Motivation for single axis solar trackers versus fixed tilt

Trackers | The economic argument for trackers is increasingly compelling. Matt Kisber, president and CEO of Silicon Ranch Corporation explains why the technology's use is increasing and examines the benefits of opting for single axis tracking systems

Tracker technologies in photovoltaic solar power plants have been increasingly utilised as plant owners strive to reduce the cost and produce more energy per unit area by tracking the sun throughout the day shown in Figure 1. Although single-axis tracker technologies can provide up to 10-24% more power compared to fixed tilt systems, a tracker design may not always make financial sense to use [1]. In regions where there is high Global Horizontal Irradiance (GHI) and relatively low Diffuse Component (DHI), the increased energy output from a single-axis tracker typically compensate for the additional material and O&M costs.

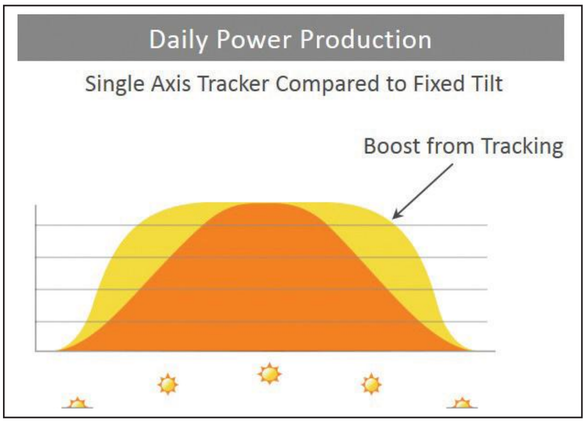

Figure 1. Additional energy output from tracking systems.

Global Horizontal Irradiance (GHI), measured in Wh/m2 is the sum of direct and diffuse solar radiation. Direct Normal Irradiation (DNI) is the amount of sunlight received directly from the sun, and Diffuse Horizontal Irradiance (DHI) radiation is the sunlight that is reflected and transmitted at an angle through the Earth's atmosphere. Areas with high GHI and relatively low DHI tend to be the best locations for single-axis trackers due to little to no weather interruption.

As shown in Figure 2, the annual GHI values for the desert in the Southwestern United States are on the order of 2100-2200 kWh/m². In comparison, annual GHI values for a Germany/UK region has GHI values on the order of 1100-1300 kWh/m². GHI and especially DNI are important metrics when considering a mounting system, as the energy gain from the tracker has to compensate for the increased system costs relative to a fixed tilt system.

Brief history

Historically, prior to the dramatic cost reduction of PV modules over the past five years, both single and dual axis trackers were installed in PV sites. Dual axis trackers were used at great expense to extract every last kWh from a PV module by rotating in

