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Design Review of 250MWp Solar Power Plant with Single Axis Tracker System

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Abstract

Recent years, solar power plants are growing like anything, the most common range of solar plants are in the range of 10 MW – 1000 MW capacity range. A design review for a 250MWp solar power plant involves a comprehensive evaluation of technical, environmental, and financial components to ensure the project's viability and long-term performance. In this article, the design reviewed with existing 250 MWp (Mega-Watt peak) solar PV-power plant, with single axis tracker system. Design review benchmarks focus on a specific aspect of the design review.

Component	: Typical Specification for 250MWp Plant
Modules	: High-efficiency Monocrystalline/Topcon (> 560Wp are preferred)
Foundations	: Pile foundations (approx..1.6m depth) for soil stability
Switch Yard	: 33kV/220kV with SCADA and RTCC panels
Structures	; Trackers with backtracking arrangement
Land Use	: Approx. 4 - 5 acres per MW (1,000-1,250 Acres total)

Key Words: Power plant, Single axis, Tracker, Photovoltaic, PV systems, PV modules, Backtracking, Topcon, Crystalline.

I INTRODUCTION

A design review of a 250MWp solar plant utilizing single-axis trackers (SAT) focuses on maximizing energy yield through bifacial technology, optimizing row spacing to manage shading, and ensuring structural integrity against wind loads.

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Fig.1: Single Axis Tracker System

Key considerations include implementing backtracking algorithms for low-sun hours, using advanced pile foundations, and adopting 1P (one-portrait) tracker configurations for increased stability. Here an example as taken for every-stage wise explanation purpose, the plant capacity was 250 MWp DC input, and 200 MW AC Output grid connected plant, with single axis (i.e. East – West) trackers. Location of this existing plant location is at Karnataka, India.

II TECHNICAL DESIGN REVIEW

The core engineering review focuses on maximizing energy yield while ensuring structural integrity and grid compliance.

2.1 Solar Modules & Mounting:

- **Module Selection:** Use of high-efficiency modules, such as 560W and above wattage Topcon (Tunnel Oxide Passivated Contact) bifacial modules, to reduce the overall land footprint.
- **Mounting Structures:** Structures are typically Hot-Dip Galvanized Iron (HDGI) for corrosion resistance, designed to withstand wind speeds up to 150 km/h.

Fig.2: Module mount on Hot-Dip Galvanized (HDG) tracker structure

- **Foundation Design:** Stability is maintained through pile foundations (often up to 1.6m deep), tailored to specific soil conditions like black cotton soil.

2.2 Electrical Systems:

- **Inverters & Transformers:** Inverters convert DC power from panels to AC, which is then stepped up by transformers for grid transmission.
- **Cabling & Earthing:** Use of XLPE-insulated aluminium cables and dedicated earthing pits for electrical protection.
- **Grid Integration:** Studies include relay protection setting calculations and coordination for 220/35kV substations.
- **Monitoring & Control:** Centralized control hubs like the PEBs MCR building house SCADA systems, RTCC panels for automatic voltage regulation, and lightning arrestors.

1. ENVIRONMENTAL & SOCIAL IMPACT ASSESSMENT (ESIA)

A critical phase of the design review ensures compliance with national and local standards.

Site Suitability: Avoiding ecologically sensitive areas as per MNRE Guidelines.
Social Impact: Reviewing transmission line routes and ensuring gender-inclusive components in project planning.

2. OPERATIONAL & FINANCIAL EVALUATION

Energy Yield Assessment (EYA): Utilizing forecasting models like ECMWF and NCMRWF to predict day-ahead power generation.
Hybridization: Integrating Battery Energy Storage Systems (BESS) (e.g., 250 MW PV with 200 MWh BESS) to manage intermittency and provide dispatchable power.
Land Requirements: A 250MW plant typically requires approximately 1,000–1,250 acres, based on the ratio of ~4–5 acres per MW for utility-scale projects.

3. SINGLE LINE DIAGRAM (SLD) OF PLANT:

Generally, a 250MW (AC) solar power plant requires a robust SLD focusing on high-voltage evacuation, typically involving Block Configuration: The 250MW plant is usually divided into 125MWAC, 50MWAC, or smaller blocks (e.g., 6.25MW). DC Side: Review string configuration (1500V DC system, 540-580 Wp+ modules), string combiner box (SCB) protection, and DC cable sizing to minimize losses. AC Side (LT & MV): Ensure proper inverter capacity matching (e.g., 125kW to 3MW+ string/central inverters) and correct transformer voltage ratio (415 – 690 / 33kV).

