Utility Scale PV Plant Performance in Australia (2016)

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Abstract

Experience in installation and operation of systems provides performance data which can be used to increase the accuracy of prediction models of future plants. The Greenough River Solar Farm at Geraldton, Western Australia, provides operational plant data to highlight the nuances of these prediction models. Soiling can be measured on site and used to predict energy performance of a system at a given geography. Irradiance is the most significant factor influencing plant output, measurements of which can provide comparable data to highly predictive models based on the typical meteorological year. Spectral shift helps explain the seasonal variation in energy output that cannot be explained by irradiance data alone.

Index Terms – photovoltaic systems, Cadmium Telluride, thin film, utility scale PV, plant performance, Australian operation

1. Introduction

This paper shares the predictive modeling approach optimised by First Solar and provides context for operational results by detailing updated performance data to date. Experience in installation and operation of systems provides performance data which can be used to increase the accuracy of prediction models of future plants. Data from the Greenough River Solar Farm (GRSF) at Geraldton, Western Australia is used to provide operational plant data to highlight the nuances of these prediction models. Installation practices and technique are an important element for a successful PV power plant, as are the processes and people required post-operation to ensure ongoing, high plant performance.

2. Greenough River Solar Farm

The 10MW (AC) Greenough River Solar Farm, located in Geraldton WA, is Australia's first commissioned and operational utility-scale power plant. First Solar received notification to proceed on construction in August 2011, and commissioned the plant in September 2012, with the construction of the plant being executed on time and on budget. This paper analyses the first three full years of operation in each of the key factors in performance prediction and operation of the plant.

3. Performance Prediction Accuracy

When making energy predictions for potential projects, First Solar uses standard simulation software such as PVSyst, as well as its proprietary simulation software PlantPredict to estimate the performance of its plant for different climatic conditions. Commercially available analysis tools do not always model all parameters accurately, and may not model some parameters. Data collected from the portfolio of plants in First Solar's operations and maintenance portfolio has been analyzed to further enhance understanding of field performance of Cadmium-Telluride (CdTe) technology, elements of which can be fed back in to the prediction models used to develop future plants.

First Solar's track record of energy predictions of plants compared to Actual Operation is within +/-5% of P50 levels as shown in Figure 1. The Predicted Energy Ratio (PER)

represents the ratio of the Performance Ratios (Specific Yield Normalized by the insolation). In other words, the PER is the ratio of measured specific yield normalized by the difference between TMY insolation and actual insolation over the period of record. Specific yield is a measure of actual AC energy versus rated DC power, and takes into account factors such as inverter clipping and module soiling.

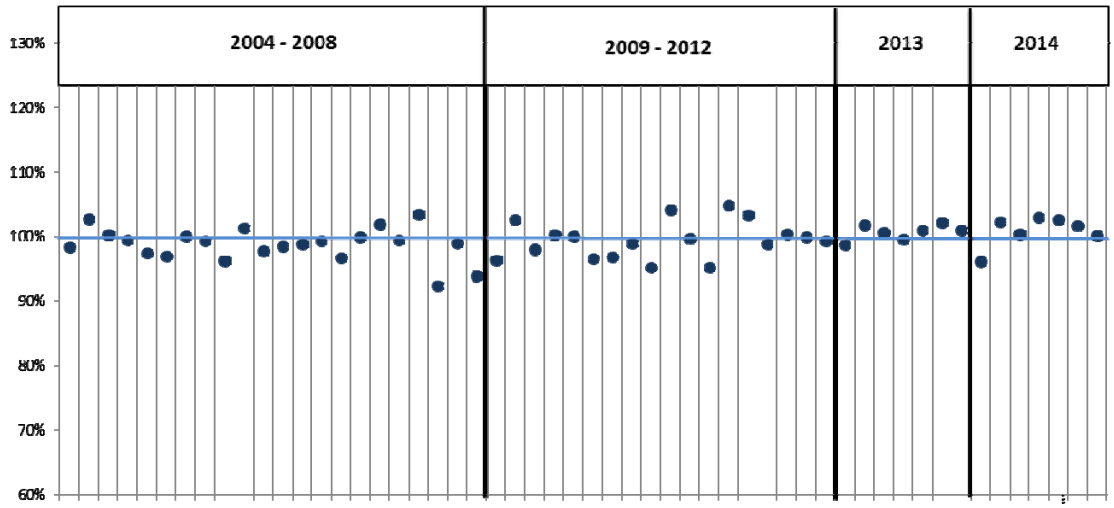

Figure 1: Average Predicted Energy Ratios of First Solar plant by commissioning date (Strevel, 2015)