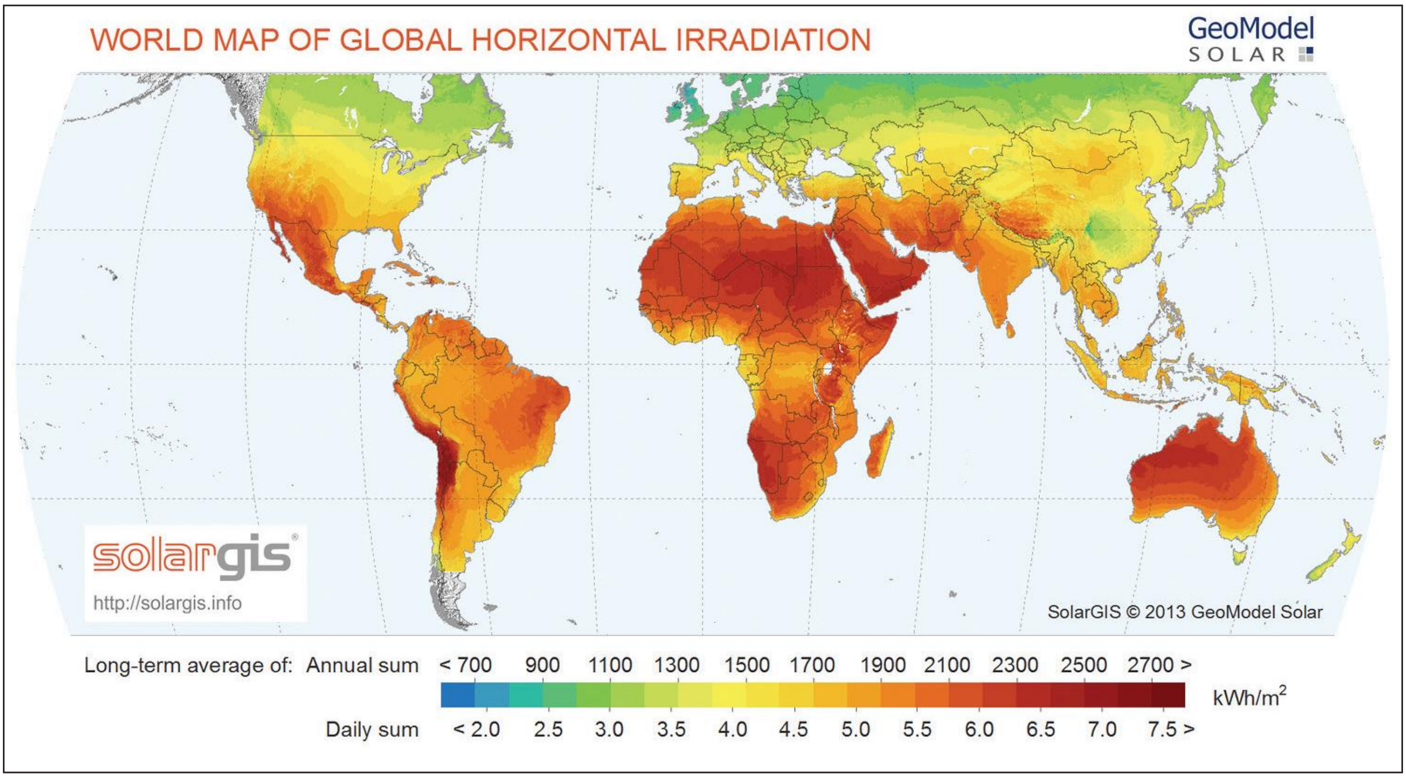

Figure 2. Global Horizontal Irradiation. Credit: SolarGIS© 2015 GeoModel Solar.

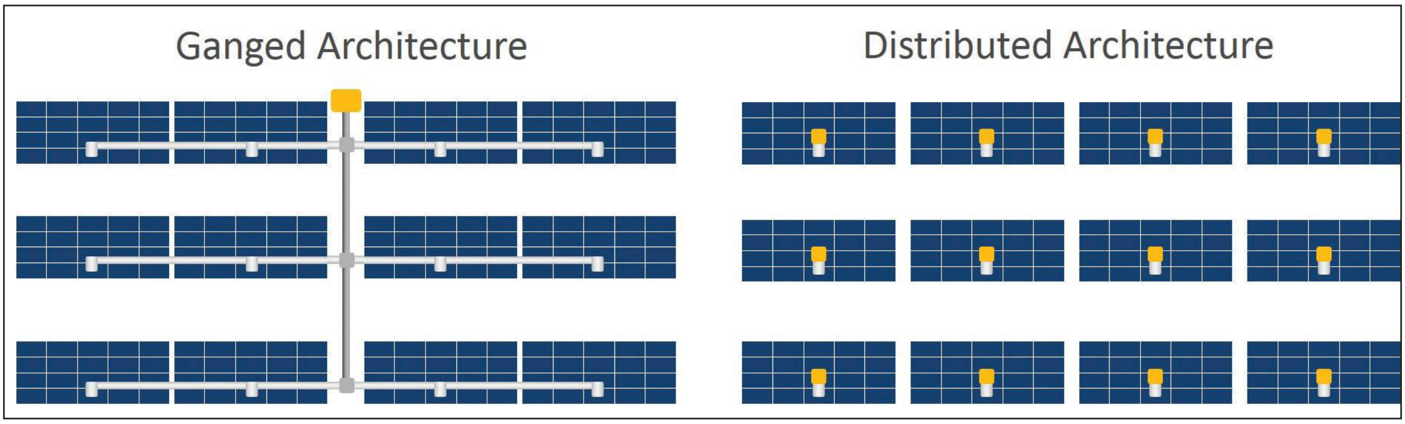

Figure 3. Tracker architectures.

