NEXTracker
A Flex Company

TRACKING YOUR SOLAR INVESTMENT

Best Practices for Solar Tracker O&M

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An exciting global power shift is under way.

More solar energy systems were installed worldwide in 2016 than any year to date, and the vast majority of this capacity was ground-mount, utility-scale—a trend that is expected to continue for several years.[1] As the solar market matures, developers and system owners are realizing that in the long term, operations and maintenance (O&M)[2] issues can have a profound effect on a project's financial performance. Savvy investors know that to ensure optimal returns, O&M considerations for all system aspects must be evaluated as part of any project's overall economics - well before breaking ground.

Solar racking is one of the most important components in any ground-mount system, since it is the backbone that must securely support and position key power-generating components—PV modules, for 20 or more years. Over the past few years, the industry has begun to move away from fixed-tilt racking structures to trackers due to their higher energy yield. Horizontal, single-axis trackers (SATs) are now the leading choice among trackers since they can deliver 20-30% more energy without the added cost and complexities of dual-axis or azimuth tracking systems.[3] Although now broadly accepted in the market, SATs may raise O&M questions for developers that may not be experienced with a specific product or technology. In this white paper, we will examine the factors to consider when evaluating solar tracker technologies from an O&M perspective. We will explore the following commonly asked questions:

1. Do SATs achieve a lower levelized cost of energy (LCOE) overall when taking O&M into account?
2. What O&M criteria should my company consider when selecting a single-axis tracker?
3. Are there standard tracker designs that lend themselves to lower O&M costs?
4. Are there standard components across linked row and unlinked row trackers?
5. What system parts and upgrades will be available for the life of my project and how should my company evaluate the viability of a long term SAT partner?

We will also discuss the importance of O&M planning to assess the true costs of tracker-based systems.[4] We will explore the system architecture (decentralized vs. centralized tracker systems), asset management, and quality and reliability issues that must be considered relative to tracker O&M. And we will highlight a real-world example of an actual 2016 weather event and its impact on the operation of independent row (decentralized) trackers.

[1]GTM Research: The Global PV Tracker Landscape 2016: Prices, Forecasts, Market Shares and Vendor Profiles, p. 7
[2]O&M, or operations and maintenance and asset management are terms that are sometimes referred to interchangeably in the PV industry. For the purposes of this white paper, asset management refers to the actual tracker assets themselves, including hardware and software.
[3]GTM Research: The Global PV Tracker Landscape 2016: Prices, Forecasts, Market Shares and Vendor Profiles, p. 17
[4]All NEXTracker calculations in this paper are based on a representative 100 MW site.

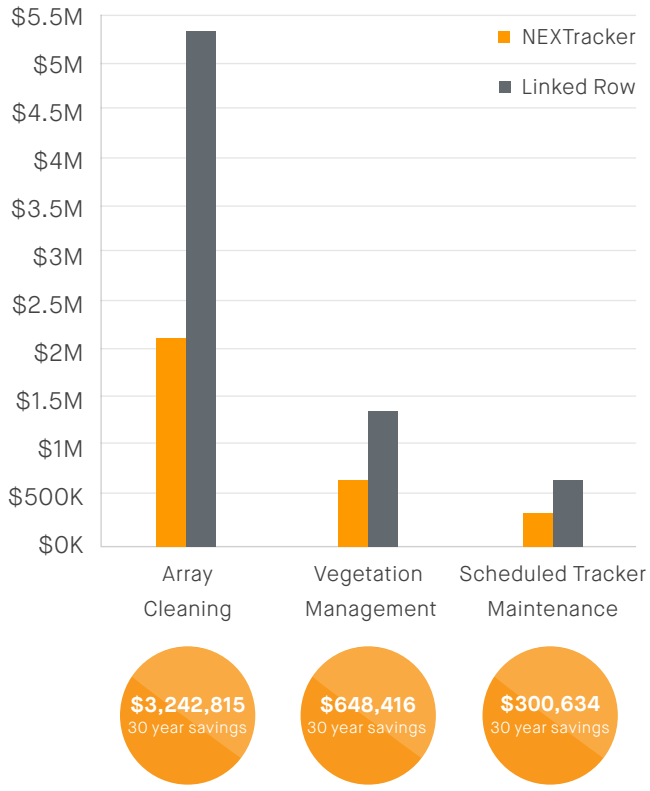
Successful O&M Planning

For any installation, planning and budgeting for system O&M are key steps in project development. These steps are critical for distributed generation applications (DG) as well as utility-scale systems, and both require thoughtful analysis of costs along multiple dimensions: conditional versus routine; preventive versus corrective; and site versus component. While time pressures can cause some developers to delay development of a thorough O&M strategy to later in the project's lifecycle, successful upfront planning can help inform decisions on system design. Basing component purchase decisions on installed cost alone often results in an incomplete view of project economics.

