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BEST PRACTICES FOR GROUND MOUNTED SOLAR AND WIND PLANTS

JUNE 2025

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This publication serves as a repository of best practices and operational insights for **solar ground-mounted and wind power plants,** intended for use by plant personnel involved in project development, operations, asset management, and sustainability initiatives. The content has been compiled from various credible sources, including data shared through industry participation in CII initiatives, CII Performance Excellence awards for Solar, Wind and Hybrid plants.

While due diligence has been exercised to capture representative benchmarks and industry-leading practices, there may be additional high-performing projects or innovations that were not captured at the time of publication.

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Foreword

Mr Ramesh Kymal

Chairman, CII Renewable Energy Council

India stands at a critical juncture in its energy transition journey. As the country moves decisively toward a low-carbon future, renewable energy (RE) has emerged not only as an environmental imperative but also as an economic and strategic opportunity. With ambitious national targets and a dynamic policy landscape, the adoption of clean energy solutions—particularly ground-mounted solar and wind—across states and sectors is gaining unprecedented momentum.

However, the pathway to accelerated RE deployment requires more than just targets; it demands clarity, consistency, and confidence in both policy and execution frameworks. In this context, this publication on **Best Practices in Ground-Mounted Solar and Wind Energy Projects** offers timely and practical insights to support high-quality and sustainable project implementation.

Drawing from successful case studies, technical standards, and real-world industry experience, the publication presents proven strategies to enhance project efficiency, reduce costs, and mitigate risks across the lifecycle—from planning and design to construction and operations. It also highlights critical considerations such as land optimization, grid integration, environmental safeguards, and maintenance protocols that are essential for scaling up deployment without compromising long-term performance.

While the compilation is grounded in secondary research and field practices, it has been strengthened by the review and feedback of subject-matter experts, whose perspectives lend practical relevance to the content.

I am confident that this publication will serve as a valuable reference for developers, EPC contractors, policymakers, investors, and energy professionals committed to accelerating India's clean energy goals. As we collectively pursue a more sustainable and resilient energy future, the adoption of standardized best practices will play a pivotal role in ensuring quality, reliability, and scalability across renewable energy projects.

Mr Ramesh Kymal
Chairman, CII Renewable Energy Council

Acknowledgment

CII–Sohrabji Godrej Green Business Centre extends its sincere appreciation to all stakeholders from the renewable energy sector who participated in the CII Performance Excellence Awards. We are deeply grateful for their continued support and for sharing their best practices, backed by data, which have greatly enriched this initiative.

We would also like to acknowledge the valuable cooperation and support provided by all participating organizations in sharing their technological advancements and case studies from operational renewable energy plants. Their contributions have been instrumental in shaping the insights presented in this publication.

A special note of thanks is extended to **Dr. P. Jayakumar** (Chairman, CII Performance Excellence Award 2025), **Mr. Sharad Saxena** (Jury Member, CII Performance Excellence Award 2025), **Mr. A S Karanth** (Jury Member, CII Performance Excellence Award 2025), **Dr S Gomathinayagam** (Jury Member, CII Performance Excellence Award 2025), **Mr. Arumugasamy Gurunathan** (Head – Public Affairs, India and APAC, Siemens Energy), and **Mr. Basappa D** (Assistant Vice President – Solar Asset Management, ReNew Power), **Mr. Kolluru Krishan** (Chairman at CVC Training Services Pvt Ltd) for generously sharing their time, expertise, and valuable inputs in the development of this publication. Their guidance has been pivotal to the success of this initiative.

Introduction

As the global transition toward renewable energy accelerates, the efficient development, operation, and maintenance of solar ground-mounted and wind power plants have become critical to meeting sustainability goals and ensuring long-term performance. This Best Practice Manual for Solar Ground-Mounted and Wind Plants serves as a comprehensive guide for developers, EPC contractors, O&M providers, asset managers, and other stakeholders involved in the lifecycle of renewable energy projects.

As of June 2025, India's total installed power generation capacity is approximately **476 GW,** with **renewable energy (RE)** sources contributing around **227 GW**, nearly **49%** of the total. This includes approximately **111 GW of solar** and **51 GW of wind** capacity, making India the 4th largest in RE and wind, and 3rd in solar globally. In FY 2024–25 alone, India added nearly **24 GW of solar** and **4 GW of wind**. Additionally, about 177 GW of RE projects are under implementation, and **72 GW** are in the bidding phase. India is firmly on track toward its target of achieving **500 GW of non-fossil capacity by 2030**, highlighting its strong commitment to a cleaner, more sustainable energy future.

The manual consolidates industry-proven methodologies, technical standards to promote optimal plant performance, safety, and cost-efficiency. It addresses each phase of the project—ranging from site selection, design optimization, and construction practices to advanced operations and predictive maintenance strategies—tailored specifically for utility-scale solar and wind power plants.

