MITIGATING EXTREME WEATHER RISK

PART 1: Understanding How Differentiated Design and Control Strategies Unlock New Opportunities for Solar Development

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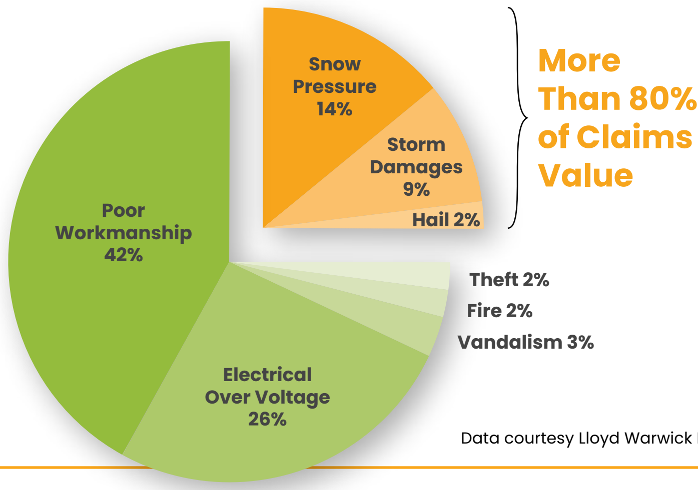
According to data published by GCube[1], a renewable energy insurance specialist, severe weather events are the root cause of most solar insurance claims. While severe weather is inevitable for some locations and increasingly common in others, weather-related catastrophic solar project losses need not be. Project stakeholders can address site- and region-specific risk profiles during project design via strategic product specification.

With the growth of the utility-scale solar market sector, increasing numbers of projects are being fielded with an AC-generating capacity of 100 MW or greater. In the U.S. alone, the Solar Energy Industries Association currently estimates that there are some 47 GW of solar in operation with another 115 GW under development or construction. Given that large project development activities are increasingly coincident with extreme weather, Nextracker has systematically addressed every major weather risk category—including hail, flooding, snow, and extreme wind—via differentiated design and control strategies in order to ensure the long-term reliability of solar assets.

Project siting is one of the most challenging issues facing project developers, owners, and insurers. Solar project development activities require large areas of land, on the order of 500 acres (200 hectares) of land per 100 MWac. Given the competitive business environment, generally characterized by narrow margins, affordable land valuations are critical to project success. Ideally, these large and economical parcels of land are proximal to transmission lines that can accommodate additional generation capacity. Locations that meet these criteria are further winnowed down according to the outcome of complex and time-consuming utility interconnection studies.

FREQUENCY OF LOSSES

PV CLAIMS DATA According to Lloyd Warwick International, an insurance loss adjusting specialist, weather-related damages—especially hail and wind losses—account for more than 80% of claims values. To the extent that project stakeholders are able to identify site- and region-specific risk profiles in advance, they can mitigate severe weather perils via strategic design, engineering, and procurement.



Data courtesy Lloyd Warwick International

Given all of these constraints, it is not surprising that some of the best locations for large utility-scale solar projects are undesirable or impractical for other types of development activities. Increasingly, these locations are coincident with increasing risk of severe weather events and include hail-prone regions, floodplains, deserts, snow-prone areas, and high-wind areas. Here, we illustrate how single-axis trackers with differentiated design and control strategies can mitigate extreme weather risks, allowing project stakeholders to meet financial expectations with these unique and varied development opportunities.

In Part 1 of this two-part white paper, we provide actionable content that project developers, EPCs, independent engineers, insurers, and financiers can use to mitigate or assess risks associated with hail, flooding, snow, sand and soiling, and plant restoration and remediation. In Part 2, we explore dynamic wind effects and explain why solar power plants that appear similar on paper may have very different risk profiles in the real world. In the process, we expose the myth of commoditization by demonstrating the real-world benefits of differentiated design and control strategies.

HAIL RISK MITIGATION

In May 2019, the 182 MW Midway Solar generating facility, located near Fort Stockton, Texas, experienced one of the biggest losses to date in the renewable energy insurance market. For a period of days, late-May thunderstorms punctuated by large-diameter hail imperiled West Texas. Residents from El Paso to Lubbock sent photos of golf ball- and baseball-sized hail to local weather stations. Even in a region and season known for severe weather, these spring thunderstorms were particularly intense.

"If we learn over time that certain technologies or control strategies perform better and carry less risk, we can price policies and premiums accordingly."