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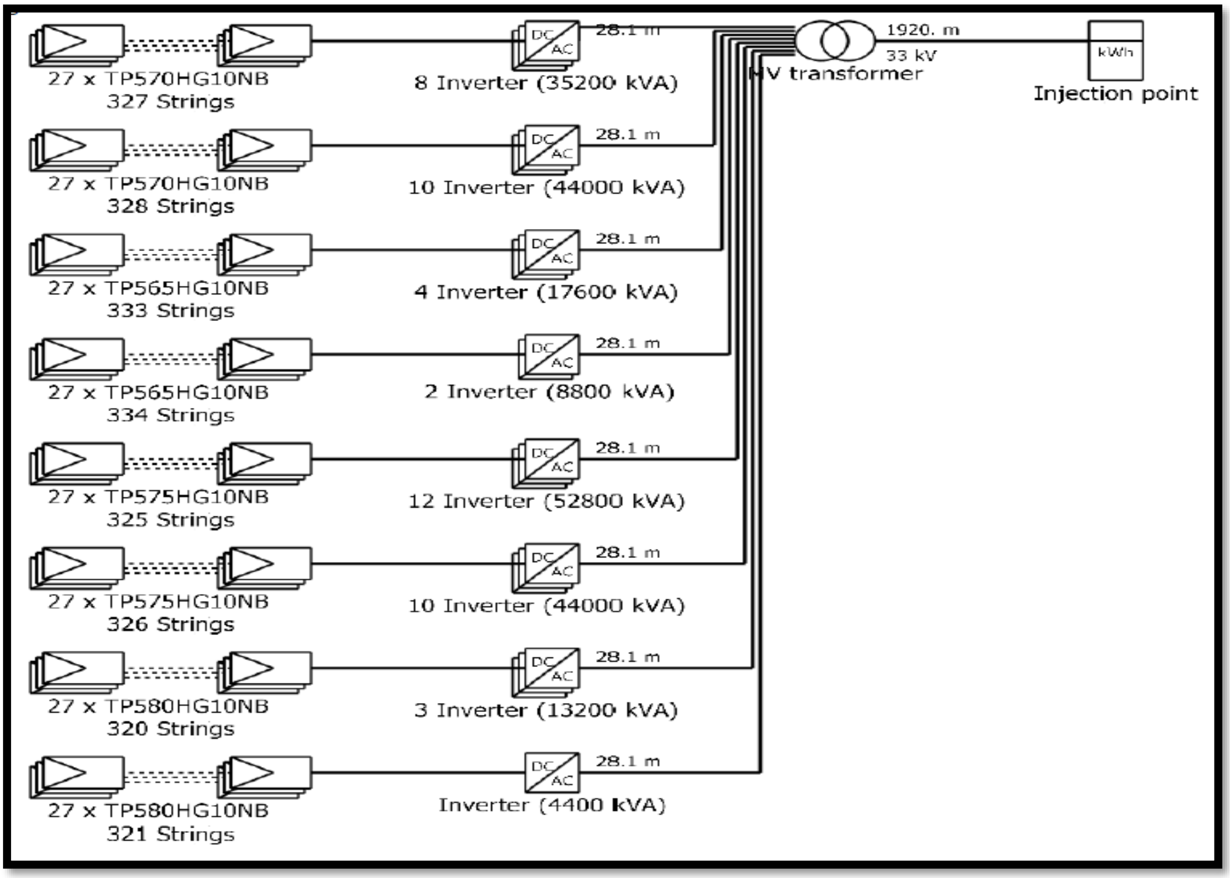

Fig.3: Single Line Diagram of 250MWp solar power plant

Inverter Duty Transformer (IDT): Review IDT loading (generally 110-140% of inverter capacity) and vector group (Dyn11 or Ynd11). Auxiliary Power: Include dedicated auxiliary transformers for plant power consumption, SCADA, and surveillance. Grid Evacuation: Ensure adequate circuit breaker sizing for 33kV switchgear and proper transformer sizing for the 33kV to Utility Voltage (132kV, 220kV or 400kV). Protection: Verify lightning protection, earth mat grid, and relay settings. Loss Optimization: Check string combiner box placement and AC cable routing for ohmic loss minimization. Critical Considerations: SCADA and Monitoring: Ensure all inverters, trackers, and switchgear are integrated into the SCADA system. Auxiliary Support: Include UPS and DC chargers for critical control circuits. Environmental Control: Ensure transformers have appropriate cooling systems and protection.

