REAL-TIME MONITORING OF REC PANELS SHOWS EXCELLENT PERFORMANCE ABOVE WARRANTED DEGRADATION RATE

As part of REC's program of monitoring the performance of solar panels in real-life conditions, including the rate of degradation in line with REC's warranty, a study on a 5.72 MW system in Richelbach, Germany was independently undertaken and demonstrated a degradation rate of 0.25% per year - much lower than stipulated in the warranty.

PV monitoring at Richelbach

On the 23rd December 2010, a 5.72 MWp solar park at Richelbach, Germany, was commissioned by EPC contractor GP Joule. The panels were supplied by REC in 2010 and ground-mounted with an inclination of 25° and orientation of true south. Each subsystem is monitored by Meteocontrol monitoring systems.

Table 1: System details

Site details	System	
System location	Richelbach, Germany	
Site owner	CEE Management GmbH	
Asset manager	Greentech GmbH & Cie. KG	
EPC contractor	GP Joule	
Module types	Section 1: 3190 x REC Premium 210 (679 kWp) Section 2: 12,760 x REC 225PE (2,872 kWp) Section 3: 3168 x REC 230PE (725 kWp) Section 4: 6292 x REC 230PE (1447 kWp)	
Inverter	Section 1: 1 x Refusol 630K Section 2: 4 x Refusol 630K Section 3: 1 x Refusol 630K Section 4: 2 x Refusol 630K	
Modules per string	22	
Irradiation data	CMP11 Pyranometer from Kipp & Zonen	Recorded at 15 minute intervals
Orientation of panels	Due south	25° from horizontal
Panel temperature	Sensor	Recorded at 15 minute intervals

Alongside the electrical data from both the DC and AC side of each inverter, the data of irradiance (at panel plane) and both panel and ambient temperature are also recorded at 15 minute intervals. The monitoring system has been in operation since December 2010, thus providing an excellent platform for evaluating the true degradation of REC panels in real life conditions.

The 5.72 MW solar park with REC panels installed in Richelbach, Germany

Derivation of panel degradation rate

In general, solar panel degradation is evaluated by the percentage of the normalized panel's actual power (DC) at Standard Test Conditions (STC) compared to its nameplate i.e.:

$$r = \frac{P_{STC}}{P_0}$$

where P_{STC} is the actual panel power under STC, P_0 is the panel nameplate, and r is the percentage of panel power after degradation. The variation of r versus time gives the degradation rate.

However, in field conditions, irradiance levels and panel temperature deviate from STC, hence the correction formula below is used to convert the measured panel power into STC, i.e.:

$$P_{STC} = \frac{P_{DC} \times 1000}{G[1 + \gamma\,(T_{MOD} - 25)]P_0}$$

where P_{DC} is the measured DC power, G is the measured irradiance (at panel plane), γ is the panel's temperature coefficient of M_{PP} power, and T_{MOD} is the panel temperature. For the REC Peak Energy Series 225 Wp and REC Peak Energy Series 230 Wp, $\gamma = -0.43\%$.

The above correction formula is only applicable for high irradiance levels as panel efficiencies become non-linear at lower irradiation. Furthermore, any sensor or inverter failures and regular system maintenance needs will also affect the accuracy of the correction. In order to increase the accuracy of such analysis, the U.S. Department of Energy's primary national laboratory for renewable energy, NREL, proposed the following guidelines to filter measured data[1]:

- Daylight data only
- Removal of any record with missing data for any parameter
- Removal of any record where G < 500 W/m²
- In addition to NREL's methods, any record with a Performance Ratio (PR) <75% or PR >95% (indicating shadowing or snow coverage, maintenance shut down, or other non standard operational mode) was removed

In the analysis of the Richelbach data, Section 1 with REC Premium panels was omitted to ensure a focus on current production panels. The NREL filter was then applied to the remaining three REC Peak Energy Series sections in order to pre-process the measured data and then the calculated value of r with respect to time (per day) was plotted. In addition, a linear regression was made to give an equation where the intercept shows the initial degradation and the slope indicates the panel degradation rate.

It should also be noted that in the monitoring of a power plant like Richelbach, DC power is usually measured for the total strings of panels (to an inverter), not for a single panel. So the degradation rate derived in such a case is the average value for multiple panels. Taking the losses through panel mismatch and soiling into consideration, the degradation rate of single panels can be considered even better than the results calculated.

1 Daryl Myers, "Evaluation of the performance of the PVUSA rating methodology applied to DUAL junction PV technology", American Solar Energy Society Annual Conference, Buffalo, New York, 11-16 May 2009.

