EXPERIENCES WITH CABLE-BASED SOLAR WINGS TRACKING SYSTEM AND PROGRESS TOWARDS TWO-AXIS LARGE SCALE SOLAR SYSTEM

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ABSTRACT: The Solar Wings Tracking system is a new light-weight cable-based tracking system, offering several advantages, including double use of land, far lower demand for raw material, simple implementation of tracking motion and inherent mechanical robustness. A first 650 kWp PV plant based on a one-axis Solar Wings tracking system has been built and put into operation in Southern Germany in December 2008. The performance of the solar park has been monitored since and successful tracking operation with excellent performance ratios of the hardware applied has been confirmed. An AC yield of 1038kWh/Wp was measured in the period from January to August 2009 resulting in an about 20% higher energy yield than a fixed installation. Furthermore, a two axis system based on the Solar Wings concept has been designed and will be implemented in November 2009. Moreover, results of tracking combined with low optical concentration based on the Solar Wings concept has been demonstrated with a measured increase of 60% of solar power in the PV module plane, on a small scale design. In summary, successful implementation of a light weight cable-based light tracking system, offering double use of land, less raw material and further benefits has been confirmed, opening up new perspectives towards large scale application and the implementation of new concepts for increased energy yield of solar parks.
Keywords: Photovoltaic Mounting System, Tracking, Photovoltaic Concentration, Balance of System

1 INTRODUCTION

Tracking of PV modules towards the sun offers a gain in energy yield ranging from 15% to 35% relative to fixed mounted PV installations depending on the design and the location of the installation. To reduce material costs the Solar Wings tracking system has been developed using cables to serve as mounting platform and applying also cables to move the modules toward the sun position. In spring 2008 a prototype has been installed and in December 2008 the first one-axis Solar Wings tracking system was set into operation at the Lonza solar park in Waldshut, Southern Germany. [1]

This paper will present experiences of this first Solar Wings 650kW installation during the construction phase and the operation since January 2009. First results of the data acquisition system to monitor the performance of the plant will be reported.

Beside the one-axis approach the progress in developing the two-axis Solar Wings tracker will be reported as well as the energy yield applying low concentration using planar mirrors. The results were measured on a small scale table top system.

2 REALISATION OF THE 650kW SOLAR-WINGS ONE-AXIS PLANT

In December 2008 the Lonza Solarpark equipped with Solar Wings single horizontally tilted axis tracking system, was connected to the grid with a nominal power of 648 kWp. It is built up of 360 individual support beams with a length of about nine meter each, carrying eight 230Wp polycrystalline silicon modules (Sunways SM230U) each (Fig. 1). The beams are mounted on the support cables located roughly 2.5 meters above ground.

The supporting cables are mounted on intermediate pillars spaced 45 meters apart and two fundaments are located at each end of the field. The whole plant consist of three fields oriented in East-West position with two rows of module beams mounted on tree supporting cables (Fig. 2,3). One linear AC motor drives the tracking cables mounted on both ends of the 310 meter long tracking cable (Fig. 3). The applied force of the linear drive is controlled by a standard force sensor. The tracking angle is adjusted every ten minutes according to the calculated position of the sun, including a back-tracking mode in the morning and evening.

Wind sensors detect heavy wind conditions and move the PV modules in a nearly horizontal position. The ultrasonic snow sensor detects a snow condition and the control system moves the panels into the "snow removal mode".

Table I: Technical features of the Lonza Solar-Park

Feature	
Number of modules per support beam	8
Length of a module beam	8.5m
Distance between two beams	5.1m
Distance between intermediate support pillars	40m
East-West length of each field	310m
Height of the beam above ground	2.5 to 3 m
Total numbers of beams	360
Tracking axis azimuth	-13°
Inclination of tracking axis	21°
Limits of the tracking angles	+/-45°
Number of tracking AC motors – linear drives	6
Time interval of tracking	10 min
Overall length of the supporting cables	2850m
Overall length of tracking cables	970m
Nominal power of each module	230Wp
Nominal power (flasher list of manufacturer)	646.78kWp
Number of 30kW inverters	21

The foundations of the tracking systems were specially adapted to the situation of that waste disposal site. The Solar Wings systems offers in this case the advantage that it can accept the expected chances in the ground level of the land fill which are expected to amount to several tenth of centimeters.