4. Prediction Factors

Although standard models provide a solid basis for energy prediction of utility-scale solar plants, some factors, such as soiling, require accurate site data to increase prediction accuracy of plant performance. Weather factors, such as insolation and temperature, will differ from the Typical Meteorological Year (TMY) which is used as an industry benchmark for energy predictions. Factors such as spectral shift have not yet been modeled in modeling programs such as PVSyst. First Solar uses awareness of these parameters to increase the accuracy of PV plant energy predictions. In these analyses the term "predicted" refers to a simulation using TMY data as input, whereas the term "expected" refers to a simulation using on-site measured data as input.

4.1. Soiling

Accumulated dirt on a module will partially and usually uniformly shade that module, such that the output is reduced for a given insolation level. Soiling can be affected both by cleaning events, such as rain, and soiling events, including high agricultural or mining activity creating high levels of airborne dirt. Soiling events can also be caused by light rain or humidity that does not completely clean modules, but provides sufficient moisture to allow airborne dirt to adhere to the surface of the module. Soiling can be measured by comparing the output of a regularly, manually cleaned module with the output of a module that has been subject to the environmental conditions of a particular site.

Figure 2 shows the soiling at the Greenough River Solar Farm since commencement of the operation of the plant. Most months have experienced adequate rain events to keep soiling to less than 1%. A soiling event in February 2013 highlights that light misty rain combined with typical agricultural activity in the area can decrease module output by up to 2%. This is still less than typical soiling assumptions used in modeling software such as PVSyst of 3% (First Solar, 2012).

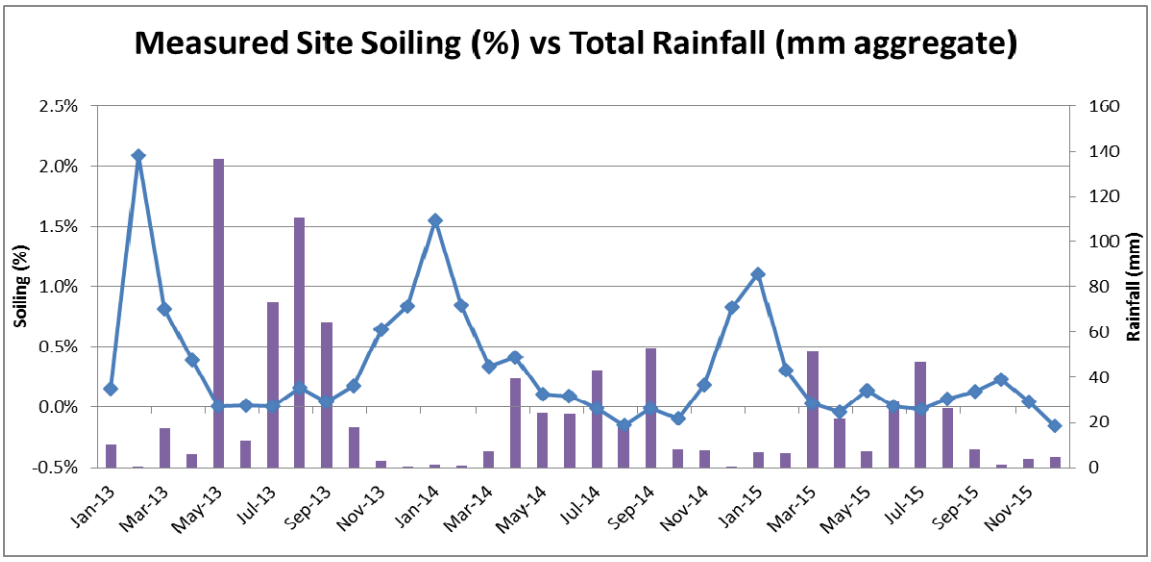

Figure 2: Measured loss due to soiling at GRSF (GRSF, 2016)

Measurements of soiling help explain some of the differences between actual and expected energy from operational plant.

4.2. Irradiance

Irradiance is the amount of sunlight that is incident on the plane of the array, typically measured by a pyranometer and expressed in W/m2. Insolation is the amount of irradiance that falls over a period of time, and is expressed in kWh/m2/year. Irradiance data is typically measured on-site for a site under development or in operation, or it can be extrapolated from satellite data. The former method is more accurate but requires installation of the monitoring equipment as well as time to accumulate data.