By adhering to these best practices, stakeholders can reduce operational risks, enhance energy yield, prolong asset life, and support a reliable and resilient clean energy infrastructure. This publication is intended to be a dynamic document, evolving with emerging technologies, data analytics, and industry innovations, thereby ensuring its continued relevance in the fast-evolving renewable energy landscape.

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Best Practice 1: Digital Twin for Utility Scale Ground Mounted Solar Plants

Digital twin refers to developing a digital replica of a physical solar power plant that is linked to the actual facility via a data-sharing interface. Digital twin enables real-time monitoring, performance evaluation, predictive maintenance, and optimization of operation of the plant.

Problem Statement:
Solar power plants typically cover extensive areas, making physical maintenance challenging and resource intensive. Addressing faults often requires significant manpower and time, leading to increased downtime and reduced operational efficiency.

Solution Implemented:
Digital twin solution has been implemented in a 250 MWp ground mounted solar plant in Andhra Pradesh. This solution supports the plant for monitoring and diagnostics through advanced prescriptive analytics that offers a powerful approach for optimizing operations and predicting failures in large DC field.

Table 1: Benefits of digital twin solution

Specifications	Unit	After Implementation of Digital Twin Solution
Plant availability (excluding grid non-availability)	%	99.95

Key Outcomes:
- Real-time monitoring and insights
- Predictive Maintenance
- Identification of faults in DC field
- Enhanced operational efficiency and plant availability
- Timely fault detection and reduction in time for repairs and rectification
- Input for Forecasting and Scheduling based on probabilities

Impact and Scalability:
It can be implemented in all types of large solar plants to reduce the downtime and increase the availability of the plant.

Best Practice 2: Robotic Cleaning of Solar PV Modules

Robotic cleaning refers to the use of automated robotic systems to clean solar photovoltaic (PV) modules without human intervention. These robots are designed to efficiently remove dust, dirt, and other debris that accumulate on the surface of solar PV panels.

Problem Statement:

Soiling losses in solar PV systems occur due to the accumulation of particulate matter such as dust, pollen, and bird droppings on the surface of the PV modules, which reduces incident solar irradiance and results in decreased energy yield. These losses can lead to significant performance degradation, increased cost of energy generation, non-uniform power output, and elevated thermal stress on affected modules.

Solution Implemented:

Automatic solar module cleaning by robots has been implemented by many utility scale ground mounted solar plants. These solutions have been incorporated at the design stage itself as at this stage it is easier to decide position of docking platform, movement of robots etc.

Figure 1: Robotic dry cleaning of solar modules in Ground Mounted Solar project

Table 2: Case study for robotic cleaning of modules

Specifications	Unit	Value
Capacity of Plant	MWp	449
Plant Location	State	Rajasthan
Annual Energy Generation	MWh	7,98,676
Annual Water Usage	Litres	Nil
Avoided water consumption*	Lakhs of Litres	677

* Based on average water consumption reported by participating plants in CII Performance Excellence Awards 2025

Key Outcomes:

- Robots can move automatically based on the set command to ensure the modules are cleaned to operate at optimal performance with reduced operation and maintenance cost.
- Avoiding usage of water for cleaning leads to water conservation, especially in places where availability of water is an issue. In addition, the robots are charged using solar power and this makes it a sustainable and environmentally friendly solution.

Impact and Scalability:

It can be implemented in all types of large solar plants to reduce the soiling loss in a sustainable manner.

Best Practice 3: Effective Cable Installation and Management

Utility-scale solar power plants span across large areas, featuring extensive installations of solar PV modules with DC and AC cables distributed across the site.

Problem Statement:

Generally, AC and DC cables are routed across the site with proper planning during the design phase. However, during operation of the plant, certain challenges such as cable punctures or failures may still arise. These issues tend to become more frequent during the rainy season, leading to increased fault occurrences and increased plant downtime.

Solution Implemented:

One of the solutions for effective cable management is design of cable trenches with sloped bottoms to facilitate water drainage and prevent accumulation during rainy seasons. Separate trenches are generally used for DC, AC, and communication cables to avoid electromagnetic interference. Buried cables are marked with warning tapes and route identification tags to aid in future location and minimise accidental damage.

Figure 2: Illustration of cable trench

Figure 3: DC and AC cables installed above the ground with colour coding

Some of the plants have also installed DC and AC cables above the ground for timely detection of faults and rectification.

Key Outcomes:

The primary outcome of implementing these cable management practices is significant reduction in fault occurrence, thereby enhancing the overall reliability of the cable network. Additionally, in the event of a cable fault, these structured methods facilitate rapid fault identification and isolation, minimising system downtime and enabling timely corrective action.

Impact and Scalability:

It can be implemented in all types of large solar plants to increase the reliability of cables and plant availability.