3.1 Construction phase

Within two weeks in December 2008 the first 650kW Solar Wings park has been installed by BMF AG, a experienced Swiss cable and ski lift manufacturer.

Figure 1: Erecting the Solar Wings tracking system by mounting the pre-assembled eight PV modules onto the supporting cables at the Lonza solar park.

Figure 2: Beams are connected to the tracking cables.

Figure 3: Solar Wings tracking system showing a view along the 310m long tracking cable, with the standard AC motor powering the standard linear drive to move the tracking cable (Lonza Solar Park).

The whole construction of the plant, including mechanical mounting and all electrical installations was started on fifth of December 08 and finalized by the grid-connected of all modules by the end of December 08.

Figure 4: Solar Wings tracking system at the Lonza solar park in Germany.

2.1 Electrical PV Design of the 650kW Prototype

The high quality PV components used included 2280 polycrystalline Silicon modules with a nominal power of 220 to 230Wp (SM230 from Sunways AG) with a module efficiency of 14%, together with 21 inverters with a nominal power of 30kW (PK30 from Sunways AG) and an euro-efficiency of 97%. The standard 6mm^2 DC cabling was mounted onto the supporting cables of the module beams.

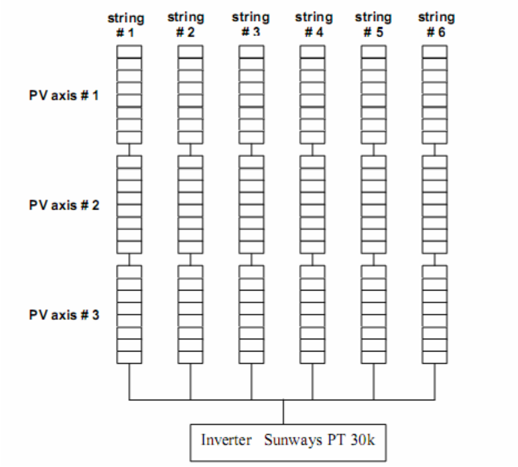

Figure 5: Electrical wiring diagram of the first 650kW Solar Wings installation at the Lonza Solarpark; Left, the wiring diagram of one of the 21 inverters (Sunways PK30, 30kW nominal power, mounted in the field) is shown, each 24 Sunways SM230 poly cryst. Si modules connected into serial within one string, mounted on 3 separated axis with a length of 9 meter each, separated by 5 meters. Right, the over all installation is shown consisting of 3 fields each powered by 7 inverters

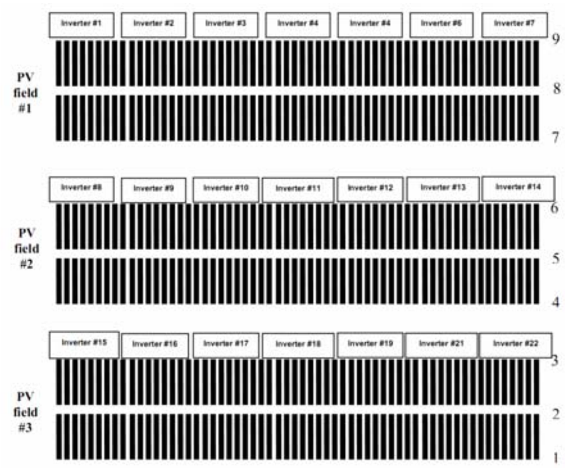

Figure 6: In each of the 3 fields seven 30kW inverters (Sunways, PK30) powers the AC-grid.

