



# IJRASET

International Journal For Research in  
Applied Science and Engineering Technology



# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 13      **Issue:** IV      **Month of publication:** April 2025

**DOI:** <https://doi.org/10.22214/ijraset.2025.68142>

[www.ijraset.com](http://www.ijraset.com)

Call:  08813907089

E-mail ID: [ijraset@gmail.com](mailto:ijraset@gmail.com)

# A Comparative Analysis of Different Methods for Predicting Solar Radiation Using Deep Neural Networks: An Innovative Approach to Sustainable Community Building.

Aditya Kushwaha<sup>1</sup>, Sushant Jhingran<sup>2</sup>

Department of Computer Science and Engineering Sharda School of Engineering and Technology Sharda University, Greater Noida

**Abstract:** *In order to deal with the electrical crisis in an efficient manner, it is imperative to promote the use of renewable energy sources, with a specific emphasis on solar energy. Nevertheless, the challenge lies in the variable patterns of solar irradiance, which are influenced by seasonal weather variations, making it a complex factor to predict. The primary aim of this study is to predict the solar radiation on inclined surfaces, while considering the impact of meteorological variables like temperature, wind speed, humidity, and air pressure. The research used the Artificial Neural Network (ANN) methodology to examine the Douala metropolitan area.*

*Consequently, the model may be used to estimate solar irradiance not only inside the specified study area but also across locations with similar climatic conditions, by using different combinations of input data. The model exhibited its proficiency in appropriately evaluating sun ray intensities by generating a noteworthy outcome via its application using (50 concealed-layer neural network networks along the logistic Sigmoid function). Keywords: solar radiation, neural networks, feed-forward neuron networks, and multilayer perceptron's.*

**Keywords:** *radiation from the sun, neural networks, networks of feed-forward neurons, and multilayer perceptron's.*

## I. INTRODUCTION

The advancement of artificial intelligence (AI) has resulted in substantial transformations across various scientific disciplines, particularly in the area of renewable energy utilisation, with a specific emphasis on solar power. The use of Artificial Neural Networks (ANNs) and its specialised subset, Recurrent Neural Networks (RNNs), has gained significance in the domain of solar radiation forecasting. The establishment of an environmentally friendly neighbourhood is predicated upon the efficient utilisation of renewable resources, the advancement of a robust energy infrastructure that concurrently preserves the environment and guarantees economic viability. Accurate forecasts for sunlight brightness have the highest priority in the running of green energy structures, as well as essential components of several environmentally sustainable initiatives. The primary aim of using artificial neural networks (ANNs) is to enhance the precision of solar radiation forecasts, therefore facilitating the seamless integration of solar energy into power grids and bolstering local sustainable communities. Given the growing concerns around climate change, there is a pressing need for effective and sustainable climate mitigation strategies. Data analytics plays a crucial role in the establishment of renewable energy forecasting systems. Artificial neural networks (ANNs), particularly recurrent neural networks (RNNs), has the capacity to assess sequential and time-series data, rendering them extremely appropriate for predicting the dynamic attributes of solar energy.

Exposure to radiation. The integration of technology for the smart grid represents a substantial paradigm shift in energy distribution, since it relies largely on the presence of dependable power generation sources. Accurate estimations of ultraviolet (UV) radiation are crucial for the successful integration of solar energy systems into intelligent power grids, as they enable the maintenance of a harmonious equilibrium between energy supply and demand. Artificial neural networks (ANNs) provide a means to enhance the reliability of solar power, ensuring optimal efficiency in smart grid technologies.

This study does a comparative analysis of several artificial neural network (ANN) methodologies, with a particular focus on recurrent neural networks (RNNs), in order to forecast solar radiation.

The examination evaluates the efficacy, adaptability, and potential for expansion, with a specific emphasis on their pivotal role in optimising the use of renewable energy. This study not only highlights the progress achieved in renewable energy forecasting technologies, but also shows the commitment to

The technique for solar irradiance and forecasting is shown.

In Figure 1. Addressing environmental degradation is crucial and aligns with the concepts of ecological stewardship. This plays a vital role in connecting the shift towards renewable energy sources with the broader improvement of ecological resilience. The present work makes a valuable contribution to the current state of knowledge by presenting a method for predicting solar radiation levels..

Our study contributes to the conversation about sustainable energy methods by providing insightful information for handling the the difficulties of switching to environmentally friendly and renewable energy sources.

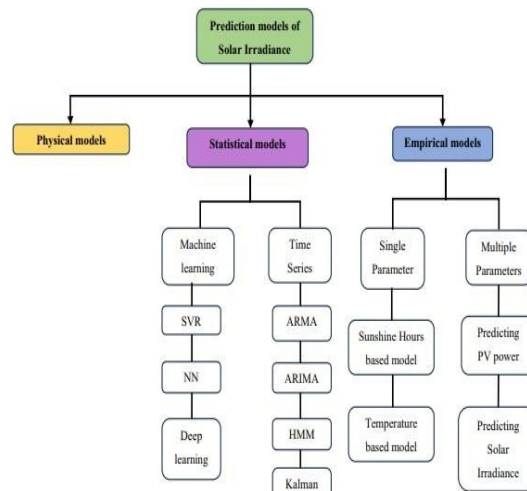


Figure 1 Method to predict the amount of solar radiation

Considering the historical developments of energy sources, the current challenges, and the pressing need for sustainable solutions, our research turns into significant and relevant in addressing the issues of contemporary energy. Long-term economic progress in Central Africa has been significantly impeded by the region's persistent energy deficit. Sustainable growth. In order to alleviate the region's considerable dependency, innovative and urgent measures are required. on outdated energy sources derived from fossil fuels and the growing demand for electricity. In spite of these challenges, precise Solar irradiance forecasts are becoming increasingly crucial for a sustainable energy strategy. The energy of the area Accurate estimates of solar irradiance may help make infrastructure more robust and reliable. It may increase solar energy production's dependability and efficiency. The urgent need to address Central Africa's energy deficit has led to an increasing focus on the pro- renewable energy sources moving as a potential remedy. Numerous scholarly studies demonstrate the important potential for solar energy in Cameroon, highlighting its critical role in the country's sustainable energy development region. In the meticulous design process, a thorough grasp of variations in solar output becomes very crucial. various systems for converting renewable energy.