Best Practice 4: Installation of Tracker for Ground Mounted Solar Plants

Solar tracker refers to a system that orients solar modules towards the sun throughout the day to maximize energy capture. Unlike fixed-tilt systems, trackers dynamically adjust the position of the modules, increasing solar exposure and improving energy yield.

Problem Statement:

Generally, solar plants have fixed tilt mechanism where modules are mounted on structures at an angle closer to the latitude of the plant location. Power generation is the maximum when the sun rays are incident normal to the surface of the PV modules. On a fixed tilt structure this happens only for a short duration around noon. Therefore, to maximize the generation, structures that make the modules track the sun are used. The decision to use trackers instead of fixed-tilt structures is taken after considering the gain in generation and the increase in cost. The use of trackers generally results in lower LCOE and lower payback periods, though the maintenance requirements and cost may increase a little.

Solution Implemented:

Solar trackers are being implemented in many utility scale projects in India. These trackers significantly enhance the performance of PV systems by maintaining optimal panel orientation throughout the day, resulting in a 10%–15% increase in energy yield depending on location and solar radiation conditions. In addition, trackers also help to smoothen the power generation curve of solar PV plants.

Figure 4: Tracker based ground mounted solar power plants

Table 3: Plant performance parameters with tracker (Case Study - 1)

Specifications	Unit	Value
Capacity of Plant	MWp	394
Location	State	Gujarat
Annual Energy Generation	MWh	7,14,380
Actual GHI	kWh/ m2/ annum	2,199
Capacity Utilization Factor (CUF)	%	20.70 %

Table 4: Plant performance parameters with tracker (Case Study - 2)

Specifications	Unit	Value
Capacity of Plant	MWp	31.71
Location	State	Karnataka
Annual Energy Generation	MWh	53,256
Actual GHI	kWh/ m2/ annum	1,769
Capacity Utilization Factor (CUF)	%	19.17 %

Key Outcomes and Cost Savings:

- As per the data shared by a couple of plants, solar trackers have supported in increased energy production during cloudy days resulting in additional revenue of approx. INR 100 lakh/ annum.
- Higher energy yield and CUF when compared to the fixed tilt plant in locations with similar radiation conditions. This reduces the payback period and increases the energy generation by 10%-15%.

Impact and Scalability:

It can be incorporated in large solar plants (in the design phase only) where GHI is high.

Best Practice 5: Performing Drone Based Thermography for Ground Mounted Solar Plants

Drone Thermography for Solar Plants is a powerful diagnostic tool used to detect and analyse thermal anomalies in solar photovoltaic (PV) systems using drones equipped with thermal cameras. It helps ensure that the solar plant operates efficiently and reliably by identifying underperforming or faulty modules.

Problem Statement:

Large-scale solar power plants often experience undetected performance losses due to hidden faults such as hotspots, bypass diode failures, string disconnections, and module degradation. Traditional manual inspections are time-consuming, labour-intensive, and limited in accuracy, making it difficult to identify and address these issues promptly.

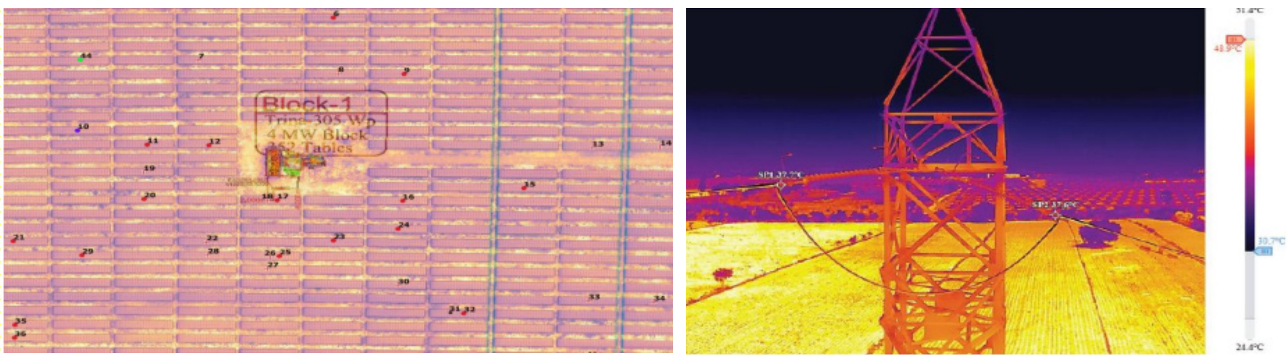


Figure 5: Drone Thermography for Solar Field and Transmission Lines

Solution Implemented:

Drone-based thermography has been implemented for PV modules and the H.T transmission line across the plants. This approach has significantly enhanced safety by reducing the need for manual inspection in high-risk areas, thereby minimizing risks to personnel.

