+2.5% Improvement in generation utilizing Anti soiling modules based on DSM technology

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Abstract. Accumulation of dust on solar modules decreases the transmittance of photovoltaic glazing, resulting in both deteriorated efficiency and daily energy losses. Actually, the soiling phenomenon in PV systems has been shown to be responsible for a medium- and long-term yield reduction of up to 16% over the first year of outdoor exposure [1]. The most prominent origin of dust is driven by wind and soil particles from the ground surface. All over the planet, the properties of dust due to geological, topographical, and environmental ambiances such as relative density, particle structure, surface effects, and vapour content differ from one location to another. In the present study, an exploration of the energy gain observed by Photovoltaic modules coated with DSM Anti-Soiling coating (ASC) installed at 150 MW solar power plant in Andhra Pradesh is presented. The experiment for the analysis of the generation data started on 6 September 2018. Four different slots, one with DSM ASC and the rest with an anti-reflective coating (ARC), with equivalent DC connected load are chosen for analysis. The washing cycle was maintained at an interval of 10 days. The study shows that the modules with ASC generate +2.5% more power than the modules with ARC.

1. Introduction
The mass and structure of dust granule have a considerable effect on their sedimentation manner and photovoltaic (PV) efficiency. These days, the decreased generation output of PV modules due to the impact of soiling on the glass surface is receiving a lot of attention. The agglomeration of the dust on the plane of the PV modules decreases the transmittance and results power losses. Previous studies show that these losses could reach 15% in dry areas [1], while another study in a desert location reports losses greater than 20% [2]. In such events, the remedy is to wash the modules with water and dry cleaning with robots [3].

The accretion of dirt on the frontal glass of PV systems continuously interferes with power generation phases. In fact, PV module energy generation is proportional to the accumulation of incident photos reaching the PV cell surface of the modules. In practical terms, the amalgamation of self-cleaning coatings enables a remarkable decrease in maintenance expenses associated to wiping activities and in the quantity of water required for solar module washing. The application of radiation by any PV cell or solar thermal appliance is limited by arrival losses due to backscattering, reflection, or exterior absorption. Thus, anti-soiling surfaces and anti-reflecting coatings can make a remarkable contribution to the respective overall process production.
The industrial science of renewable power, in specific photovoltaic’s (PVs), is troubled by diverse specifications (examples, technology, environment, region, and assimilation). The environmental criterion has a broad influence on the power generation and effectiveness of PVs. Some environmental criterion includes direction, moisture, solar radiation and temperature, wind speed, and the presence of dirt.

The soiling on the sun-facing area of installed PV modules is a well-known obstacle, generally resulting in reductions of about 5% to 25% in power output, depending on environmental conditions and maintenance and cleaning proceedings [4], [5] & [6]. Soiling happens very quickly, so losses due to soiling can be severe even with continued pattern of cleaning. In different circumstances, soiling fluctuates tremendously, even in a specific region, as the effects of climate, microclimate, atmosphere, the configuration of wind-borne dust, local dust and other contaminants, and many other characteristics determine the soiling that happens in any time span.

2. DSM Technology

DSM Anti-Soiling coating (ASC) consists of anti-reflective and anti-soiling properties designed specifically for dry environments. It improves the internal rate of return by requiring fewer cleaning cycles and reducing performance loss. It comprises of 100% inorganic material, which provides an excellent UV resistance under high irradiance and its anti-reflective properties are comparable to regular anti-reflective coatings (ARCs). It reduces the soiling rate by preventing dust and sand from sticking to the module, while using wind and gravity as cleaning processes. This also reduces cleaning costs by increasing the intervals between cleaning cycles. The Taber Oscillation test was designed to test coatings in lenses and windows (according to ASTM F735), and DSM adapts such a setup for soiling tests by using standardized ‘Arizona Sand’. The ASC shows virtually no loss in optical performance in such tests, while ARC and uncoated glass exhibit a loss of roughly 2% to 4%.

Traditional anti-soiling coatings are based on two physical principles. These effects are based on hydrophobic or hydrophilic properties, which are, respectively, “water-repellent” or “water-attracting”. “Water-repellent” hydrophobic coatings have a low surface energy and a contact angle between the surfaces and water above 120 degrees (super-hydrophobic), which is relevant for enhanced cleaning. Materials used for hydrophobic coatings are mainly “fluoropolymers”.

“Water-attracting” hydrophilic coatings have high surface energies, leading to low contact angles and, assuming the presence of abundance of water, to a closed water film on the surface. With contact angles of less than 10 degrees (super-hydrophilic), moving of dirt particle of the surface is assured under terms of surface inclination. Titanium oxides (TiOx) and silicon oxides (SiOx) materials are used for such coatings. Also, some hydrophilic coatings have the photocatalytic functionality, being able to precisely decompose organic element after solar activation [7].

However, there is hardly any rain to remove the dust in dry areas. Sometimes dew can enhance cleaning, but it can also have an adverse effect (e.g., stripes, and concentration of dirt). Another problem is that water doesn’t run off easily at low installation angles. Furthermore, coatings containing fluorine or organic components are sensitive to UV degradation, leading to a limited lifetime.