The purpose of a proactive O&M strategy is to maximize system energy output while minimizing operational costs, thereby improving the project's financial return. In the chart to the right, O&M costs for array cleaning and vegetation management are found to be considerably higher, for example, than typical linked row tracker systems.

Finding the right partner to help develop a comprehensive O&M strategy upfront is an important part of system component selection. This will ensure that project owners select the right components and have a plan for the project's entire service life that covers aspects such as site management, predictive maintenance execution, system monitoring, and long-term asset management.

O&M Cost Comparison Between NEXTracker & Linked Row
(30 year NPV)



The strategy should be designed in a way that minimizes intervention by skilled labor to keep costs as low as possible.

"We're excited to see a tracker design that will reduce preventive maintenance needs dramatically and make the cost of performing it more akin to a fixed tilt ground mount. Independent rows improve accessibility and lower the cost of mowing a site."

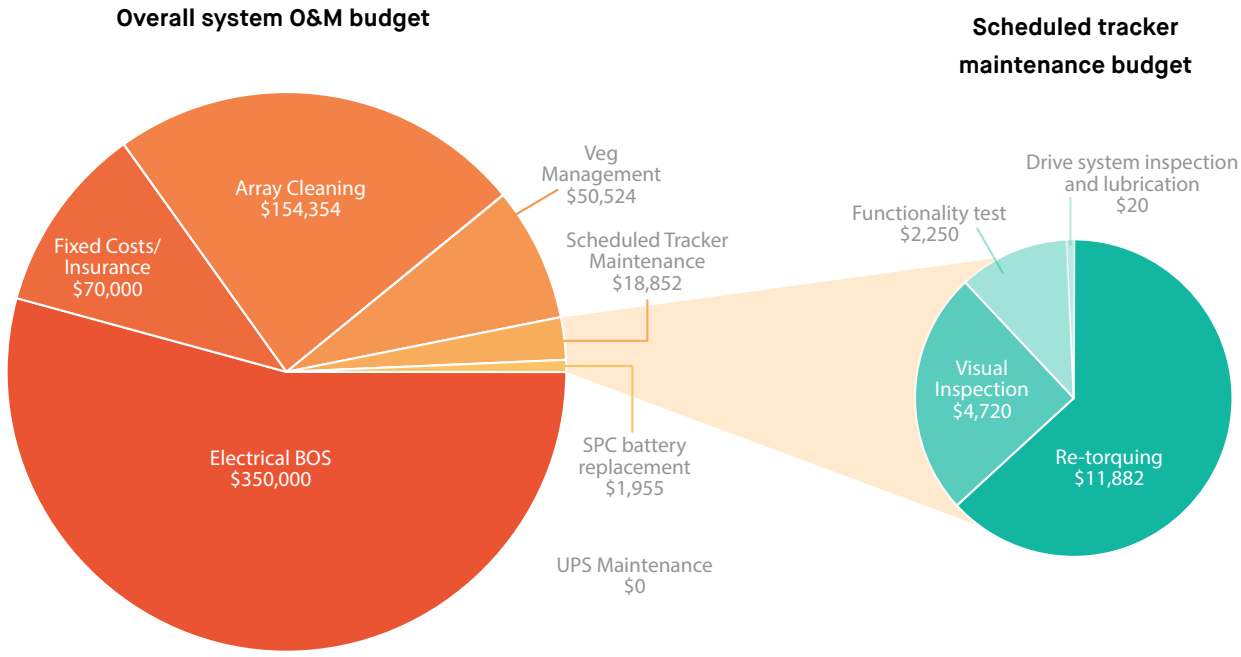
- Phillip Stephenson, Vice President, O&M, Borrego Solar

BORREGO SOLAR

O&M Considerations In Racking Type Selection

When planning for O&M, it is important to understand how costs scale with and are influenced by project attributes such as installed power capacity, land area, and racking type. Certain costs that represent a large portion of the total O&M budget, such as inverter maintenance, scale with the capacity of the plant but are independent of racking type. Vegetation management and PV module cleaning costs, on the other hand, are driven both by land area as well as the specific racking technology. There are also costs that relate solely to a specific component.