Key Outcomes:

- **Time Efficiency:** Rapid inspection of large PV areas, reducing manual effort and maintenance time.
- **Fault Detection:** Accurately identifies hotspots, diode failures, soiling, and underperforming modules/ strings.
- **Reduced Downtime:** Enables faster diagnostics and repairs, minimizing generation loss and supporting warranty claims.
- **Enhanced Safety:** Eliminates manual access to high-risk zones and aids in site issues like vegetation overgrowth.

Impact and Scalability:

It can be implemented in large solar plants.

Best Practice 6: Onsite Nanocoating on Modules for Performance Improvement

Nanocoating refers to the application of an ultra-thin, transparent nanostructured layer (usually less than 100 nanometre) on the glass surface of solar modules. This coating enhances surface properties to improve performance and reduce maintenance.

Problem Statement:
Solar power plants located in dusty or polluted environments frequently experience performance losses due to soiling on module surfaces. Traditional cleaning methods are labour intensive, water-dependent, and increase operational costs. There is a need for a durable, cost-effective surface treatment that reduces dirt accumulation, minimizes cleaning frequency, and improves energy output. Implementing nanocoating offers a potential solution to enhance self-cleaning properties and long-term performance of PV modules.

Figure 6: Solar module with nano coating

Solution Implemented:
This is implemented by a utility scale solar plant and has seen an increase in approximately 10% in the same string over a period of 30 days. The table below shows the difference in generation.

Name of String	Generation kWh	Time Period
String 3 (Before Coating)	1,059	30 Days
String 3 (After Coating)	1,176	30 Days

Key Outcomes:
An average improvement of 10% in power generation was observed in the same string after applying the nanocoating. This indicates that, over the trial period, the nano-coated modules generated more energy, primarily due to reduced soiling losses and improved surface cleanliness.

Impact and Scalability:
It can be implemented in large utility scale ground mounted and rooftop plants.

Best Practice 7: In-house Drone-Based Electroluminescence (EL) Testing

Electroluminescence (EL) testing is a non-destructive imaging technique used to detect defects (especially related to cells) in solar photovoltaic (PV) modules. It involves applying a small electrical current to a solar module in the dark, causing it to emit infrared light (electroluminescence). A special infrared-sensitive camera captures this light to reveal internal cell-level defects.

Problem Statement:

Solar modules undergo various stages of handling right from manufacturing to installation at site. If not handled carefully, there is a high risk of developing defects such as microcracks in cells, broken or inactive cells, finger interruptions, soldering faults, potential-induced degradation (PID), delamination, hotspots, or internal shading due to hidden defects. Any of these issues can significantly affect the overall performance and energy output of the solar plant.

Solution Implemented:

EL testing is being performed in many utility-scale solar plants. This test ensures the reliability and quality of installation by helping to identify defects before and after the plant becomes operational.

Figure 7: EL Testing of Solar plant

Key Outcomes:

It ensures module quality before installation, improves plant performance by identifying underperforming modules, and supports warranty or insurance claims with a proof of damage. Additionally, EL images serve as a benchmark for tracking degradation over time and aid in long-term maintenance diagnostics

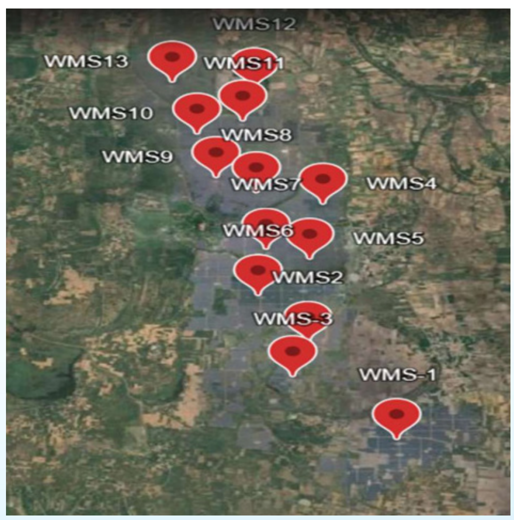
Best Practice 8: Installation of Zonal Weather Monitoring System:

A Weather Monitoring System (WMS) is a critical component of a solar power plant used to measure and record real-time environmental and atmospheric data that can impact solar energy generation.

Problem Statement:
Weather is dynamic in nature, constantly changing with time, which makes real-time monitoring essential for accurate performance assessment and efficient operation of solar power plants.

Figure 8: Weather Monitoring System

Solution Implemented:
While typically only one or two Weather Monitoring Systems (WMS) are installed in a solar plant, deploying them at multiple locations in large projects can greatly enhance performance estimation and analysis. It provides localized data for accurate performance benchmarking, supports loss analysis, and improves efficiency monitoring. Additionally, it aids O&M by enabling timely weather-based decisions for cleaning, safety, and maintenance.