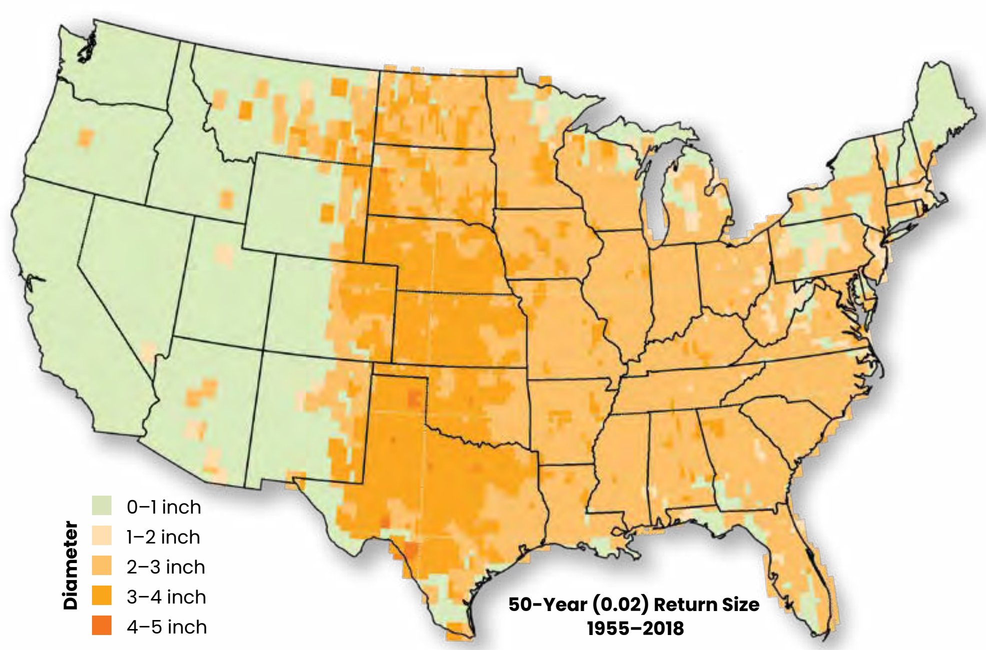
—Brian Tyluki,
SVP and Senior Underwriter, GCube

One particular line of storms not only shattered car windows in San Angelo but also swept across the 1,500-acre Midway Solar farm. According to *Insurance Insider*, losses associated with this weather event were on the order of $70M to $80M.[2] Presumed to be 100% underwritten by GCube and backed by its 22 capacity providers, Midway Solar losses were orders of magnitude larger than GCube's average claim size of $1M, based on roughly 500 claims per year.

Several other utility-scale solar plants also incurred significant hail loss claims in 2019. Spurred on by these historic losses and a general increase in severe-

LIKELY EXTREME HAIL SIZE OVER 50-YEAR INTERVAL

LARGE-DIAMETER HAIL RISK This map plots probable maximum hail size for the continental U.S. over a 50-year interval. These results are based on more than six decades of actual hail strike data (1955–2018) and determined statistically using extreme value theory. Per these results, capital assets with a viable operational and financial lifetime exceeding 30 years—such as large utility solar farms—are at risk of experiencing a greater than 2-inch hail event in most locations east of the Continental Divide.



weather events, carriers not only increased their rates, but also decreased exposure by capping individual policy coverage levels or reducing their underwriting line size from 100% down to 20% or 40%. This is standard operating procedure, notes Brian Tyluki, senior vice president and senior underwriter at GCube. "What insurers tend to do when we identify issues and trends," explains Tyluki, "is to address those concerns via pricing—high deductibles or increased premiums—and policy wording with regards to sublimits. If we learn over time that certain technologies or control strategies perform better and carry less risk, we can price policies and premiums accordingly."

Within the large utility-scale solar project ecosystem, Nextracker is the only company to offer a complete data-driven hail mitigation strategy. In addition to having technologies and controls proven to significantly increase PV module survivability during hail events, Nextracker's solution to hail risk is backward compatible with previously fielded systems. Extensive testing to identify the optimal hail stow angle is at the core of our hail strategy, which takes advantage Nextracker's ability to rotate an entire solar farm into a defensive stow position in less than one minute.

Most importantly, because we have a connected platform, we are able to push software and firmware updates out into the field as needed to reduce risk or improve performance, providing for a future-proof solution. This connectivity is what allows us to implement advanced risk-mitigation strategies—via NX Navigator, a proprietary solar power plant monitoring and control software platform—in both new and legacy systems.