3 PERFORMANCE OF THE 650kW SOLAR-WINGS ONE-AXIS PLANT

The yield of a single axis tracking PV parks depends strongly on the irradiation at the location, the orientation of the axis and event of shading due to the neighboring collectors.

It has been reported in [2] that East-west tracking on a horizontal north-south axis at the location 32°N (Israel, GCR 29%) will have a 17% higher energy yield compared to fixed installation. Using a horizontal tracking axis perpendicular to the above installation the yield will be about 3% lower a according to the calculation in. Due to the serial connection of the modules into a string the losses are about 2% extra to the linear shading. [2]

The electrical performance of the one-axis Solar Wings Systems according to Table I was calculated by the use of PVSYST and an increase in AC energy yield of 17% relative to fixed installation was predicted. [3]

2.1 Measured performance of 650kW prototype

The performance of the first Solar Wings plant in Waldshut is monitored by the Fraunhofer ISE since first of January 2009. The following values are measured: relevant electrical DC and AC values, the reading of cryst. Silicon irradiance sensors, one fixed at inclination of 30° and on sensor mounted in the tracked module plane, as well as readings of ambient and module temperature sensors are monitored.[4]

In Fig. 7 the measured temperature of the modules is found to be about 20 degrees higher at 800W/m2 and linear extrapolated to become about 24.5°C higher at 1000 W/m^2 relative to the ambient temperature. Thus it is found that the average module temperature of about 40°C at 800W/m2 is much lower than the given NOCT of 45°C due to the better cooling conditions of the modules mounted about 2.5m above ground.

The measured average inverter efficiency of 97% above 20% of nominal power is in excellent accordance with the given euro efficiency value of 97% by the manufacturers data sheet. (Fig. 8)

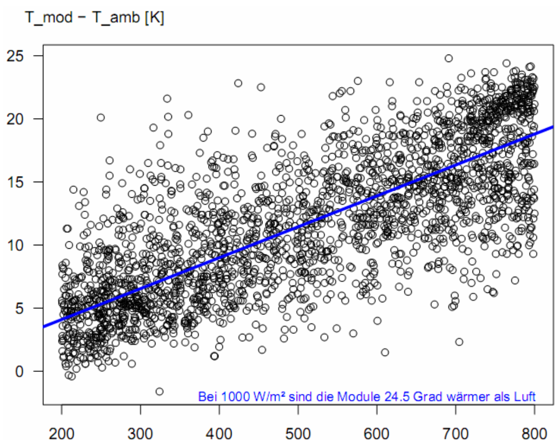

Figure 7: Measured temperature difference between PV modules and ambient temperature versus irradiance [W/m^2] during July 2009 (average ambient temperature 20.1°C in July 2009) [4]

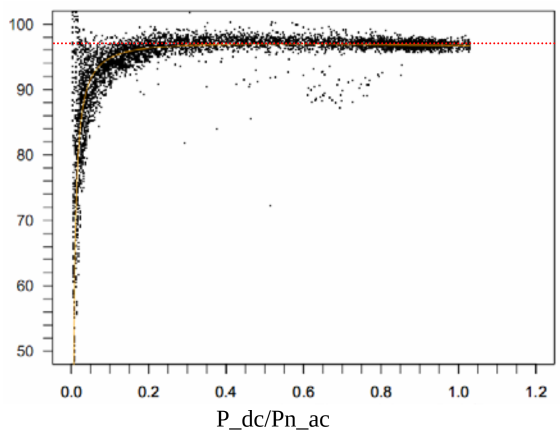

Figure 8: Measured efficiency [%] of the inverter (PK30, Sunways) versus the ratio of DC input power divided by the nominal inverters AC power in July 2009

[4].

