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Research Paper

SOLAR PHOTOVOLTAIC PANEL DEGRADATION AND OUTPUT POWER PREDICTION USING ENVIRONMENTAL INPUTS

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Abstract

Solar energy has emerged as a key renewable energy source due to the growing demand for clean and sustainable power. Solar photovoltaic (PV) panels convert sunlight into electricity; however, their performance gradually declines over time because of degradation and varying environmental conditions. Factors such as solar radiation, temperature, humidity, wind speed, and air pressure significantly influence the efficiency and output power of PV systems. Accurate prediction of PV panel output and understanding degradation patterns are therefore essential for optimizing performance, planning maintenance, and improving energy management.

This project, titled “Solar Photovoltaic Panel Degradation and Output Power Prediction Using Environmental Inputs,” focuses on analyzing the impact of environmental parameters on PV panel performance and predicting power output using machine learning techniques. The dataset used includes features such as solar radiation, air temperature, wind speed, sunshine duration, air pressure, relative humidity, and corresponding power generation values.

Data preprocessing and feature selection are performed to ensure data quality and identify the most influential factors affecting power output. Machine learning models are trained to learn the relationship between environmental conditions and PV system performance. The trained model can predict output power based on given environmental inputs, enabling early detection of performance degradation and inefficiencies.

The proposed system enhances the monitoring and maintenance of solar PV systems by providing accurate predictions and insights. It assists solar plant operators in making informed decisions regarding maintenance scheduling, performance optimization, and energy planning. The implementation is carried out using Python and relevant machine learning libraries, ensuring flexibility and scalability.

I. Introduction

Solar energy is one of the most important renewable energy sources used for electricity generation in the modern world. With the increasing demand for clean, sustainable, and eco-friendly energy, solar photovoltaic (PV) systems are being widely adopted across residential, commercial, and industrial sectors. Solar PV panels

convert sunlight directly into electrical energy using semiconductor-based photovoltaic cells. These systems offer several advantages such as low operating cost, minimal maintenance, long lifespan, and zero emissions during operation, making them a reliable alternative to conventional energy sources.

Traditional energy sources such as coal, oil, and natural gas are limited in availability and contribute significantly to environmental problems like air pollution and climate change. Due to these challenges, there is a global shift toward renewable energy solutions, among which solar energy has emerged as one of the most promising options. Governments and organizations worldwide are promoting solar power to reduce dependency on fossil fuels and support sustainable development.

However, despite their advantages, solar photovoltaic panels are not immune to performance degradation. Over time, their efficiency decreases due to factors such as aging, environmental exposure, dust accumulation, temperature variations, humidity, and mechanical stress. This gradual reduction in performance is known as solar panel degradation. As a result, the ability of PV panels to convert sunlight into electricity declines, affecting overall energy generation.

Environmental conditions play a crucial role in determining the output power of solar PV systems. Parameters such as solar radiation, temperature, humidity, wind speed, and atmospheric pressure directly influence panel performance. For instance, higher solar radiation increases power output, whereas high temperatures can reduce the efficiency of photovoltaic cells. Similarly, dust and environmental pollution can block sunlight and decrease energy production. Therefore, understanding the relationship between environmental factors and PV system performance is essential for optimizing energy generation.

II. Literature Survey

The prediction of solar photovoltaic (PV) panel output power and the analysis of degradation behavior have gained significant attention in recent years due to the growing importance of renewable energy systems. Researchers have extensively explored the use of **Artificial Intelligence (AI)** and **Machine Learning (ML)** techniques to improve the accuracy of solar power forecasting and system performance monitoring. This section reviews key research contributions in the field.

Mellit & Kalogirou (2013) conducted a foundational study on the application of Artificial Neural Networks (ANN) for photovoltaic power prediction. Their work demonstrated that ANN models can effectively capture nonlinear relationships between environmental parameters such as solar radiation, ambient temperature, and wind speed, resulting in accurate power output predictions. This study laid the groundwork for the use of AI techniques in solar energy forecasting.

