Applying Advanced Wind and Precipitation Sensing to Improve Solar Plant Weather Data Reliability and O&M Decisions

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Introduction

Every PV performance model is only as good as the weather data it ingests. Wind measurement gaps and biases cascade into unnecessary tracker stows and inflated uncertainty in yield predictions — a site- and technology-specific loss whose magnitude depends directly on the consistency of on-site wind data[1]. Incomplete precipitation records undermine soiling-loss estimates, one of the largest unresolved loss categories in performance modeling, and weaken the ground-truth basis for post-event forensics. At utility-scale sites, conventional anemometers and rain gauges are often the weakest link in this measurement chain: moving parts degrade, catchment gauges undercatch in wind, and silent failures concentrate during the very conditions that drive the largest modeling errors. This poster presents two sensing approaches designed to close that gap across the full plant lifecycle: a six-path ultrasonic wind sensor with signal-focusing reflectors, and a 61 GHz narrow-beam radar precipitation sensor.

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[1] Darawali, Tafur, Benson, "Advanced Solar PV Energy Pre-Construction Losses; Losses due to uneven terrain, tracker wind stowing, and sub-hourly clipping error," UL Solutions, PVPMC 2022.

WINDCAP® Ultrasonic Wind Sensor WM80

Problems with current anemometers

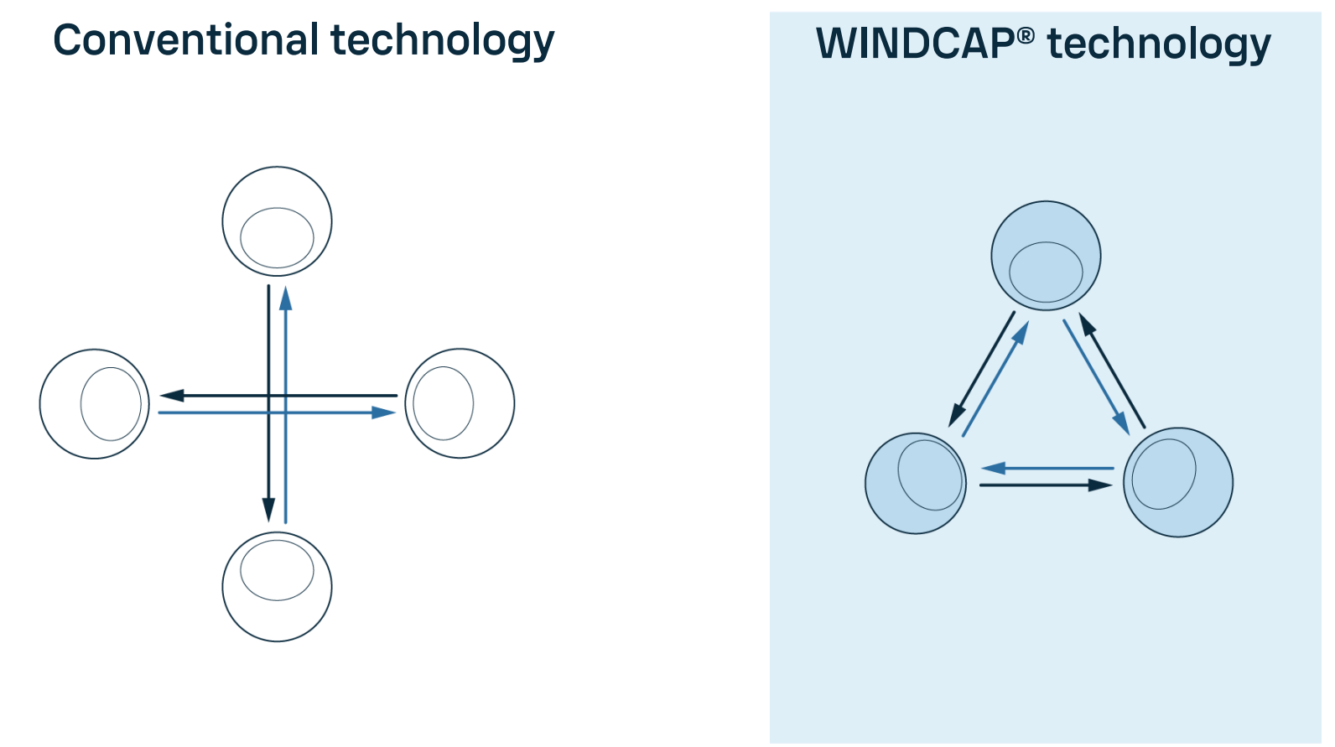
Tracker control, stow decisions and performance analytics rely on continuous wind data — yet conventional anemometers introduce gaps and errors exactly when they matter most.