Hail Testing Hail impact testing has long been a part of PV module safety and reliability testing. Product qualification standards developed and refined in the late 1970s, for example, feature a hail assessment test based on 11 impacts of a 1-inch (25-milimeter) diameter ice ball at terminal velocity of 51.5 miles per hour (23 meters per second).[3] While hail testing standards are little changed in 40 years, insurers are well aware that severe weather risks have changed over the past four decades—and not for the better.

Product safety standards are designed to achieve acceptably low probabilities of failure based on a continuum of risk. However, some regions of the world are historically more hail-prone than others; these areas include the central region of the continental United States, southeastern South America, equatorial Africa, and the southern foothills of the Himalayas, as well areas in the Middle East and North Africa. Moreover, giant hail events are increasing in frequency, severity, and range due to global changes in weather patterns. In other words, the risk profile for hail is increasing. Value-engineering may also change risk profiles, insofar as PV glass and module frames are getting thinner as collector aperture areas are increasing.

In 2019, Nextracker began actively studying hail impact damages—in partnership with Renewable Energy Test Center (RETC)—with the goal of identifying substantive ways to lower project risk for our downstream partners and other industry stakeholders. One of the first things we discovered is that all PV modules pass product certification hail impact tests, which are based on the terminal velocity of a 1-inch (25-milimeter) hailstone. While product qualification test standards may set a reasonable baseline for module hail-impact tolerance, these minimum test requirements are insufficient to help industry stakeholders understand the risk of hail damage in fielded projects. In other words, industry-standard qualification test requirements are not rigorous enough to characterize perils in hail-prone regions.

Therefore, we engaged RETC to conduct calibrated hail cannon tests based on varying hailstone diameter, impact velocity, and module-impact angle. Together with RETC, we designed these beyond-certification impact tests to not only characterize large-diameter hail risks in large-scale solar farms but also to assess the effectiveness of potential risk-mitigation strategies.

The first series of hail-resistance tests studied how stow angle and direction affect hail resilience. Does facing into the wind or away from the wind provide better hail resistance? What influence does stow angle have on hail damage? To augment these empirical tests, RETC has also surveyed the hail literature to understand geographic risk. What is the correlation between location and the likelihood of large hail strikes? What is the relationship between hailstone diameter and impact vector? To what extent is large hail coincident with high winds?

Based on an analysis of these test results, RETC determined PV modules are at risk of breakage when hailstones have a diameter in excess of 1.5 inches (3.5 centimeters) and are traveling at terminal velocity. On the one hand, these findings are cautionary. Statistically speaking, the probability of damaging hail invariably increases with longer project lifetimes. Moreover, project location significantly influences the statistical probability of damaging hail. On the other hand, we also identified strategies that can significantly lower the risk of hail damage to PV modules, regardless of the baseline risk profile determined by project location or lifetime.

Specifically, RETC determined that 300% more kinetic impact energy is required to shatter framed PV glass in modules stowed at 60° versus a flat stow position. Based on the resulting increase in survivability, RETC's independent engineering report concludes that stowing modules facing into the wind at 60° during a hailstorm "can significantly increase the survivability of PV panels from 81.6% to 99.4%."[4]

Research and statistics regarding hail impact vector and wind speed probabilities further validate stowing modules facing into the wind at a 60° tilt angle for hail-risk mitigation. As hail diameter increases, for example, hailstones generally have a more vertical vector. Moreover, historical wind station data indicates that wind speeds in excess of 40 miles per hour (18 meters per second) are rarely coincident with module-damaging hailstone diameters.

"The NX Navigator hail-stow feature can significantly increase the survivability of PV panels from 81.6% to 99.4%."

—RETC, *Hail Resistance Testing and Analysis of Results*

Hail-Stow Controls With NX Navigator, operators can remotely control the position of all Nextracker-mounted systems based on weather or other site-specific conditions using a convenient single-button command for an entire PV power plant. Unlike AC-powered tracker systems, Nextracker's single-axis trackers are entirely self-powered; as a result, there are no AC power surges or peak-demand charges associated with moving all of the trackers in large solar farm in unison. In terms of these controls, our systems are always "getting smarter." Since we

HAIL LOSSES Some of the strongest markets for large utility-scale solar projects are at elevated risk of large-diameter hail exposure. For example, the Midway Solar generating station in Texas, shown here, experienced a $70M to $80M hail-damage claim in 2019. NX Navigator's hail stow feature mitigates large-diameter hail risks by facing trackers into the wind at a 60° tilt angle, which reduces impact force on PV glass. Once hail stow is initiated at the plant level, individual NX Horizon single-axis trackers will rotate to this 60° defensive stow in less than a minute.

have a connected platform, we routinely push new firmware out to the field over time. This allows us to retroactively add functionality that was never anticipated at the time of construction. Hail is a perfect example.