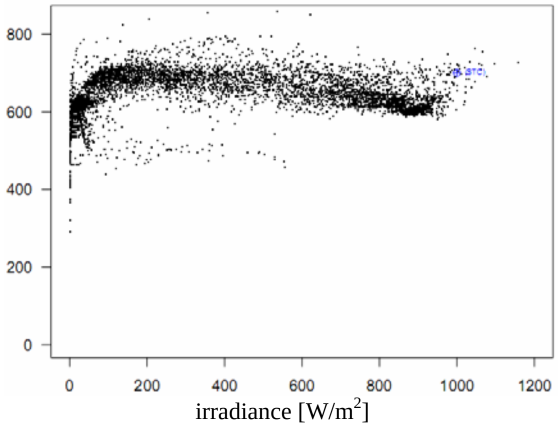

Figure 9: Measured inverter DC voltage versus irradiance in July 2009 (see Fig. 8) [4]

The measured DC voltage at the inverters input was in the range between 600V and 700V. (Fig. 4)

The measured performance values of the 650kW plant are given in table II for each month since the first month of operation.

Table II: Performance data of the first Solar Wings one axis tracking system (see Table I) since starting of operation. The irradiance measured by a crystalline ISE reference sensor mounted in a fixed position with a inclination of 30° and oriented at the same azimuth of as the tracking axis.

1. year of operation	Solar input fix 30° [kWh/m2]	AC yield [Wh/Wp]
Jan 09	27.9	29.51
Feb 09	54.3	55.00
Mrz 09	80.1	93.88
Apr 09	133.7	154.81
Mai 09	151.8	168.98
Jun 09	156.3	179.2
Jul 09	151.9	171.97
Aug 09	162.2	184.52
Sum	918.2	1037.87

By extrapolation of the measured values an AC energy yield of about 1370 kWh/kWp is expected for the first year of operation at an expected measured irradiance values of 1214kWh/m2 for the fixed installed irradiance sensor (inclination angle 30°). If we calculate a so called fixed performance ratio by dividing the AC yield by the measured irradiance in a fixed non tracked plane inclined by 30°, a performance ratio of 1.13 is found according to Table II. If we compare this value with the performance ratio of a roof mounted system using the same components assuming a performance ratio of 0.9 for that system, an increase in produced AC-power relative to fixed will be about 23% due to one-axis tracking. Thereby an uncertainty value of about 4% including sensor uncertainty of 2% is assumed.

The average of the measured performance ratio for the analysed period Jan to Aug 09 was at the high value of 92% based on the irradiance measured in the tracked module plane.

It has to be mentioned that this high performance value is only possible if the inverter efficiency is very high (see Fig. 8) and the power rating of the used PV modules is reliable (here nominal power of the plant was calculated by summing up all the flasher list values of the module manufacturer.)

2.2 Measurement results of a dish 2 axis tracker model

To even further increase the output per nominal power of a PV module the Power Wings concept was introduced [1]. By the use of planar mirrors which are also tracked independently on a parallel axis to the sun, additional light will reflected onto the tracked PV module. These tracked mirrors also mounted in a same way onto the supporting cable and moved by a separate tracking cable.

At the ZHAW a dish prototype was constructed and outdoor measurements were done using a mini-module consisting of two serial connected 5” silicon cells and a Aluminum plate was used as mirror (Fig. 10). On a clear sky day an increase of the daily sum of the measured short circuit current of +32% was measured relative to the measured fixed mounted reference mini-module (Fig. 11).

Figure 10: Experimental setup at the ZHAW University of Applied Sciences Zurich.[5]