Key Outcomes:

Weather monitoring system can capture following information and can help in estimating the real performance of plant:

Solar Radiation:

a) Global Horizontal Irradiance (GHI)
b) Plane of Array Irradiance (POA)
c) Diffuse and Direct Irradiance (DHI, DNI)

Environmental Conditions:

a) Ambient temperature
b) Module temperature
c) Wind speed and direction
d) Relative humidity
e) Precipitation

It can help in reducing the maintenance cost by appropriately estimating and scheduling the maintenance activity.

Best Practice 9: AI-Driven Image Analytics System for Real Time Supervision

AI-Driven Image Analytics System is a crucial part of modern solar power plants. It enables real-time supervision, diagnostics, and improves the overall safety of the plant using advanced technologies like cloud computing, IoT sensors, and artificial intelligence.

Problem Statement:

When the solar plant covers a very large area, it often happens that animals enter the premises, which can lead to fault occurrences. Additionally, high vegetation in certain parts of the plant increases the risk of ground faults.

Solution Implemented:

AI-Driven Image/ Video Analytics System is being implemented at utility scale solar plants for enhancing the safety of the plant.

Figure 9: AI-Driven Image and Video Analytics System

Key Outcomes:

Smart Surveillance & Safety Solutions:

- **Automatic Vehicle Entry/Exit Detection** for gate access management
- **Vehicle Over-speed Detection** within premises
- **Face Recognition-Based Attendance System** for site employees and visitors
- **Fire and Smoke Detection** for early hazard alerts
- **Human Fall Detection** to ensure on-site safety and quick response
- **Cost Savings** by reducing dependence on manual security personnel

Table 5: Reference Performance Data for Utility Scale Solar Plants

Plant	DC Capacity	Age of Plant (in Years)	Location of Solar Plant	Actual GHI	Energy Generation	CUF based on DC capacity of plant	Wate Consump-tion	Energy Benchmark-ing
	MWp	As on 31-12-2024		kWh/ m^2/ annum	MWh	%	Litres/ kWp/ Year	MWh/ MWp
Plant-1	More than 50 MWp	4.00	Andhra Pradesh	1,954	5,66,433	25.86%	0.00	2,265
Plant-2		2.00	Rajasthan	2,068	7,98,676	20.29%	0.00	1,777
Plant-3		6.00	Andhra Pradesh	2,003	1,07,812	16.74%	69.83	1,466
Plant-4		3.00	Rajasthan	2,068	7,20,262	19.58%	0.00	1,714
Plant-5		2.00	Gujarat	2,199	7,14,380	20.70%	26.64	1,813
Plant-6		7.00	Chhattisgarh	1,876	2,10,840	16.20%	0.95	1,419
Plant-7		8.00	Tamil Nadu	1,773	10,72,040	15.67%	5.13	1,372
Plant-8	Less than 50 MWp	7.00	Karnataka	1,769	53,256	19.17%	40.29	1,679
Plant-9		9.00	Telangana	1,096	8,692	15.13%	457.00	1,324
Plant-10		2.00	Kerala	2,022	22,760	17.05%	695.00	1,493
Plant-11		3.00	Tamil Nadu	1,932	20,839	17.77%	54.00	1,556
Plant-12		8.00	New Delhi	1331	9,662	14.07%	96.00	1,232
Plant-13		7.00	Karnataka	1945	30,607	18.78%	60.00	1,645

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WIND

Best Practice 10: Silicon Coating on Compact Substations (CSS) Panel

Problem Statement:

In wind farms where compact substations (CSS) are used to connect wind turbine generators (WTGs) to high voltage feeders, heavy monsoon rainfall can cause significant moisture ingress into the CSS panels. This moisture intrusion often leads to frequent tripping and failures of critical components such as current transformers (CTs), potential transformers (PTs), circuit breakers, and cables. These recurring equipment failures compromise system reliability and result in increased maintenance costs and operational downtime.

Table 6: Plant performance parameters

Specifications	Unit	Value
Capacity of Plant	MWp	126
Annual Energy Generation	MWh	1,70,316
Capacity Utilization Factor	%	15.43 %

Solution Implemented:

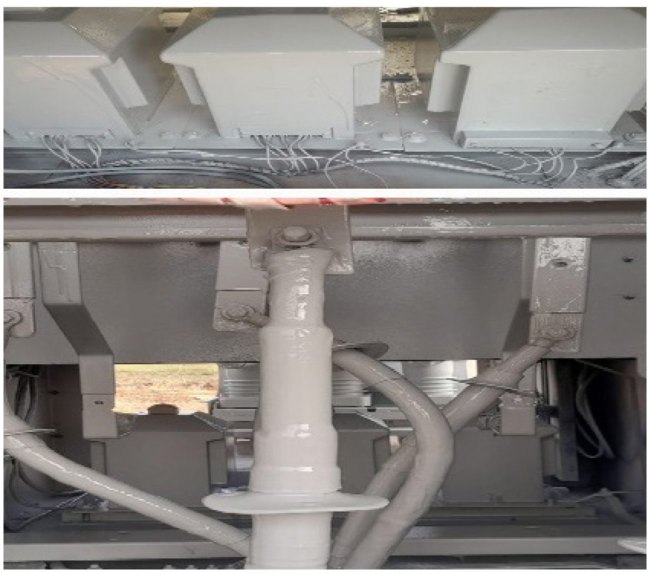

Figure 10: Before Implementation

Figure 11: After Implementation

To mitigate moisture ingress during heavy monsoon conditions, a silicon coating was applied to the internal structure and equipment of the compact substations installed across all wind turbine generators (WTGs). This coating enhances moisture resistance, helping to prevent equipment failures and improve overall system reliability during adverse weather conditions. In addition to the silicon coating, tin sheds were installed, exhaust fans were fitted, and anti-tracking paint—offering an insulation level of 121 kV/mm—was applied to further strengthen protection against moisture-related faults. This has resulted in savings of about INR 2 lakh per annum.

Key Outcomes:

By preventing moisture-related failures and corrosion, silicon coatings extend the lifespan of electrical components and reduce maintenance frequency and operation and maintenance costs..

Impact and Scalability:

Silicon coating can be applied across wind power plants to provide uniform protection for a wide range of components such as current transformers (CTs), potential transformers (PTs), breakers, and cables.

Best Practice 11: Power Curve Analysis for Wind Turbine Generators (WTG)

A wind turbine power curve is a graph that illustrates the amount of power a wind turbine can generate at varying wind speeds. It serves as a critical tool for evaluating the performance and suitability of wind turbines. By analysing a turbine's power curve, one can accurately assess the available wind resource and predict power generation, leading to more informed planning and decision-making.

Problem Statement:

Unscheduled maintenance resulting from unexpected wind turbine failures leads to increased operational costs and reduced efficiency. In the absence of continuous performance monitoring through power curve analysis, early indicators of underperformance or component degradation often go unnoticed, thereby raising the risk of costly repairs and extended downtime.

Solution Implemented:

Power curve analysis can be conducted for multiple wind turbine generators (WTGs) to identify faults, compare performance across units, detect underperforming turbines, and proactively prevent potential failures.

Key Outcomes:

- Early detection of underperforming turbines through continuous monitoring
- Identification of faults by analysing performance anomalies
- Prevention of major failures through timely maintenance interventions
- Benchmarking and performance comparison across multiple wind turbine generators.

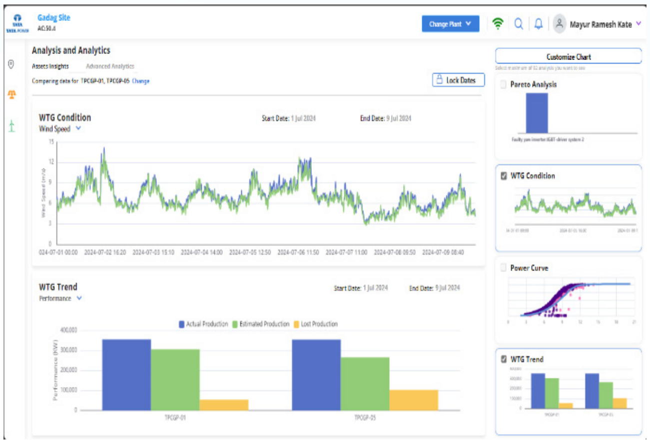

Figure 12:Power Curve Analysis of WTG

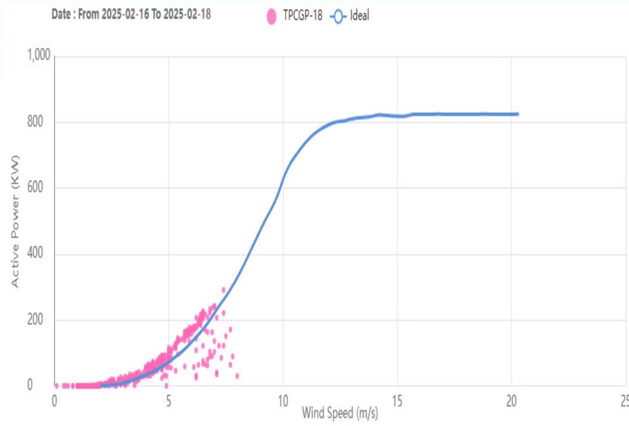

Figure 13:Problem Identification

Figure 14:Power Curve Analysis of different WTGs

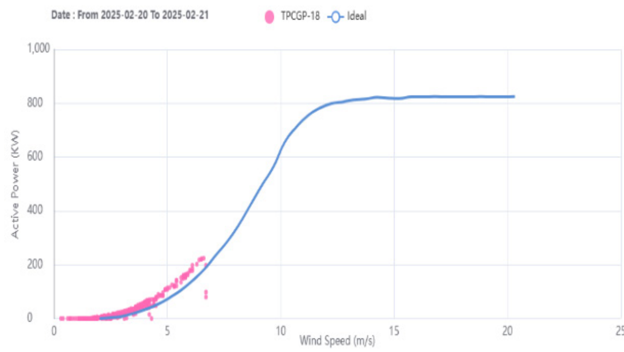

Figure 15: After Resolution of the problem

Impact and Scalability:

Power curve analysis is suitable for wind farms of all sizes and can be scaled fleet-wide across multiple sites. It supports remote, real-time monitoring and works across different turbine models.