Prior to 2018, few in the solar or insurance industries considered hail to be a major weather risk on par with the risks associated with wind. That perception changed due to a small number of projects experiencing very large losses. In response to this change in risk profile, Nextracker developed and implemented its protective 60° hail stow mode. Because Nextracker uses software to control connected systems, we can improve on these features over time.

D. E. Shaw Renewable Investments (DESRI), a market-leading renewable energy asset owner and manager, has implemented these types of innovative project-control strategies across its portfolio. "As an early adopter of TrueCapture three years ago, we benefited from increased energy yield production, lower operating costs, and better availability," says Bryan Martin, executive chairman of DESRI. "Nextracker keeps adding functionality designed to further optimize our projects. Earlier this year, we started using NX Navigator's snow shed capabilities at our northern sites to reduce losses attributed to snow cover. We are also implementing NX Navigator's hail stow to help protect our systems from extreme weather in hail-prone regions."

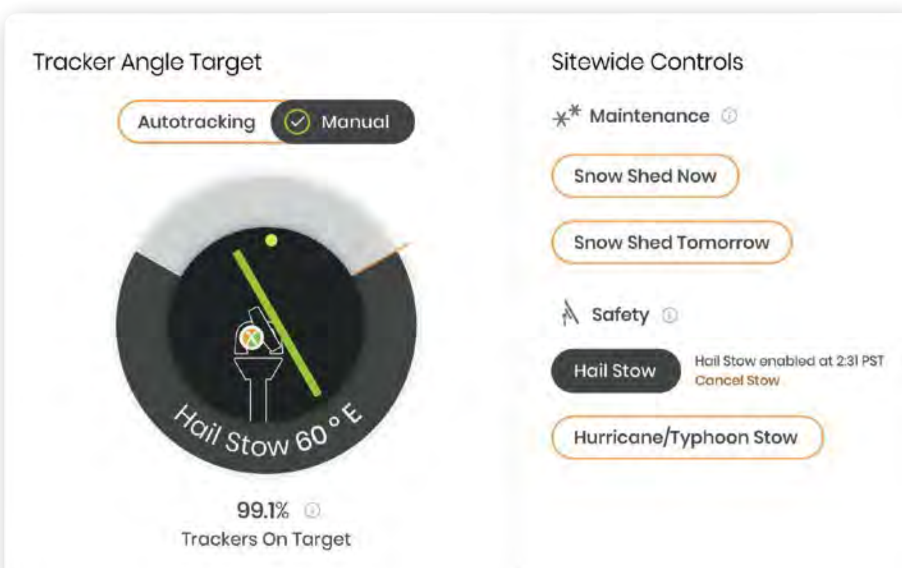
> *"As we identify novel opportunities to mitigate risk or improve performance, we are able to push new changes in control algorithms out to the field."*
>
> — Arathi Gopinath,
> Director of Asset Performance Management,
> Nextracker

"The beauty of software integration into hardware," observes Arathi Gopinath, Nextracker's director of asset performance management, "is that as we learn from the field and identify novel opportunities to mitigate risk or improve performance, we are able to push new changes in control algorithms out to the field. These upgrades not only provide best-in-class performance to new customers or new projects but also to existing customers with fielded projects. In this regard, Nextracker systems are similar to a smartphone or a Tesla EV."

"One thing that sets Nextracker apart is that it goes to great lengths to understand the large losses and issues facing insurers," says GCube's Tyluki. "The largest losses we are seeing are related to modules, which are difficult for tracker manufacturers to address. There may come a point in time when technology ultimately dictates whether we can support a project and underwrite a risk. If a project in a specific area does not have some proven technology, maybe we decline to offer coverage. We are not there yet as we need time to review the data."

NX NAVIGATOR GRAPHICAL USER INTERFACE (DETAIL)

HAIL STOW INITIATION Asset managers and plant operators can use NX Navigator to remotely trigger hail stow, hurricane or typhoon stow, or snow shed. Once a user-initiated command is given, all trackers will move to the specified defensive position within one minute.



FLOOD RISK MITIGATION

A key thing to understand when it comes to mitigating risk is that you cannot simply silo risk assumptions into one category. During a storm or extreme weather event, there may be multiple coincident risks—such as high wind, hail, and flooding. To address each of these risks requires an intelligent and targeted response as opposed to a one-response-fits-all strategy.