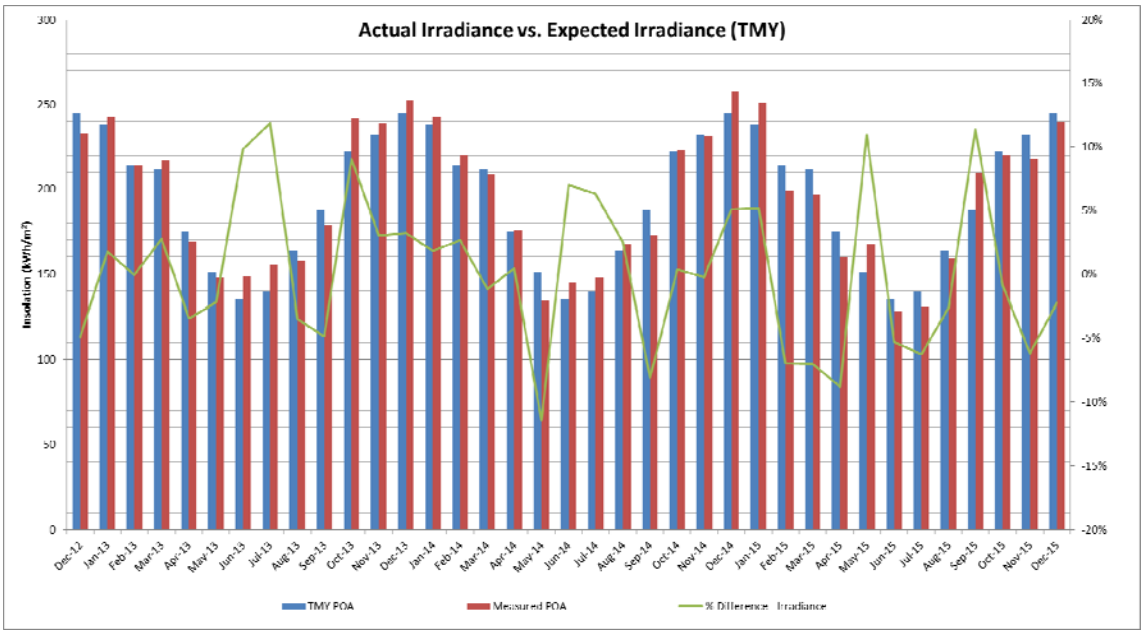

Figure 3: Actual Irradiance vs Predicted Irradiance (TMY) for GRSF (GRSF, 2016)

Of all measured weather parameters, irradiance has the biggest impact on system output, and therefore accounts for the majority of the difference between actual and predicted

performance data for the majority of the difference between actual and predicted performance data. Figure 3 shows that the measured irradiance roughly follows the predicted irradiance as modeled in the TMY in terms of shape. The largest negative variance month to month in the first year of operation was 4.9% of the actual irradiance vs predicted irradiance, and over the first 3 years of operation the highest negative variance month to month was 11.4%. The largest positive variance month to month in the first year and for the full three year period was 11.9%.

4.3. Spectral Shift

Typical PV system modeling assumes a constant solar spectrum based on an air mass of 1.5. However the solar spectrum shifts with local weather due to moisture in the atmosphere causing a spectral shift in the light incident to the plane of array. This phenomenon varies for different PV technologies. First Solar has been able to measure the impact of atmospheric changes on CdTe performance, based on weather data for a given site (Nelson et al, 2014). Commercially available simulation programs do not currently take spectral shift into account when predicting plant performance. Typically programs such as PVSyst under-predict in humid months and over-predict in dry months.