Looking at tracking systems specifically, it should be emphasized that tracker O&M is a small percentage of a system's overall O&M budget and significantly less than inverter and other balance of system (BOS) O&M costs. In fact, the portion of the overall O&M budget related to decentralized trackers is approximately 3%.



Levelized Cost Of Tracker O&M

When evaluating fixed-tilt structures versus trackers, O&M costs should be considered on a per kilowatt hour (kWh) basis since energy output varies significantly between these system types. For example, if the tracking system adds 3% more O&M cost on a capacity basis, it will produce 20% more energy. The O&M cost for the tracker then becomes 17% less on a per energy unit basis.

For a 100 MW site, O&M tracker cost is **17% less** on a per energy unit basis than fixed tilt

System Design And Technology Considerations

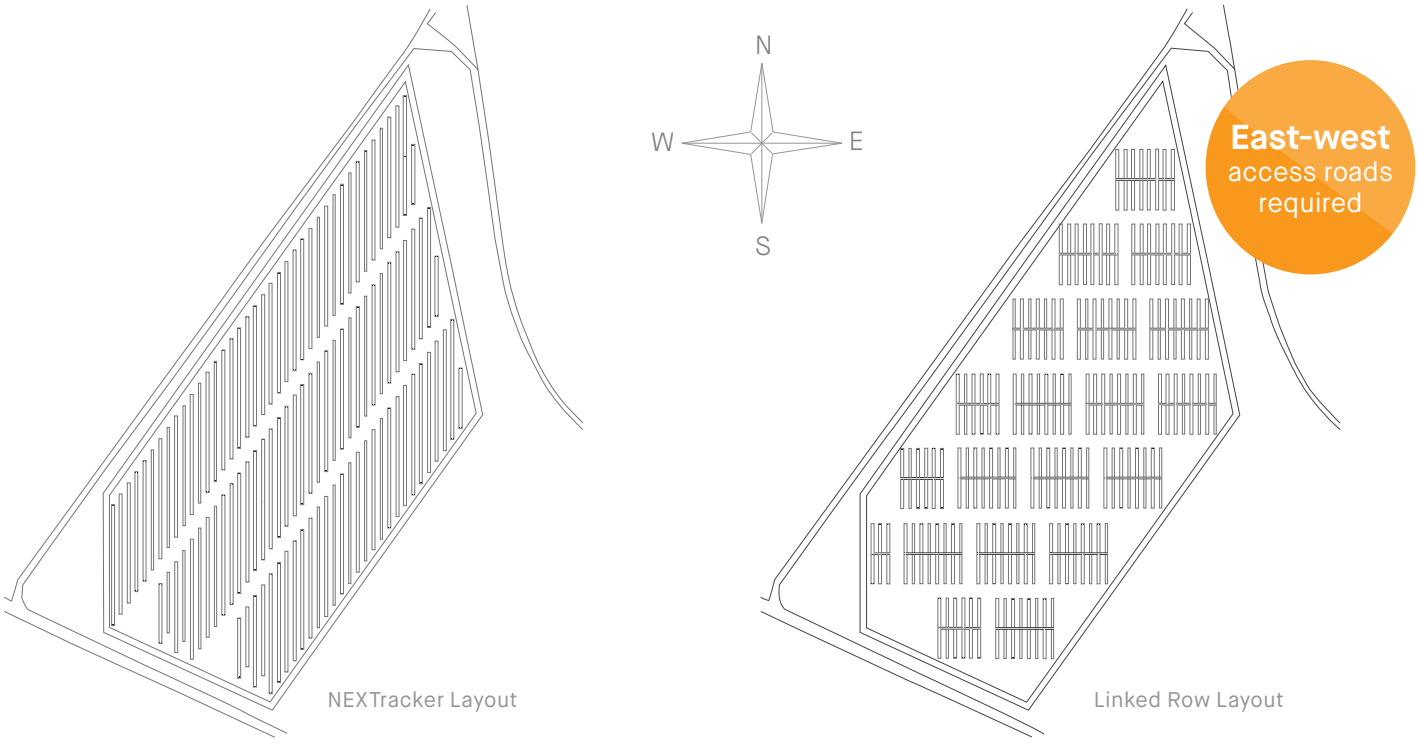
The Power of Independence

The specific type of horizontal tracker selected for a project can have a profound impact on O&M planning and costs. In determining which type of tracker to use, it's important to think through system architecture. SATs can generally be categorized in two ways: centralized and decentralized. In a centralized or linked-row system, rows are connected via drive lines and cables and typically require trenches for power wiring. Decentralized trackers such as the NX Horizon™ are composed of independent rows, with no hard links between the rows or trenched cables since each row is powered by its own self-powered motor drive and controller. In the case of independent row trackers, it should be noted that not all independent row trackers are self-powered.

