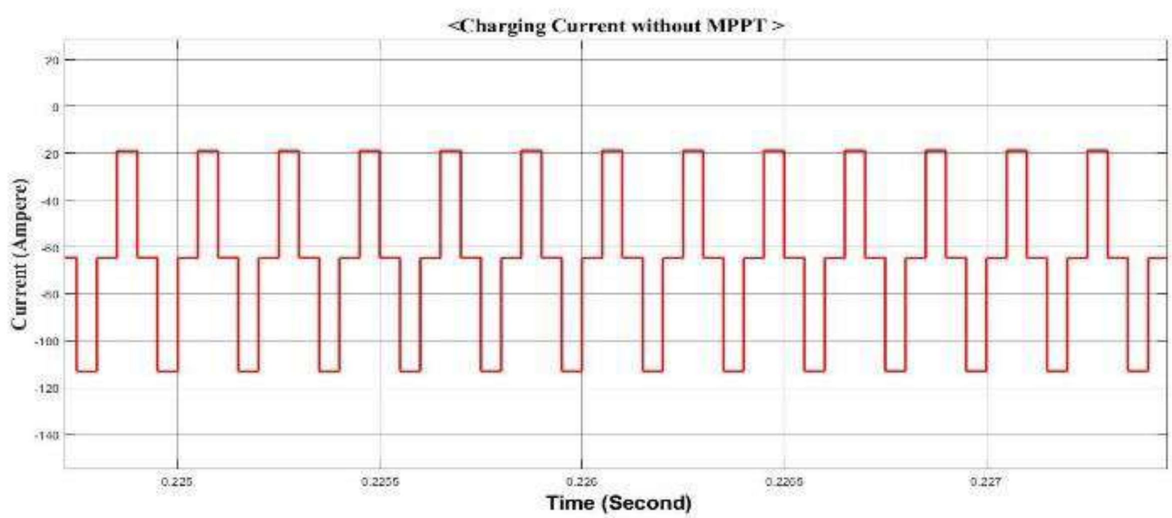


Fig.5- Without MPPT Battery charging Current

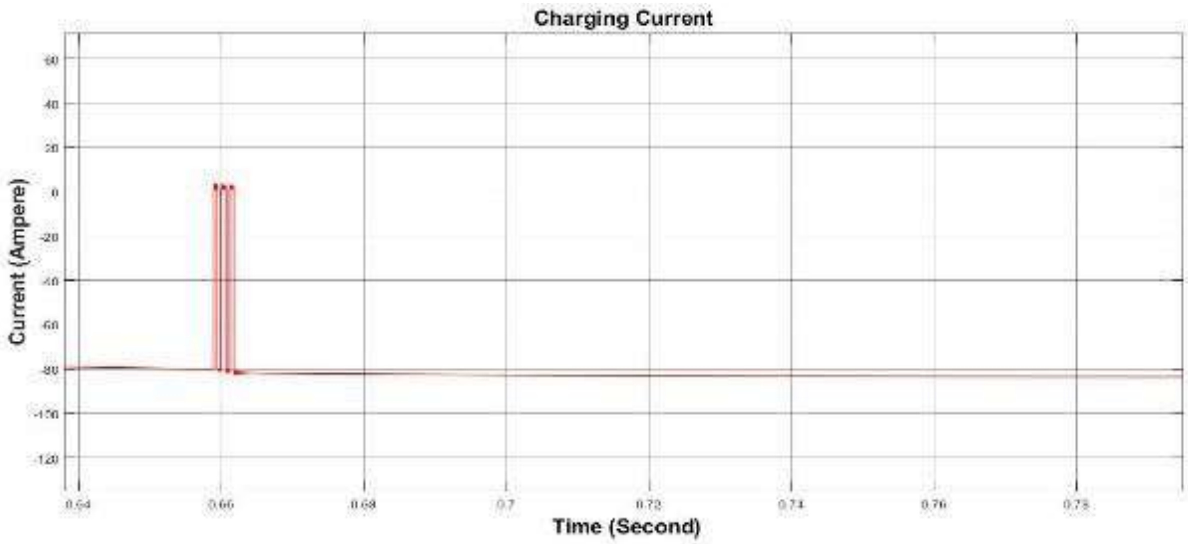


Fig.6- With MPPT Battery charging Current with ANN control

Interpretation of Battery Charging Characteristics: Traditional vs. ANN-Enhanced Methods

The difference between traditional charging and charging augmented with ARTIFICIAL NEURAL NETWORKS within the DC microgrid is clearly brought out in this simulation study on the characteristics of battery charging. The basic issue with traditional charging in the absence of maximum power point tracking is charging currents that show erratic behavior due to variable solar irradiance. This usually imposes on the condition of the battery an inefficient number of charging cycles, which may eventually stress the condition of the battery.

