IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Dynamic Generative AI Framework For Smart Solar Panel Efficiency Enhancement

MUTCHU NANDITA*[1], SIRAMDASU NAVYA SREE[2], VADDEBOYINA ARYAN REDDY[3], VALETI SRIDHARBABU[4], PALAPARTHI VENKATA NAGA SRINIVAS[5]

1Student, Department of CSE(AIML), Bapatla Engineering College, Bapatla 522101, AP, India.
2Student, Department of CSE(AIML), Bapatla Engineering College, Bapatla 522101, AP, India
3Student, Department of CSE(AIML), Bapatla Engineering College, Bapatla 522101, AP, India
4Student, Department of CSE(AIML), Bapatla Engineering College, Bapatla 522101, AP, India
5Assistant Professor, Department of CSE(AIML), Bapatla Engineering College, Bapatla 522101, AP, India

Abstract: Now a days Solar Energy is very useful. Many people are using solar panels, but they don't know how to use solar panels correctly due to lack of knowledge about panels. In this project "Dynamic Generative AI Framework for Smart Solar Panel Efficiency Enhancement" an assistant is introduced, to help users understand solar panels easily. Users can give inputs as per their doubts such as panel condition and any queries. Then Assistant analyses the inputs and gives best tips in a simple natural language in bilingual language. This system uses Gemini-2.5-Flash large language model through its API key to generate human-like text based on panel condition, location. Overall, this project gives an hallucination rate of 20%, ROUGE-L score of 78% and METEOR score of 80%. This confirms effectiveness of Gemini-2.5-flash model in generating solar maintenance tips.

Index Terms - Solar Energy, Solar Panels, AI assistant, Panel efficiency, Gemini-2.5-Flash, Bilingual suggestions

Introduction

Solar Energy is becoming very useful today. Solar Energy is one of the useful renewable energy sources. It is very safe to the environment, very clean and green. So, most of the people are using solar panels, but they don't know how to use solar panels in a correct way due to lack of knowledge about sunlight, temperature and panel condition. The proposed system uses the Gemini-2.5-flash large language model as an intelligent assistant to generate human-like text easy to understand responses. It helps in providing tips and also supports bilingual explanations to help users. It also includes AI-based image generation feature. This feature generates images of solar panels based on selected panel condition. These images help users to understand the condition of solar panels and identify possible problems.

Overall, this project helps users understand and use the solar panels. It helps in improving solar panel efficiency, decreases energy loss. The assistant checks the sunlight and temperature. User enters the simple values or doubts related to solar panels or solar energy. The assistant understands and analyses the values. It gives solutions in a simple language to improve solar panel efficiency. It helps users to use solar energy in a better way.

Rule-Based on Solar Monitoring System

Nowadays, many people use solar panels without any smart work. They check the panels by hand and use calculations to know the power generated by solar panels. Some of the systems give only simple information about sunlight or panel work. Old systems cannot find the problems in panels. Users need the technical knowledge to use them. Some of the big systems use weather predictions, but they are used in big industries. Small homes do not get smart help. Users do not use AI to help in real-time. Because if this, solar panels do not give full power and the energy is wasted.

Many of the systems tells how the panel is working but they don't know if there are dust, broken parts or electrical damages. They also don't give any tips for users to make panels work properly and users cannot see images of panel problems so they may miss small issues that reduce the power. Also, these systems only react after the problem happens. They don't give real-time alerts or tips to keep the panels safe. Small homes or single users cannot use smart monitoring because of this solar panels do not give full power and energy is wasted.

Due to all these problems, people cannot get full benefit from their solar panels. They waste electricity and money. They also don't know how to take care of the panels properly. If there was a system that would check panels immediately, give tips and show images of problems, users could fix small problems on time and get more power from their panels. This will help small homes and big industries to save energy and reduce loss.

I. Literature Survey

Solar photovoltaic (PV) systems are gaining significance as a clean and sustainable energy source. However, the efficiency of these systems is largely impacted by environmental factors such as weather variability, physical damage, dust accumulation, and electrical issues. To overcome these issues, Artificial Intelligence (AI) and Machine Learning (ML) approaches are being incorporated into solar energy monitoring systems to analyse panel conditions and provide immediate corrective measures for possible failures. These smart systems are more reliable and efficient, with reduced downtime and improved energy output [1].