Essama et al. (2022) investigated the use of various machine learning algorithms for predicting solar PV power output. The study utilized environmental features including solar irradiance, temperature, humidity, and time-related variables. Their findings highlighted that machine learning models can significantly improve prediction accuracy compared to traditional statistical approaches, especially when dealing with complex and dynamic environmental data.

Al-Dahidi et al. (2024) compared multiple machine learning models such as Multiple Linear Regression, Decision Tree, Random Forest, Support Vector Regression (SVR), and Multi-Layer Perceptron (MLP) for PV energy prediction. The study showed that ensemble methods like Random Forest and advanced models like MLP provide higher accuracy and better generalization capabilities, particularly when handling large datasets with multiple influencing factors.

Alrashidi & Rahman (2023) proposed a hybrid data-driven approach combining Support Vector Regression and Artificial Neural Networks to enhance short-term photovoltaic power forecasting. By integrating different models, their approach improved prediction accuracy and robustness. The study emphasized the importance of hybrid models in capturing complex patterns in environmental data and reducing prediction errors.

Aouidad & Bouhelal (2024) explored machine learning-based solar power forecasting using both regression and classification techniques. Their research utilized large-scale environmental datasets to train predictive models. The results indicated that machine learning approaches can effectively forecast solar energy production and support better energy management and system optimization.

Overall, the reviewed literature demonstrates that **machine learning and hybrid models play a crucial role in improving solar PV power prediction accuracy**. Environmental parameters such as solar radiation, temperature, humidity, and wind speed are consistently identified as key factors influencing PV performance. These studies provide a strong foundation for the present project, which focuses on analyzing PV panel degradation and predicting output power using environmental inputs.

III. System Analysis

Solar photovoltaic (PV) systems require accurate monitoring and prediction to ensure efficient energy generation. Traditional systems often fail to capture the complex relationship between environmental factors and panel performance. System analysis focuses on identifying key inputs such as solar radiation, temperature, humidity, wind speed, and air pressure. The system must handle large volumes of environmental and historical data. Data preprocessing is required to manage missing values and noise. The system should provide accurate power prediction and degradation analysis. Real-time prediction capability is essential for practical use. Scalability is important for large solar plants. Performance evaluation metrics must be considered. Overall, the system aims to provide an intelligent and data-driven monitoring solution.

Existing System

In the existing system, solar power output is estimated using basic mathematical models or historical averages. These methods rely mainly on solar irradiance and do not consider multiple environmental factors. Traditional monitoring systems lack predictive capabilities. They cannot accurately detect degradation over time. Maintenance decisions are often reactive rather than proactive. The system does not handle dynamic environmental changes effectively. Manual monitoring is time-

consuming and inefficient. There is limited use of advanced data analytics. Prediction accuracy is low. Overall, the existing system is less efficient and lacks intelligence.

Disadvantages of Existing System

- Low prediction accuracy
- Limited consideration of environmental factors
- No real-time prediction capability
- Cannot detect panel degradation effectively
- Manual monitoring required
- Time-consuming process
- Inefficient maintenance planning

Proposed System

The proposed system uses Machine Learning techniques to predict solar PV output power and analyze panel degradation. It considers environmental inputs such as solar radiation, temperature, humidity, wind speed, and air pressure. Data preprocessing ensures clean and structured input. Feature selection identifies important parameters affecting power output. Machine learning models such as Linear Regression, Random Forest, and Neural Networks are used. The system predicts output power based on input conditions. It helps detect performance degradation over time. The system provides real-time predictions. It supports proactive maintenance planning. Overall, it offers an intelligent and automated solution.