two degrees of freedom that are typically orthogonal to each other. Single axis trackers rotate around a horizontal (or close to horizontal) axis and track from east to west during the day. Unless trackers are located close to the equator, they don't point the module directly at the sun like a dual axis tracker, but they do track far closer to orthogonal compared to a fixed tilt system. Dual axis trackers have higher energy output per installed watt (kWh/kW) compared to single axis trackers, but require much more land, are more prone to mechanical failures, require higher than normal routine maintenance and have significantly higher capital costs. Due to the disadvantages regarding reliability, bankability and ease of installation, the vast majority of utility-scale tracker systems have migrated to single axis trackers.

Single axis tracker architectures

Single axis tracker systems can be categorised into either ganged or distributed architectures, shown in Figure 3. Both architectures rotate the modules using controllers and motors, but fundamentally differ by how many modules are controlled by each motor.

Trackers with ganged architectures are systems that primarily use a single motor (depicted in yellow) to drive multiple rows of modules. Typically, a single motor in a ganged system can drive more than twenty rows in common systems.

Conversely, a distributed architecture system contains one or more motor/actuator assembly per row. Essentially, it's a trade-off between extra mechanical components of a ganged system (e.g. drive shafts, gearboxes, universal joints) and extra electrical components of a distributed system (e.g. actuators, wiring). The primary differences in these designs impact site layout, installation processes and O&M costs.

Site layout

To date, the majority of the utility-scale PV plants in the US have enjoyed level and open terrain, allowing for relatively less-flexible array designs (i.e. large rectangular arrays). There is a clear trend toward smaller, more-irregular sites that require more complex array designs. Sites with irregular shapes and/or sloped grounds can lead to design challenges that should be taken into consideration before committing to a tracker technology. Distributed architecture systems allow for a minimum space requirement of a single tracker unit, which can be as small as 480ft^2. By contrast, ganged systems may require minimum rectangular areas of up to an acre or more.

Different wiring permutations are available with small tracker pixels which allow for layouts that maximise coverage of imperfect sites, shown in Figure 5. Additionally, due to the small footprint of the distributed architecture, sites with slopes and/or rolling hills can utilise a tracker system. In contrast, ganged architectures have a large footprint, which require open topography for an efficient layout and may require more site grading and site prep costs.

Trenching for DC wire can be costly, and trenching is different based on site design and tracker topology [Figure 5]. In a typical large-scale tracker array the inverter is placed in the centre with the DC collection from the PV modules in trenches along the main East/West access road. In a distributed architecture these trenches also carry all the tracker control wiring to minimise cost. Depending on the configuration of a ganged architecture system, there may be a need for further trenching in a North/South direction to provide power to the large DC motors, shown in Figure 5.

AC/DC plant optimization

The distributed tracker approach provides more flexibility in design to find optimal DC/AC power ratios. The larger mechanically driven trackers see significant price increases if the tracker does not have the maximum number of tracker rows per drives. This happens because one of the larger cost components for mechanical trackers is the drive motors and controls. As a result, the cost per Wdc of a mechanical tracker increases significantly as rows are reduced. In contrast, the smaller sizes of

