Performance and reliability of tracker and fixed-tilt mounting systems

Mounting | Fixed and tracker solar mounting systems offer various relative cost and performance benefits. But as JA Solar's Zhang Lan Jun and Gong Tie Yu describe, surprising results from field analysis of different systems used in China hold important lessons for developers wondering which one to choose

Generally JA Solar uses three types of solar mounting structure in ground projects: fixed-tilt, single-axis tracker and dual-axis tracker.

The fixed-tilt structure is a widely used solution for most scenarios, offering simple installation and the lowest cost whilst being well designed for high wind speed and earthquake situations. There is almost no maintenance requirement during the system life, the only disadvantage being the relatively lower power output in high latitude areas.

Single-axis structures have the benefit of better production performance. Horizontal tracking is commonly used for single-axis solutions, the axis of rotation being parallel to the ground. Multiple posts of the axis of rotation of a tracker unit can be shared between trackers to lower the installation cost [1]. One motor can control multiple arrays. Regular maintenance is required for bearings and gears.

Dual-axis structures can produce the highest unit yield [2]. There are two small servo motors to adjust the tilt angle and azimuth. With complex tracking controls and servo mechanisms, dual-axis structures usually combine historical data with light sensors to catch the sun direction precisely. But the complex controls and infrastructure may cause additional material cost, more regular maintenance work and higher failure rates.

Sample project information

Interesting insights into how the different systems operate cane b gained through comparison between tracker system and fixed-tilt system. The analysis is based on a typical project located in Qinghai Province, China, latitude 36.3. Total installation capacity is 5MW: a 2MW dual-axis system, a 2MW horizontal single-axis system and a 1MW fixed-tilt system (pictured). All solar modules are JA SOLAR JAP60 series 235Wp polycrystalline. There is abundant solar resource, according to climate data: annual irradiation on 35º optimal plane is about 1800kWh/m2/year, and over 60% of which is direct irradiation. The average temperature ranges from -8.9˚C to 16.6˚C and wind speeds from 6m/s to 23m/s. The altitude of the sample project is 2,990m above sea level. The landscape type is yellow earth with dust and sand.

▼ Fixed-tilt racking system parameter:
Tilt angle: 35º
Installation tolerance: ±1º
Racking unit quantity: 109
Solar module quantity per each unit: 40pcs
Total installation capacity: 1.024MW
Average Failure Rate per Year: ≤0.1%
Inverter: 2x 500kW transformerless inverter

▲Single-axis tracking system parameter:
Tilt range: ±80º
Tracking tolerance: 0.3º
Tracking method: light sensor with historical data
Racking unit quantity: 438
Solar module quantity per each unit: 20pcs
Total installation capacity: 2.058MW
Nominal average failure rate per year: ≤5%
Inverter: 4x 500kW transformerless inverter

The results

Typical conditions in Qinghai in June are high irradiation and variable weather. This will put controller and driving mechanisms, tracking sensor and tracking algorithms under windy, sandy, rainy, cloudy situation over more than 10 hours of daytime operation. All arrays use the same 500kW transformerless inverter and the same JA SOLAR 235Wp polycrystalline high quality solar modules; 0.2S class power meters are installed on the AC output side of the

◄ Dual-axis tracking system parameter:
Tilt range: -10º-70º
Azimuth range: 0º-320º(180º for south)
Tracking tolerance: 0.2º
Tracking method: light sensor with historical data
Total racking unit quantity: 433
Solar module quantity per each unit: 20pcs
Total installation capacity: 2.035MW
Nominal average failure rate per year: ≤5%
Inverter: 4x 500kW transformerless inverter

inverters. Production data exported from the monitoring system over the challenge month shows some interesting results.

Everybody was very surprised that the most productive system was the single-axis tracking system instead of the dual-axis system. The single-axis system gains an additional 46.9% power than the fixed-tilt system. The dual-axis system had 43.9% more production than the fixed-tilt array. We all know that the dual-axis tracking array should have the best productivity system in theory. Previous research shows single-axis tracker systems may have more than 25% greater output than fixed-tilt [3], while dual tracker systems can produce 41% more power than a fixed-tilt system at peak generation [4]. Why was it that in this case a single-axis was able to achieve such outstanding performance and what was it that caused the dual axis does not to perform as well as expected?

