MANTECH Publications

Journal of Research in Computer Science and Engineering
Volume 10, Issue 3, September-December, 2025
ISSN: 2457-0818 (Online)

Solarix

Mrudula M. Ligade[1], Suhani M.Patil[2], Jai R. Mudgal[3], Samruddhi S. Bhosale[4], Manasi A. Shendure[5], Mrs. Mriam T. Naik[6]

[1,2,3,4,5]Student, Assistant Professor[6]

[1,2,3,4,5,6]Department of Computer Science & Engineering

Sharad Institute of Technology College of Engineering (Yadrav-Ichalkaranji)

Email ID: *mrudulaligade05@gmail.com[1], suhanipatil6682@gmail.com[2], jaimudgal8272@gmail.com[3], bhosalesamruddhi2004@gmail.com[4], manasishendure@gmail.com[5], mariamnaik@sitcoe.org.in[6]*

ABSTRACT

Solar panel efficiency is crucial for sustainable energy production, as any fault or obstruction in the panel can significantly reduce energy output. To ensure optimal performance and detect potential issues, real-time monitoring of solar panels is essential. Traditional methods often rely on manual inspections, which are time- consuming and prone to human error. Therefore, an automated system for detecting solar panel faults is necessary.This project proposes a machine learning-based solution for solar panel fault detection and classification using Convolutional Neural Networks (CNN). The system consists of two models: one for detecting the presence of solar panels and another for classifying faults into categories such as "Bird-drop," "Dusty," "Electrical-damage," "Physical-Damage," and "Snow-Covered." The solution is designed to process real-time video streams from a camera, continuously updating the predictions on the user interface. Additionally, detected faults are stored in a database for further analysis.

KEYWORDS: *Solar Panel Fault Detection, Convolutional Neural Networks (CNN), Machine Learning, Image Processing, Real-time Monitoring, Solar Panel Efficiency.*

INTRODUCTION

With the growing global focus on renewable energy, solar power has become one of the most promising and widely adopted sustainable energy sources. Solar but their performance can

Page 123-131 © MANTECH PUBLICATIONS 2025. All Rights Reserved

decline over time due to issues such as dust buildup, bird droppings, and physical or electrical damage. These problems can significantly reduce power generation if not detected early.

This project presents an automated system for solar panel detection and fault classification using advanced machine learning and computer vision techniques. The proposed model employs Convolutional Neural Networks (CNNs) to first identify the presence of solar panels in real-time camera feeds and then classify faults affecting their efficiency. The system distinguishes between six common conditions— Clean, Dusty, Bird-drop, Electrical-damage, Physical- damage, and Snow-covered—allowing for precise fault identification and prioritization of maintenance tasks.

The integration of artificial intelligence with renewable energy monitoring enables a proactive approach to solar farm management. By automating fault detection and analysis, the proposed system minimizes manual inspection efforts, reduces downtime, and ensures optimal energy output. In addition, the collected data can be used for long-term analysis to predict future maintenance needs, improve operational efficiency, and contribute to the development of smarter, self-monitoring solar energy systems.

To enhance accuracy, each detected solar panel is divided into nine sections, and faults are analyzed at the sectional level. Detected issues and their corresponding severity levels are stored in a MySQL database, providing insights into performance losses and maintenance requirements. The complete solution is integrated with a Flask-based web interface for real-time visualization and data management.

In the future, the system can be enhanced by integrating IoT sensors and drones to automate inspection over large solar farms. Machine learning models can be upgraded to deep learning architectures like YOLOv8 or EfficientNet for faster and more accurate detection. The integration of cloud-based services such as AWS or Google Cloud can help store large datasets and generate automated performance reports. Predictive analytics can also be used to forecast potential panel degradation, enabling preventive maintenance and reducing operational costs.

Page 123-131 © MANTECH PUBLICATIONS 2025. All Rights Reserved

Problem statement- Develop an automated system to detect solar panel faults in real-time.