For this existing plant, it has 8.33MW capacity blocks of 25-nos, 4.4 MVA capacity of central inverters of 2-nos for each block, inverter-duty transformers (660V/33kV), with33kV MV switchgear, and a 33kV/220kV or 33kV/400kV pooling substation. The Single Line Diagram (SLD) of Plant shown in fig. 3

4. KEY DESIGN REVIEW AREAS

Solar Tracker Technology & Configuration:

- **1P vs. 2P Trackers:** 1P (single portrait) trackers are preferred for improved wind stability and less shading compared to 2P, despite longer row lengths.
- **Backtracking Algorithm:** Mandatory for a 250MW site to minimize row-to-row shading during early morning/late afternoon, optimizing energy yield.
- **Tracking Accuracy:** The tracker system should maintain an accuracy of within +/- 2 degrees, for maximum irradiance.

Fig. 4: Trackers with backtracking arrangement

- **Trackers With Backtracking**

  Bifacial with trackers: Simulate bifacial installations and photovoltaic systems on single or dual-axis trackers, with safety and backtracking options.

  Structural and Civil Design:

- **Wind Load Analysis:** Extensive wind tunnel testing is crucial for tracker stability, especially for larger arrays.
- **Foundation Design:** Mechanized steel pile foundations are typically used, based on detailed geotechnical reports (minimum ground clearance for trackers).
- **Structural Design:** Use of torque tubes and slewing bearings to handle torque and weight, with anti-corrosion coating.

  Electrical Design & Optimization:

- **Bifacial Modules:** Integration with bifacial modules on trackers can increase energy gain by 15-30% compared to fixed tilt.
- **String Monitoring:** Due to the large scale (250MW), comprehensive string monitoring to detect tracker movement failures is vital.
- **Control System:** Smart controllers with remote monitoring and anemometer-driven "stow" positions for high wind.

Layout and Optimization:

- **Inter-row Spacing:** Optimized to balance ground coverage ratio (GCR) with energy yield (typically lower GCR than fixed tilt).
- **Slope and Topography:** Mitigation strategies for sloping ground (e.g., shorter tracker rows, specific post-mounting techniques).

Fig.5: A Gang-type tracking system with an actuator stroke-rod

5. SUMMARY

In this project, it is used four types of PV-arrays with TP565HG 10NB, TP570HG 10NB, TP575HG 10NB and TP580HG 10NB of PV-modules. PV-Arrays (27-Modules series in each String) with (4.4 MVA of each) inverter's details are indicated below.

a) 27 x 375 Strings of 570 Wp connected with 08 Nos of inverters = 35.2 MVA (46.17 MWp).
b) 27 x 328 Strings of 570 Wp connected with 10 Nos of inverters = 44.0 MVA (50.4792 MWp).
c) 27 x 333 Strings of 565 Wp connected with 04 Nos of inverters = 17.6 MVA (20.31966 MWp).
d) 27 x 334 Strings of 565 Wp connected with 02 Nos of inverters = 08.8 MVA (10.19034 MWp).
e) 27 x 325 Strings of 575 Wp connected with 12 Nos of inverters = 52.8 MVA (60.5475 MWp).
f) 27 x 326 Strings of 575 Wp connected with 10 Nos of inverters = 44.0 MVA (50.6115 MWp).
g) 27 x 320 Strings of 580 Wp connected with 03 Nos of inverters = 13.2 MVA (15.0336 MWp).
h) 27 x 321 Strings of 580 Wp connected with 01 Nos of inverters = 04.4 MVA (05.02686 MWp)

Actual total connected input DC = 258.38 MWp (Asper above a – h capacity)
Actual total Inverter's Capacity = 220 MVA (Asper 50 Nos x 4.4 MVA)
Actual total IDT transformers AC = 208.25 MVA (Asper 25 Nos x 8.33 MVA)

6. CONCLUSION:

Review of a 250MWp solar power plant with a single-axis tracker (SAT) system typically concludes that the project is technically feasible and economically superior to fixed-tilt alternatives for utility-scale deployment. The key Conclusion, implementing a single-axis tracker system is increased annual energy production by 25% to 35% compared to a fixed-tilt installation with 8-10% of more investment (one-time) at the time of plant erection.

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