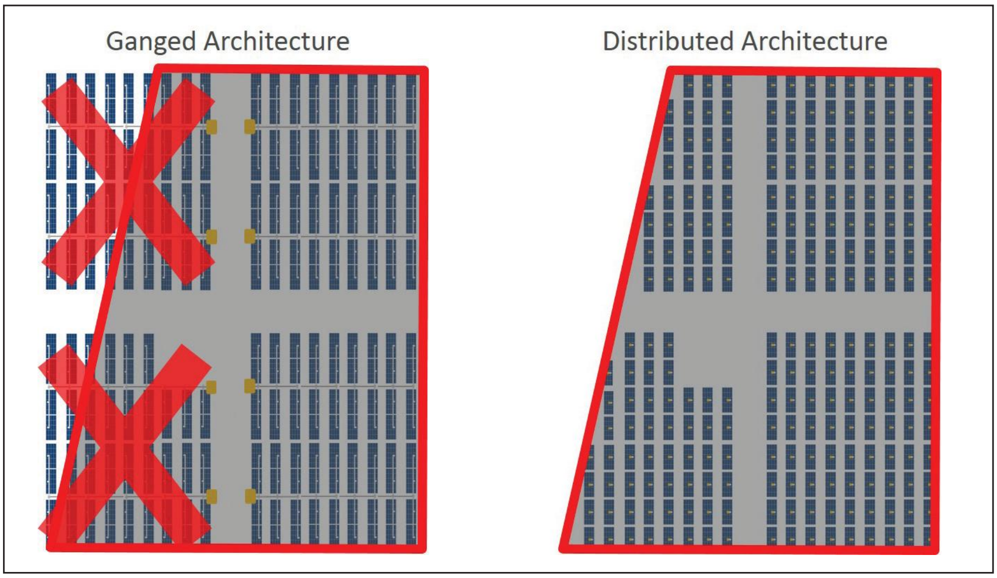

Figure 4. Distributed architectures can maximise irregular site arrays.

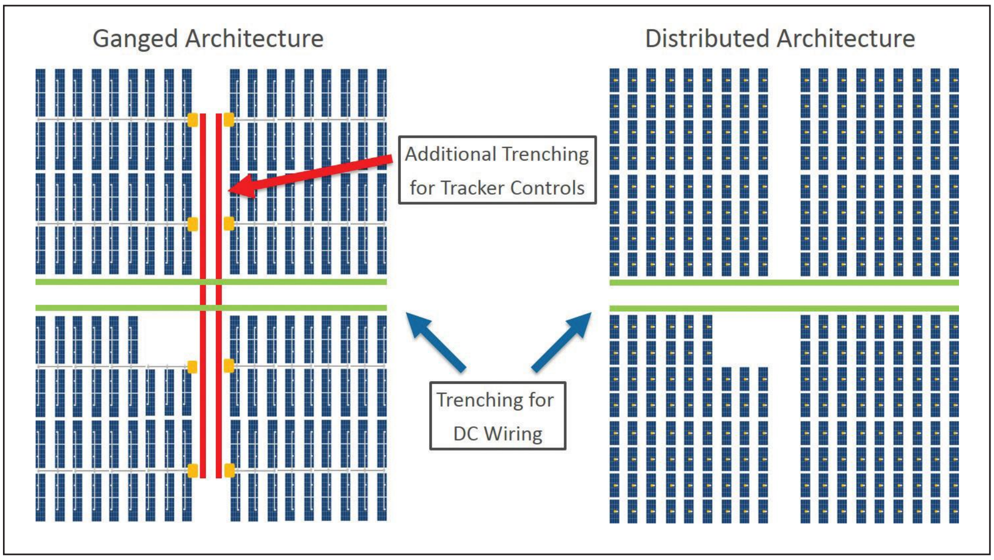

Figure 5. Trenching comparison for both tracker architecture blocks.

distributed trackers do not have this cost impact. The tracker cost per Wdc is consistent, regardless of the number of trackers. The distributed approach provides PV system designers the opportunity to search for the best DC capacity to match with any number of inverters without significant tracker cost impacts.

Optimising plant layouts and the DC/AC capacity ratios is one of the best opportunities for solar EPCs to bring additional value to customers. By manipulating the DC capacity, designers are able to find the best balance between capital investment and long-term plant performance.

