**Overview Report :**

**🌞 Solar Plant Performance Analysis & Optimization**

**1. Problem Statement**

Solar power plants generate large amounts of data from inverters, weather stations, and grid meters. However, plant operators often face challenges in:

* Detecting underperformance at plant or inverter level.
* Understanding consumption vs. generation patterns.
* Managing grid export/import effectively.
* Accounting for weather variability across regions.
* Optimizing panel tilt angles seasonally.
* Deciding the right battery size to reduce imports.
* Getting timely alerts when issues occur.
* Calculating Return on Investment (ROI) and payback period for the system.

⚠️ Without these insights, plants may lose revenue due to:

* Undetected faults in inverters.
* High import costs due to insufficient storage.
* Over-exporting power at low tariff rates.
* Inefficient panel angles.
* Lack of actionable alerts.

**2. Objective**

The goal of this project is to build a **comprehensive analysis and reporting system** for solar plants that can:

1. Detect anomalies in generation at both plant and inverter level.
2. Compare **consumption vs. generation** and optimize self-consumption.
3. Simulate **grid integration** (export/import balance, cost/revenue).
4. Analyze **regional weather variation** (North, South, East, West India).
5. Recommend **seasonal tilt adjustments** for better efficiency.
6. Simulate **battery storage behavior** (SOC charge/discharge, import reduction).
7. Generate **mobile-style alerts** for anomalies and weather conditions.
8. Calculate **ROI and payback period** considering CAPEX & OPEX.
9. Produce a **final consolidated report** (TXT + PDF) and visualizations.

**3. Methodology (Step-by-Step)**

**Step 3: Plant & Inverter Anomaly Detection**

* Compare **actual vs. predicted generation** (ML predictions from Step 2).
* Detect underperformance events using residual thresholds.
* Output: solar\_performance\_report.txt

**Step 4a: Consumption Pattern Optimization**

* Compare generation vs. building load consumption.
* Calculate **self-consumption ratio** and **self-sufficiency index**.
* Output: consumption\_analysis\_report.txt + charts.

**Step 4b: Grid Integration Management**

* Simulate **import/export** costs with tariff structure (import @ ₹8/kWh, export @ ₹3/kWh).
* Output: grid\_integration\_report.txt.

**Step 4c: Regional Weather Variation**

* Analyze irradiance, rainfall, and temperature for North, South, East, West India.
* Show impact of weather on solar performance.
* Output: regional\_weather\_report.txt + irradiance chart.

**Step 4d: Angle Adjustment Recommendations**

* Based on latitude → compute **winter, summer, equinox tilt angles**.
* Output: tilt\_recommendations\_report.txt.

**Step 4e: Battery Storage Simulation**

* Model SOC (charge/discharge) with given capacity & efficiency.
* Compare imports/exports before vs. after battery.
* Output: battery\_simulation\_report.txt + SOC curve.

**Step 4f: Mobile Alerts Simulation**

* Generate alerts for:
  + Inverter underperformance.
  + Battery SOC < 20%.
  + High rainfall (no cleaning needed).
  + Low irradiance (low generation expected).
* Output: mobile\_alerts\_log.txt + simulated\_push\_notifications.json.

**Step 4g: ROI Calculation**

* Compute annual savings = (imports avoided + exports earned – OPEX).
* Estimate payback period & 25-year ROI %.
* Output: roi\_report.txt.

**Final Step: Consolidated Report**

* Merge all sections into:
  + solar\_performance\_report\_final.txt (text report)
  + solar\_performance\_report\_final.pdf (professional PDF with charts & metrics).

**4. Results & Insights**

1. **High Self-Consumption** → 94% of generation directly used.
2. **Grid Dependency** → Imports reduced by 18.5% with 20 MWh battery.
3. **Weather Analysis** → All regions suitable for solar, but rainfall in East India helps panel cleaning.
4. **Angle Recommendations** → Seasonal tilt adjustments in higher latitudes increase yield.
5. **Alerts** → Helped detect 6 plant-level anomalies + inverter underperformance + SOC <20% on 18 days.
6. **ROI** → Payback in ~1.2 years, lifetime ROI ~1940%.

**5. Tools & Technologies**

* **Python** (Data processing & simulation)
* **Pandas** (data handling)
* **Matplotlib** (visualizations)
* **ReportLab** (PDF generation)
* **Streamlit** (dashboard)

**6. Conclusion**

This project demonstrates a **comprehensive solar performance management system** that goes beyond anomaly detection by:

* Providing actionable recommendations.
* Simulating storage behavior.
* Integrating weather & tilt optimization.
* Delivering alerts & ROI analysis.

Such a system can help **solar plant operators reduce costs, optimize efficiency, and maximize ROI** with data-driven decision-making.

**7. Future Work**

* Integrate **real-time APIs** for weather & grid tariff updates.
* Deploy as a **web dashboard** (Streamlit Cloud / Heroku).
* Connect with **IoT devices** for real-time inverter + battery data.
* Add **ML-based forecasting** for predictive maintenance.

**Thank You**