This thorough comprehension is essential for determining choices in a number of system engineering domains, such as complex design, ideal scale, and exacting performance evaluations and prudent methods of energy management. It is indisputable that solar photovoltaic electricity is essential to determining the future of sustainable energy. The Solar radiation, the most abundant energy source on Earth, has the power to significantly alter things. trustworthy resources, such highlight the amazing fact that the Earth absorbs a significant quantity of solar energy. from the sun in an hour is enough to provide all of the world's energy needs for a whole year

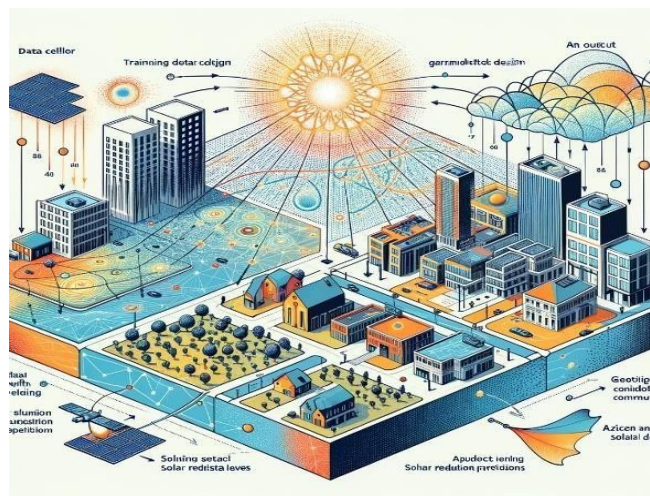
## II. LITERATURE REVIEW

The estimations has been greatly enhanced by recent developments in predictive modelling, which is of utmost importance for the optimisation of solar energy systems in sustainable communities.

This paper examines the utilisation and efficacy of Recurrent Neural Networks (RNNs) and Artificial Neural Networks (ANNs) in the prediction of solar radiation, with a particular focus on their implications for the design and management of environmentally friendly power plants. Recurrent Neural Networks (RNNs), primarily Long Short-Term Memory (LSTM) networks, have potential in the prediction of solar radiation as a result of its capacity to effectively capture temporal relationships inherent in the data. Research suggests that RNNs excel at short-term forecasting by comprehending time series data. Artificial neural network (ANN) models, which are widely used for predicting solar radiation, have the ability to represent nonlinear interactions without requiring explicit assumptions about the distribution of data. The inherent flexibility and adaptability of these entities make them well-suited for a wide range of forecasting situations. They excel at modelling nonlinear interactions without requiring explicit assumptions about the underlying data distribution. Sharma et al. (2019) state that artificial neural networks (ANNs) have the ability to combine several meteorological and temporal inputs in order to provide precise predictions of solar irradiation. Artificial neural networks (ANNs) possess inherent flexibility and adaptability, rendering them well-suited for a diverse array of forecasting situations, including both short-term hourly forecasts and long-term seasonal patterns.

Although both RNN and ANN models provide significant benefits for predicting solar radiation, their effectiveness may differ depending on the unique application scenarios. In their study, Zhang et al. (2021) provide a thorough analysis, highlighting that Recurrent Neural Networks (RNNs) tend to surpass Artificial Neural Networks (ANNs) in situations that need intricate temporal examination, such as short-term prediction. Nevertheless, Artificial Neural Networks (ANNs) are often more readily available and simpler to deploy, exhibiting strong performance across a wide range of prediction applications. The selection between recurrent neural network (RNN) and artificial neural network (ANN) models should be guided by the particular demands of the solar energy project, including factors such as the forecasting timeframe, data accessibility, and computing capabilities. The continuous progress of these models shows considerable promise in enhancing the efficacy and sustainability of solar energy systems, therefore making a valuable contribution towards the overarching objective of sustainable community development.

This study introduces an innovative research approach that employs an Artificial Neural Network (ANN) model to forecast solar radiation levels in urban environments.



This research is crucial for advancing city planning and optimising solar energy utilisation in the future. The research assesses urban qualities of 20 cities globally by using extensive datasets and including limited urban information across many parameters, such as geographic coordinates, average height, and the Azimuth angle. The artificial neural network (ANN) model is trained to identify intricate connections among these factors, accurately forecasting the lowest solar radiation annually with a loss of 0.01, a mean squared error of 0.01, and an R2-squared value of 85%.

The introductory section emphasises the importance of sustainable urban planning in addressing the environmental, health, and social consequences associated with urbanisation. Artificial neural networks (ANN) have shown great potential in improving the modelling of urban texture and radiant energy for sustainable urban design. The study examines prior research on remote sensing, digital elevation data, and the impact of urban morphology on solar radiation. It proposes a new method that combines artificial neural networks (ANN) with OpenStreetMap data to improve the accuracy of predictions.

