Operation & Maintenance – The Key for Reliable Performance in a CPV Power Plant

Johannes Wüllner[1, a)], Marc Steiner[1], Maike Wiesenfarth[1], A.W. Bett[1]

[1]*Fraunhofer Institute for Solar Energy Systems ISE, Heidenhofstr.2, 79110 Freiburg, Germany.*

[a)]Corresponding author: johannes.wuellner@ise.fraunhofer.de

Abstract. The 44.19 MW_p concentrator photovoltaic (CPV) power plant CPV 1 in Touwsrivier, South Africa is three years in operation. Lessons learnt for optimizing the power production are presented. The plant configuration is described and the key steps for reliable and efficient operation and maintenance are discussed. By introducing structured operation and maintenance procedures, the produced energy of the plant could be significantly increased. Without these new maintenance procedures the power plant output was less than originally predicted. Eventually, after introducing the proper maintenance concept in July 2017 for the first time, the total produced energy cumulated over a 12 month period was above the predicted modelled energy. This proves the importance to develop and apply site specific structured operation and maintenance procedures.

INTRODUCTION

By the end of 2017, 387 MW of concentrator photovoltaic (CPV) systems were installed globally (updated from [1]). Besides plants from Amonix in the US [2] and Suncore in China [3], one of the largest CPV power plants in operation is the 44.19 MWp Touwsrivier power plant CPV 1. It was installed by the company Soitec Solar and began commercial operation in 2014. First operation data during the commercial operation date (COD) showed excellent performance exceeding even the predicted modelled power production [4]. However, the long-term performance is of importance. Therefore, we discuss performance data of the power plant over three years and we show that suitable maintenance procedures are needed in order to achieve the predicted energy output.

THE TOUWSRIVIER CPV POWER PLANT CPV 1

The CPV power plant CPV 1 in Touwsrivier, South Africa, consists of an installed DC power of 44.19 MW_p delivered by 1500 systems of Soitec´s Concentrix™ Technology CX-S530-II [4], [5]. Touwsrivier was selected since it is a good location for CPV technology providing a DNI in a typical meteorological year (TMY) of 2528 kWh/m²/year. Moreover, the CPV plant brings infrastructure and possibilities for employment to an area with a very high unemployment rate. The plant has been in operation since December 19, 2014 (COD – commercial operation date). The characteristics of the Touwsrivier CPV power plant are listed in Table 1 and a photo is presented in Fig. 1. In 2011, CPV 1 applied in a public bidding round of the REIPP-Programme (Renewable Energy Independent Power Producer Procurement Programme) in direct competition with flat plate PV projects. The CPV project was successfully awarded one of the first projects in this programme and received a 20 year power purchase agreement (PPA) from the utility Eskom Holdings SOC Ltd. Even though the PPA price is competitive in this high DNI area, it is noteworthy to point out a speciality of a successful awarding in the bidding process in South Africa: the pricing is weighted only by 70% and the remaining 30% considers the innovative and successful integration of the project into the society. Hence, the benefit for the local community is an important factor for being awarded a project i.e. creating jobs, local content and the broad-based black economic empowerment (B-BBEE) are important aspects. For this reason, the success of the project was also related to the innovative economic and local set-up of the plant. Firstly, it was one of the premier solar projects to be debt financed through a rated and listed bond. Secondly, to secure the support of the local community and a reliable plant operation, social aid and B-BBEE programmes were installed. For example, 1% of the plant revenue is paid into a community trust and this finances the SE.ED

Programme where enterprises and socio-economic development are supported. In addition, local jobs are created for the operation and maintenance of the plant.

TABLE 1. Plant configuration and project details, see also [5], [6], [7].