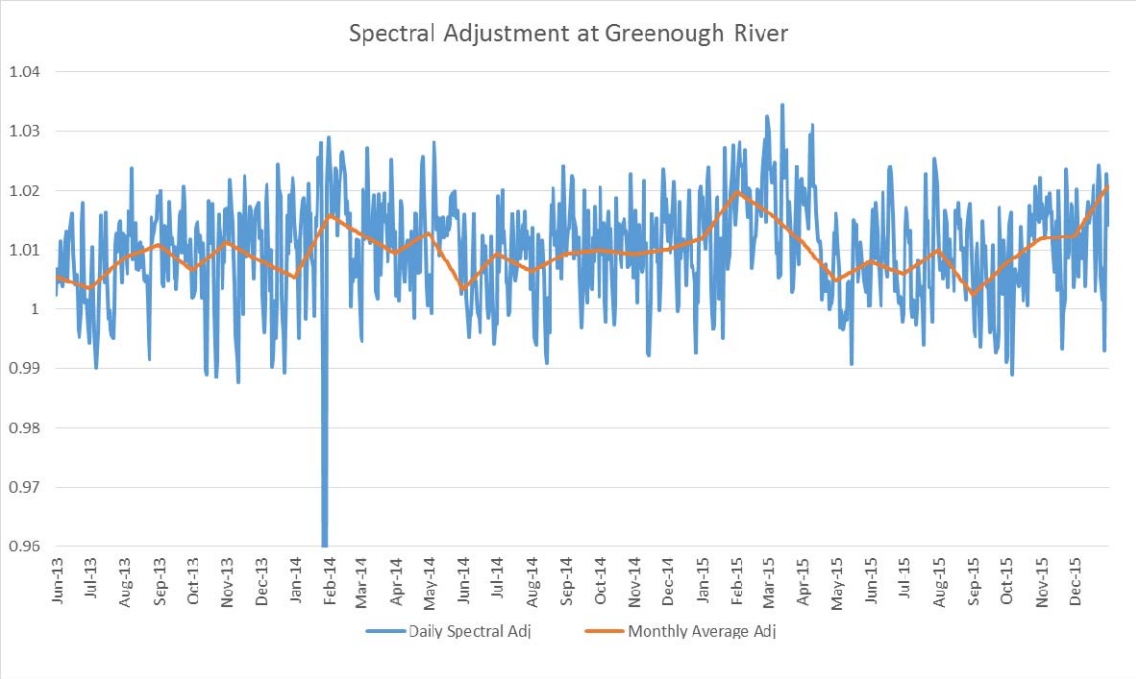

Figure 4: Estimated spectral shift at GRSF (GRSF, 2016)

Using actual weather data from the GRSF, Figure 4 shows how the actual energy is 0.24% to 1.98% above predicted energy, giving a performance advantage compared to commercial prediction models. First Solar accounts for these shifts in its predictive modeling to improve accuracy.

Accounting for spectral shift over and above modeling program outputs enhances the accuracy of First Solar's energy predictions, increasing the certainty of energy predictions to customers and financiers alike.

5. Operation of the Greenough River Solar Farm

Outages on a PV plant are normal and expected, particularly during the initial stages of a newly operational plant. The performance data in Figure 5 was captured during this initial period of fine tuning and optimisation.

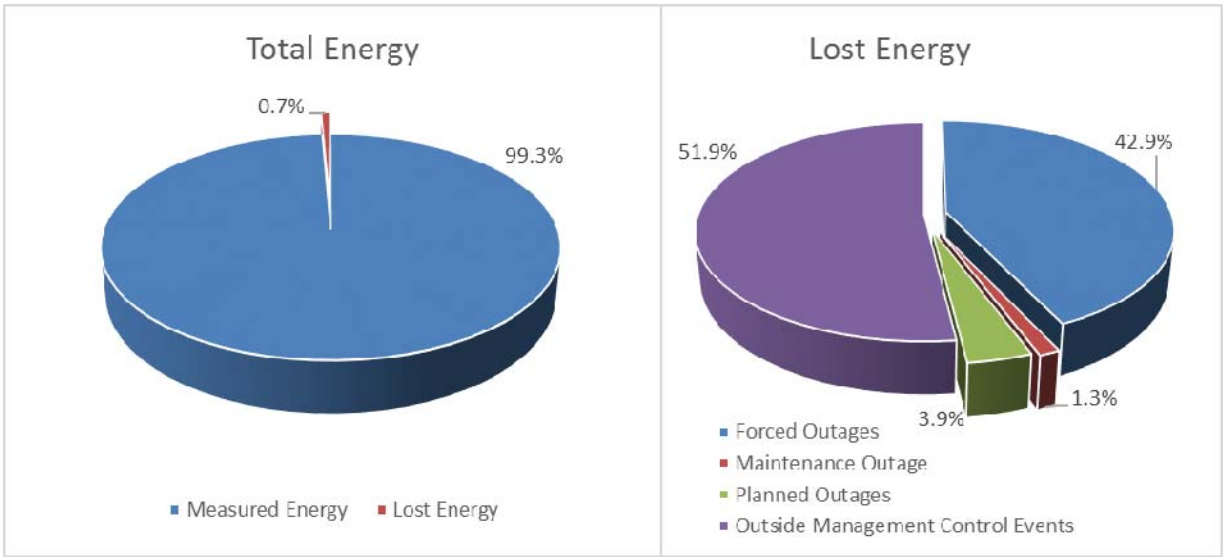

Figure 5: Lost energy due to outages at GRSF (GRSF, 2016)