Site Access and Flexibility

From an O&M perspective, row independence is an important consideration because it enables more flexible layouts and easier access between rows. In the comparison below, it's apparent that there are unutilized areas of the linked-row site layout and access roads must be developed during the engineering design phase of the project to allow service vehicles to access the site for routine service.

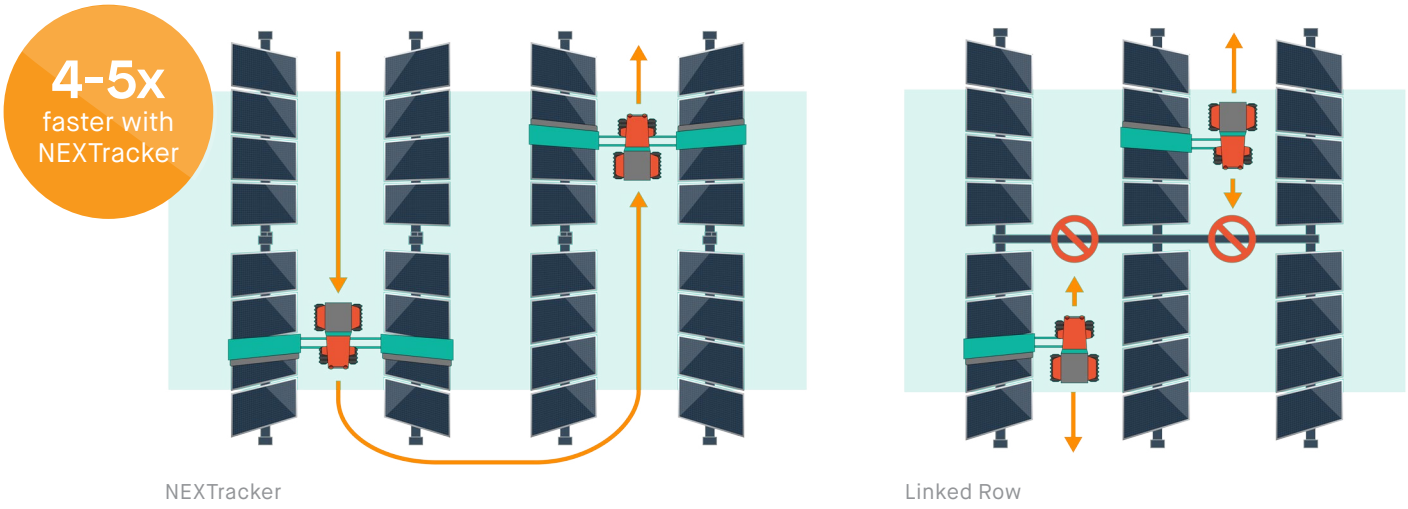
In addition, decentralized trackers enable a system to optimize land use—allowing more PV to be installed and thereby increasing the plant's power output.



Actual layout of 3 MW CalCom Solar project using NX Horizon in Salinas, California compared to layout of same site with typical linked row tracker.

Panel Cleaning and Vegetation Management

Routine panel cleaning is essential to achieving higher energy performance but it can be a costly operating expense. With linked-row systems, motors and drives are typically located between rows, which increases the cost and complexity of cleaning. Conversely, self-powered, unlinked-row systems provide unlimited access throughout the site. This leaves rows unimpeded for maintenance vehicles, making module cleaning and vegetation management four to five times faster than in linked-row systems—significantly lowering cleaning and upkeep costs and ultimately reducing the associated O&M expenditures by up to 55%.[5] As shown in the graphic below, vehicles do not have to turn around or back up which saves labor costs for vegetation management and panel cleaning. Additionally, adjacent rows can be turned face-to-face so that both rows can be cleaned on the same pass.



Unimpeded NEXTracker arrays versus blocked pathway of linked row tracker

"From a functional standpoint, NEXTracker's independent rows are extremely helpful and well thought out. Being able to isolate and travel freely in any direction saves time. And time is money."