Site	
Location	Touwsrivier, Western Cape, South Africa
Typical meteorological year (TMY)	2528 kWh/m²/year
Land area	212.0 ha
Plant Configuration	
Capacity	44.19 MWp, 36 MWAC
Technology	Soitec´s Concentrix^{TM} Technology
System	CX-S530-II with 12 modules
No. of systems	1500
Module	CX-M500 modules with 2455.0 Wp (CSTC)
Inverters	GPtech PV630WD inverter, 30 building blocks, with 2 central inverters and 1.2 MW nominal power
Installation completed	Dec. 2014
Participants	
Owner	Pelegreen Energy (Pty) Ltd, Government Employee Pension Fund, Soitec Solar GmbH, Touwsrivier Trust
Asset management	Pele Energy Group
EPC and O&M	Group Five Ltd. reSA O&M Services (O&M subcontractor)
Financial	
Bidding	REIPPP[2)] - Round 1 (2011)
PPA	20 years with Eskom Holdings SOC Ltd.
Debt Financing	Bond transaction with non-disclosed holders
Credit rating	Positive evaluation and rating by Moody´s (Baa1.za, outlook stable, 30/05/2018)
Social	SE.ED[3)] programme: 1 % of plant revenue into community trust

[1)] SPV: special purpose vehicle company
[2)] REIPPP: Renewable Energy Independent Power Producer Procurement programme
[3)] SE.ED: Touwsrivier Socio-economic and Enterprise Development

FIGURE 1. Photo of Soitec´s Touwsrivier CPV power plant © reSA.

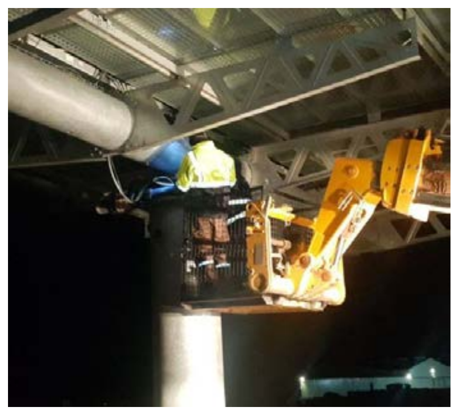
OPERATION AND MAINTENANCE

With the COD in December 2014, the commercial operation of the power plant started. 40 to 50 employees working on the site needed to be trained in safety procedures to ensure a safe work environment. This involved education on aspects of CPV technology, but also on local environmental hazards. For example, at this specific site, it is important to be capable of handling snakes that live in the area.

From a technical point of view, cleaning and stable tracking are the main tasks to ensure proper performance of the plant. The modules are cleaned with water (no additives) to protect the environment and groundwater (see Fig. 2). It is important to clean during night time or dawn in order to not affect operation time of the plant. The cleaning cycle is strongly dependent on the local environment and the season. In Touwsrivier each CPV system is cleaned every six weeks. The six DNI sensors mounted on meteorological stations and trackers on the site are cleaned once per week. A Supervisory Control and Data Acquisition (SCADA) system was installed. It helps to raise the overall efficiency by discovering failures quickly and securing a fast reaction time for repair work. Special jigs were developed to allow faster repairs.

For efficient maintenance, quality control procedures were established together with a preventive maintenance plan. A tool to monitor the performance in the 30 blocks of the plant was developed. With this tool the worst performing individual CPV system of each block can be detected and a deeper analysis can be conducted to identify the cause of the problem. Again, the repair work was executed during night and dawn (Fig. 2). Last but not least, it is important that the team on site is motivated to perform at their best. For this reason financial incentives correlated to the performance of the plant have been established.

(a)



(b)

FIGURE 2. Pictures of O&M works at the Touwsrivier power plant (a): cleaning of a CPV system © J. Wüllner. (b): tracker repairs during night © reSA.

POWER PLANT ENERGY PRODUCTION

The offer of the company Soitec Solar to build a power plant in Touwsrivier contained a detailed forecast of the energy production for the period of the PPA. This energy forecast, respectively the correlating revenue stream, played a key role in the financing of the project. Thus, this forecasted energy is the most important key performance indicator (KPI) for the power plant performance in all related contracts and the energy prediction has to be reliable and accurate. The well-founded prediction from Soitec Solar was one of the major factors in securing financing and the good rating of the project done by Moody’s (see Table 1). In the CPV 1 power plant the KPI is called *modelled energy*.

The base function of the modelled energy is calculated using the software PVSyst with the approach described in [8],[9]. For the PVSyst model, the input data of TMY ambient condition (ambient temperature, wind speed, DNI) was used and was slightly adapted by site specific correction factors based on ground measurements nearby (see below). In addition, typical PV specific losses have been considered in this model such as degradation and soiling. Also, specific CPV losses have been considered such as tracker self-consumption and non-operation during high wind speeds. The CPV system is taken out of operation and remains in a safety position for wind speeds higher than 14 m/s.

