Tackling solar's dust problem

Soiling | The build-up of dust and other particles on PV modules can impact on the efficiency of a power plant. Understanding how soiling can vary in different regions of the world is crucial in maximising plant performance, writes Dmytro Podolskyy

Due to the increasing interest in renewable energy around the world, solar plants are more frequently being installed in challenging conditions. Many of the locations are arid or desert-like areas, as they provide very high solar irradiance and the land is rarely used for other purposes. Examples of such sites are in the USA, North Africa, the UAE, Saudi Arabia, the Atacama Desert in Chile, Australia and India.

In such areas soiling by dust and sand is a serious issue that affects the efficiency of the plant and understanding it is crucial for the whole process of calculating the viability of a project. Soiling-related issues need to be studied to understand output losses, schedule maintenance, calculate life-cycles of components and evaluate bankability.

Soiling is a complex process that strongly depends on the local environment. Surface conditions, wind patterns, humidity and the temperature of the air are the main natural parameters that affect soiling. Anthropogenic factors also play important roles; agricultural activities, traffic and air pollution contribute to deposition of dust and pollutants on PV panels and CSP plant mirrors.

The causes of soiling

In solar energy projects the main contributors to soiling are the following:

- Dust, pollen, sand and other airborne particles naturally accumulate on the surfaces of PV modules, concentrating mirrors and lenses. This reduces the energy output of solar plants and household installations. This effect is stronger when the solar plant is located in an arid area with agricultural activities and loose soil.
- Airborne pollutants such as vapours, smog and soot can form a layer on PV modules that is harder to clean than dust or sand. This is especially relevant in urban and industrial areas.
- Deposition of sand and dust in arid areas can be increased by night dew as the dust and sand sticks to wet surfaces. During the day the dust dries out and is baked by the sun and the next night more accumulates on the dew-damp surface.

Particle build-up on PV modules can undermine system performance.

Source: Hassan Qasem

The process repeats, forming a thick layer of dust that can completely block the light.

- Dirt often accumulates on the lower part of PV panels that have a raised mounting frame, providing partial shading and reducing the efficient area of the PV module. This is especially relevant in areas close to the equator as the panels are usually installed with low tilt angles to receive the maximum amount of solar radiation during the day.
- Mould can grow on the surface of PV panels in warm and wet areas. The heat accumulated during the day and the humidity during night-time provide the conditions for micro-organisms to proliferate and form an opaque layer on the surface of PV modules.
- Bird droppings in some locations can be sufficient to provide partial blocking of cells in modules. This affects the current flow in the modules and usually causes a drop of efficiency of the module or of a complete string.

The relative significance of the various contributors to soiling at any given location will vary throughout the year due to the local climate and weather processes.

How soiling is measured

Soiling can be estimated in a number of ways, depending on the required precision and the practical application. As it is hard to estimate soiling theoretically, due to its local and variable nature, a number of empirical methods are used by researchers and solar plant operators.

In smaller projects the effect of soiling is often estimated by using a reference PV cell or module that is subject to the same environment as the rest of the installation. The output of the module is compared to the expected theoretical reference output and the soiling rate is calculated. This method separates the measurements of the efficiency of the plant from the soiling measurements to provide independent data for analysis. However, it can miss the influence of several variable parameters such as the available irradiance, degradation of the modules and the effects of temperature and wind.

Another practical method is to use two reference PV modules installed at the same site and at the same angle as the working modules. One module is used as a reference and cleaned regularly (manually or automatically), the other is left un-cleaned. Comparing the energy output from the two modules gives a good estimate of the total energy loss of the plant. When the difference in outputs of the modules reaches a certain value the cleaning of the entire plant can be scheduled.

The optimal soiling level threshold to trigger cleaning the modules is calculated from the loss of output compared to the cost of the cleaning procedure. This method provides a simple method to optimise returns by reducing the loss of energy in a PV plant.

PV panel soiling tests at KISR in Kuwait.

