Solar Power Forecasting Using Machine Learning

AI-Based Prediction System for Grid Stability

Sector: Renewable Energy – Solar

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Gen AI Capstone Project

Why Solar Forecasting Matters

Context : India is expanding solar rapidly, but solar power is volatile and weather-dependent.

Core Problem : Grid operators must balance supply and demand in real time .

- Solar power is weather-dependent and unpredictable
- Grid system require exact supply-demand power drop
- Sudden cloud cover → massive power drop
- Poor forecasting leads to:

1. Grid instability
2. Voltage fluctuations
3. Backup fossil activation

Objective : Build a Machine Learning model to accurately forecast solar DC power generation using historical weather and inverter data.

Model Inputs & Prediction Target

Output:

DC_POWER (Watts)
Target variable to predict.

Inputs:

- IRRADIATION → sunlight intensity
- MODULE_TEMPERATURE → panel efficiency impact
- AMBIENT_TEMPERATURE → environmental cooling
- SOURCE_KEY → inverter identity
- hour → daily pattern
- month → seasonal pattern

Data Engineering:

Feature Engineering

- Label encoding
- Chronological 80–20 split

ML Architecture & Design

Pipeline Flow:

- Load historical solar CSV data
- Feature engineering
- Time-based train-test split
- Train Random Forest Regressor
- Evaluate model
- Deploy as Streamlit web application

Why Random Forest?

- Handles non-linearity
- Works well for solar bell-curve behavior
- Robust to noise
- Low overfitting risk

They link exactly to the problem of underperformance and misallocation.

Performance & Validation

Metrics Achieved:

- R^2 = 0.93
- MAE = 460 W
- RMSE = 933 W
- TimeSeries Cross-Validation R^2 = 0.81 ± 0.09

Interpretation:

- Model explains 93% of solar generation behavior
- Very low average prediction error
- Stable performance across time windows
- Prevented data leakage using chronological split

Deployment & Real-World Impact

Application Features:

- Single prediction via sliders
- Batch CSV prediction
- 24-hour solar forecast simulation
- Feature importance visualization
- Downloadable results

Real-World Benefits:

- Improves grid stability
- Reduces fossil backup dependency
- Helps plant managers schedule generation
- Enables smarter renewable integration