LITERATURE SURVEY

Machine Learning-Based Fault Detection: Mellit et al. (2018) introduced a fault detection system using Support Vector Machines (SVM) and Decision Trees. Their research showed that machine learning algorithms can outperform traditional methods by learning from large datasets. However, their approach relied only on sensor data and did not include image-based analysis, limiting its ability to detect visible surface faults.[1]

Image-Based Fault Detection Using CNN: Liang et al. (2019) utilized Convolutional Neural Networks (CNNs) for detecting cracks and defects in solar panels through image data. Their work proved that CNNs are highly effective in identifying physical damage but did not account for environmental issues like dust, snow, or bird droppings — which our project includes for more comprehensive detection.[2]

Computer Vision Techniques for Surface Monitoring:
Haque et al. (2020) applied computer vision algorithms to identify dust accumulation on solar panels. Their study emphasized the value of texture analysis and real-time monitoring through cameras. While effective, their model focused only on a single fault type, whereas our system detects multiple fault categories across different sections of the panel.[3]

Data-Driven Maintenance and Storage Systems:
Seyedmahmoudian et al. (2019) proposed a data management approach that used databases for tracking fault patterns and enabling predictive maintenance.

Inspired by this, our project integrates MySQL for storing detected faults, fault severity, and energy impact, ensuring continuous performance tracking and analysis.

Real-Time and Multi-Class Fault Detection Models: Wang et al. (2021) and Rahman et al. (2020) explored real-time IoT-based monitoring and ensemble machine learning techniques, respectively. Building upon their work, our project combines real-time fault visualization via Flask with a dual-classifier model — one for solar panel detection and another for multi-fault classification — to enhance accuracy and responsiveness.

Page 123-131 © MANTECH PUBLICATIONS 2025. All Rights Reserved

Hybrid Deep Learning Models for Performance Prediction:

Zhang et al. (2021) developed a hybrid model combining Convolutional Neural Networks (CNN) and Long Short- Term Memory (LSTM) networks to predict solar panel efficiency. Their system analyzed both image and historical performance data, achieving high prediction accuracy.

However, it required extensive training and was not optimized for real-time fault detection, which our project addresses using CNNs for faster image-based classification.

Sectional Analysis for Precise Fault Localization:

Singh and Sharma (2020) proposed a sectional fault detection method that divides the solar panel into smaller regions to improve the precision of fault identification. This approach enhances maintenance efficiency by pinpointing the exact location of faults. Our project adopts a similar concept by dividing panels into nine sections, assigning unique IDs to each, and detecting multiple faults within a single panel.

Proposed Methodology

Real-Time Input Acquisition and Preprocessing

The system begins by capturing continuous video input through a USB camera. Each frame from the live feed is resized and normalized to maintain consistent input quality across varying lighting conditions. Normalizing pixel values (by dividing them by 255) ensures that the model processes standardized data, allowing for stable and accurate detection even in dynamic outdoor environments.

1) Solar Panel Identification Using CNN

The first stage of the model identifies whether a solar panel is present in the frame. This classifier, trained on diverse datasets, distinguishes between “Solar_Panel” and “No_Panel” categories. When a panel is detected, a green bounding box is drawn around it using OpenCV. If no panel is found, the system halts further processing to avoid unnecessary computation.

2) Sectional Division of the Detected Panel

After successful detection, the identified solar panel area is divided into nine uniform segments following a grid-based approach. Each segment (e.g., Section_0_0, Section_1_1) is

Page 123-131 © MANTECH PUBLICATIONS 2025. All Rights Reserved

assigned a unique ID. This division enhances fault localization by enabling the system to analyze specific areas instead of the entire panel, ensuring detailed and section-wise fault analysis.

3) Fault Detection Through Deep Learning Model

Each of the nine sections is passed to a second CNN classifier trained to recognize six common solar panel conditions — "Bird-drop," "Dusty," "Electrical- damage," "Physical-Damage," "Snow-Covered," and "Clean." Each detected condition corresponds to a predefined severity value, representing its impact on energy output. For instance, faults like dust or bird droppings contribute to energy loss, while "Clean" sections indicate optimal performance.

4) Visualization and Fault Localization

The detection results are visualized in real-time using OpenCV. Faulty sections are highlighted with red bounding boxes, and the identified fault label is displayed on the image. Clean sections remain unmarked. This visual feedback allows users to easily spot problem areas and interpret the health status of each section through the Flask-based dashboard.

5) Classification into Faulty and Non-Faulty Panels

Based on the detection results, the system creates two lists *Faulty_Panel* and *No_faulty_Panel*. Sections labeled as "Clean" are added to the latter, while all other fault types are recorded in the *Faulty_Panel* list. This classification helps maintenance teams prioritize critical repairs and plan regular cleaning schedules efficiently.