Accurate forecasting of sunlight intensity is a crucial step in maximizing solar power production. Conventional weather forecasting systems may not be effective in dealing with dynamic variations of weather. Modern AI and ML algorithms, including Support Vector Regression (SVR), Artificial Neural Networks (ANN), and LSTM networks, have been found to be more accurate in forecasting sunlight intensity by learning the patterns of the environment. [2]

Optimal positioning and smart control of solar panels have a substantial impact on power generation. AI-based systems can dynamically adjust solar panel orientation, tilt, and power distribution in real-time to maximize sunlight exposure. This adaptive control strategy maximizes energy efficiency, reduces losses, and maintains optimal system performance despite varying environmental conditions. [3]

Machine learning-based solar forecasting further enhances energy planning by evaluating past weather and solar irradiation patterns. These forecasting models offer more accurate sunlight forecasts than traditional approaches, enabling effective scheduling, load management, and renewable energy resource planning. [4]

Recent studies demonstrate the increasing application of Generative AI in the energy domain. Generative AI models can effectively model system operation, optimize energy strategies, and facilitate decision-making. Although these technologies provide immense opportunities for innovation and efficiency, they also pose challenges in terms of computational complexity, reliability, and integration with existing infrastructure. [5]

AI-based spatial optimization algorithms are also employed for optimizing the positioning of solar panels. By analysing the direction of sunlight, roof orientation, geometric shape, and installation space, intelligent systems optimize positions to receive maximum sunlight. This optimized positioning results in higher electricity production and less energy loss. [6]

Partial shading is a major problem that affects solar panel efficiency. AI-assisted detection systems can easily detect shaded areas created by obstructions like trees or buildings. After detection, the system automatically adjusts solar panel positioning or parameters to optimize sunlight reception, thus increasing efficiency and extending the life of solar panels. [7]

Environmental factors also influence solar panel performance. AI models that process temperature, humidity, cloud, and radiation data can precisely calculate power production potential. These models offer valuable suggestions to ensure maximum efficiency, optimal maintenance, and uninterrupted power supply. [8]

II. Proposed Solution

In this project a smart AI assistant is introduced for solar panels. Users can give any queries so that assistant gives easy tips to improve efficiency. It also shows images of panel problems and works in bilingual language. This system helps users get more power from solar panels and reduce energy loss.

1. Smart AI Assistant

This system uses AI to help users understand solar panels in a simple way. Users can enter the location, panel condition and doubts. The assistant analyses the inputs and gives best output tips to save the energy.

2. Real-Time Suggestions

This assistant works in real-time and gives solutions and answers quickly. It provides guidance immediately, so that users can make changes to their panels without waiting. So that energy loss is decreased.

3. Bilingual Support

This system supports English and Telugu language tips. Users can read and understand tips easily. This makes the system user-friendly for everyone.

4. Panel Condition Visualization

This system can generate images of solar panels based on their condition. It also stores past data to track the performance. This helps users identify problems early and maintain panels for better efficiency.

5. Energy Optimization Tips

This assistant gives practical tips to save energy and reduce losses. Like cleaning panels, avoiding shading. This helps users get maximum power from their solar panels every day.

III. Methodology

The system collects basic user inputs such as sunlight, temperature, panel condition to analyse the solar panel performance. These inputs are processed using the Gemini-2.5-Flash Large Language Model, it generates easy human like text and bilingual tips to improve efficiency and reduce energy loss.