Prospecting of new sites before deciding to embark upon a large-scale commercial solar park requires a more comprehensive study of potential soiling issues. Such a study needs to take into account several factors: differences between soiling rates on PV modules with different tilt angles, varying PV technology characteristics, effectiveness of

Weather station and solar irradiance measurement

Source: Hassan Qasem

anti-soiling coatings, efficiency of cleaning methods, soiling of concentrating mirrors for CSP plants, etc.

The variation in effects at different times of the year are very important for calculating the return on investment of future projects and need to be monitored. For such studies researchers use specially designed scientific stations that monitor soiling, solar radiation and meteorological parameters.

Scientific soiling monitoring stations

Kuwait Institute for Scientific Research (KISR)

Kuwait has very high levels of irradiance and many ambitious solar projects are being developed in the country, and in the whole Middle East North Africa (MENA) region. Understanding soiling-associated issues in solar energy projects is an important research topic. Dr. Hassan Qasem, a research scientist at the Energy and Building Technologies Department of the Kuwait Institute for Scientific Research (KISR) studies the accumulation of dust and sand on PV modules and its effects on the efficiency of a solar plant, depending on the PV technology used, installation tilt angle, dust particle size and other parameters.

Dr. Qasem's research is based on laboratory testing of dust samples' physical and optical properties as well as on outdoor testing. His set up consists of multiple PV modules and glass samples installed at a range of tilt angles outdoors. To monitor irradiance and weather conditions a meteorological station is installed on site. The station includes two pyranometers (to measure horizontal and tilted global irradiance), wind speed and direction, ambient temperature, relative humidity, precipitation and a data logger [1].

The results of the research enable a better understanding of the spectral effects of dust on PV modules and how the methodology may be applied to other sites. This knowledge can provide important information for selecting and developing the most appropriate PV technology for projects in Kuwait and the MENA region.

First Solar

First Solar of the USA installs solar energy projects based on its frameless thin-film PV module technology all around the world, more than 8GW to date. A good understanding of soiling is crucial for the success of such projects. The researchers at First Solar study soiling at various sites using a wide geographical network of stations covering the USA, India, Australia and the Middle East. The research has been conducted on both fixed panels and on tracking systems and these stations provide insights into the local differences in soiling patterns.

Source: First Solar

First Solar extensively tests soiling effects across a broad geographical area.

The research methodology includes the correlation of energy output with rain events and cleaning processes in order to develop an optimal strategy for operations and maintenance practices tailored to a specific site, to reduce the costs associated with soiling losses and cleaning. Such practices also give a confident basis for the prediction of energy output for the future.

'The variation in effects of soiling at different times of the year are very important for calculating the return on investment of projects'

It has been demonstrated that, apart from optimisation of cleaning schedules, smarter installation design can considerably reduce the losses from soiling. The stowage position for tracking panels at night can be optimised to reduce soiling losses considerably. The reduction of soiling on fixed panels by using a steeper tilt angle can more than offset a slight loss in the theoretical maximum output.

First Solar's soiling stations include several reference modules with different cleaning patterns as well as weather stations with pyranometers and meteorological sensors to monitor local irradiance and climate conditions. The most advanced stations have a precision automatic sun tracker to measure accurately all the components of solar irradiance; DNI, GHI and DHI [2,3].

Mainstream Renewable Power, Chile

The Atacama Desert in Chile is considered to be the place with the highest solar irradiation on Earth and many solar projects are being developed in the area. But the soiling conditions are quite different from those in the USA or Middle East and it is necessary to study them with accuracy in order to predict the profitability of future projects.

Soiling in this region is not only determined by different dust and sand types, there are also very unusual climatic phenomena characteristic of this region which can affect soiling rates, for example the Camanchaca. This is a fog which forms in the early hours of the morning along the coast of the Pacific Ocean and moves inland covering the desert area, but without precipitating as rain. In some regions it has been shown that the water can condense on PV panels, forming a very sticky crust on the panel surface. In other regions, this same phenomenon can result in the panels self-cleaning and very

much reduced soiling.