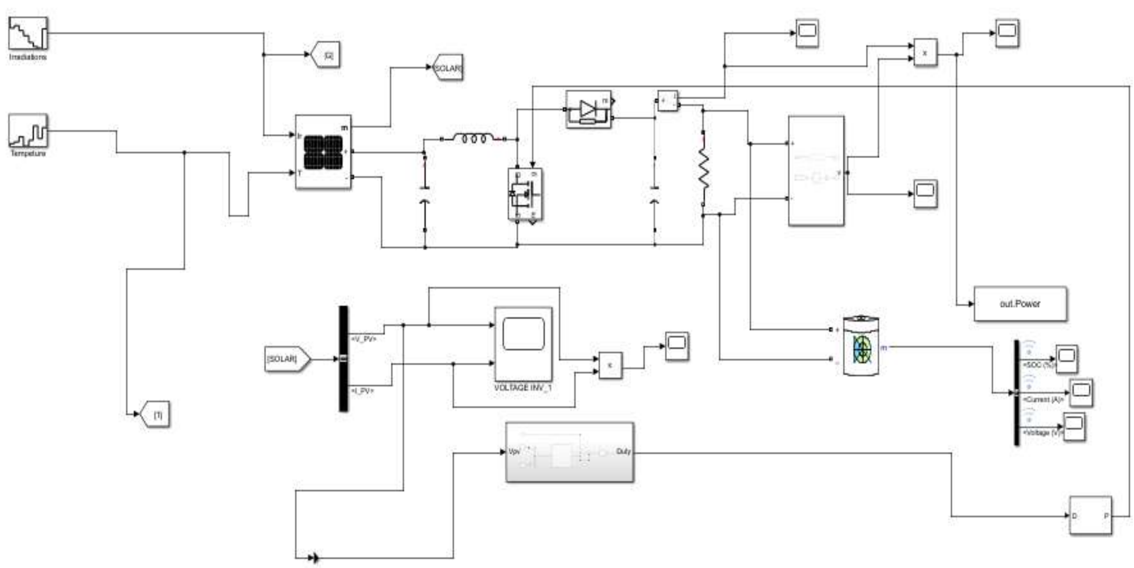


Fig.7- Simulation of ANN based Microgrid system

On the other hand, ANN-based methods integrate MPPT with advanced ANN algorithms that stabilize and optimize the charging currents based on the real-time environmental data. This may optimize the energy utilization and even extend the life of the battery significantly since such conditions that would lead to battery degradation may be prevented. Improvement in ANN integration with MPPT systems is a breakthrough in battery charging technology, so it has to adapt to the ability to assure optimal charging. This is a top invention in terms of efficiency and reliability in application and use of renewable systems, especially when solar is the source.

Power Quality Improvement: Highlight how ANN-based strategies have smoothed power inconsistencies, referring to the visual results from your simulations.