- Mechanical cup-and-vane sensors degrade through bearing wear, corrosion and icing, and require periodic recalibration
- Conventional 4-transducer / 4-path ultrasonics have directional blind spots and can lose signal in heavy rain, dust, and at high wind speeds

Six-path ultrasonic measurement using three transducers

A three-transducer arrangement in an equilateral triangle lets each pair exchange ultrasonic signals in both directions, forming six independent measurement paths instead of the four used in conventional designs.

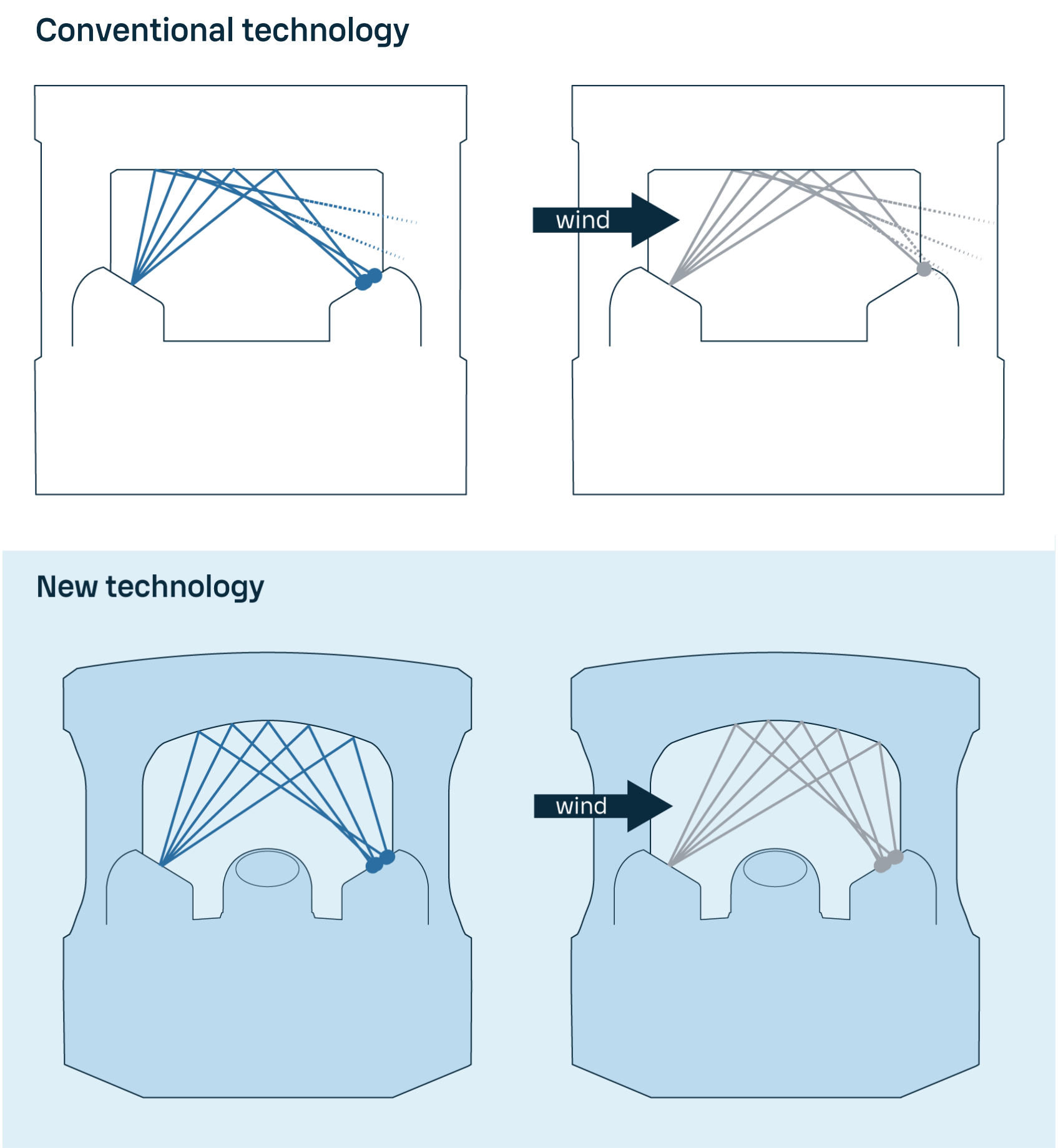
- 50% more measurement paths capture wind information that conventional layouts miss
- Built-in redundancy: accurate readings can still be reconstructed when individual paths are momentarily disturbed or blocked
- No directional blind spots — consistent accuracy across all wind directions, improving robustness in turbulent and disturbed flow typical at solar sites