- Adrian Freeman, Project Manager, Operations, Swinerton Renewable Energy

SWINERTON RENEWABLE ENERGY

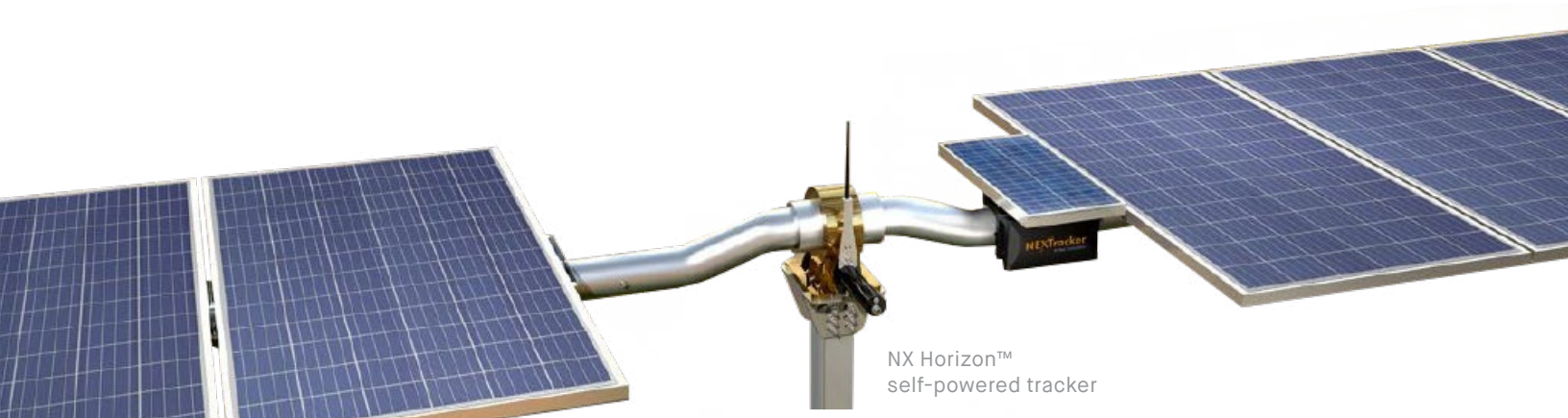
[5]*Figure based on NEXTracker internal analysis and based on 100 MW site data. Feb. 2017.*

Redundancy and Resiliency

All SAT systems are composed of mechanical components that drive the action of the rows to follow the sun and thus maximize energy production. These components may include motors, batteries, dampers, and controllers. The key question to ask when evaluating SAT providers is, could the failure of any individual hardware component threaten the system's overall production? In the case of a decentralized SAT, for example, each row's independent motor is powered by its own dedicated solar panel (with integrated battery backup), making external power cables obsolete.

This reduces the risk of asset downtime since each row is essentially its own independent system. Having individual, self-powered motors control each row increases the overall resiliency of the solar plant by eliminating the risk of malfunctions that can lead to downtime for a larger portion of the installed capacity.

While trackers have evolved to encompass a wide range of mechanical approaches to following the sun, the simplest solutions are often the most elegant—and the most cost-effective from an O&M perspective.



NX Horizon™
self-powered tracker

Drive System and Power Requirements

NEXTracker provides a mechanically simple yet elegant design that reduces O&M cost. By having no row linkages, the greasing and inspection of joints and connections are eliminated. NEXTracker systems are also mechanically self-balanced, so that the power required to move each row is very low, placing minimal stress on the internals of the motor. Each motor produces about 0.1 horsepower, requiring only 25 watts of power to rotate 90 panels on the row continuously. This balanced tracker design enables each row to rotate through a 120 degree range, capturing up to two percent more energy throughout the day.

Fasteners

Fastener maintenance is a key but often overlooked aspect of racking system maintenance. NEXTracker has performed considerable cost evaluations of the tracker portion of O&M budgets on sites small and large. In our analyses, we've found that linked-row trackers typically use 85% more fasteners than are used on NX Horizon self-powered trackers. The majority of NX fasteners are permanent and "swaged" or fastened, requiring little or no maintenance.

Torque vs. Tension

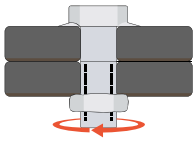
Much has been said about the advantages of tension over torquing on mechanical systems. Simply put, torque is the twisting force required to spin a nut up a bolt. Torquing is by nature inexact because of the many factors that can affect friction—from surface texture to debris, rust and humidity. By contrast, "tension" involves the use of hydraulic tools to stretch screws and swage or fasten bolts to a structure. In fact, the swaging of a lockbolt is five times stronger than its nut-and-bolt counterpart fastening system.

Maintaining this system hardware—the nuts and bolts of a mounting structure—can be a tedious and costly process. Dispatching crews to check the torque on screws or lubricate joints are activities that can add thousands of hours to an annual O&M budget, but in a centralized SAT it must be done, since failure of a single component can impact system performance dramatically.