### III. METHODOLOGY

NIXTime Data	Time	Radiation	Temperat	Pressure	Humidity	WindDirec	Speed	TimeSunR	TimeSunSet
L.48E+09	9/29/2016	23:55:26	1.21	48	30.46	59	177.39	5.62	6:13:00 18:13:00
L.48E+09	9/29/2016	23:50:23	1.21	48	30.46	58	176.78	3.37	6:13:00 18:13:00
L.48E+09	9/29/2016	23:45:26	1.23	48	30.46	57	158.75	3.37	6:13:00 18:13:00
L.48E+09	9/29/2016	23:40:21	1.21	48	30.46	60	137.71	3.37	6:13:00 18:13:00
L.48E+09	9/29/2016	23:35:24	1.17	48	30.46	62	104.95	5.62	6:13:00 18:13:00
L.48E+09	9/29/2016	23:30:24	1.21	48	30.46	64	120.2	5.62	6:13:00 18:13:00
L.48E+09	9/29/2016	23:25:19	1.2	49	30.46	72	112.45	6.75	6:13:00 18:13:00
L.48E+09	9/29/2016	23:20:22	1.24	49	30.46	71	122.97	5.62	6:13:00 18:13:00
L.48E+09	9/29/2016	23:15:22	1.23	49	30.46	80	101.18	4.5	6:13:00 18:13:00
L.48E+09	9/29/2016	23:10:22	1.21	49	30.46	85	141.87	4.5	6:13:00 18:13:00
L.48E+09	9/29/2016	23:05:23	1.23	49	30.47	93	120.55	2.25	6:13:00 18:13:00
L.48E+09	9/29/2016	23:00:25	1.21	49	30.47	98	144.19	3.37	6:13:00 18:13:00
L.48E+09	9/29/2016	22:55:20	1.22	49	30.47	99	139.8	6.75	6:13:00 18:13:00
L.48E+09	9/29/2016	22:50:19	1.21	50	30.47	99	140.92	2.25	6:13:00 18:13:00
L.48E+09	9/29/2016	22:45:31	1.23	50	30.47	99	147.61	5.62	6:13:00 18:13:00
L.48E+09	9/29/2016	22:40:23	1.22	50	30.47	99	113.78	4.5	6:13:00 18:13:00
L.48E+09	9/29/2016	22:35:19	1.21	50	30.47	99	123.03	10.12	6:13:00 18:13:00
L.48E+09	9/29/2016	22:30:22	1.22	50	30.47	99	173.73	6.75	6:13:00 18:13:00
L.48E+09	9/29/2016	22:25:19	1.22	50	30.47	98	91.43	6.75	6:13:00 18:13:00

Figure 2 Dataset

The methodology section provides an overview of the technical procedures and data gathering techniques used, with a particular focus on the significance of parametric design and remote sensing in creating datasets for the artificial neural network (ANN) model. The findings illustrate the efficacy of the model in forecasting yearly solar radiation, indicating its potential use in the field of urban planning for the purposes of enhancing energy efficiency and promoting sustainability. Conversations delve into the consequences of solar radiation patterns on urban planning, promoting the deliberate positioning of buildings and green areas to maximise the use of solar energy. The originality of this study is derived from its extensive geographical coverage and its specific emphasis on examining the influence of building height and urban layout on solar radiation. This research offers valuable information for urban planners and designers of solar energy systems. The finding underscores the potential of the artificial neural network (ANN) model in forecasting solar radiation, hence emphasising the study's significance in the realms of urban planning and sustainability endeavours. This study represents a notable advancement in comprehending and enhancing the utilisation of solar energy in urban settings, providing essential approaches for the promotion of sustainable urban growth.

Data is being gathered to the Satellite Singal and through the survey analysis of different region in Figure 2

#### A. Data Cleaning and Preparation

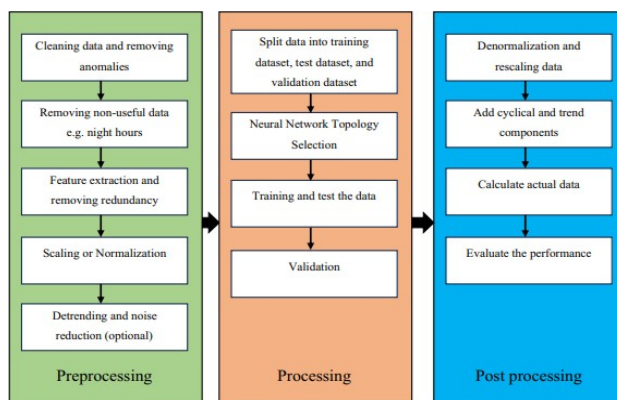


Figure 3 Model For Predicting

- Sunlight Intensity
- tangible models
- Practical models
- Models of statistics

- Device
- Momentum
- sequence
- Kalman
- Hmm
- In-depth
- gaining knowledge
- ARIMA
- NN
- SVR
- ARMA
- Forecasting
- Sun
- The radiance
- The temperature
- founded model
- Forecasting
- PV electricity
- Hours of Sunshine
- founded model
- Several
- Specifications
- Individual
- Measurement

B. Data Analysis

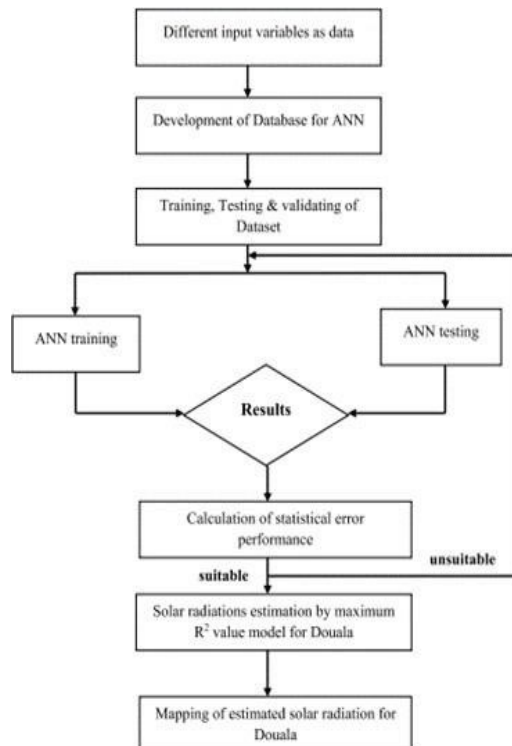


Figure 4 A structure demonstrating the many treatments involved in establishing the ranking of a parameter.

The literature has recorded a wide range of statistical models for the purpose of forecasting solar brightness . . . Two types of statistical models may be distinguished: time series techniques, such as ARMA, ARIMA, HMM, and machine learning algorithms like RVS, Deep Learning, and Neural Networks. In time series methodology, solar irradiance is a time series made up of three parts. These elements consist of the mean, the periodic components, and the long-term trend. The autoregressive moving average (ARMA) (p, q) on average is the most often used method for predicting time series. It is represented by Equation.(3): Two parts make up equation (3): an autoregressive (AR) component in the first section and a second section's moving average (MA) component. You may use the Yule-Walker technique to determine the variables. It is essential to do a stationarity test on the time series before using this method. Time series prediction approaches may be deemed disadvantageous due to this necessity. Machine learning methods are now widely used. The Support Vector Machine is the most widely used method for machine learning. machine (SVM), a method for supervised learning. SVM is a useful computational tool for this kind of work of categorization and prediction. SVM establishes decision boundaries by using the idea of decision planes.