For hail-risk mitigation, for example, we want to send the entire site to appropriate high-tilt stow angle and direction. Flooding, meanwhile, only impacts specific areas of a site and is best mitigated using a low-tilt stow angle. Nextracker is the only company with a platform that is both smart enough and flexible enough—in terms of product design and control strategy—to effectively address these types of coincident risks.

Flood-Resilient Architecture Successful utility-scale solar farm developments require large areas of land, but are sensitive to land costs. As a result, many projects are built in floodplains or flood-prone areas that are not suitable for other types of development. In this risk profile scenario, project designers must elevate electrical equipment and the lowest edge of the PV panels above the 100-year water surface elevation. In response to increasing weather severity and development activities, project owners and insurers are increasingly using the 200-year water surface elevation as the basis of design in flood-prone areas such as Texas.

While flood-hazard maps are based upon the best available information, flood risk is dynamic and changing in light of increasing storm severity. In other words, flood levels and frequency in the future may be higher than they are today. Moreover, floods can occur in areas that are not traditionally associated with flood risk. Freeze-thaw cycles can lead to flooding, as meltwater builds up behind intermittent ice dams. Plant construction activities can obstruct water runoff and lead to ponding and flooding. This dynamic and changing risk landscape is of particular concern to insurers and project owners, as submerged equipment can lead to future failures.

"There may come a point in time when technology ultimately dictates whether we can support a project and underwrite a risk."

—Brian Tyluki, SVP and Senior Underwriter, GCube

The best way to adapt project designs to prevent flood damage is to locate sensitive equipment as high above grade as possible. This is challenging in linked-row tracker systems with driveshafts, open gears, controllers, and large electrical motors that must be located far enough below the torque tube to provide clearance for module rotation. By comparison, each balanced row in a Nextracker system is self-powered. The controller, motor, battery, and solar charger that power and control each row are mounted to the torque tube itself. This elevated design configuration provides a minimum of 3.3 feet (1 meter) of flood clearance.

HIGH AND DRY Though not located in a floodplain, this project in Idaho experienced extreme site water during a freeze-thaw event. This ad hoc kayaking lake formed when unseasonably warm weather caused heavy snow to quickly melt. Since the ground was still frozen, water ponded behind ice dams in low areas of the site. Due to the elevated height of the electrical and mechanical components, the system continued to operate and experienced no flood damage. Note that trackers in unflooded areas of the site continue normal operation during defensive flood stow.

NEXTRACKER'S EXTREME WEATHER STOW AND LOAD SHED MODES

	Hurricane Stow	Hail Stow	Wind Stow	Snow Shed	Flood Stow
Priority Order	**1**	**2**	**3**	**4**	**5**
Action	Moves all trackers to maximum tilt angle facing east or west (per user) for maximum wind protection	Moves all trackers to maximum tilt angle facing east or west (per user) to minimize hail impact force	Moves trackers to a defensive stow position, based on site configuration, facing into the wind	Moves all trackers to maximum tilt angle to dump snow; normal tracking resumes after snow shed	Selectively moves trackers in flood zones to 0° tilt (flat) angle for maximum ground clearance
Initiated	By user (with optional weather alert)	By user (with optional weather alert)	By weather station sensor	By user (with optional weather alert)	By weather station sensor
Cleared	By user	By user	By weather station sensor	Automatic	By weather station sensor

RISK PRIORITIZATION Nextracker prioritizes its NX Navigator software-controlled responses to extreme weather according to severity of risk. This intelligent and targeted control strategy is ideal for addressing coincident risks. Moreover, the platform's connectivity allows Nextracker to push new features into the field, improving performance and safety over time.

In addition to locating key control and drive components well above grade, Nextracker uses control boxes, bearings, and slew gears that are sealed against water and sand. These product design features are inherently flood-resistant. Moreover, the system is resilient against power outages because the self-contained and self-powered decentralized architecture requires no grid power to the rows.

Flood-Stow Controls A smart tracker control system is what allows Nextracker to take full advantage of its flood-resilient tracker architecture. Generally speaking, flooding impacts only specific areas of a site. By combining a decentralized tracker with intelligent controls, we are able to target flood-mitigation efforts specifically to those flood-prone areas.

Targeted flood risk mitigation starts with a review of a site's hydrology study to identify low-lying areas that are at risk of flooding. We can then mitigate flood risk by deploying strategically placed ultrasonic water-level sensors. For redundancy, best practice is to use multiple flood sensors. However, there is no need to install flood sensors at every low-lying site location. Since the power blocks communicate with one another, a representative set of sensors can characterize flood water depth across an entire site.