Advantages of Proposed System

- High prediction accuracy
- Considers multiple environmental factors
- Real-time power prediction
- Detects panel degradation
- Supports proactive maintenance
- Reduces operational costs
- Improves system efficiency

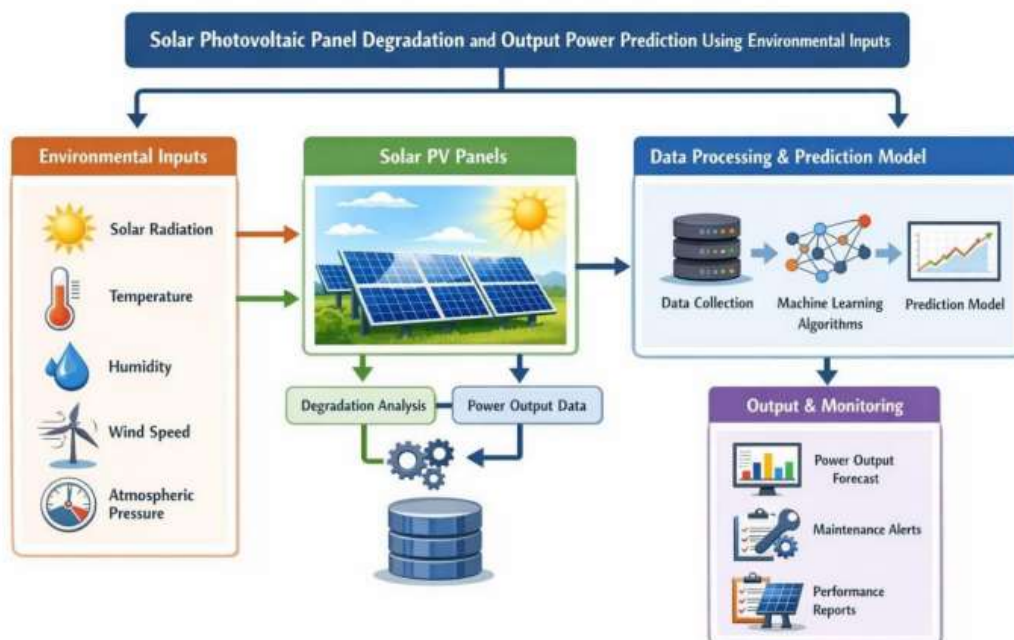
IV. Methodology

The methodology begins with collecting solar PV datasets containing environmental and power output data. Data preprocessing is performed using Pandas and NumPy to clean missing values. Feature selection is applied to identify important variables. The dataset is split into training and testing sets. Machine learning models such as Linear Regression, Random Forest, and ANN are applied. The models are trained to learn relationships between inputs and output power. Predictions are made on test data. Performance is evaluated using metrics like RMSE and accuracy. Hyperparameter tuning improves model performance. The best model is selected for deployment.

System Architecture

The system architecture consists of input, preprocessing, model, prediction, and output layers. The input layer collects environmental data. The preprocessing layer

cleans and transforms data. The processed data is passed to the machine learning model. The model analyzes patterns and predicts power output. The degradation analysis module evaluates performance loss. The prediction results are sent to the output layer. The system can be integrated with a user interface. Real-time processing ensures quick results. The architecture supports scalability and efficient data flow. Overall, it provides a structured and intelligent framework.



V. Result and Output





VI. Conclusion

The project “Solar Photovoltaic Panel Degradation and Output Power Prediction Using Environmental Inputs” successfully demonstrates the application of machine learning techniques in improving the monitoring and performance analysis of solar energy systems. By analyzing environmental parameters such as solar radiation, temperature, humidity, wind speed, and air pressure, the system effectively predicts the output power of photovoltaic panels and identifies performance degradation over time.

Through proper data preprocessing, feature selection, and model training, the developed system is able to learn the relationship between environmental conditions and solar power generation. Machine learning models such as regression and ensemble methods provide accurate and reliable predictions, enabling better understanding of system behavior under varying conditions. The results confirm that environmental factors play a significant role in determining the efficiency and output of solar PV systems.