C. Comparative Analysis

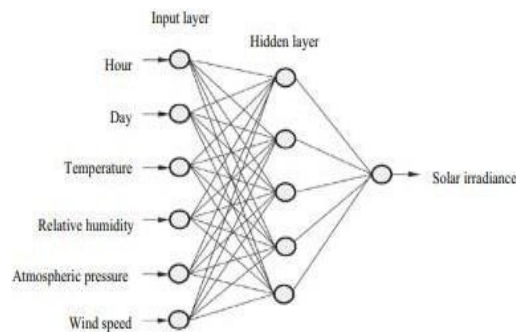


Figure 5 The current research proposes an artificial neural network (ANN) model for evaluating the value of the radiation from the sun.

In order to construct a confusion matrix, it is customary to need two distinct sets of data: the real labels, which represent the actual results, and the projected labels, which represent the outcomes predicted by a model. Based on the first examination of the dataset, it seems to include a range of environmental parameters and radiation measurements. However, it does not explicitly provide a classification conclusion or prediction that may be used for the construction of a confusion matrix.

A confusion matrix often requires a classification situation that involves either binary or multiclass classification. May I inquire if there is a particular variable that you like to forecast or categorise from this dataset? One such approach involves the categorization of radiation levels based on a predetermined threshold, so transforming the issue into a binary classification task. Subsequently, the dataset may be divided to mimic both predicted and actual results. Please inform me of your preferred course of action.

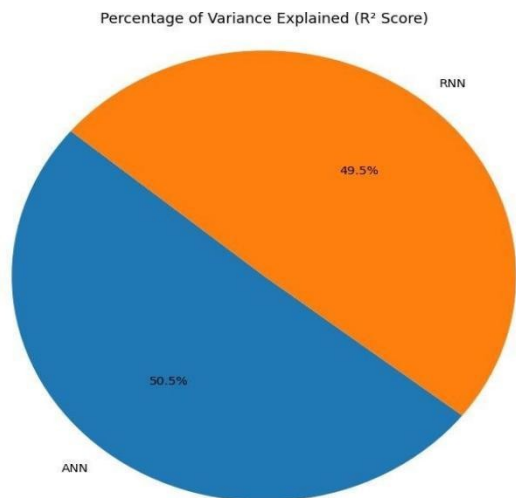


Figure 6 Comparative Analysis

In comparative analysis the ANN shows the 91.4% percent accuracy rate shows in Figure 7 and in figure 8 RNN confusion Matrix individual 89.9% so combinedly the result accuracy is 55% and RNN is 45.5%

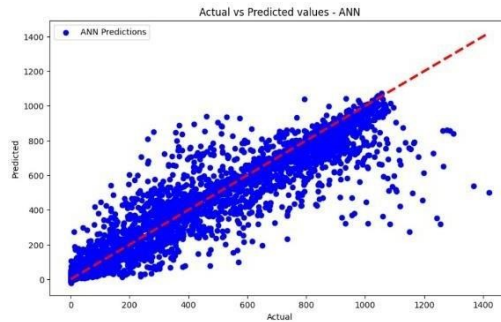


Figure 8 ANN confusion matrix result

#### IV. RESULTS AND DISCUSSION

This paper presents a comprehensive investigation of the performance of the ANN model, backed by statistical data and graphical representations. The purpose of the discussion is to analyse the data, make comparisons between different models, and explore the consequences for the development of sustainable communities.

#### V. CONCLUSION AND FUTURE WORK

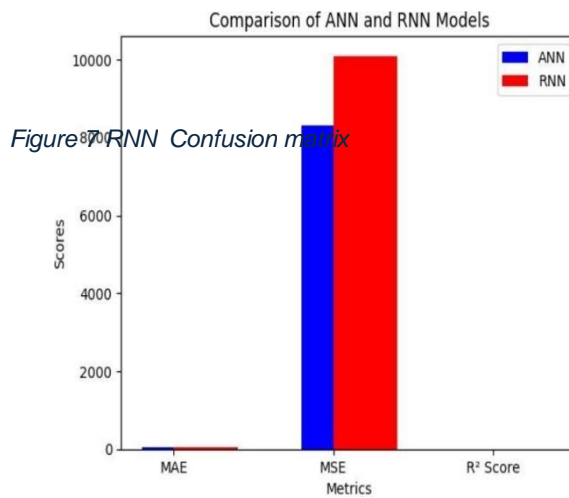
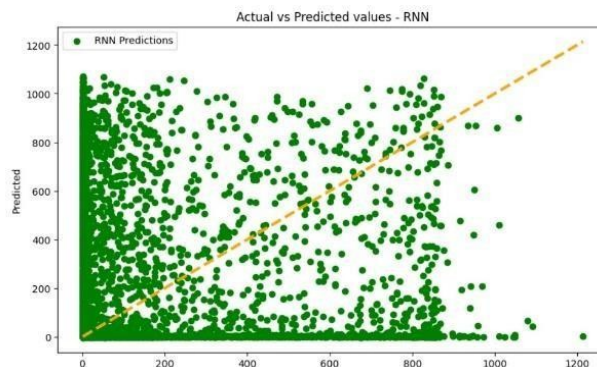


Figure 9 RNN Confusion matrix



This research introduces efficient artificial neural network (ANN) and recurrent neural network (RNN) methods for predicting solar radiation. These findings have implications for improving solar energy systems and promoting sustainable community development. Subsequent investigations might delve into supplementary environmental factors, hybrid deep neural network (DNN) models, and intelligent solar energy system configurations aimed at fostering sustainable communities