Analysis of varying results

On-site maintenance crews have confirmed all the modules run very well by testing each string. Neither the DC source circuit nor output circuit has any insulation problems or short circuit fault record. No fuse in the combiner boxes has melted. All surge arresters still remain in 'green' state. None of the 10 500kW inverters has ceased operating in any day. The power meter is designed not to allow metering tolerances to exceed ±0.2% in any circumstances. On-duty staff also confirmed with the national grid that there was no energy injection limit order over the whole month. After getting detailed production data, people began to shift the focus of the investigation into the solar tracking systems.

The 1MW fixed-tilt system has two arrays, each with a capacity of 500kW. Production results are almost the same, as expected, but some differences emerged. The performance of Array 1 is a little lower than Array 2 on day 22. The primary reason was found to be that a new temporary lighting tower had been constructed next to the solar project site. After the light pole was removed, power from the two arrays returned to the same levels.

The single-axis tracking system has four sub arrays. Each 500kW array generated almost the same power on most days. Small differences between the arrays was due to random clouds across the large project area. The only failure situation is in Array 4, which ceases operating for several hours in a day due to the failure of a bearing. Array total availability is still not less than 95%; the data is consistent with the nominal value. The tracking system has a production advantage over the fixed-tilt system over 10 hours of daytime in a high latitude area.

The dual-axis tracking system also has four 500kW arrays. But none of the arrays gave satisfactory results. Actually the tracking system began to have some problems after 6 June. The failure was not limited to a small range of units. The on-site maintenance team was very busy fixing problems for two weeks and got it back in operation by 19 June. According to data from day 19 to day 29, although the dual-axis system operated well, there was no significant improvement in production compared to the single-axis system. Which factor leads to this poor score?

Weak points of a complex system

Initial inspections performed by the O&M crew showed that the primary mechanism looked good, but found the servo motor had

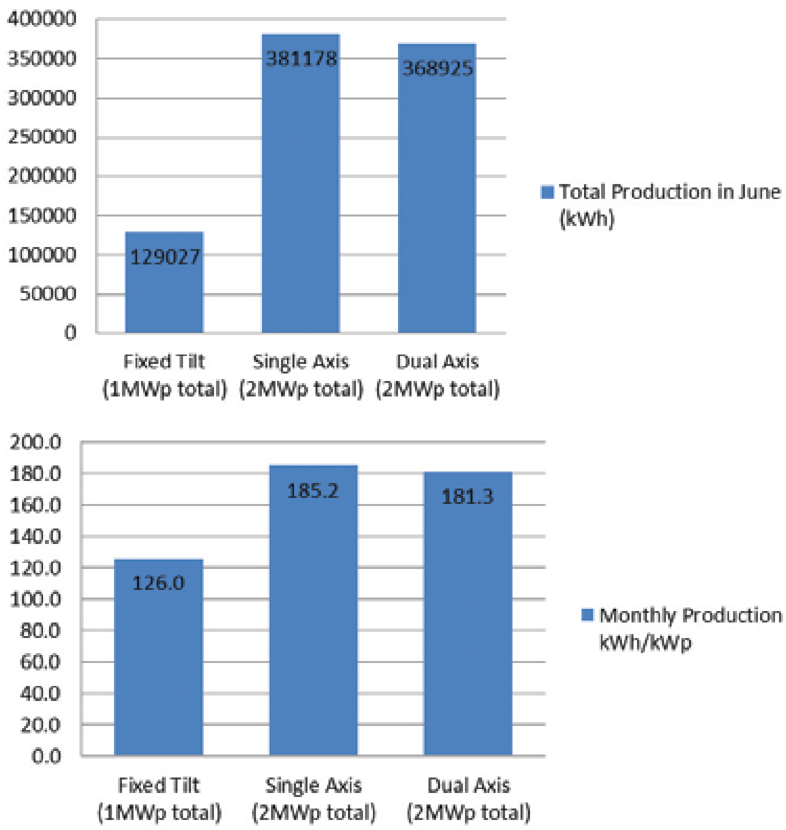


Figure 1: Total and unit production from the three systems over the month of June.
Source: QHBX

Figure 2 (top): Fixed-tilt array production. *Source: QHBX.*

Figure 3 (bottom): Single-axis array production. *Source: QHBX*

burned out abnormally in some dual-axis tracker units. After detailed investigation, they found the reducer gear protection cover was not fully airtight, so sand could run into the gear bearing in windy weather. The motor got stuck and temperature rose quickly after the bearing failed. The controlling system lacked the necessary failure protection so did not cut off motor power supply until the tracker structure arrived at a given position. This would damage the servo motor, explaining why so many units failed after one week of operation.