4.1 Classification of Gemini LLM

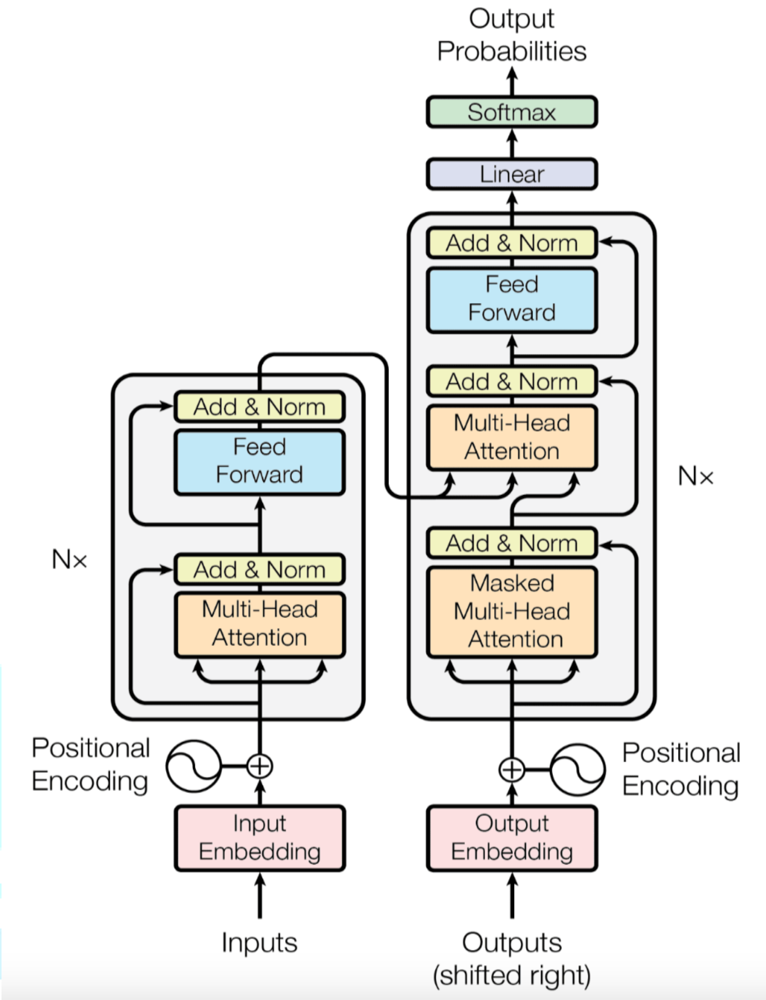

Figure 1: Gemini LLM Architecture

4.2 The Gemini LLM Step-by-Step Architecture

The system first starts and it sets up the screen and layout for users to understand. This layer is for taking user input.

Let the system state at initialization be:

$$S0 = \{UI, F\}$$

Where:

UI represents layout components

F represents input forms

The application waits for user input:

$$I\ ready=1$$

Loads all required APIs and AI models.

$$M = \{MLLM, MIMG\}$$

Where:

MLLM = Gemini Large Language Model

MIMG = Flux Image Generator

Model readiness condition:

$$M_{status} = \begin{cases} 1, & if\ models\ loaded\ successfully \\ 0 & ,otherwise \end{cases}$$

The user gives input to the system.

Input Vector

$$X = [L, C1, C2, \dots, Cn, O]$$

Where:
L = location
Ci = solar panel condition parameters
O = output choice (text audit or image visualization)

Input Embedding:

$$E_{input} = XW_e$$

Positional Encoding:

$$E_{pos} = E_{input} + P$$

Processes the user input information.
Multi-Head Attention

$$Q = E_{pos} W_Q, \quad K = E_{pos} W_K, \quad V = E_{pos} W_V$$

$$Attention(Q, K, V) = softmax\left(\frac{QK^T}{\sqrt{d_k}}\right) V$$

This tells the importance of every condition for solar efficiency
Feed Forward Network

$$FFN(x) = max(0, xW1 + b1)W2 + b2$$

Add & Norm Operation

$$LayerNorm (x + Sublayer (x))$$

Maps conditions to efficiency impact and converts raw data into useful information.
Baseline Efficiency (TOPCon)

$$\eta_{base} = \eta_{TOPCon}$$

Condition-Based Efficiency Degradation

$$\Delta\eta = \sum_{i=1}^{n} w_i . C_i$$

Where:
w_i = impact weight of each condition

Actual Panel Efficiency:

$$\eta_{actual} = \eta_{base} - \Delta \eta$$

Key Performance Indicators(KPIs)

Efficiency Percentage:

$$\text{Efficiency (\%)} = \left(\frac{\eta_{actual}}{\eta_{base}}\right) \times 100$$