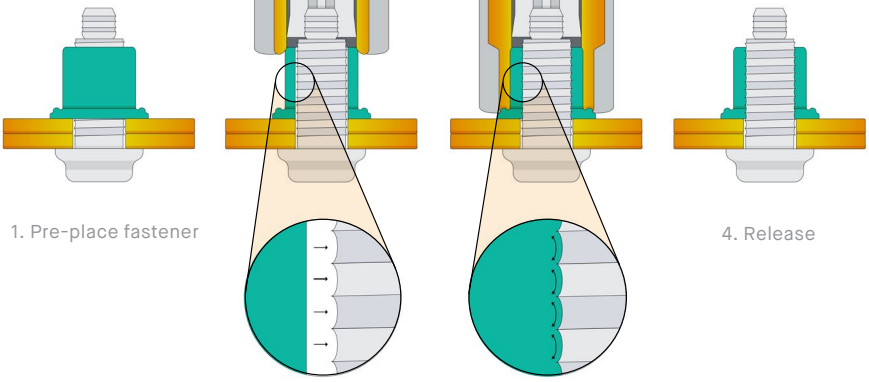
In this diagram, torque involves twisting the bolt. By contrast, with tension the swaged collar forms over the lock thread and eliminates the gap. Regular nuts and bolts have a gap, which can cause loosening by vibration.[6]

Clearly, system hardware that does not require torquing but instead relies on the tension between components will reduce the need for manual checks. NEXTracker uses highly durable, permanent fasteners that do not loosen over time, eliminating the need for periodic torque checking. No oils or lubricants are required in the maintenance of the system, as all motors and gears are sealed.

Torque Fastening



Four Steps to Tension Fastening



[6]*Huck Tool fastener video on swaging versus torqueing: https://www.youtube.com/watch?v=XMjQTl_x3fc&t=281s*

"NEXTracker's veteran solar engineering team had seen the effects of extreme weather events on solar power plants in the past, so durability during hurricane winds, floods, and harsh weather conditions was top of our mind for our designs. Hurricane Matthew was a real-world test of those designs, and we were excited to receive the report that every NEXTracker system in Matthew's path had zero damage and no downtime for our project owners."

- Tyroan Hardy, Chief Operating Officer, NEXTracker

Actual Virginia solar power plant during Hurricane Matthew flooding of September 2016. NX Horizon unharmed due to flood clearance.

CASE STUDY:

Hurricane Matthew Report Card

In the fall of 2016, the U.S and Caribbean experienced one of the worst hurricane seasons in the region in 30 years. Destructive winds and torrential rains ravaged the southeastern United States. Because of NX Horizon's robust design and flood sensors, all systems in the affected areas remained intact—with zero damage.

NEXTracker's balanced design and component elevation played a big role in avoiding damage. Before the storms, trackers were placed into stow at 30 degrees in anticipation of high winds. Because of NX Horizon's rapid speed to stow, this transpired within minutes. Most third-party trackers use a rectangular torque tube, which increases torsional load and slows the stowing procedure.

All key mechanical components—e.g., motor, elevated slew gear/drive, controller—avoided damage due to their high clearance from ground level above high flood zones. As a result, the trackers' mechanical function and structural integrity were not impaired.