Patricia Darez, the energy analysis group manager of Mainstream Renewable Power, conducted the pioneering research in the Atacama Desert that demonstrated this effect. The researchers at Mainstream Renewable Power use an experimental soiling monitoring station which includes measurement of the electrical output of four panels with different cleaning patterns, as well as using an anti-soiling coating to study its efficiency. The station features solar irradiance and weather monitoring equipment [4].

This pioneering research provides an understanding of the conditions in this remote region, which is not yet well modelled but has very high potential for solar development. Such research is important to reduce the uncertainties and increase the financial value of future projects in the area.

Source: Adio Stefoni (MRP)

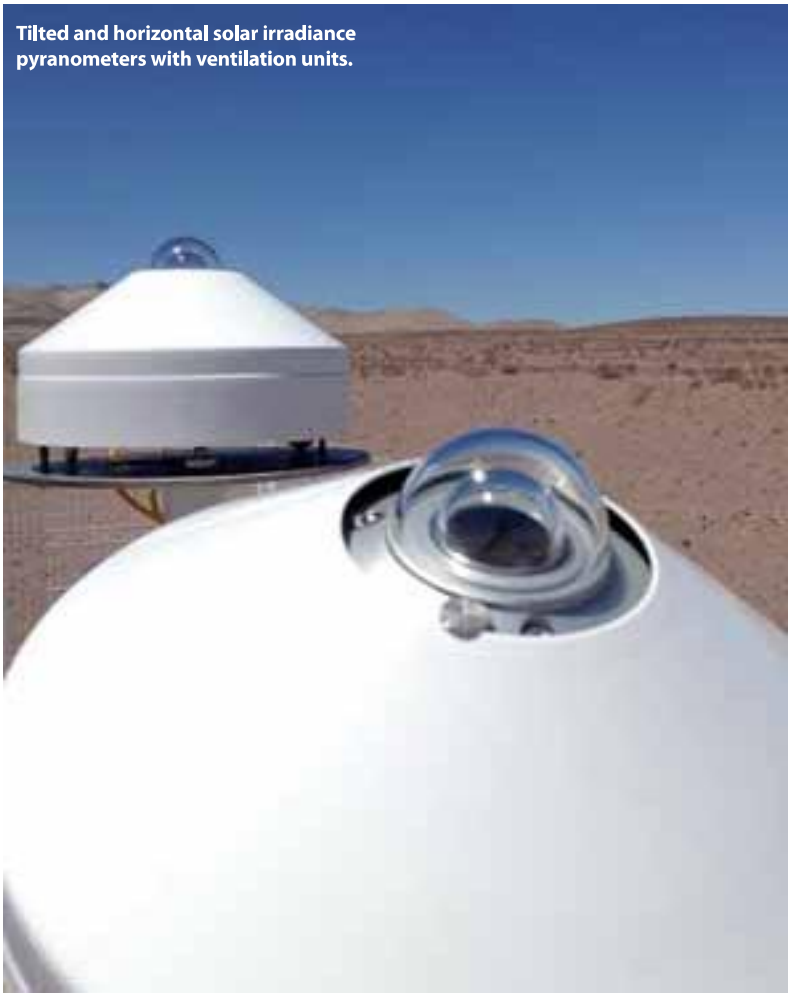
Mainstream Renewable Power soiling research station in the Atacama Desert.

Accurate monitoring

Soiling is one of the main factors that reduce energy generation in PV projects and needs to be accurately monitored and analysed to develop efficient practices to mitigate the losses and efficiently predict energy generation. It is important to develop the routines and methodologies to study and understand all the effects of soiling on PV and CSP systems.

Instruments of high quality and performance are required for reliable soiling studies. Monitoring of parameters such as irradiance, ambient temperature, humidity, wind and precipitation with the lowest uncertainties are important for obtaining reliable data. To optimise the value of local data high-quality soiling research stations need to be integrated with the radiation and weather stations used for prospecting and the monitoring of solar energy plants.

A good monitoring system that is properly maintained will enable the determination of changes in efficiency resulting from soiling and other environmental parameters that will lead to reducing the associated losses and make solar energy projects more profitable. ■



Tilted and horizontal solar irradiance pyranometers with ventilation units.

Source: Adio Stefoni (MRP)

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