## REFERENCES

- [1] Panda, S. et al. Residential demand side management model, optimization and future perspective: A review. *Energy Rep.* 8, 3727–3766. ISSN 2352-4847 <https://doi.org/10.1016/j.egyr.2022.02.300> (2022).
- [2] Meena, C. S. et al. "Innovation in green construction industry for sustainable future. *Energies* 15(18), 6631. <https://doi.org/10.3390/en15186631> (2022).
- [3] Yang, C., Wu, Z., Li, X. & Fars, A. Risk- constrained stochastic scheduling for energy hub: Integrating renewables, demand response, and electric cars. *Energy* 288, 129680. <https://doi.org/10.1016/j.energy.2023.129680> (2024).
- [4] Liu, Y., Liu, X., Li, X., Yuan, H. & Xue, Y. Model predictive control-based dual-mode functioning of an energy-stored quasi-Z-source photovoltaic power system. *IEEE Trans. Ind. Electron.* 70(9), 9169–9180. <https://doi.org/10.1109/TIE.2022.3215451> (2023).
- [5] Hu, F. et al. Research on the development of China's photovoltaic technology innovation network from the standpoint of patents. *Energy Strategy Rev.* 51, 101309. <https://doi.org/10.1016/j.esr.2024.101309> (2024).
- [6] Shirkhani, M. et al. A review of microgrid decentralized energy/voltage control architectures and methodologies. *Energy Rep.* 10, 368–380. <https://doi.org/10.1016/j.egyr.2023.06.022> (2023).
- [7] Yao, L., Wang, Y. & Xiao, X. Concentrated solar power plant modeling for power system research. *IEEE Trans. Power Syst.* <https://doi.org/10.1109/TPWRS.2023.3301996> (2023).
- [8] Duan, Y., Zhao, Y. & Hu, J. An initialization-free distributed method for dynamic economic dispatch issues in microgrid: Modeling, optimization and analysis. *Sustain. Energy Grids Netw.* 34, 101004. <https://doi.org/10.1016/j.segan.2023.101004> (2023).
- [9] Panda, S. et al. A thorough assessment of demand side management and market design for renewable energy support and integration. *Energy Rep.* 10, 2228–2250. ISSN 23524847 <https://doi.org/10.1016/j.egyr.2023.09.049> (2023).
- [10] Gupta, S. et al. Estimation of solar radiation with account of terrestrial losses at a specified location—A review. *Sustainability* 15, 9962 <https://doi.org/10.3390/su15139962>; <https://doi.org/10.1049/cth2.12504> (2023).
- [11] Khelifi, R. et al. Short-term PV power forecasting using a hybrid TVF-EMD-ELM method. *Int. Trans. Electr. Energy Syst.* 2023(6413716), 14. <https://doi.org/10.1155/2023/6413716> (2023).
- [12] Ssekulima, E. B., Anwar, M. B., AlHinai, A. & ElMoursi, M. S. "Wind speed and solar irradiance forecasting techniques for enhanced renewable energy integration with the grid: a review. *IET Renew. Power Gener.* 10(7), 885–989. <https://doi.org/10.1049/iet-rpg.2015.0477> (2016).
- [13] Sharma, H. et al. Feasibility of solar grid-based industrial virtual power plant for efficient energy scheduling: A case of Indian Power Sector. *Energies* 15(3), 752. <https://doi.org/10.3390/en15030752> (2022).
- [14] Chandra, S. et al. Influence of artificial and natural cooling on performance characteristics of a solar P.V. system: A case study. *IEEE Access* 9, 29449–29457. <https://doi.org/10.1109/ACCESS.2021.3058779> (2021). Figure 21. Measured and predicted solar irradiance considering temperature, wind speed, air pressure, and relative humidity. 22 Vol. (1234567890) Reports from Science In 2024, at 14:3572 There is a 10.1038/s41598-024-54181-y available. [www.scientificreports.nature.com](http://www.scientificreports.nature.com)
- [15] Song, X., Wang, H., Ma, X., Yuan, X. & Wu, X. Robust model predictive current control for a nine- phase open-end winding PMSM with great computational efficiency. *IEEE Trans. Power Electron.* 38(11), 13933–13943. <https://doi.org/10.1109/TPEL.2023.3309308> (2023).
- [16] Zhang, X. et al. Voltage and frequency stabilization control approach of virtual synchronous generator based on tiny signal model. *Energy Rep.* 9, 583–590. <https://doi.org/10.1016/j.egyr.2023.03.071> (2023).
- [17] Li, S., Zhao, X., Liang, W., Hossain, M. T. & Zhang, Z. A rapid and accurate calculation technique of line breaking power flow based on Taylor expansion. *Front. Energy Res.* <https://doi.org/10.3389/fenrg.2022.943946> (2022).
- [18] Mellit, A., Eleuch, H., Benghanem, M., Elaoun, C. & Pavan, A. M. An adaptive model for prediction of global, direct and diffuse hourly solar irradiance. *Energy Convers. Manag.* 51(4), 771–782. <https://doi.org/10.1016/j.enconman.2009.10.034> (2010).
- [19] Li, S. et al. Differential low-temperature AC breakdown between synthetic ester and mineral oils: Insights from both molecular dynamics and quantum mechanics. *IEEE Trans. Dielectr. Electr. Insulat.* <https://doi.org/10.1109/TDEI.2023.3345299> (2023).
- [20] Li, X. et al. Dimensional diversity (0D, 1D, 2D, 3D) in Perovskite solar cells: Exploring the possibilities of mix-dimensional integrations. *J. Mater. Chem. A* <https://doi.org/10.1039/D3TA06953B> (2024).
- [21] Mazumdar, B. M., Saquib, M. & Das, A. K. An empirical model for ramp analysis of utility-scale solar PV power. *Solar Energy* 107, 44–49. <https://doi.org/10.1016/j.solener.2014.05.027> (2014).
- [22] Bajaj, M. & Singh, A. K. Grid integrated renewable DG systems: A study of power quality problems and state-of-the-art mitigation methods. *Int. J. Energy Res.* 44, 26–69. <https://doi.org/10.1002/er.4847> (2020).
- [23] Hussien, S., Ayalew, F., Bajaj, M., Sharma, N.K., Jurado, F. & Kamel, K. An review of current achievements in energy storage for solar power systems. In *IEEE International Conference on Automatica—Congreso de la Asociación Chilena de Control Automático, Curicó Chile, October 24–28* (2022).
- [24] Dashtdar, M., Bajaj, M. & Hosseinimoghadam, S. M. S. Design of optimum energy management system in a residential microgrid based on smart control. *Smart Sci.* <https://doi.org/10.1080/23080477.2021.1949882> (2021).
- [25] Lin, X. et al. Stability investigation of three- phase grid-connected inverter under the weak grids with asymmetrical grid impedance by LTP theory in time domain. *Int. J. Electr. Power Energy Syst.* 142, 108244. <https://doi.org/10.1016/j.ijepes.2022.108244> (2022).
- [26] Song, J., Mingotti, A., Zhang, J., Peretto, L., & Wen, H. Accurate damping factor and frequency estimate for damped real-valued sinusoidal signals. *IEEE Trans. Instrum. Meas.* <https://doi.org/10.1109/TIM.2022.3220300> (2022).
- [27] Alzahrani, A., Shamsi, P., Dagli, C. & Ferdowsi, M. Solar irradiance forecasting using deep neural networks. *Proc. Comput. Sci.* 114, 304–313. <https://doi.org/10.1016/j.procs.2017.09.045> (2017).
- [28] Mohanty, S. et al. Demand side management of electric cars in smart grids: A study on solutions, difficulties, models, and Optimising. *Energy Rep.* 8, 12466–12490. ISSN 2352–4847 <https://doi.org/10.1016/j.egyr.2022.09.023> (2022).
- [29] Gao, Y., Doppelbauer, M., Ou, J. & Qu, R. Design of a double-side flux modulation permanent magnet machine for servo application. *IEEE J. Emerg. Sel. Top. Power Electron.* 10(2), 1671–1682. <https://doi.org/10.1109/JESTPE.2021.3105557> (2021).
- [30] Zhang, X., Wang, Z. & Lu, Z. Multi-objective load dispatch for microgrid with electric cars using modified gravitational search and particle swarm optimization technique. *Appl. Energy* 306, 118018. <https://doi.org/10.1016/j.apenergy.2021.118018> (2022).