To predict the power plant performance with high accuracy, it is essential to know the ambient conditions with the best precision. Therefore, since 2011 Soitec Solar has measured ambient conditions on a demo system installed nearby at Aquila-Game-Farm [2], long before construction on the final site started. This demo system provided an excellent database for the prediction of the plant performance. These measurements were used to adapt the data for the TMY taken from [].

Excluding the DNI measurement during the construction phase with dispersed dust at the closely located Touwsrivier power plant in 2013/14, the measured DNI in the periods 2011, 2012 and 2015 – 2017 was 2 % lower than expected from TMY.

In Figure 3 the monthly averaged energy production at CPV 1 is shown as a function of time in comparison to modelled energy data. The average is done for each month separately for the years 2015, 2016 and 2017. Additionally, Figure 3 shows the initial monthly energy production calculated using PVsyst. The course of the data shows a lower energy production during winter time. This is typical and can be explained by lower DNI (less solar energy). The years 2016 and 2017 show a comparatively good agreement with the modelled energy. In contrast, the year 2015 data show its minimum in produced monthly energy in July instead of June. One of the reasons was a longer lasting winter than usual.

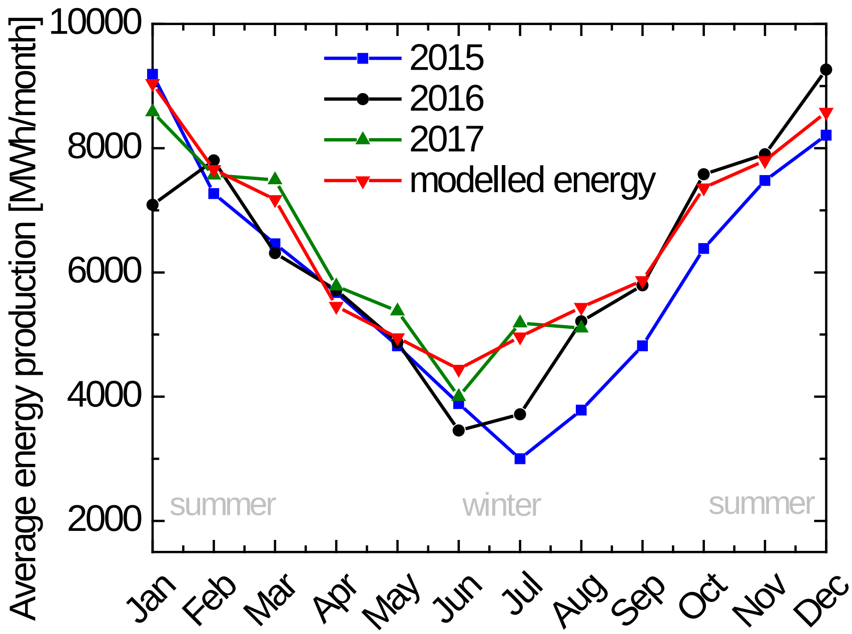


FIGURE 3. Modelled and produced monthly energy of the Touwsrivier power plant in the years 2015, 2016, and 2017. The modelled energy was calculated with PVSyst and additionally considers several PV specific loss factors, e.g. soiling and degradation.

Figure 4 shows the AC energy of the plant as a 12-month rolling average. This means that the first data point '2015-11' is the cumulated energy production in the one-year period December 2014 to November 2015. In this way seasonal effects are eliminated and a comparison to the contractual yearly values is simplified. Additionally, Figure 4 shows the power plant AC energy production as modelled. The considered losses and input data are the same as for the modelled data shown in Fig. 3. As the model considers degradation of the module performance, the predicted AC energy constantly decreases.

Figure 4 shows that after one year of operation, the modelled yearly production was not obtained even though the measured and modelled production fitted well in the early stage of operations [4]. In addition, Figure 4 shows that the produced AC energy of the power plant increases constantly starting in 07/2016. Considering the 12-month rolling period and cumulated energy, this means that there was a higher AC energy production in July 2016 than in July 2015. The increase in energy production was shortly after reSA O&M Services started with new O&M

procedures on the site (05/2016). The trend successfully continued until 07/2017. At this point the yearly energy production even exceeded the predicted AC energy by more than 1.5%. This indicates obviously that applying well-organized and adopted O&M procedures are essential for the best performance of a power plant. Since in the modelled energy production a yearly degradation rate was assumed, the high energy output also indicates that no degradation of the CPV technology occurred.