Signal-focusing reflector design

Concave-shaped reflectors focus the ultrasonic signal onto the transducers, replacing the flat surfaces used in conventional ultrasonic anemometers.

- Up to 10× higher signal-to-noise ratio compared with conventional flat-top arrangements
- Reflector geometry maintains optimal focus across the full wind-speed range, validated up to 90 m/s
- Stronger signal preserves measurement quality through heavy rain, dust, sand and hail. The closed top also shields the transducers from direct exposure and reduces fouling



Conclusions

Combining six-path measurement with signal-focusing reflectors produces wind data that remain reliable in the harshest conditions a PV plant encounters.

- High data availability through icing, dust, rain, and extreme wind events
- No moving parts — zero recalibration and minimal O&M over the plant lifetime
- More dependable input to tracker control and stow logic — fewer false stows, better protection against structural damage
- Reduces weather-related uncertainty in performance analytics and supports better, evidence-based O&M decisions

WM80 Datasheet
www.vaisala.com/WM80

PRECICAP® Radar Precipitation Sensor RM60

Problems with current rain gauges

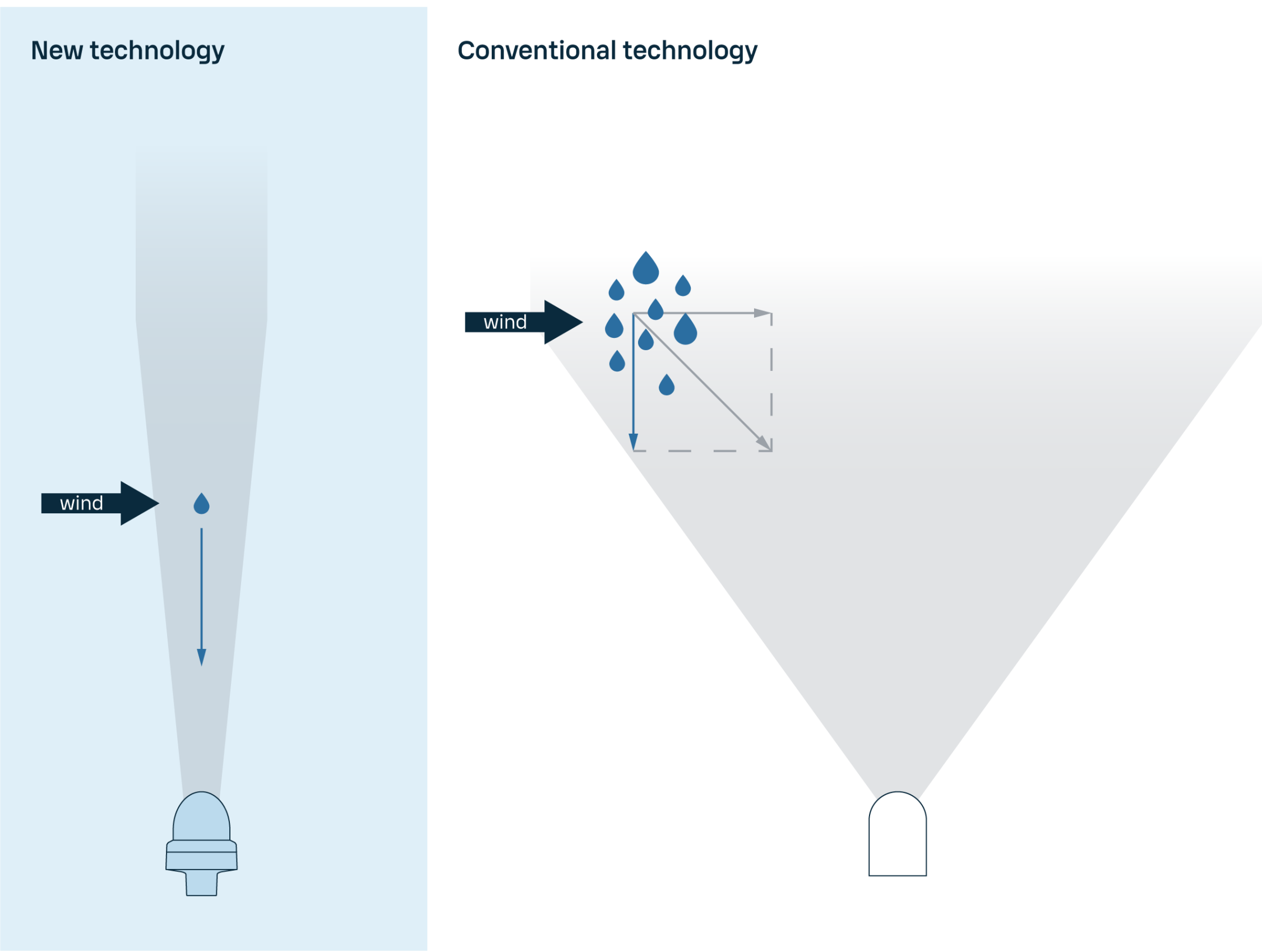
Conventional gauges impose a permanent maintenance burden on every station and leave the largest data gaps during the events that matter most for solar O&M.