- [31] Shao, B. et al. Power coupling analysis and better decoupling management for the VSC coupled to a weak AC grid. *Int. J. Electr. Power Energy Syst.* 145, 108645. <https://doi.org/10.1016/j.ijepes.2022.108645> (2023).
- [32] Shen, Y., Xie, J., He, T., Yao, L. & Xiao, Y. CEEMD-fuzzy control energy management of hybrid energy storage systems in electric automobiles. *IEEE Trans. Energy Convers.* <https://doi.org/10.1109/TEC.2023.3306804> (2023).
- [34] Alfaris, F., Alzahrani, A. & Kimball, J. W. Stochastic model for PV sensor array data. In 2014 International Conference on Renewable Energy Research and Application (ICRERA), Milwaukee, WI, USA. 798–803 <https://doi.org/10.1109/ICRERA.2014.7016495> (IEEE, 2014).
- [35] Yang, Y., Zhang, Z., Zhou, Y., Wang, C. & Zhu, H. Design of a simultaneous information and power transmission system based on a modulating characteristic of magnetron. *IEEE Trans. Microwave Theory Tech.* 71(2), 907–915. <https://doi.org/10.1109/TMTT.2022.3205612> (2023).
- [36] Wang, Y., Xia, F., Wang, Y. & Xiao, X. Harmonic transfer function based single-input single-output impedance modeling of LCCHVDC systems. *J. Mod. Power Syst. Clean Energy* <https://doi.org/10.35833/MPCE.2023.000093> (2023).
- [38] Anil Kumar, B. et al. A new framework for boosting the power quality of electrical vehicle battery charging based on a modified Ferdowsi converter. *Energy Rep.* 10, 2394–2416. ISSN 2352–4847 <https://doi.org/10.1016/j.egyr.2023.09.070> (2023).
- [39] Rekioua, D. et al. Optimization and intelligent power management control for an autonomous hybrid wind turbine photovoltaic diesel generator with batteries. *Sci. Rep.* 13, 21830. <https://doi.org/10.1038/s41598-023-49067-4> (2023).
- [40] Fu, C., Yuan, H., Xu, H., Zhang, H. & Shen, L. TMSO-Net: Texture adaptive multi-scale observation for light field image depth estimate. *J. Vis. Commun. Image Represent.* 90, 103731. <https://doi.org/10.1016/j.jvcir.2022.103731> (2023).
- [41] Chen, Y., Zhu, L., Hu, Z., Chen, S. & Zheng, X. Risk propagation in multilayer heterogeneous network of linked system of large engineering project. *J. Manag. Eng.* 38(3), 4022003. [https://doi.org/10.1061/\(ASCE\)ME.1943-5479.0001022](https://doi.org/10.1061/(ASCE)ME.1943-5479.0001022) (2022).
- [42] Shboul, B. et al. A novel ANN model for hourly solar radiation and wind speed prediction: A case study across the north & south of the Arabian Peninsula. *Sustain. Energy Technol. Assess.* 46, 101248. <https://doi.org/10.1016/j.seta.2021.101248> (2021).
- [43] Dolara, A., Leva, S. & Manzolini, G. Comparison of alternative physical models for PV power output prediction. *Solar Energy* 119, 83–99. <https://doi.org/10.1016/j.solener.2015.06.017> (2015).
- [44] De Soto, W., Klein, S. A. & Beckman, W. A. Improvement and validation of a model for photovoltaic array performance. *Solar Energy* 80(1), 78–88. <https://doi.org/10.1016/j.solener.2005.06.010> (2006).
- [45] Li, P., Hu, J., Qiu, L., Zhao, Y. & Ghosh, B. K. A distributed economic dispatch approach for power-water networks. *IEEE Trans. Control Netw. Syst.* 9(1), 356–366. <https://doi.org/10.1109/TCNS.2021.3104103> (2022).
- [46] Hou, X. et al. A self-powered biomimetic mouse whisker sensor (BMWS) targeting at terrestrial and space objects perception. *Nano Energy* 118, 109034. <https://doi.org/10.1016/j.nanoen.2023.109034> (2023).
- [47] Luo, J., Zhuo, W., & Xu, B. A deep neural network-based assistive decision technique for financial risk prediction in carbon trading market. *J. Circuits Syst. Comput.* <https://doi.org/10.1142/S0218126624501536> (2023).
- [48] Hassan, J. ARIMA and regression models for prediction of daily and monthly clearness index. *Renew. Energy* 68, 421–427. <https://doi.org/10.1016/j.renene.2014.02.016> (2014).
- [49] Phinikarides, A. et al. ARIMA simulation of the performance of several solar technologies. In 2013 IEEE 39th solar Specialists Conference (PVSC), Tampa, FL, USA. 0797–0801 <https://doi.org/10.1109/PVSC.2013.6744268> (IEEE, 2013).
- [50] David, M., Ramahatana, F., Trombe, P. J. & Lauret, P. Probabilistic forecasting of the solar irradiance using recursive ARMA and GARCH models. *Solar Energy* 133, 55–72. <https://doi.org/10.1016/j.solener.2016.03.064> (2016).
- [51] Gana, N. N. & Akpootu, D. O. Angstrom Type Empirical Correlation for Estimating Global Solar Radiation in North-Eastern Nigeria.
- [52] Veldhuis, A. J. et al. An empirical model for rack-mounted PV module temperatures for Southeast Asian regions tested for minute time scales. *IEEE J. Photovolt.* 5(3), 774–782. <https://doi.org/10.1109/JPHOTOV.2015.2405762> (2015).
- [53] Alzahrani, A., Shamsi, P., Ferdowsi, M. & Dagli, C. H. Chaotic behavior in high-gain interleaved dc–dc converters. *Proc. Comput. Sci.* 114, 408–416. <https://doi.org/10.1016/j.procs.2017.09.002> (2017).
- [54] Alzahrani, A., Shamsi, P. & Ferdowsi, M. Analysis and design of bipolar Dickson DC–DC converter. In 2017 IEEE Power and Energy Conference at Illinois (PECI), Champaign, IL, USA. 1–6 <https://doi.org/10.1109/PECI.2017.7935733> (IEEE, 2017). 23 Vol.: (0123456789) Reports from Science In 2024, at 14:3572 There is a 10.1038/s41598-024-54181-y available. [www.scientificreports.nature.com](http://www.scientificreports.nature.com)
- [55] Alzahrani, A., Shamsi, P. & Ferdowsi, M. A new interleaved non-isolated high-gain DC–DC boost converter using Greinacher voltage multiplier cells. In 2017 IEEE 6th International Conference on Renewable Energy Research and Applications (ICRERA), San Diego, CA. 222–227 <https://doi.org/10.1109/ICRERA.2017.8191270> (IEEE, 2017).
- [56] LeCun, Y., Bengio, Y. & Hinton, G. Deep learning. *Nature* 521(7553), 436–444. <https://doi.org/10.1038/nature14539> (2015).
- [57] Zhang, L. et al. Research on the orderly charging and discharging method of electric cars considering journey characteristics and carbon quota. *IEEE Trans. Transport. Electrification* <https://doi.org/10.1109/TTE.2023.3296964> (2023).
- [58] Zhang, L., Sun, C., Cai, G., & Koh, L. H. Charging and discharging optimization technique for electric cars considering elasticity demand response. *eTransportation* 18, 100262 <https://doi.org/10.1016/j.etrans.2023.100262> (2023).
- [59] Mo, J. & Yang, H. Sampled value attack detection for busbar differential protection based on a negative selection immune system. *J. Mod. Power Syst. Clean Energy* 11(2), 421–433. <https://doi.org/10.35833/MPCE.2021.000318> (2023).
- [60] Yang, M., Wang, Y., Xiao, X. & Li, Y. A robust damping control for virtual synchronous generators based on energy reshaping. *IEEE Trans. Energy Convers.* 38(3), 2146–2159. <https://doi.org/10.1109/TEC.2023.3260244> (2023).
- [61] Yan, Z. et al. Mechanism and technology assessment of a new alternating-arc-based directed energy deposition technique via polarity-switching self-adaptive shunt. *Addit. Manuf.* 67, 103504. <https://doi.org/10.1016/j.addma.2023.103504> (2023).
- [62] Wang, Z., Li, J., Hu, C., Li, X. & Zhu, Y. Hybrid energy storage system and management method for motor drive with high torque overload. *J. Energy Storage* 75, 109432. <https://doi.org/10.1016/j.est.2023.109432> (2024).
- [63] Koumi Ngoh, S., Ayina, O., Monkam, L. & Kemajou, A. Estimation of the Global Solar Radiation Under Sudan-Type Tropical Climate Using Artificial Neural Network Model. 22–33 (2013).