Best Practice 12: Fitting Water Drainage Hose Pipe at Nacelle Glass Reinforced Plastic (GRP) Joint

Water drainage hose pipe fitment at nacelle refers to the installation of a hose pipe system at the nacelle's GRP body in a wind turbine to allow for proper drainage of accumulated water—typically from rain, condensation, or maintenance.

Problem Statement:

During the rainy season, water ingress can be observed in the generator winding area through gaps located at the 1 o'clock and 11 o'clock positions on the GRP joints of the nacelle. These gaps develop over time due to the aging and deterioration of the GRP material and its sealing. The accumulation of water within the nacelle, without a proper drainage pathway, significantly increases the risk of electrical faults and potential winding failures in the generator.

Solution Implemented:

A retrofitting solution was implemented by a wind plant in Maharashtra by creating a dedicated drainage path at the GRP joint gaps. This system collects water ingress and channels it away from the generator winding area. The water is then directed to an open space at the rear of the nacelle, allowing it to drain out naturally. This simple yet effective solution prevents water accumulation, thereby safeguarding the stator windings and internal components of the nacelle.

Key Outcomes and Benefits:

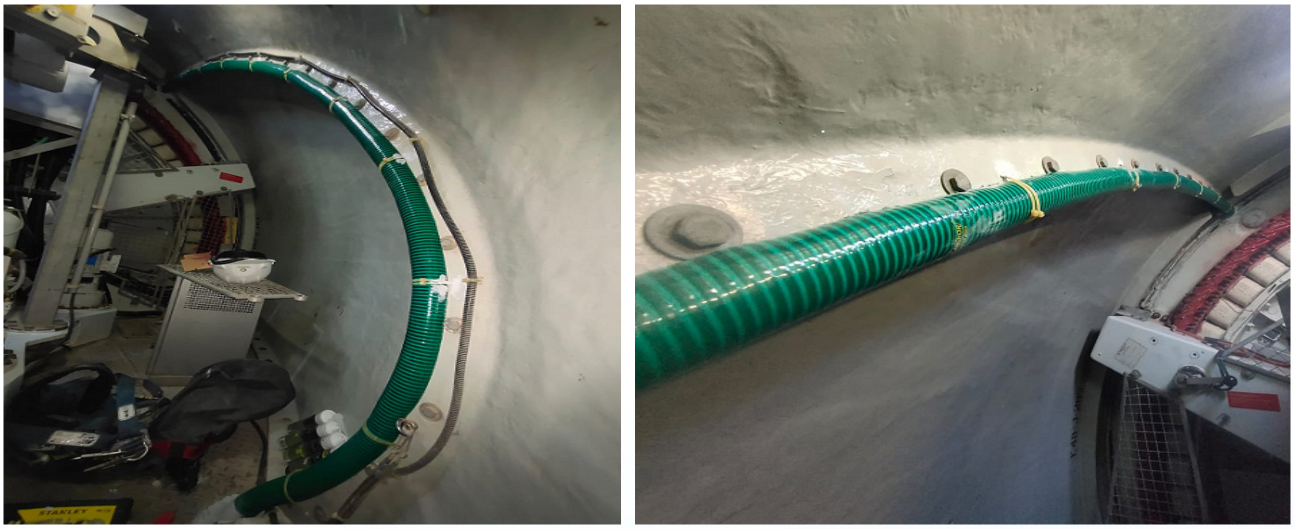

Figure 16: Water drainage hose pipe fitment at nacelle Glass Reinforced Plastic (GRP) joint

- Generator failures reduced from 6 in FY23 to 1 in FY25
- Repair time reduced from 1,344 hours in FY23 to 192 hours in FY25
- Repair costs and generation loss worth approximately INR 22 lakh were saved.

Impact and Scalability:

This solution is low-cost, easy to implement, and can be replicated across all similar wind assets, regardless of size or location. It is particularly effective for turbines operating in high-rainfall or coastal regions where water ingress is a recurring issue.

Best Practice 13: AI-Enabled Digital Twin

Digital twins act as data-driven virtual models of individual turbines or entire wind farms, providing operators with detailed insights into asset health and performance. By combining real-time monitoring with predictive analytics, these models enable maintenance teams to assess component wear, detect potential failures early, and take proactive measures to ensure optimal performance and reduce unplanned downtime.