6) Database Integration for Performance Tracking

To maintain performance records, all detection outputs are stored in a MySQL database. The database includes section IDs, fault types, timestamps, and corresponding severity values. It also calculates aggregate statistics such as total faulty and clean sections, energy losses, and overall efficiency trends, supporting long-term monitoring and analytical reporting.

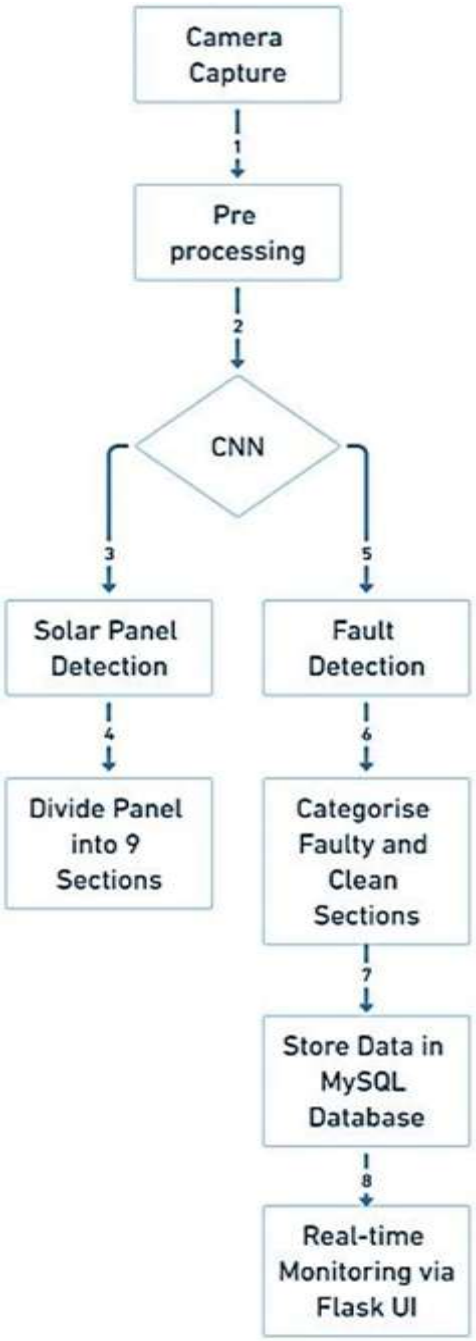
7) Flask-Based User Interface for Real-Time Monitoring

The entire system is integrated into a Flask web application that displays live camera feeds and detection results. The interface provides options for fault detection, data refresh, and

Page 123-131 © MANTECH PUBLICATIONS 2025. All Rights Reserved

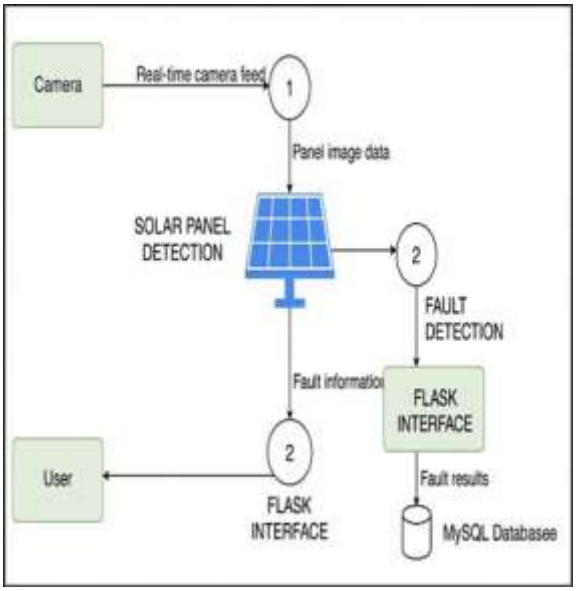
historical data viewing. A GridView component shows recent detection records directly from the database, enabling users to monitor solar panel conditions and performance interactively and efficiently.

FLOW CHART



Page 123-131 © MANTECH PUBLICATIONS 2025. All Rights Reserved

SYSTEM ARCHITECTURE



Explaintation

The system architecture of the *Solar Panel Detection and Fault Classification* project is designed to enable smooth communication between different components, ensuring efficient detection, classification, and monitoring of solar panel conditions. It mainly consists of four interconnected parts — the **camera**, the **solar panel detection module**, the **fault detection module**, and the **Flask-based web interface** linked with the **MySQL database**.