- [64] Voyant, C., Haurant, P., Muselli, M., Paoli, C. & Nivet, M.-L. Time series modeling and large scale global solar radiation forecasting from geostationary satellites data. *Solar Energy* 102, 131–142. <https://doi.org/10.1016/j.solener.2014.01.017> (2014).
- [65] Kalogirou, S. A. Artificial neural networks in renewable energy systems applications: A review. *Renew. Sustain. Energy Rev.* 5(4), 373–401. [https://doi.org/10.1016/S1364-0321\(01\)00006-5](https://doi.org/10.1016/S1364-0321(01)00006-5) (2001).
- [66] Kalogirou, S. & Senc, A. Artificial intelligence approaches in solar energy applications. In *Solar Collectors and Panels, Theory and Applications* (Manyala, R. ed.) <https://doi.org/10.5772/10343> (Sciyo, 2010).
- [67] Benganem, M. Artificial intelligence algorithms for prediction of solar radiation data: A review. *IJRET* 3(2), 189. <https://doi.org/10.1504/IJRET.2012.045626> (2012).
- [68] Hontoria, L., Aguilera, J. & Zufiria, P. Generation of hourly irradiation synthetic series using the neural network multilayer perceptron. *Solar Energy* 72(5), 441–446. [https://doi.org/10.1016/S0038-092X\(02\)00010-5](https://doi.org/10.1016/S0038-092X(02)00010-5) (2002).
- [69] Hontoria, L., Aguilera, J., Riesco, J. & Zufiria, P. Recurrent Neural Supervised Models for Generating Solar Radiation Synthetic Series.
- [70] Voyant, C., Muselli, M., Paoli, C. & Nivet, M.-L. Optimization of an artificial neural network specialised to the multivariate forecasting of daily global radiation. *Energy* 36(1), 348–359. <https://doi.org/10.1016/j.energy.2010.10.032> (2011).
- [71] Mellit, A. & Pavan, A. M. A 24-h forecast of sun irradiance using artificial neural network: Application for performance prediction of a grid-connected PV facility in Trieste, Italy. *Solar Energy* 84(5), 807–821. <https://doi.org/10.1016/j.solener.2010.02.006> (2010).
- [72] Premalatha, N. & Valan Arasu, A. Prediction of solar radiation for solar systems by utilising ANN models with varying back propagation algorithms. *J. Appl. Res. Technol.* 14(3), 206–214 <https://doi.org/10.1016/j.jart.2016.05.001> (2016).
- [73] Mohamed, Z. E. Using the artificial neural networks for prediction and verifying solar radiation. *J. Egypt. Math. Soc.* 27(1), 47. <https://doi.org/10.1186/s42787-019-0043-8> (2019).
- [74] Bouchouicha, K., Hassan, M. A., Bailek, N. & Aoun, N. Estimating the worldwide solar irradiation and optimizing the error estimates in Algerian desert climate. *Renew. Energy* 139, 844–858. <https://doi.org/10.1016/j.renene.2019.02.071> (2019).
- [75] Notton, G., Paoli, C., Ivanova, L., Vasileva, S. & Nivet, M. L. Neural network technique to estimate 10-min solar global irradiation values on slanted planes. *Renew. Energy* 50, 576–584. <https://doi.org/10.1016/j.renene.2012.07.035> (2013).
- [76] Akkaya, B. Comparison of multi-class classification algorithms on early detection of cardiac disorders. In *y-BIS 2019 Conference: Recent Advances in Data Science and Business Analytics* (2019). [https://www.academia.edu/41940316/Comparison\\_of\\_Multi-class\\_Classification\\_Algorithms\\_on\\_Early\\_Diagnosis\\_of\\_Heart\\_Disease](https://www.academia.edu/41940316/Comparison_of_Multi-class_Classification_Algorithms_on_Early_Diagnosis_of_Heart_Disease) ses. Accessed 7 June 2023.
- [77] Dalar, A. Z., Kocadagli, A. Y. & Kose, A. M. Ozan Kocadagli Ali Erkoç Bilge Baser Nihan Acar Denizli Tahir Ekin LOC of y-BIS (2019).
- [78] Capizzi, G., Napoli, C. & Bonanno, F. Innovative second-generation wavelets production using recurrent neural networks for sun radiation forecasting. *IEEE Trans. Neural Netw. Learn. Syst.* 23(11), 1805–1815. <https://doi.org/10.1109/TNNLS.2012.2216546> (2012).
- [79] Faceira, J., Afonso, P. & Salgado, P. Prediction of solar radiation using artificial neural networks. In *CONTROLO'2014—Proceedings of the 11th Portuguese Conference on Automatic Control* (Moreira, A. P., Matos, A. & Veiga, G. eds.) *Lecture Notes in Electrical Engineering*. Vol. 321. 397–406 [https://doi.org/10.1007/978-3-319-10380-8\\_38](https://doi.org/10.1007/978-3-319-10380-8_38) (Springer, 2015).
- [80] Mellit, A., Benganem, M., Arab, A. H. & Guessoum, A. A simple model for producing sequences of global solar radiation data for isolated sites: Using artificial neural network and a library of Markov transition matrices method. *Solar Energy* 79(5), 469–482. <https://doi.org/10.1016/j.solener.2004.12.006> (2005).
- [81] Cao, J. C. & Cao, S. H. Study on predicting sun irradiance using neural networks with preprocessing sample data using wavelet analysis. *Energy* 31(15), 3435–3445. <https://doi.org/10.1016/j.energy.2006.04.001> (2006).
- [82] Khorasanizadeh, H. & Mohammadi, K. Prediction of daily global solar radiation by day of the year in four cities situated in the sunny parts of Iran. *Energy Convers. Manag.* 76, 385–392. <https://doi.org/10.1016/j.enconman.2013.07.073> (2013).
- [83] Hassan, G., Youssef, E., Ali, M., Mohamed, Z. & Hanafy, A. Evaluation of alternative sunshine-based models for forecasting worldwide sun radiation—Case study: New Borg El-Arab city, Egypt. *Therm. Sci.* 22(2), 979–992. <https://doi.org/10.2298/TSCI160803085H> (2018).