The data from these flood sensors is used to actively control the tracker angle to provide additional flood clearance. Via programming, we can set the flood-stow threshold to a specific water depth—such as 1 foot (0.3 meters) or 2 feet (0.6 meters)—as directed by the owner or EPC. The ability to intelligently move modules to a flood-stow position in drainage areas allows plant designers to reduce pile height, above and below grade. This targeted response to sheet flooding allows project stakeholders to simultaneously mitigate risks and drive down system costs.

The ability to independently control the individual tracker rows also has meaningful production benefits. If flooding occurs after a storm has passed—which is not uncommon when rainfall is greatest upstream in a watershed—the system as a whole can track normally while only the trackers in the flood zone are stowed. Since the system measures flood water depth at multiple locations in real time, the controller can return a plant to normal operation as soon as flood waters subside. All of these operations either happen automatically or can be triggered remotely, meaning there is no need to dispatch resources to the site to initiate flood stow or restore normal plant operations.

SNOW RISK MITIGATION

Nextracker's ability to push control algorithm changes and enhanced features out to the field has also improved the platform's snow resilience over time. As a safety feature, Nextracker systems have long benefited from an automated snow stow mode that prevents snow accumulation on the array tables. This self-powered snow stow functionality limits maximum snow loads and provides snow load protection. While effective as a safety feature—Nextracker has not experienced snow-related failures—snow soiling losses are a tradeoff associated with an automated snow stow mode.

With the release of the NX Navigator monitoring system and our energy-enhancing TrueCapture software, plant operators have the ability to intelligently mitigate snow loads while optimizing system production. Many people think of TrueCapture as a software that optimizes production and revenue. While that is true, it is also a very powerful operations and maintenance (O&M) platform. Effectively, it is a closed-loop system that notifies stakeholders at the exact moment that a row—anywhere in a plant or a portfolio—is no longer operating properly.

As part of the process of optimizing plant performance in real time via machine-learning and data analytics, software is able to determine instantaneous performance losses due to snow. If the snow losses become significant, the system will initiate a snow shedding command that rotates the tracker tables. After dumping the snow and clearing the front of the modules, the tracker will return to normal operation. These snow-shed capabilities not only minimize snow loads but also increase energy yield.

"Earlier this year, we started using NX Navigator's snow shed capabilities at our northern sites to reduce losses attributed to snow cover."

— Bryan Martin, Executive Chairman, DESRI

Nextracker is also able to eliminate or mitigate damage to solar panels and other equipment associated with snow buildup on the ground. We do this in part by monitoring and analyzing motor current on every individual tracker. Nextracker controllers apply only the precise amount of current required to move the motor. Since we are constantly monitoring our connected fleet, we have digital signatures for many probable tracker failure modes.

During a snow event, therefore, the data monitoring and control system knows exactly which rows are working properly and which rows are operating with more difficulty. We know this in real time based on a digital twin analysis. In much the same way as safety features built into a garage-door opener ensure that a garage door reverses direction when it senses resistance associated with an obstruction, we are able to ensure that trackers are not damaged by rotating forcibly into snow drifts or piles of snow shed off of the tracker tables.

SNOW SHED The ability to intelligently shed snow not only increases system production by reducing snow cover, but also mitigates against damage resulting from snow loads. Authorized operators can shed snow on demand or preschedule up to two daily snow shed operations.

SAND AND SOILING MITIGATION

Self-powered, decentralized trackers have an inherent advantage over linked-row trackers when it comes to routine O&M activities such as panel cleaning and vegetation management. This advantage is largely due to the fact that maintenance vehicles are able to drive unimpeded between rows without needing to back up or turn around when reaching a driveline. Moreover, adjacent rows of modules can be turned face-to-face, expediting semi-automated truck-based module cleaning operations.

In some locations around the world where array soiling is a concern, annual or seasonal cleaning activities are adequate to remediate soling losses and meet plant performance requirements. Other locations—including the Middle East, North Africa, India, and parts of Latin America—experience extreme soiling and cementation, a process whereby dust particles stick to one another and cement themselves to the surface of the glass. In parts of India and China, for example, soiling rates can reach 1% to 2% per day.[5] Soiling rates are even greater during sandstorms.

Not surprisingly, water is often in short supply in regions where the daily soiling rates are most extreme. In arid regions that require ongoing soil mitigation efforts, fully autonomous waterless cleaning machines are often a preferred solution for maintaining plant performance. These robotic cleaning systems employ dry cleaning methods that are effective at removing dust. They require minimal on-site labor and are designed for high-frequency operation with minimal downtime. Communications-enabled cleaning robots can even integrate with a plant's SCADA system for monitoring and control.