Problem Statement:

Traditional asset monitoring lacks real-time insights and predictive capabilities, leading to inefficiencies and delayed fault detection. An AI-enabled digital twin is needed to replicate physical systems, enable data-driven decisions, and optimize performance through predictive analytics.

Solution Implemented:

The integration of AI-driven analytics with digital twins enables wind farms to process and analyse vast amounts of inspection and performance data. This approach supports predictive maintenance by identifying minor, often-overlooked faults before they escalate into major issues. By leveraging AI insights alongside digital twin models, operators can enhance power generation, minimize downtime, and proactively manage maintenance activities for improved operational efficiency.

Key Outcomes:

- Automated identification of underperforming turbines
- Extension of asset lifespan through proactive maintenance
- Prediction of potential component failures using data-driven insights
- Detection of anomalies such as abnormal vibrations, excessive temperatures, or irregular energy outputs
- Real-time monitoring and actionable insights for improved decision-making
- Reduction in operation and maintenance costs by up to 11%
- Decrease in field inspections by 60% and lead time to repair by up to 85%

Impact and Scalability:

Digital twins are most valuable for large-scale wind farms, where operational complexity and maintenance costs are high.

Best Practice 14: 360° Blade Access Platform (BAP)

The 360° Blade Access Platform (BAP) is engineered to facilitate comprehensive inspection and repair of wind turbine blades and towers. This modular platform is easy to install and can be quickly reconfigured for either blade or tower access with the addition of a few minor components, enhancing flexibility and efficiency in maintenance operations.

Problem Statement:

Wind turbine blade inspection and repair present significant challenges due to limited accessibility, high safety risks, and the substantial costs associated with cranes and traditional elevated work platforms. These constraints lead to slower maintenance processes and increase operational expenses.

Solution Implemented:

The 360° Blade Access platform (BAP) is implemented to eliminate the use of large cranes and reduce repair time.

Figure 17: Blade Access Platform

Key Outcomes:

- Safe, adaptable and easy to operate
- Easy to transport - lowers cost to mobilize
- Convenient to reconfigure for blade inspection or tower access
- Low maintenance costs with use of standardized modular components
- Reduce wind turbine downtime.

Impact and Scalability:

360-degree blade access platforms are scalable for onshore wind turbine maintenance due to their modular design and adaptability to different blade sizes and turbine types.

Table 7: Reference Performance Data for Utility Scale Wind Plants

Plant	Capacity	Age of Plant	Location of Wind farm	Wind Power Density	Hub Height	Generation	CUF
	MW	As on 31-12-2024		W/m^2	meter	MWh	
Plant-1	More than 50 MW	2	Madhya Pradesh	220	130	8,52,760	29.80%
Plant-2		1	Gujarat	300	140	5,79,715	33.99%
Plant-3		7	Andra Pradesh	263	90	4,92,755	24.80%
Plant-4		7	Andhra Pradesh	244	111	2,02,840	22.16%
Plant-5		9	Rajasthan	240	90	1,70,316	15.43%
Plant-6	Less than 50 MW	18	Tamil Nadu	400	80	59,237	24.63%
Plant-7		5	Gujarat	183	120	1,06,065	34.59%
Plant-8		17	Maharashtra	139	76	91,094	20.63%

Confederation of Indian Industry

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Confederation of Indian Industry

The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the development of India, partnering Industry, Government and civil society through advisory and consultative processes.

CII is a non-government, not-for-profit, industry-led and industry-managed organisation, with around 9,700 members from the private as well as public sectors, including SMEs and MNCs, and an indirect membership of over 365,000 enterprises from 318 national and regional sectoral industry bodies.

For more 130 years, CII has been engaged in shaping India's development journey and works proactively on transforming Indian Industry's engagement in national development. CII charts change by working closely with the Government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness, and business opportunities for industry through a range of specialised services and strategic global linkages. It also provides a platform for consensus-building and networking on key issues.

Through its dedicated Centres of Excellence and Industry competitiveness initiatives, promotion of innovation and technology adoption, and partnerships for sustainability, CII plays a transformative part in shaping the future of the nation. Extending its agenda beyond business, CII assists industry to identify and execute corporate citizenship programmes across diverse domains, including affirmative action, livelihoods, diversity management, skill development, empowerment of women, and sustainable development, to name a few.

For 2025-26, CII has identified "Accelerating Competitiveness: Globalisation, Inclusivity, Sustainability, Trust" as its theme, prioritising five key pillars. During the year, CII will align its initiatives to drive strategic action aimed at enhancing India's competitiveness by promoting global engagement, inclusive growth, sustainable practices, and a foundation of trust.

With 70 offices, including 12 Centres of Excellence, in India, and 9 overseas offices in Australia, Egypt, Germany, Indonesia, Singapore, UAE, UK, and USA, as well as institutional partnerships with about 250 counterpart organisations in almost 100 countries, CII serves as a reference point for Indian industry and the international business community.

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