#### Author contributions

I.M.M., S.K.N., R.J.J.M., B.F.N.K.:

Conceptualization, Methodology, Software,

Visualization, Investigation,

Writing: Preparing the first draft. Resources, Validation, Supervision, Data Curation; R.O., S.R.D.N., J.G.T.

Writing—Review & Editing; M.B. & M.B.:

Resources; Project management; Supervision; Writing—Review & revising.

conflicting interests

The writers say they have no conflicting agendas.

More details

Please send correspondence and material requests to M.B., M.I.M., or M.B.

Visit [www.nature.com/reprints](http://www.nature.com/reprints) for details about rights and reprints.

Note from the publisher: Springer Nature maintains its neutrality on jurisdictional assertions in published maps and connections with institutions. 24

Vol. (1234567890)

Reports from Science

In 2024, at 14:3572



There is a 10.1038/s41598-024-54181-y available. [www.scientificreports.nature.com](http://www.scientificreports.nature.com)

Open Access This work is distributed under an

International Creative Commons Attribution 4.0

A licence that allows for the following: usage, sharing, adaption, distribution, and replication in any format or format, as long as you provide a link to the original work and give due acknowledgment to the author(s) or sources Creative Commons licence, and state if any modifications were made. Any photos or other content from third parties used in this are covered under the article's Creative Commons licencing, unless a credit line to the original source specifies otherwise content. If content is not covered by the Creative Commons licence for this article and your intended usage is not If your usage goes beyond what is allowed by law or statutory regulation, you must get permission directly from the owner of the copyright. Go to <http://creativecommons.org/licenses/by/4.0/> to get a copy of this licence.

Copyright 2024 The Author(s), updated publication 2024



10.22214/IJRASET



45.98



IMPACT FACTOR:  
7.129



IMPACT FACTOR:  
7.429



# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089  (24\*7 Support on Whatsapp)