Since 2017, Nextracker has been working with robotic cleaning system manufacturers to develop specialized solutions compatible with our 1P NX Horizon and 2P NX Gemini single-axis tracker applications. To ensure that long-term module reliability is not compromised, we developed detailed robot qualification criterion. A well-designed system, for example, must avoid excessive point loading and module deflection that could lead to cell microcracking.

To date, Nextracker has qualified four robotic cleaning systems, based on extensive testing and evaluation, for use with our portfolio of smart tracker products.

ROBOTIC CLEANING SYSTEMS **Nextracker has qualified four waterless automated cleaning systems for use with its single-axis trackers. These robotic systems can be used in regions that experience dust storms—such as the Middle East and Latin America—to mitigate the performance risks associated with extreme soiling and dust accumulations.**

All four solutions are specifically engineered for compatibility with tracker-specific design features. Moreover, we have ensured that the technical specifications for each of these solutions meet or exceed applicable codes, standards, engineering, and component-quality requirements.

For optimal robotic cleaning activities, Nextracker-mounted systems can be designed in an end-to-end configuration. By enabling the robot to move from table to table, it is possible to take full advantage of the maximum per charge cleaning distance, which is typically 1.2 miles (2 kilometers) or more. Nextracker manufactures the ancillary mechanical components—such as row-to-row connecting bridges, and end-of-row docking and reversing stations—and offers these directly to its customers as optional accessories.

Since dust is also a concern for mechanical and electrical components, Nextracker uses sealed products and dust-tight enclosures to prevent dust egress. Moreover, these components are located at least 3.3 feet (1 meter) above grade. This additional ground clearance reduces exposure to wind-blown sand and dust and provides relief against radiant heat effects.

RESTORATION AND REMEDIATION

As climate change increases storm frequency and intensity, owners, insurers, and other stakeholders need to take steps to minimize downtime and revenue losses after extreme weather events. Nextracker's systems have survived hundreds of hurricanes. In addition to a proven record of in-field durability, our systems require minimal site grading, reducing erosion potential.

In the wake of a damaging extreme weather event, independent smart trackers have a significant advantage over monolithic systems that lack connectivity. When disaster strikes, replacing damaged parts has little impact on project rate of return, whereas loss of energy production has a large impact on financial performance. Maintaining plant availability is therefore critical to minimizing losses.

Nextracker products are connected devices backed by powerful analytics. No other tracker system provides plant operators with so much actionable, granular information about plant status. We collect 13 data points every five minutes for every network-connected tracker row.

By constantly assessing information and patterns within that data, we gain detailed insights into plant performance that are invaluable to plant restoration and remediation operations. We can tell customers what the current signature looked like when a tracker was newly commissioned, what it looked like five weeks ago, and what it looks like after a storm. Based on the nature of that current signature and how it has changed over time, we can tell if a damper slipped suddenly or if a foundation is slowly subsiding and causing the torque tube to bind.

"Because we are able to communicate with every tracker, we know the location of any issues as well as the probable failure mode and remedy."

— Arathi Gopinath,
Director of Asset Performance Management,
Nextracker

Since Nextracker knows the operating status of every single tracker row, information provided by our monitoring and control systems can eliminate days and weeks of damage-assessment activities. The control system can alert asset managers to the precise location of storm-related failures. It can even flag trackers that appear to be operating normally for corrective or preventative maintenance based on characteristic current signatures.

Courtesy Solar Support

STORM RECOVERY In the wake of extreme weather, production and revenue losses can exceed replacement part costs. Nextracker's data monitoring system allows plant operators and asset managers to assess tracker heath and performance on a row-by-row basis. This granular O&M information expedites power plant restoration and remediation activities.

"Predictive analytics has a big role to play in getting customers to 100% uptime," says Gopinath. "We can use predictive analytics to identify impending failures and bring these to the attention of asset managers or O&M providers. Because we are able to communicate with every tracker, we know the location of any issues as well as the probable failure mode and remedy. This information can then inform maintenance activities, which is important for optimizing energy capture and mitigating extreme weather risk."

"One thing that sets Nextracker apart is that it goes to great lengths to understand the large losses and issues facing insurers."

—Brian Tyluki,
SVP and Senior Underwriter, GCube

COME RAIN OR SHINE

For insurers, locational risk factors into every peril analysis and policy. Location-specific natural catastrophe coverages account for the relatively higher risk of earthquakes in California or hurricanes in Florida. These policy responses to site- or region-specific risk profiles are premised on the ready availability of historical loss data, which enables the insurance industry to assess locational risks and price or qualify coverage accordingly. This type of information is less available for relatively new asset classes that are fielded in underdeveloped locations.