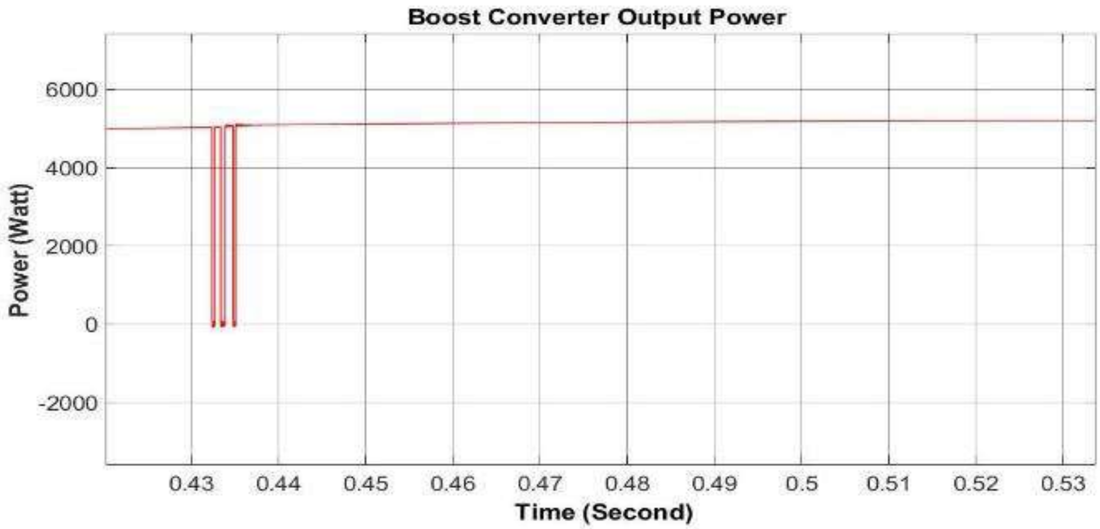


Fig.8- Boost Converter Output Power without control

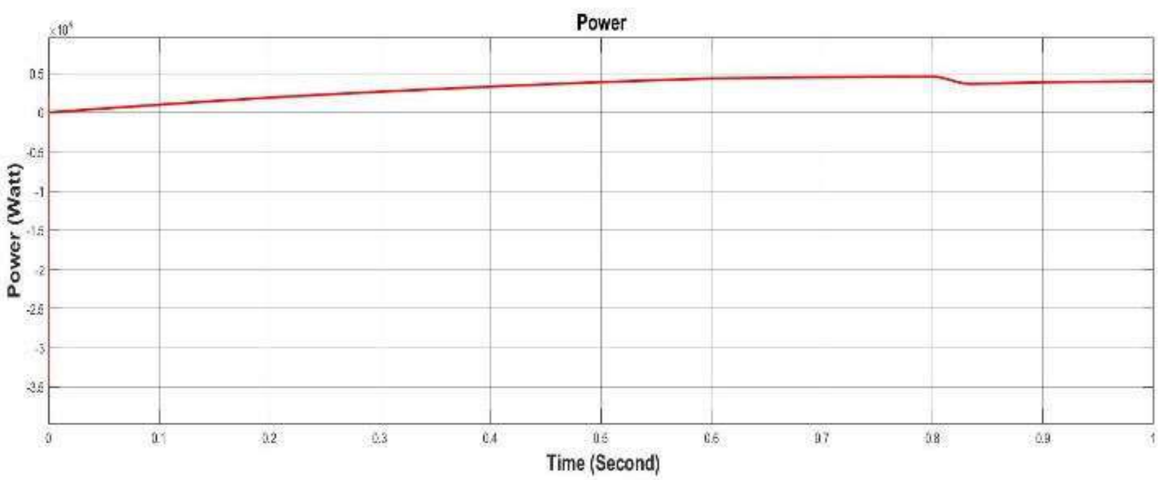


Fig.9- ANN based Boost solar Power

Interpretation of Power Quality Improvement through ANN-Based Strategies

Simulation studies of the proposed system have shown that although traditional methods of MPPT under the complexity of solar conditions guarantee constant power, they experience inconsistencies because of the non-linearity of solar irradiant. It is, however, through ANNs combined with MPPT via this method that there is an enabler for significant enhancement in power stability and quality. The use of the ANN is in predicting and mitigation efficiency against such fluctuations, thereby providing a smooth power supply to the loads, more so during variable weather and loading scenarios. At the same time, efficiency and sustainability of the microgrid system are drastically improved, depicting value in the used ANNs for the modernization of renewable management.