DSM’s ASC is based on our proprietary core-shell particle technology and designed to reduce soil dust bond and maximize elimination of dust. It reduces the soiling rate by preventing dust and sand from sticking to the module while using wind and gravity as the “cleaning process”, thus reducing the output loss in between cleaning cycles and making it easier to clean the modules.

3. Methodology

All the assessments defined in this paper are designed at demonstrating the expected impact of ASC application at solar power plants. Figure 1 shows the actual three different plots, each with 50 MW capacities, were installed, and each plot was distributed in six blocks. Four blocks were installed with 10 MW capacity and the other two were installed with 5 MW capacity. Actual site location is mentioned in the Figure 2. Three inverters were selected for analysing the generation. For precise results, the comparison was done in terms of slots.
Figure 1. Aerial drone view of M/s ACME 150 MW SPV Plant, A.P.

Figure 2. The site is located at Galiveedu, Anantapur, Andhra Pradesh State, India (14° 01’ N, 78° 30’ E) about 200km north-east of Bangalore.

Figure 3. Anti-Soling coated (ASC) modules installed at the Galiveedu site.

Table 1. Details of connected DC load for ARC & ASC slots

| Inverter Details | Capacity(KW) |
|------------------|--------------|
| P6 B6 I2-Slot 2 (ASC) | 793.8 |
| P6 B1 I1-Slot 2 (ARC) | 819.2 |
| P6 B2 I1-Slot 1 (ARC) | 819.2 |
| P6 B2 I1-Slot 2 (ARC) | 857.6 |

The measured generation variation of different slots mentioned in Table 1 was collected and analyzed on a daily basis between 6 September 2018 and 31 March 2020. Of the 19 months observed, the data of 4 months was disrupted due to communication problems and therefore omitted from the analysis. These modules were installed during July and August 2018 at the site as shown in Figure 3. The washing cycle was maintained at an interval of 10 days throughout the study cycles. The comparison was done between the ASC and ARC modules.

4. Analysis and Discussion

As per the standard test conditions, the output of maximum power generated from installed modules helps in monitoring the rate of soiling. The difference in between the generating units of the ARC and ASC modules authenticates that the implementation of such anti soiling coatings is able to reduce soiling deposition and accumulation on the front glass of the installed modules. The reference ARC modules demonstrate noteworthy loss directly linked to soiling phenomenon, more than +2.5% of the nominal generating units. Investigational activities have proven that a self-cleaning coating exercise can eradicate soiling-related losses during the year of installation, allowing for
consistent savings in terms of the operation and maintenance of solar power plants. The monthly gain and accumulated specific energy difference between AS and AR coated modules are shown in Figure 4.

![Figure 4](image-url)

**Figure 4.** This bar graph shows the monthly gain (green line) from September 2018 to March 2020. The accumulated specific energy difference (kWh/kWp) between AS and AR coated modules is represented with yellow bars on a monthly basis.

The generation measured on a daily basis was captured and its equivalent performance ratio (PR) was calculated with the specific insolation of that particular day. The respective PR% results are mentioned in the Table 2 and shown in Figure 5.

| Inverter Detail | Performance Ratio (%) |
|-----------------|------------------------|
| P6 B6 I2-Slot 2 (AS) | 82.86 |
| P6 B1 I1-Slot 2 (ARC) | 80.74 |
| P6 B2 I1-Slot 1 (ARC) | 80.01 |
| P6 B2 I1-Slot 2 (ARC) | 80.71 |

Table 2. Details of calculated PR% for ARC & ASC slots

The PR is calculated based on the following formula:

\[
\text{Performance Ratio \%} = \frac{\text{Slot-wise Generation (kWh)}}{\text{DC capacity (kW)} \times \text{Plant Availability} \times \text{Grid Availability} \times \text{Insolation (kWh/m}^2\text{/day)}}
\]
5. Conclusion
A habitual occurrence is observed on the installed modules due to aggregation of surrounding dust. Collected soil curtails performance of installed modules. The results show in Figure 4, depicts a +2.5% average increase in Photovoltaic module power generation for the anti-soiling modules, recommending that the preferable washing cycle should be 10th day after every washing cycle.

The activity furnished in said research was focused on validating the utilization of ASC being a feasible option for Photovoltaic module preservation. As a matter of fact, the main concerns of PV plant managers and owners are soiling-related losses, the losses are accountable for increasing the return time of investment in case of noteworthy power generation losses throughout the viability of the plant. Furthermore, module soiling can develop confined hindrance on the front surface of glass, which can expedite to electrical delay.

The effect of ASC would be even durable for PV techniques installed at dusty sites, and the earnings in PV yield would be enormous.

In addition, during the soiling evaluation, the transmittance values were remarkably decreased. Finally, the AS coated glass shows a higher gain in transmittance after soiling than the ARC glass substrates.

6. References
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