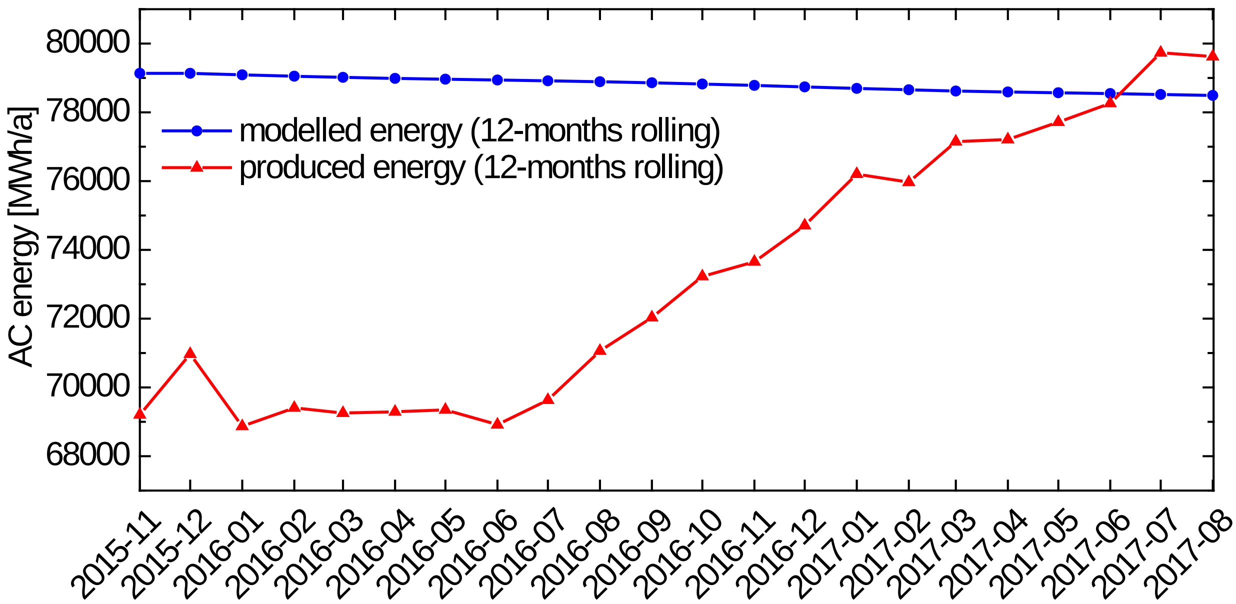


FIGURE 4. Modelled and produced AC energy as 12-month rolling (cumulated energy over the 12 past months) as a function over time. The graph shows data gathered between December 2014 and August 2017. For instance, the first data point '2015-11' is calculated as rolling average from the first year of operation (12/2014 – 11/2015). The modelled energy decreases constantly because of assumed module performance degradation. The produced/measured AC energy increases from 2016-06 constantly due to improvements in the operation and maintenance procedures of the power plant. In 2017-07, for the first time, the 12-month rolling energy production exceeded the predicted.

CONCLUSION

Operation and Maintenance (O&M) is the key to reliable high performance of a CPV power plant. The Touwsrivier CPV power plant went into operation in December 2014. While the very first measured energy output fitted well with the predicted performance [4], the summed energy output after one full year of operation was lower than expected. By adapting and improving the maintenance and operation procedures on site, the produced yearly energy increased significantly.

It is noteworthy that for the operation of a CPV power plant, most O&M challenges are not CPV specific topics. Therefore, experience from PV power plants can be adopted for CPV and are very helpful. Thus, it is important that the O&M is planned thoroughly with clear procedures and documentation. Health and safety for the employees and environmental considerations must also be considered. This involves good training of the employees and respecting local conditions. Finally, it is crucial to have high acceptance from the workers on the site as well as the local community.

Three years of commercial operation show that CPV is, if properly managed, a reliable and – in the case of the CPV 1 project – an economical technology. Most notable is that the predicted energy production can be achieved if the O&M procedures are adapted and well organized. Moreover, after improving the O&M, in the year 2017 the energy produced by the power plant even exceeded the predicted energy production

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