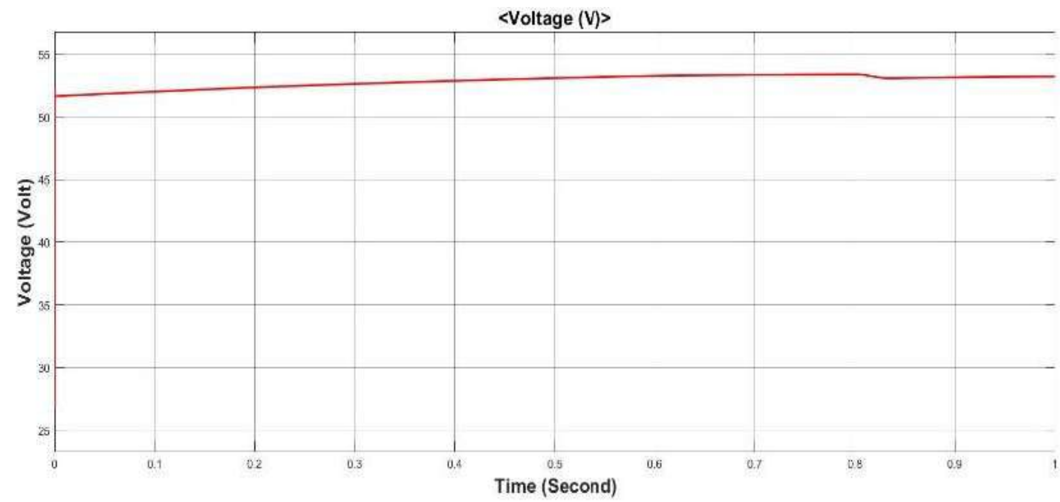


Fig.10- ANN-Based Battery Charging Voltage and Current Graphs

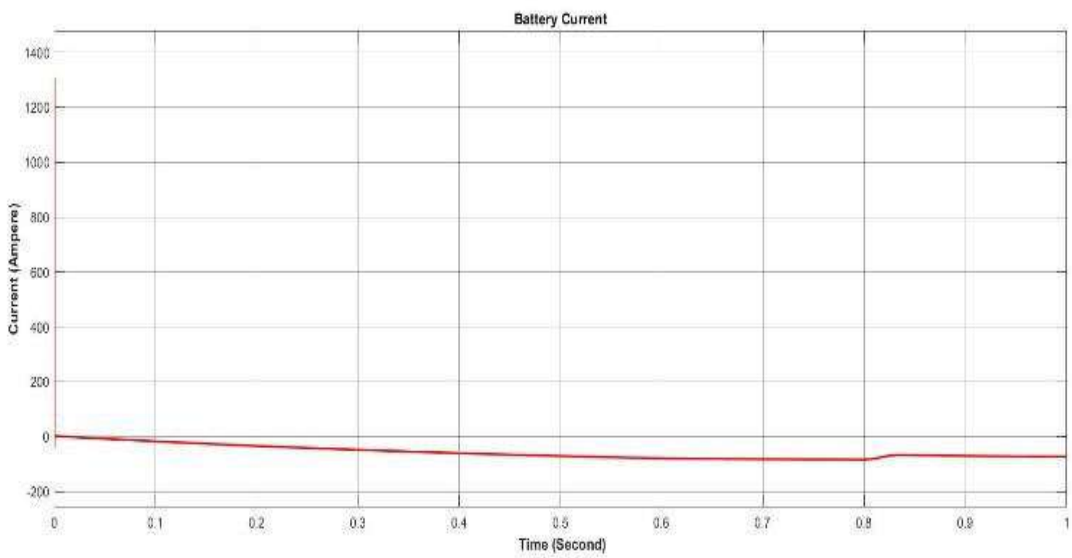


Fig.11- ANN based battery charging current

Interpretation of ANN-Based Battery Charging Voltage and Current Graphs

Simulation results clearly demonstrate the benefits of using Artificial Neural Networks (ANNs) in managing battery charging processes within a DC microgrid. The graphs show that ANNs maintain a stable and consistent charging voltage, which is essential for preserving battery health and optimizing energy storage. This stability helps to avoid the harmful voltage fluctuations often seen in traditional systems, which can degrade battery performance over time.

Additionally, the current graph illustrates how ANNs dynamically adjust the charging current in response to the battery's state of charge and the availability of energy from renewable sources. This adaptive approach not only improves charging efficiency but also extends the battery's life by preventing the stresses associated with rapid charging cycles. Overall, the integration of ANNs into battery management enhances energy utilization and ensures that the battery operates within its optimal electrical conditions, thus maximizing its effectiveness and longevity.