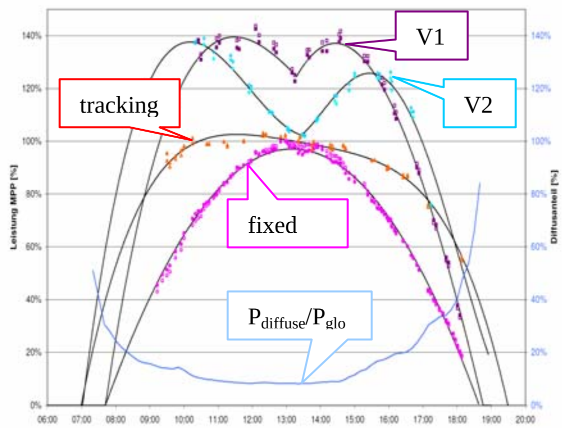

Figure 11: Daily measurement results performed with the ZHAW-dish model (see Fig. 4) in Winterthur, on the 2008-09-09. Different tracking variants like, one-axis

tracking at an inclined axis of 30°; and one-axis tracking together with additional low concentration with planar mirrors and fixed mounted with an inclination of 30° and no tracking are given. Left fig: absolute Isc values normalized to the noon Isc of fixed mounted modules.[5]

Different methods of tracking the mirrors and PV modules are analysed. The tracking method V2 tracks the PV module always perpendicular to the direct sun beam. Additionally, the mirror will reflect light onto the neighbouring PV module reaching a maximum of irradiance power between three and four o'clock in the afternoon. At noon no additional light will reflected onto the PV module because the mirror an den the PV plane are nearly oriented parallel.

Applying a second method of tracking V1 where either the PV module or the mirror is facing the sun directly. With that Power Wings tracking strategy an increase of input power is also possible at noon. The maximum of sun power is found between two and three o'clock in the afternoon.

Both tracking methods V1 and V2 performed an increase in solar energy on the module plane of about 62% that particular day.

4 TWO AXIS SOLAR WINGS PROTOTYPE PLANT

In November 2009 the first Solar Wings two-axis tracking system will be installed in Flums, Switzerland. Again 8 PV modules (SM230, Sunways) are mounted on a module beam with 9 meter in length hold on two supporting cables with intermediate pillows separated again by 40 meters. The angle of the mounting bar for the two supporting cables can be set with an additional drive motor enabling full two axis tracking (Fig. 12). The first Wings two axis prototype will have an nominal power of 70kW.

Figure 12: Concept of the first Solar Wings two-axis tracking system. The first prototype with 70kW nominal power will be installed in Nov 2009 in Switzerland

4.1 Solar Wings – Savings in Electricity Generation Cost

The Solar Wings concept offers several benefits, including double use of land, use of land that could not be used with standard systems, but also savings in maintenance and operating cost. The simple and efficient design of Solar Wings results in addition in low construction cost for the solar plant. The main cost components of Solar Wings are the mounting assembly for the panels and the cable support structures with the foundations. Cost for cables and installation represent only a small fraction of the cost. For a solar park with high efficiency modules the cost increase with Solar Wings tracking is currently 15% to 20% for standard modules, resulting in substantial savings in generation cost (Target: >10% reduction of investment / kWh) compared to fixed installation, when considering an energy yield increase of 30% to 35% in Southern locations.

Savings are even more pronounced with Power Wings. Targeted energy yield increase is 70% compared to a fixed installation at a cost increase of approximately 40%, resulting in reductions of investment cost / kWh of 20% compared to a comparable fixed installation with high efficiency modules.

Solar Wings bears substantial potential for further cost optimizations in the near future, considering the low raw material consumption of the system and experience curve-based cost optimizations as production volume increases.

4 SUMMARY and OUTLOOK

The first Solar Wings one-axis tracking system installed in December 2008 with a nominal power of 650kW reveals an excellent average performance ratio of 92%. Relative to fixed mounted PV installations an increase in produced AC power of 23% during the first year of operation was demonstrated.

The first two-axis Solar Wings prototype will be installed in Switzerland in Nov 2009. This system will track the PV modules about 6 meters above the ground level over an outdoor storage facility for industrial goods. Thus the double use of land will be demonstrated, due to the fact, that even trucks will pass underneath the Solar Wings tracked PV modules.

In the next months experience of the two-axis Solar Wings system will be collected and further progress in developing the Power Wings concept is expected.

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