Operation and maintenance

O&M costs are necessary to consider during design. Over the 25-30 year lifetime of a PV power plant, trackers will require repairs and maintenance. Common failure modes of tracker systems are motors, gearboxes, and controller electronics. Distributed architectures balance the higher volume of failures with the fact that each failure has less impact on the overall output of the plant and the fact that replacing parts is easier as they are generally smaller. There are essentially no "emergency" repairs, since a failure impacts so few modules. For ganged systems, a failure can result in full blocks ceasing to track, causing more impact to the output of the plant. Furthermore, overall O&M of a distributed system is made easier by the fact that there are no east-west drive shafts causing obstruction to travel through the site in a north-south direction. Complications like this can add significantly to down time and costs.

Since the widespread deployment of utility scale tracking systems has only happened in the last 3-5 years, O&M estimates and failure predictions were previously the single tools that tracker suppliers could use to determine what typical O&M costs and rates would be. Today, with several gigawatts of trackers installed in the US, suppliers can more accurately determine what costs are associated with O&M, shown in Figure 6. The amount of spare parts in inventory and number site attendants are now well defined to maintain a low O&M cost.

Efficiency during installation

With falling material costs, the cost of installation is becoming a larger fraction of the overall system cost. Installation of ganged and distributed architectures are notably different. Distributed architectures require more electrical labour due to additional actuators, controllers and wiring while ganged architectures have a more complicated mechanical arrangement which requires extra alignment and positioning.

Design features such as open-top bearings to allow easy installation of torque tubes, pre-fabricated wiring harnesses and factory assembled components can realise substantial cost savings in the field. Simplified design of larger structural members like torque tubes enable supply chain efficiency by allowing shipment directly from steel mills without post processing.

New/future developments

As the US utility solar market continues to shift from fixed tilt to tracker based systems, improvements continue to be rolled out giving trackers a steeper cost reduction rate compared to fixed tilt systems. A number of new suppliers have gained traction in the past 12 months fueled by high demand as we approach the reduction of the federal solar investment tax credit (ITC) in 2017. Larger arrays are becoming more economical as inverter sizes are increasing, developments in tracker controller design have allowed for fewer controllers per array, and module efficiencies are rising.

Advances have continued in the calculation of wind forces on a tracker structure aided by more sophisticated wind tunnel studies. This new knowledge enables features such as wind stowing, a way of minimising the forces on structural members, giving more efficient use of material and lower costs.

Tracking algorithms continue to be optimised to extract more energy from ever improving modules. Examples include tailoring the movement of the tracker to suit the module technology (like "Backtracking" for C-Si and "Truetracking" for CdTe modules [2]), and creative ways to maximise the cleaning effect of rain by adjusting the tracker as weather systems pass by.

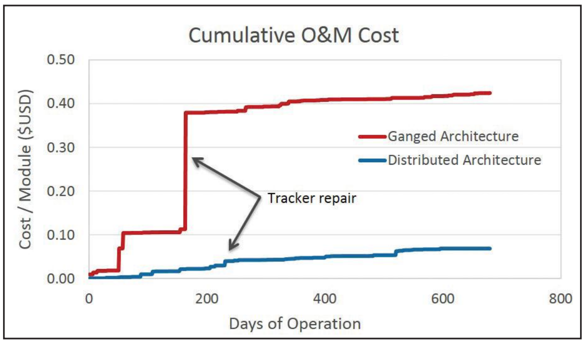

Figure 6. Example of ganged versus distributed O&M costs in desert south-west US.

In summary, tracking systems are in continuous development to reduce costs and enhance reliability. The systems are becoming more competitive in more locations and will continue to gain traction globally as new markets mature and get comfortable with the bankability of utility scale tracker-based solar PV plants. ■

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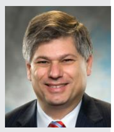

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[2] Ngan, Lauren. "Increased Energy Production of First Solar Horizontal Single-axis Tracking PV Systems without Backtracking." *IEEE Xplore*. IEEE, 16 June 2013. Web. 27 July 2015.