Camera Input (Real-time Data Collection):

The process begins with a real-time video feed captured through a camera. This camera continuously monitors the solar panels installed in the field or testing area. The camera acts as the primary input device, sending live images or video frames to the solar panel detection module for analysis. This live data ensures that the system can detect faults as soon as they occur, enabling real- time monitoring.

Solar Panel Detection Module:

Once the camera captures the live feed, the image data is sent to the *Solar Panel Detection* module. This part of the system is responsible for identifying whether a solar panel exists within the frame. It uses a **Convolutional Neural Network (CNN)** model trained to distinguish between “Solar Panel” and “No Panel.” If a solar panel is detected, the model highlights it by drawing a green bounding box around the panel. This ensures that only relevant parts of the image are sent forward for detailed analysis, which helps reduce false

Page 123-131 © MANTECH PUBLICATIONS 2025. All Rights Reserved

detections and unnecessary computations.

Fault Detection Module:

After a panel is detected, the next step is to analyze its condition. The *Fault Detection* module receives the cropped or focused panel image from the previous stage and classifies it into one of six categories — **Clean, Dusty, Bird- drop, Electrical-damage, Physical-damage, or Snow-covered.**

To make the analysis more precise, the system divides the detected panel into **nine smaller sections**, and each section is examined individually. This allows the system to identify multiple faults within a single panel. For example, one section could be clean while another could be dusty or physically damaged. The detected faults are highlighted with red bounding boxes, and labels are displayed on each section.

Flask Interface (User Interaction Layer):

The *Flask Interface* acts as the bridge between the user and the system's backend. It provides a simple and interactive web dashboard where users can see the live camera feed, the detected panels, and their corresponding fault information in real- time. The interface updates automatically whenever a new fault is detected. Users can also check historical data, such as previously detected faults, clean sections, and performance summaries.

Database Management (MySQL Integration):

To store all detection and classification results, the system uses a **MySQL database**. Each record includes details like panel ID, section ID, fault type, severity value, and the timestamp of detection. The database helps in tracking the total number of faulty and clean sections, as well as estimating energy loss or gain. For example, a "Clean" section might add to energy production, while "Electrical-damage" reduces it. This stored data can later be analyzed to study long-term performance trends and plan maintenance schedules effectively.

User Interaction and Output:

Finally, all processed fault information is displayed to the user through the Flask web interface. The operator can view real-time panel status, energy loss data, and maintenance

Page 123-131 © MANTECH PUBLICATIONS 2025. All Rights Reserved

recommendations. This interactive setup allows for quick decision-making, helping engineers focus on panels that require urgent attention and improving overall system performance.

CONCLUSION

The proposed system automates the detection of faults in solar panels, ensuring real-time monitoring and accurate identification of issues. It improves efficiency, supports proactive maintenance, and reduces the need for manual inspections. With potential for future enhancements, the system offers a significant advancement in optimizing solar energy performance and sustainability.

REFERENCES

1. Xiang Chen et al., “Research on Real-Time Identification Method of Model Parameters for the Photovoltaic Array,” Applied Energy, vol. 342, 2023
2. Chenxi Li et al., “A Fast MPPT-Based Anomaly Detection and Accurate Fault Diagnosis Technique for PV Arrays,” Energy Conversion and Management, vol. 234, 2021.
3. Yasemin Onal, and Umit Cigdem Turhal, “Discriminative Common Vector in Sufficient Data Case: A Fault Detection and Classification Application On Photovoltaic Arrays,” Engineering Science and Technology, an International Journal, vol. 24, no. 5, pp. 1168-1179, 2021.
4. Wenchao Miao, K.H. Lam, and Philip W.T. Pong, “A String-Current Behavior and Current Sensing-Based Technique for Line–Line Fault Detection in Photovoltaic Systems,” IEEE Transactions on Magnetics, vol. 57, no. 2, pp. 1-6, 2020.
5. Heidi Kalliojärvi-Viljakainen, Kari Lappalainen, and Seppo Valkealahti, A Novel Procedure for Identifying the Parameters of the Single-Diode Model and the Operating Conditions of a Photovoltaic Module from Measured Current– Voltage Curves,” Energy Reports, vol. 8, pp. 4633- 4640, 2022
6. Khatib, T., & Elmenreich, W. (2018). Modeling of dust effect on photovoltaic systems in the Middle East region. Renewable and Sustainable Energy Reviews, 81, 2700-2711. doi:10.1016/j.rser.2017.06.043

Page 123-131 © MANTECH PUBLICATIONS 2025. All Rights Reserved