The proposed system offers several practical benefits, including real-time prediction, improved maintenance planning, and early detection of performance issues. By identifying degradation patterns, solar plant operators can take timely actions such as cleaning panels, replacing faulty components, or optimizing system settings. This helps in maintaining system efficiency, reducing operational costs, and ensuring consistent energy production.

Overall, this project highlights the importance of data-driven approaches in renewable energy management. The integration of machine learning with solar monitoring systems enhances decision-making, improves reliability, and supports sustainable energy development.

References

- [1] Kumar, R. D., Prudhviraj, G., Vijay, K., Kumar, P. S., & Plugmann, P. (2024). Exploring COVID-19 through intensive investigation with supervised machine learning algorithm. In *Handbook of Artificial Intelligence and Wearables* (pp. 145-158). CRC Press.
- [2] Swathi, B., Vijay, K., Sushanth Babu, M., & Dinesh Kumar, R. (2024, November). Machine Learning Techniques in Cloud Based Intrusion Detection. In *The International Conference on Artificial Intelligence and Smart Environment* (pp. 557-564). Cham: Springer Nature Switzerland.

- [3] Sv satyakrishna, shirisha rangu ,bhargavi nalacheruve.(2024) Prospective investigation on colorectal cancer with SMOTE on machine learning Algorithm
- [4] Dr.G.Vishnu Murthy, BhargaviNalacheruve 1Professor, Department of computer Science & engineering, Anurag University, TS, India. 2Student, Department of computer Science & engineering, Anurag University, TS, India.
- [5] V. N. S. Manaswini, K. K, C. Nigam, S. S. Ali, R. Niranjana, and Suman, “Real-Time Object Detection in Drone Surveillance Using YOLOv5,” in Proc. 2025 3rd Int. Conf. IoT, Communication and Automation Technology (ICICAT), Gorakhpur, India, 2025, pp. 1–6, doi: 10.1109/ICICAT68430.2025.11414670.
- [6] B. Soundarya, V. N. S. Manaswini, M. Ayyakrishnan, R. D. Kumar, “Contextual Analysis of Big Data Analytics in Intelligent Transportation Frameworks,” in Intersection of Artificial Intelligence, Data Science, and Cutting-Edge Technologies: From Concepts to Applications in Smart Environment, Lecture Notes in Networks and Systems, vol. 1353, Cham: Springer, 2025, doi: 10.1007/978-3-031-88304-0_79.
- [7] R. D. Kumar, V. N. S. Manaswini, “Applications of blockchain in smart cities: detecting fake documents from land records using blockchain technology,” in Blockchain for Smart Cities, Elsevier, 2021, pp. 105–117, doi: 10.1016/B978-0-12-824446-3.00017-X.
- [8] Tejavath Veeramma, Badarla Anil, Guguloth Ravinder, “An advanced movie recommender using collaborative filtering and sentiment analysis,” International Research Journal of Modernization in Engineering Technology and Science, vol. 7, no. 7, July 2025, doi: 10.56726/IRJMETS81618.
- [9] Ravi Kumar Banoth, Ramana Murthy B V, “Automatic crop recommendation system using LightGBM and decision tree machine learning models,” Journal of Machine and Computing, vol. 5, no. 1, pp. 343, Jan. 2025, doi: 10.53759/7669/jmc202505026.
- [10] Ravi Kumar Banoth, Dr. B.V. Ramana Murthy, “Smart agriculture through IoT and machine learning for analyzing carbon footprints,” in Proc. Int. Conf. Computer Science and Communication Engineering (ICCSCE), Apr. 2025.
- [11] Ravi Kumar Banoth, B. V. Ramana Murthy, “Soil image classification using transfer learning approach: MobileNetV2 with CNN,” SN Computer Science, vol. 5, art. no. 199, 2024, doi: 10.1007/s42979-023-02500-x.