Study on the dust properties and application of self-cleaning materials in PV power plant operation and maintenance

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1. Dust properties
2. Self-cleaning technology
3. SSG self-cleaning film
The development of PV technology, besides the material of the silicon cell, orientation of the panels, also has an important influence factor on the output power - the dust on PV glass.
Dust effect on PV power station

- Shaded solar radiation
- Hot spot
- Corrode glass panel
Where does the dust and contaminant come from?

- Soil desertification
- Atmospheric circulation dust
- Artificial dust
- Car emissions
- Industrial emissions
Dust properties in different areas in China

West: Soil desertification serious, becomes sand or parched soil.

East: Soil organic matter and microbe more, it is cohesive soil, and industrial pollution and haze serious.

South: Cohesive soil and red soil. Much rain.
Dust classification and properties

**Cohesive soil**
- Particles small, low porosity
- Combines with water and organic matter
- Easy harden, hard to removal

**Sand soil**
- Particles big, big porosity
- The more density the less easy to accumulate
- Hard to harden, easy to removal
When a certain amount of organic matter exist in the dust, it is easy to becomes organic-chemical harden. That is very hard to removal.
Organic-chemical harden

In the presence of organic and chemical components, the dust slowly becomes a solid form as time goes on.

Physical attachment becomes chemical adhesion.

Form organic-chemical harden.
Water harden

In the dry case: the dust is smooth, uniform, loose, the adhesion force is small, easy to clean.

Absorb dew or rain to splash: the dust becomes dot, flaky, gully stripe, even form saline-alkali stain, has solid shell, adhesive force becomes big, hard to clean.
The effect of dust density on output power.

1. \( Y=ax^2 + bx + c \) \((x \leq C)\) exponential
2. \( Y=A\ln(x) + B \) \((x > C)\) logarithmic

- \(x\) – dust density \(\text{g/m}^2\)
- \(y\) – the power output down \(\%\)

The constant terms are limited by the dust kinds and the uniformity of distribution.

Reference values:
- \(a=-25, \ b=14.2, \ c=-0.001\)
- \(A=3.3, \ B=7.9, \ C=0.13\)
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What is self-cleaning technology?

Self-cleaning coated glass—In the sunlight or ultraviolet radiation, the organic matter that attaches to the glass surface is degrade, and the hydrophilicity produced, making the pollutant easy to be cleaned.

—JC/T 2168-2013 Self-cleaning coated glass

Easy clean  Organic degrade  Hydrophilic
Decomposing organic matter (photolysis)

In ultraviolet radiation, TiO$_2$ shows the properties of semiconductors, forming electrons and holes, capturing oxygen and water in the air, forming negative oxygen ions and hydroxyl groups. Negative oxygen ions and hydroxyl groups convert organic pollutants into carbon dioxide and water.

In the process of photolysis, TiO$_2$ ACTS as a medium and does not participate in the reaction itself.
Decomposing organic matter

◆ TiO₂ has the ability to decomposing all kinds of organic pollutants and without producing intermediate toxic substances.
◆ Kill bacteria and purify air.
Decomposing organic matter

The methyl blue solution becomes clear.

Bird droppings become blurred.

The Escherichia coli was attacked 240 minutes, the cell wall ruptured.
Super hydrophilic and hydrophobic theory

**Super hydrophilic:** Water washes the whole panel of dust. The film and water is easier to combine than the film and dust. When it rains or other clean water, the film will be easy to combine with water. The dust automatically separates from the film layer.

**Super hydrophobic:** Water on the film layer will be water droplets, this can avoid contaminate the base panel by dirty water, but has no good washing ability.
Super hydrophilic

Super hydrophilic can be obtained in two ways:

The suitable roughness of the film surface can obtain super hydrophilic. The water is trapped in the hollow of the film surface, and the rest of the water flows through a patchwork of solid and liquid.

The process of photolysis formed super hydrophilic. When TiO\textsubscript{2} exposed to the sunlight, it shows super hydrophilicity. When the sunlight stopped, the material slowly loses its hydrophilicity.
The surface roughness influence the dust adhesion.

The surface roughness of the self-cleaning film can be controlled in a few to dozens of nanometers. The dust is mainly micron-size particles.

When the roughness of the film surface is relatively large, the contact area of the dust and film decreases, and the dust slip down easily.
Dust can slip down more easily

◆ Control the roughness of self-cleaning film surface, we can obtain the dust more easily to slip down.

◆ Anti-static technology can also be used to prevent charge accumulate.

◆ The dust can slip down automatically under its own gravity and wind force to keep the PV modules clean.
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SSG (Solar Spread Growing)

SSG is a TiO$_2$ active self-cleaning glass film layer.

SSG = AR + self-cleaning

SSG layer has been used on more than 400MW PV power stations in China. Generally increase the power generation 3% ~ 5%.

Action

- Trans increase 2%
- Super hydrophilic
- Decompose O-matter
- Dust slip down auto
**Ionic bonding**

**Bridging particles**

**Active nanoparticles**

** Combination method**

$\text{TiO}_2$  

$\text{SiO}_2$  

$\text{SiO}_2$  

$\text{SiO}_2$  

$\text{Si}$  

$\text{Glass}$
Ionic bonding

Large specific surface area

Active nanoparticles

With the base glass to form ionic bonding

TiO_2

SiO_2

SiO_2

SiO_2

Glass
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<tr>
<th>Test project</th>
<th>Test standard</th>
<th>Test conditions</th>
<th>Requirement</th>
<th>Results</th>
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<td>HF10</td>
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The earliest project cases in China (4.5 years)

Since March 2013, the use time has been four and a half years.

PV station in Golmu, Qinghai province
customers 100% satisfied
Thank you!