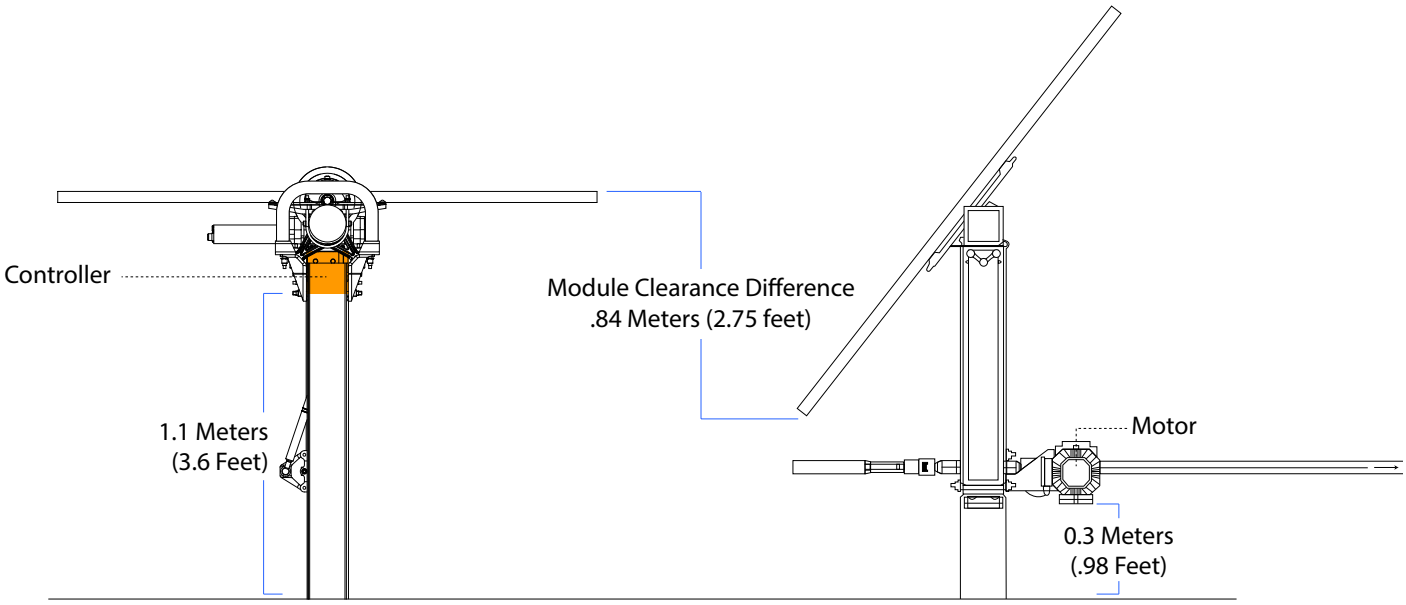
Even at the NEXTracker system sites worst hit by flooding—such as Virginia and North Carolina—none of the NX Horizons' drive components came into contact with rising waters. The system was able to employ predictive O&M so that costly corrective O&M was avoided.

Environmental Considerations and Flood Clearance

All NEXTracker drive and control components are protected against ingress of moisture, dust and sand, and are rated IP65[7] or higher. Fully sealed gearboxes and motors are maintenance free for life, and no critical components are exposed to the elements.

One of the more meaningful aspects of ground-mount systems is that they can be built on land that is unsuitable for other development, such as flood-plain areas. But care must be taken to ensure that the racking and software solution is designed to have longevity in the field and require minimal maintenance. In the case of NEXTracker, the high clearance of the system and all its components ensures that if flood waters rise, the system will be unaffected. Assuming mechanical parts are not submersible, linked-row trackers in this instance are ill-prepared because most have mechanical and moving parts below the flood zone, endangering site operations until the flood waters recede and parts replaced. On average, most linked-row trackers are at 0.3 meters above ground, well within risk height and the flood damage zone.

With the NEXTracker Flood Stow System, we are able to detect programmable flood depths through a self-powered ultrasonic sensor. Using our proprietary flood stow system, up to 2.75 feet of piers can be saved compared to a conventional 52.5 degree system, saving the customer money across the site in steel costs.



[7]IP65 refers to the ingress protection of mechanical components and that they are protected from total dust ingress per the international IP Enclosure Ratings & Standards.

Managing Tracker Assets Intelligently

Managing tracker assets* and planning for routine maintenance are ongoing functions of any solar plant. Managing these assets intelligently—based on real-time data analysis—can mean the difference between a plant that operates minimally versus a plant that outperforms its owner's expectations. When making a purchasing decision on trackers, system owners need to think about the asset management implications over the 25-year-plus lifetime of the system, including long-term availability and viability of components, reverse compatibility, form fit and function replacements and parts storage. Enhancing our bankability, NEXTracker's parent company Flex has 30 offices and 100 manufacturing facilities around the world, providing additional assurance that NEXTracker systems will be maintained over the lifetime of the plant.

In the case of centralized SATs, the asset management function can best be described as mission critical. In the case of unlinked systems, each row operates independently so owner-operators are not at risk of losing power generation of the tracker block. In our analysis, a breakdown of these critical components such as the motor, communication systems and gear will affect only one row (25 kW) as opposed to 700 kW for a linked-row tracker. In fact, the kilowatt-hour loss per year is approximately 150 kWh for NEXTracker's system versus 8500 kWh for linked-row trackers. That's a difference of 8350 kWh lost in a given year, which could add up to a considerable loss for large utility-scale plants.

NEXTracker 70 MW project site, Javiera, Atacama Desert, Chile

*As previously noted, "Asset management" and "O&M" are terms that are sometimes referred to interchangeably in the PV industry. For the purposes of this white paper, asset management refers to the actual tracker assets themselves, including hardware and software.