Difference from Peak Efficiency:

$$\text{Efficiency Difference} = \eta_{\text{base}} - \eta_{\text{actual}}$$

Finally,
Linear Transformation:

$$z = h\,W_{\text{out}} + b_{\text{out}}$$

Softmax for Output Selection:

$$P(y_i) = \frac{e^{z_i}}{\sum_j e^{z_i}}$$

Output Decision:

$$\text{Output} = \{\text{Text Audit, Image Visualization, O=0 O=1}\}$$

Dashboard Progress Bar:

$$\text{Progress} = \min(100, \text{Efficiency (\%)})$$

User can continue or end the system:

$$S_{\text{next}} = \{S_0, \text{End, continue exit}\}$$

4.3 Work Flow

First, the system collects the data about the sunlight, temperature, panel angle and location. This data can be taken from user. The collected data is cleaned and organized. Missing values or wrong information can be removed so that AI can do its work properly. The system calculates the current efficiency (ηcurrent) of the solar panel and finds deviation from peak efficiency using the below formula

$$\Delta\eta = \eta\text{current} - \eta\text{base}$$

The system also calculates efficiency utilization percentage using below formula

$$U = \min((\eta\text{current} / 25) \times 100, 100)$$

A Generative AI model is used to give suggestions, it predicts the panel efficiency, power output and possible problems.AI can also generate new images of solar panel based on panel condition. This system gives suggestions in English and Telugu Language. Users can select the language they needed. This system works in real-time. It shows efficiency values, images and maintenance tips using a simple Stream lit interface.

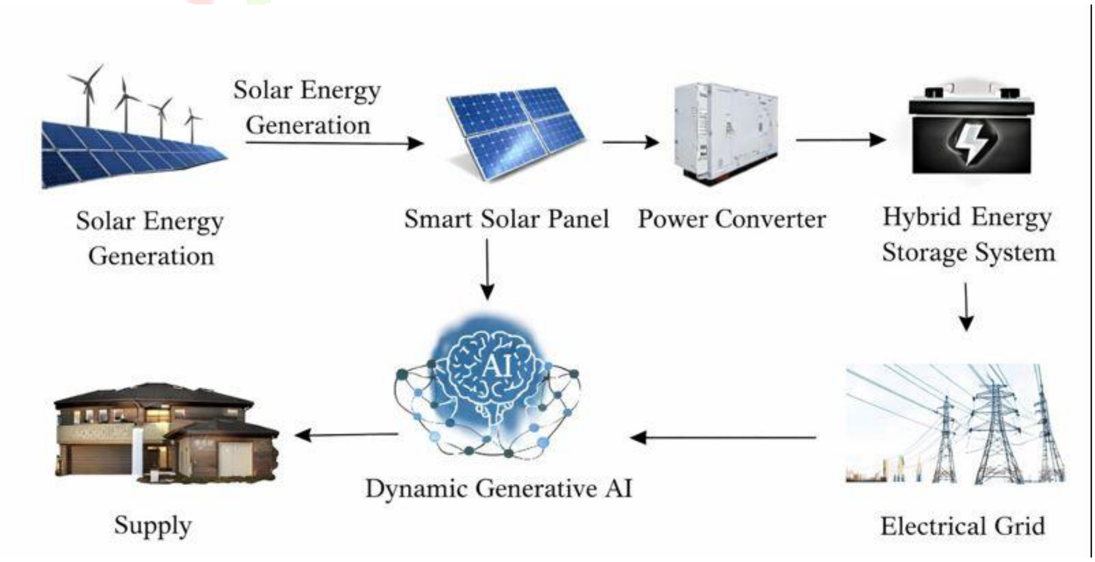

Figure 2: Architecture of a Dynamic Generative AI-Based Framework for Smart Solar Panel Efficiency Enhancement

IV. Results and Discussion

The Solar AI Assistant displays a clear and easy dashboard. It displays the efficiency location and panel condition. It also tells how much the panel's efficiency is being used, so that users can understand the panel performance quickly.

This Assistant also provides a bar graph for panel efficiency under different conditions. Clean panels give high efficiency. This helps users quickly to compare the effect of panel conditions on power generation.

Overall, the system gives simple, useful suggestions and tips to improve solar pane, efficiency. It helps uses maintain panels better, avoid energy wastage and make full use of solar power in homes.