"Solar is somewhat unique from a risk assessment perspective," says GCube's Tyluki. "Relative to other types of power generation, solar is a fast-growing, emerging asset class based on newer technology. By comparison, traditional power generation facilities are subjected to considerably more due diligence, have larger operating budgets and a more mature supply chain, and are more easily characterized using historic data."

As a nascent subsector within the power and energy sector, large utility-scale solar projects are every bit as challenging for insurers as they are for project developers and owners. For an accurate statistical evaluation, insurers require access to large amounts of operational and loss history data for asset risk assessment and pricing. Compared to other large capital investments in power and energy, loss history data is generally insufficient—based on the limited length of time in the field—for insurers to confidently assess solar project risk.

"Power generation in North America has been a poor-performing market sector," says Tyluki. "This is largely due to the impacts of catastrophic events, which are not limited to traditional natural disaster categories—such as hurricanes and floods—but also include wildfires and extreme hail. In addition to belonging to a poor-performing insurance market sector, solar carries relatively more uncertainty in terms of risk assessment. Solar projects are constantly growing in size and being developed in new regions or in parts of the country where you would never find a traditional plant. It is very difficult to characterize risk for locations—such as flood plains—where there is no history of development."

When an airplane goes down, data stored on the flight recorder—the so-called "black box"—provides a record from which accident investigators can learn. The final report, published upon completion of the investigation, provides a public record of the event complete with safety recommendations. The transparency and dialogue associated with this process ultimately benefit all stakeholder groups.

Solar project failures are a different sort of black box. When solar farms are brought down by premature product failures or catastrophic weather losses, the root causes are often hidden behind NDAs due to concerns about intellectual property or reputation. Extensive due diligence is the best way to overcome this opacity and lack of transparency.

Cherif Kedir, president and CEO of RETC, points out that, "Some regions of the continental United States currently experiencing the most growth in solar development—such as Texas, Florida, Georgia, and the Midwest—are notorious for hurricanes, strong thunderstorms, hailstorms, or tornados. As more utility-scale solar projects are deployed in these emerging markets, new project sites are at higher risk. This is why it is important to design and install solar projects using products that mitigate the risks associated with not only high winds but also the hail and flooding that often accompany extreme weather events."

Risk Versus Reward While fielding increasing numbers of ever-larger solar projects across challenging locations is not without risk, those industry stakeholders who successfully mitigate site-specific extreme weather risks via strategic product specification stand to reap great rewards. For many of the locations around the world where large utility-scale solar project development activities are now taking place, climate and weather risks are not only a fact of life but also are intensifying over time.

In this context, there is no greater project risk than the indiscriminate belief in one-size-fits-all solutions, which stems in part from the flawed notion that increasing project and market scale invariably leads to commoditization. Reliable in-field operation over a 25- to 40-year service life is not a coincidence. In Part 2 of *Mitigating Extreme Weather Risk,* we illustrate the extent to which—and explain why—solar power plants that appear similar on paper can present very different risk profiles in the real world.

In Part 1 of this two-part white paper, we have demonstrated how intelligently controlled independent-row single-axis trackers can mitigate site-specific risks associated with a variety of severe weather categories. In Part 2, we will demonstrate how differentiated design and control strategies can mitigate risks associated with high-wind conditions and dynamic-wind effects, which are a leading cause of PV power plant production losses and damage claims.

PERFORMANCE OPTIMIZATION Nextracker's patented smart panel sensors provide real-time shading information for each tracker row. This data feeds into TrueCapture, an intelligent monitoring and model-based predictive control software that allows Nextracker customers to maximize system performance benefits. These same smart monitoring and granular control strategies also mitigate performance risks associated with climate and weather, such as optimizing plant production during smoky conditions.

About the Authors

Alex Roedel is the Senior Director of Design and Engineering at Nextracker. With over 15 years in the solar industry leading design and engineering for Fortune 1000 companies such as SunPower and SPG Solar, Alex is responsible for the design and engineering of over 40 GWs of installed projects. He leads a global team of design engineers and is the company's customer-facing technical lead with developers and EPCs worldwide. Alex earned his B.S. in mechanical engineering from the University of California, Santa Barbara.

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Nextracker, a Flex company, is a leader in the energy transition, providing critical yield enhancing PV system technology, expertise and strategic services to capture the full value and maximize the efficiency of solar plants. Delivering the most comprehensive portfolio of intelligent solar tracker and control software solutions for solar power plants, Nextracker is transforming PV plant performance with smart technology, data monitoring and analysis services.

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