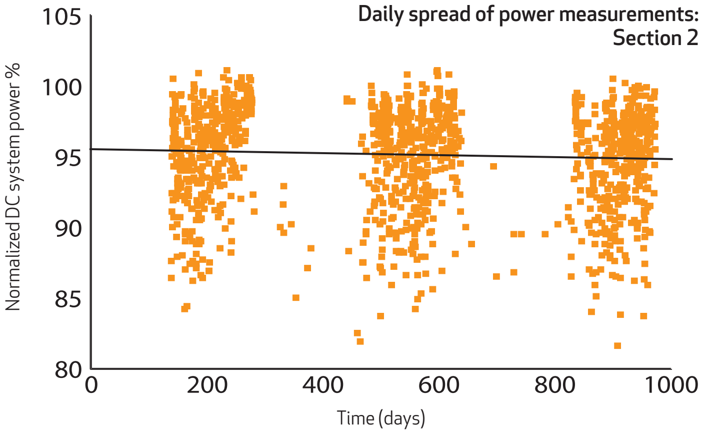
Results of analysis

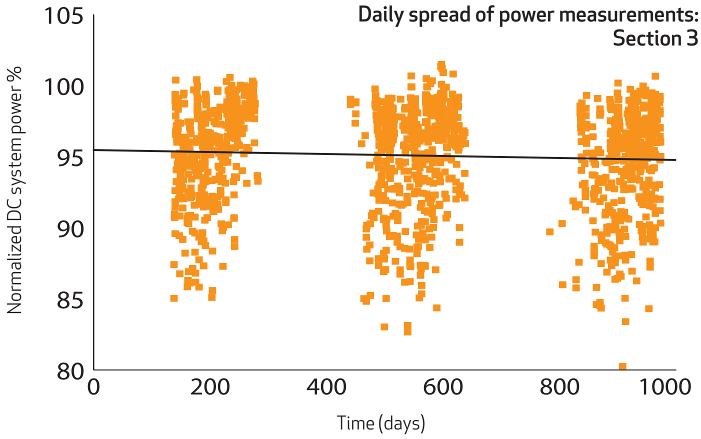
The Richelbach system was commissioned at the end of December 2010 and the performance data for this study has been collected from January 1, 2011 to the end of August 2013. The parameters monitored are listed below:

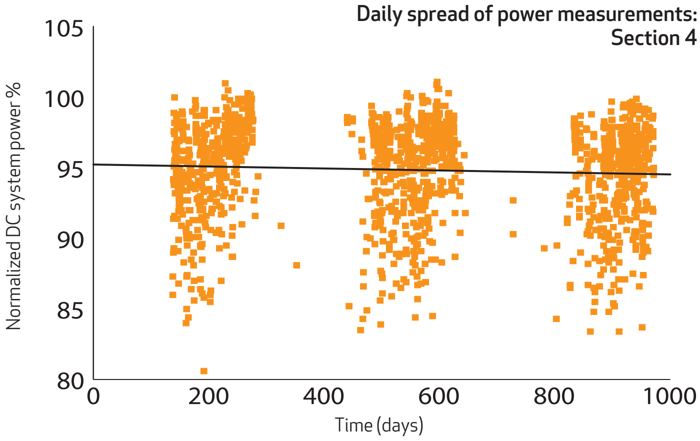
Category	Parameters
DC	Current, voltage, power for each inverter
AC	Voltage, power, energy for each inverter
Weather	Irradiance, panel temperature
Others	Time stamp

For each inverter, both DC (input) and AC (output) parameters of current, voltage and power are recorded at intervals of 15 minutes. Meteorological data such as irradiance (with the same inclination as the panels), the temperature of the panels and ambient surroundings were also recorded as well as time stamps. High calibration sensors (Kipp and Zonen CPM11) are used in the measurement and the readings are averaged over a number of sensors for improved statistical analysis. With the application of the NREL filter rules, degradation (*r*) was calculated and plotted against time as shown in the graphs below, where the X-axis is number of days and Y-axis is the normalized DC system power (P_{STC}/P_0). The gradient of the linear trendline depicts the degradation rates of each section.

Power measurements after DC and inverter losses







It is clear from the results that the rate of system degradation is minimal and is reflected on all three sections. To obtain a quantified result of yearly degradation, a linear regression is applied to the three graphs above, which gives the following gradients:

Sections	Gradient
2	$-6.98 * 10^{-6}$
3	$-5.74 * 10^{-6}$
4	$-7.01 * 10^{-6}$

A factor of 365 is then multiplied to the gradient to get an annual rate. The results for all subsystems are listed in the table below:

Section	Degradation	
	Total 2.67 yrs (% vs nameplate)	Average annual rate (%/year)
2	-0.68	-0.25
3	-0.56	-0.21
4	-0.68	-0.25
Weighted average	-0.66	-0.25

The results show that after the first year's operation, the DC system STC performance with REC Peak Energy Series panels is well within the range given in the warranty - and still above this value 2.67 years later. The overall annual panel degradation rate of the three sections and the mean of 0.25% continues to be well below the warranted annual degradation value of 0.7%.

Conclusion

Real-time monitoring for the Richelbach plant shows the REC systems performing extremely well in real-life conditions and showing a system degradation rate of 0,25% annually. Considering losses through mismatch and cabling, the degradation rate for single panels can be assumed to be even lower. This performance can be explained in part due to REC's positive power sorting tolerance of –0W to +5W, which ensures panels are delivered at or above nameplate power. Furthermore, the superior quality focus of REC ensures that the annual degradation rate of REC panels is much lower than the warranted values.

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