RESULT SUMMARY

The results of the simulation are presented, elucidating the advantages and disadvantages of the ANN-based methodology. It also looks into the possibilities for scalability and integration with other cutting-edge technologies like blockchain and the Internet of Things. The performance of the ANN is assessed by simulating a number of situations, including fault events, peak load circumstances, variability in renewable energy, and regular operation. The outcomes are contrasted with baseline situations that use conventional control techniques. This paper intends to show the potential for considerable improvements in power quality in DC microgrids with high penetration of distributed renewable energy sources by methodically implementing and assessing ANN-based control techniques.

V. CONCLUSION

To sum up, the incorporation of Artificial Neural Networks (ANNs) into DC microgrid management represents a noteworthy progress in improving battery charging procedures and power quality optimization. We can dynamically handle the difficulties presented by renewable energy sources by utilizing ANNs, guaranteeing reliable and effective power distribution. ANNs' adaptive capabilities protect the health of the batteries by averting harmful fluctuations, and they also enhance the microgrid's overall operational efficiency. The findings of this study highlight how ANN technology has the ability to completely transform energy management systems, increasing their resilience and capacity to support sustainable urban energy infrastructures. Future research directions include investigating hybrid control strategies that integrate artificial neural networks (ANNs) with other machine learning approaches, improving the ANN's capacity to manage larger, more complicated microgrid systems, and conducting additional experimental validation in a variety of operational scenarios. This paper intends to show the potential for considerable improvements in power quality in DC microgrids with high penetration of distributed renewable energy sources by methodically implementing and assessing ANN-based control techniques.

REFERENCES

1. Rangarajan, S.S., Raman, R., Singh, A., Shiva, C.K., Kumar, R., Sadhu, P.K., Collins, E.R. and Senjyu, T., 2023. DC microgrids: A propitious smart grid paradigm for smart cities. *Smart Cities*, *6*(4), pp.1690-1718.

2. Maurya, R., Prakash, S. and Singh, A.K., 2023. Challenges, configuration, control, and scope of DC microgrid systems: A review. *Journal of Electrical Engineering & Technology*, *18*(3), pp.1655-1674.

3. Talaat, M., Elkholy, M.H., Alblawi, A. and Said, T., 2023. Artificial intelligence applications for microgrids integration and management of hybrid renewable energy sources. *Artificial Intelligence Review*, *56*(9), pp.10557-10611.

4. Rani, P., Parkash, V. and Sharma, N.K., 2024. Technological aspects, utilization and impact on power system for distributed generation: A comprehensive survey. *Renewable and Sustainable Energy Reviews*, *192*, p.114257.

5. Alotaibi, I., Abido, M.A., Khalid, M. and Savkin, A.V., 2020. A comprehensive review of recent advances in smart grids: A sustainable future with renewable energy resources. *Energies*, *13*(23), p.6269.

6. Sharma, S., Gupta, S., Zuhaib, M., Bhuria, V., Malik, H., Almutairi, A., Afthanorhan, A. and Hossaini, M.A., 2023. A Comprehensive Review on STATCOM: Paradigm of Modelling, Control, Stability, Optimal Location, Integration, Application, and Installation. *IEEE Access*.

7. Pijarski, P. and Belowski, A., 2024. Application of Methods Based on Artificial Intelligence and Optimisation in Power Engineering—Introduction to the Special Issue. *Energies*, *17*(2), p.516.

8. Nanda, B. and Jena, R., 2018. Power Quality Analysis by using Active Filter in AC/DC Microgrid. *International Journal of Scientific Research in Science and Technology (IJSRST)*, *4*(9), pp.47-56.

9. Rajesh, P., Shajin, F.H., Rajani, B. and Sharma, D., 2022. An optimal hybrid control scheme to achieve power quality enhancement in micro grid connected system. *International Journal of Numerical Modelling: Electronic Networks, Devices and Fields*, *35*(6), p.e3019.

10. Praiselin, W.J. and Edward, J.B., 2018. A review on impacts of power quality, control and optimization strategies of integration of renewable energy based microgrid operation. *International Journal of Intelligent Systems and Applications*, *12*(3), p.67.