Outages can either be operational in nature, such as equipment failures, out of service for planned maintenance or upgrade, or outside management control, such as grid curtailment or outages. In the first three years of operation these outages made up 0.7% of the energy of the plant.

When the soiling, irradiance and spectral shift measurements are combined with outage data from the plant, actual energy output can be more accurately compared to expected energy output, as in Figure 6.

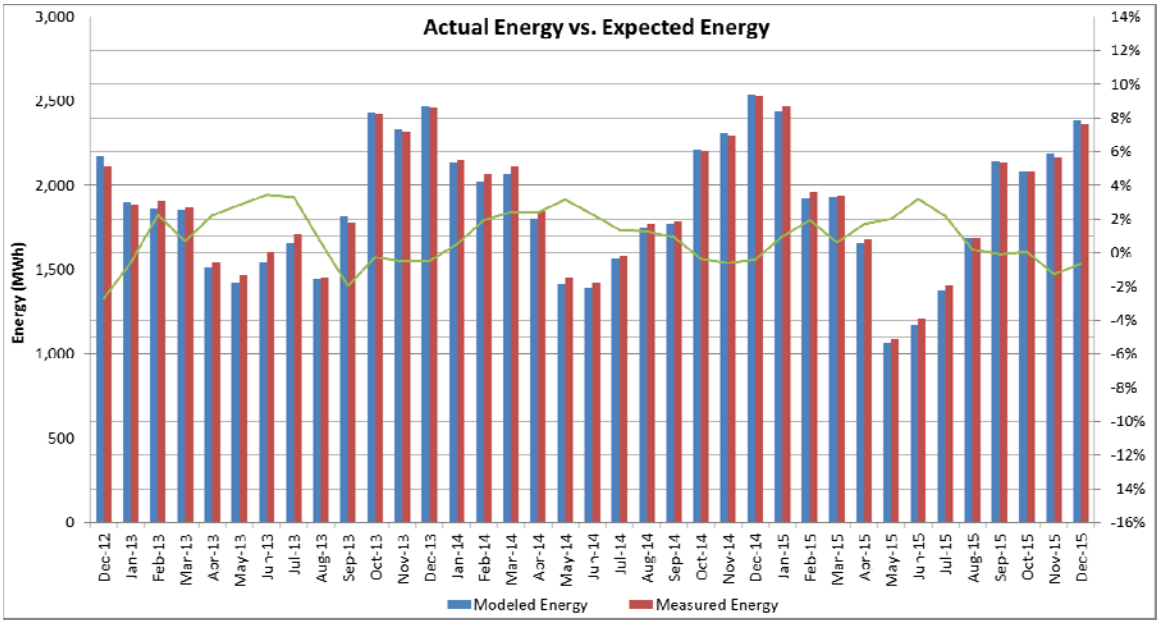

Figure 6: Actual vs Expected Performance for GRSF, adjusted for soiling, spectrum, weather, and outage lost energy (GRSF, 2016)

The highest actual output month was December 2014 with a peak monthly energy of 2529 MWh. This correlates with the highest expected monthly energy.

To ensure the long-term integrity of plant performance, it is vital that appropriate processes and people are put in place to operate and maintain the site. As per conventional utility-scale plants, full time operations and maintenance staff and processes are commonplace. First Solar has full-time staff dedicated to optimising GRSF performance.

6. Conclusion

Experience in installation and operation of systems provides performance data which can be used to increase the accuracy of prediction models. Soiling, insolation and spectral shift data based on actual measurements from the Greenough River Solar Farm at Geraldton, Western Australia provide greater accuracy in measurement of the plant performance when using prediction modeling methods. Installation practices and technique are an important element for a successful PV power plant, as are the processes and people required post-operation to ensure ongoing high plant performance.

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GRSF performance data courtesy of Synergy and GE Energy Financial Services

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