Corrective-Based Maintenance

Corrective-based maintenance means there are unscheduled repairs or replacements needed that were not anticipated or expected. An example of this is when a motor or inverter stops functioning unexpectedly. When it comes to O&M, labor costs are the biggest factor when maintaining solar power plants, and each truck roll avoided and man-hour saved translates directly to the bottom line. This is often considered corrective or condition-based maintenance.

Successful asset management for any solar plant begins with visibility. With the advent of smart devices and the Internet of Things, monitoring even the largest solar plants down to the component level is possible. But the data that this constant monitoring produces can become overwhelming for system owners. To understand the true implications of system issues, an intelligent cloud-based O&M strategy must be developed that weighs the cost of truck rolls against possible impacts to system performance and the value of the energy produced.

O&M providers who work day in and day out in the field know there are always outlier incidents that require immediate analysis to determine if action is required. Having access to minute-by-minute tracker performance data helps system owners and their O&M partners understand when and where to place maintenance resources to manage assets effectively while keeping a low LCOE (levelized cost of energy).

NEXTracker's Digital O&M™ Analytics Platform provides real-time and historical data analysis, monitoring of row-specific tracker angles, controller health and battery performance, and motor and slew gear performance, among other metrics. Powerful and secure, this system is integrated into Flex's Connected Intelligence cyber-secure network. Through a single map view, system operators can identify issues at a glance with flag alerts, and drill down to individual rows to see alert status, over-current, and expected versus actual tracker angles.

Built To Last: Quality And Reliability Considerations

Depending on exact power purchase agreement (PPA) requirements, solar plants are expected to operate for 20-30 years or more, often in the harshest environments. Project owners must be able to trust that the providers that build their plants have the necessary quality and reliability processes in place—and the experience to support projects throughout their lifetime.

A NEXTracker project from Utah, USA

NEXTracker, a FLEX company, has contracted or installed more than 7 GW of projects worldwide, in every climate, region and soil type under the sun. With Flex's 100 manufacturing sites in 30 countries, NEXTracker solutions are scalable, reliable and highly bankable for the long term.

Testing and Third-Party Validation

Manufacturers must have a quality and reliability program that includes internal as well as third-party testing and evaluation. When evaluating tracker suppliers, be sure to ask about accelerated life tests, outdoor tests, and factory acceptance testing (FAT) of all system components, including materials and electronic components.

NEXTracker motors undergo all of these tests, including accelerated testing of more than 25,000 days (68.5 years), with no failing seals or significant signs of wear. NEXTracker's Self-Powered Controller (SPC) has been evaluated for reliability according to Telcordia SR-332, a globally accepted standard for calculating the mean time between failure (MTBF) of electronic components.

The structural parts of trackers must be extensively evaluated as well. NEXTracker components have been certified by independent third-party engineers, including Kleinfelder, Cermak Peterka Petersen Inc., and Structurology LLC.

Best-in-Class Suppliers

A solar plant's performance can be directly traced to the quality of its material suppliers. Trusted tracker manufacturers have a detailed, ongoing process in place for vetting and monitoring suppliers for their quality and reliability. All suppliers should meet ISO 9001 certification at a minimum as well as FAT and material-specific certificates of conformance.

NEXTracker components are sourced from best-in-class vendors, each of which is a world leader in its domain. Tracker performance is constantly monitored in the field to ensure all components continue to meet strict expectations.

Warranty Maintenance Schedules

Before a purchase decision is made on any tracker, it's important to understand warranty terms. Reputable tracker providers should supply customers with a maintenance manual that includes a recommended schedule of predictive maintenance. System owners working in concert with suppliers or O&M providers should have a thorough understanding of the specific activities required to fulfill warranty obligations, which will guide O&M budgeting as well.

PowerworX Academy hands-on installer training offered to worldwide customers.

Training and Support

Solar plants are capital-intensive, long-term investments. Ensuring that EPCs, installers and O&M providers have the training and techniques to correctly install, commission and maintain the system over time is fundamental to a project's success.

NEXTracker provides in-depth, hands-on installation training for the boots on the ground to properly install and maintain the NEXTracker Self Powered Tracker (SPT). The NEXTracker PowerworX™ program is registered with the North American Board of Certified Energy Practitioners (NABCEP) for continuing education credits.

Conclusion

Developing a predictable O&M strategy at the outset of a project will ensure the bankability and ROI throughout the system's lifetime. Project owners and developers that thoroughly evaluate O&M considerations of their tracker investments will find that the higher energy performance, predictive analytics and long-term reliability of single-axis, self-powered trackers will provide a lower overall levelized cost of energy than fixed-tilt racking or conventional tracking systems.

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