Figure 3: Final Output Website Page

This screen shows the output of the Solar AI Assistant. It displays panel efficiency, location, panel condition and efficiency usage in a clear and simple dashboard.

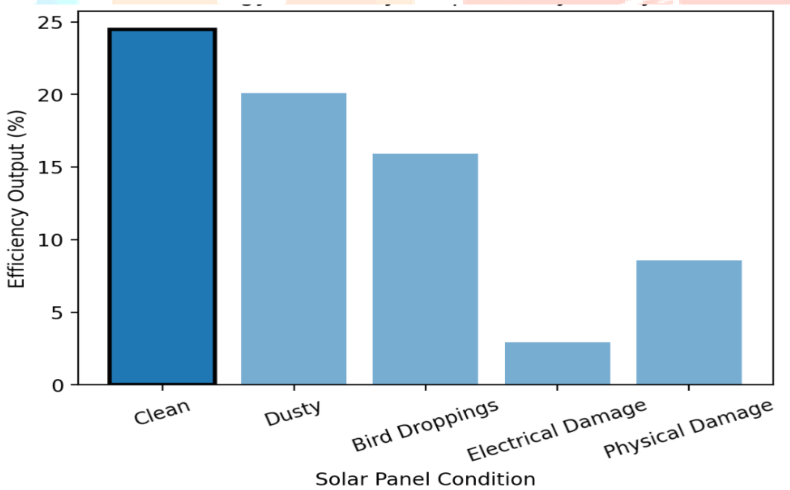

Figure 4: Comparative Efficiency Analysis

Table: Performance and Maintenance Levels of Solar Panels

Feature	Efficiency Output	Maintenance Urgency
Clean	24.5%	Routine
Dusty	20.09%	Low
Bird Droppings	15.93%	Medium
Physical Damage	8.58%	High
Electrical Damage	2.94%	Critical

Conclusion:

This project makes a smart assistant for solar panels using AI. It helps most of the users to know the best panel conditions and maintenance easily. This system can show the new panel images based on their conditions such as clean, dirty, electrical damages, physical damages and works well in English and Telugu languages. It gives real-time results and saves the energy. Overall, this project gives an hallucination rate of 20% , ROUGE-L score of 78% and METEOR score of 80% for solar panel performance guide and simple to use for every user.

V. REFERENCES

[1] Shamma AI Neyadi; Mariam AI Kuwaiti; Shaikha AI Daheri; "Optimization of Large-Scale Solar Panels Distribution using Genetic Algorithm", IEEE Middle East and North Africa Solar Conference, 2023

[2] Shreyanshu Garg; Ashvi Agrawal; Shubham Goyal; "Solar Irradiance Forecasting using Different Statistical Techniques", IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), 2020

[3] Tianpei Zhou; Wei Sun; "Optimization of wind-PV hybrid power system based on interactive multi-objective optimization algorithm", IEEE Proceedings of 2012 International Conference on Measurement, Information and Control", 2012

[4] Priyamvada Chandel; Leena Roy; "Solar Radiation Prediction Based on Hybrid Machine Learning Technique", IEEE 3rd International Conference on Technological Advancements in Computer Sciences (ICTACS), 2023

[5] Linqi Gao; Qiang Yu; "New Energy Prediction Method under the influence of Meteorological Factors Based on Generative AI", IEEE International Conference on Electronics, Energy Systems and Power Engineering (EESPE), 2025

[6] Devarsh Bhatt; Praveen Kumar Sharma; Chandrasinh Parmar; "AI-Driven Solar Panel Placement Optimization", IEEE Seventh International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN), 2025

[7] Mehnaz Fathima C; Anshitha Karkera; Mohammed Shayaan Fayaz; "Partial Shading Detection and Adaptive Angle Adjustment of Solar Panel using Agentic AI Framework and Feedback Control", IEEE Third International Conference on Emerging Applications of Material Science and Technology (ICEAMST), 2025

[8] Rahmat Salam; Rifqi Fahrudin; Ignatius Agus Supriyono; Selamat Zebua; Ester Ananda Natalia; Po Abas Sunarya; Farinan Hidayat; "AI-Driven Optmization of Solar Panel Efficiency Considering Environmental Factors", IEEE 4th InternationalConference on Creative Communication and Innovative Technology (CCIT), 2025