The technical team also checked the dual-axis controller and its tracking program. The controller used a well-known international brand, but the developer chose open-loop control infrastructure instead of a closed-loop control method. No linear position feedback sensor was installed, so the controller did not know the exact azimuth and tilt parameter in real-time. Only two zero-point sensors were installed to provide initial position references for the flat state. Meanwhile, the technical team found that the tracking controller did not use a 'pulse width modulation' (PWM) motor control; it simply used a contactor switch, which can lead to tracking position mismatch.

PWM controlling can be applied to control the amount of power delivered to a motor with a continuously changing value, so tracking control systems can reduce motor output power before reaching at target point, and thus minimise any mismatch [5]. In this project, the dual-axis tracker system used only the contactor controlling method, meaning any tracking mismatch would accumulate over time unless the user resets the whole system. These facts explain why we cannot see any benefit from dual-axis tracking compared to single-axis tracking systems.

The more complex a system, the lower its MTBF – or 'mean time between failures'. This is one of the key indicators to measure the reliability of a system. Lower MTBF systems need more maintenance work and labour time to fix. The more downtime, the less energy is produced and the longer it takes to achieve payback and profit. Dual-axis tracking systems have double the number of components than single-axis systems, which means the quantity of possible failures modes also doubles [3].

Lessons from the field

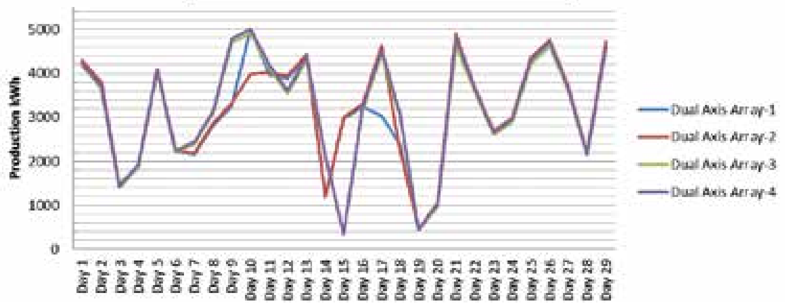
Although this analysis is limited to one month of operation, all three types of solar structures were tested under high irradiation sun, cloud, heavy rain, wind and sandy conditions. The dual-axis tracking system may produce more power than single-axis tracking systems in theory. But complex components and tracking controllers lower the reliability performance of the dual-axis system in variable environments. The stability of the single-axis system is satisfactory for the client; its tracking accuracy was sufficient to keep at a nominal level with proper control all the time so power production increased significantly. Fixed-tilt systems usually require little additional maintenance other than cleaning and regular checking; the only disadvantage is a lower power output in high latitude areas.

The O&M team needs to take extra effort with regular maintenance to keep fault risks down whenever the dual-axis tracking system is deployed. In addition to checking the tightness of screws and mechanical drive parts, maintenance engineers should check all protection covers and motors carefully as well. Control systems including sensors are another key point in maintenance work. O&M teams should pay attention to the power output curve falling continuously in sunny weather as this may be the evidence of tracking system failure.

This case also can teach a lesson to future solar power plant owners. It is very important to choose a high-quality tracking system supplier. The decision maker should consider not only the hardware parameters and price of tracking systems, but also software infrastructure and reliability. Although dual-axis systems offer performance advantages over single-axis systems, the higher failure risk can negate all extra income. The simpler system one could be a better choice to consider in the long term.

A tracking solar system will have an advantage over the fixed-tilt system in high irradiation and latitude areas. If someone is looking for a reliable, lower maintenance solar tracker solution in a high-irradiation area, a single-axis tracker is the better choice. ■

Figure 4: Dual-axis array production. *Source: QHBX.*



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