- Tipping-bucket and weighing gauges require routine cleaning, calibration, and sometimes heating
- Wind-induced undercatch is the dominant systematic error and grows with wind speed; mitigation requires shields, fences, or pit installations
- Clogging, mechanical jams, and delayed servicing produce silent failures, often during heavy events

Narrow-beam radar geometry

Patented PRECICAP Doppler radar technology employs a vertical narrow-beam geometry, directing a focused radar beam straight upward so that hydrometeors are measured as they fall through a confined measurement volume directly above the instrument.

- This vertical orientation ensures that particles traverse the beam regardless of wind speed or direction, structurally decoupling the measurement from wind-induced errors
- Because the beam geometry itself provides wind resilience, no ancillary infrastructure such as wind shields, fencing structures, or purpose-built pits is required



Near-field measurement with 61 GHz frequency

The near-field measurement allows for stronger returning radar signals and eliminates disturbances from nearby moving objects

- Individual hydrometeors are detected and identified, with each particle encoding both a size and a Doppler-derived fall velocity information
- Sensitivity extends down to the lightest drizzle — a known weakness of 24 GHz and tipping-bucket approaches
- Intensity, accumulation, type (rain, drizzle, snow, hail), drop size distribution, and reflectivity factor are derived from the same physical measurement
- Classification is based on single hydrometeor physics rather than estimation based on bulk-signals of the rain mass

Autocalibration

The sensor continuously verifies its measurement performance against the known physical properties of real hydrometeors — drop shapes, fall velocities, and the dielectric constant of water — during precipitation events.

- Echo-power normalization is traceable to SI base units (length defining the measurement volume, time defining frequency) and to physical constants of water and raindrops
- No periodic manual calibration is required, and no calibration drift accumulates over the service life
- Embedded self-diagnostics flag anomalies rather than letting data degrade silently

Conclusions

Vertical narrow-beam geometry, near-field 61 GHz Doppler measurement, and autocalibration together deliver continuous, physically traceable precipitation data across the full lifecycle of a utility-scale PV plant.

- No collection surface, no moving parts, no heating — eliminating routine cleaning and scheduled maintenance across the site
- Reliable detection from drizzle to heavy rain to hail, including true drop size distributions — supporting soiling analytics, hail damage forensics and rapid response to severe-weather events
- Ground-truth data cuts weather-related uncertainty in PV performance modeling and supports better, evidence-based O&M decisions

Note: The first release reports true drop size distribution across 22 size classes for liquid precipitation and detects and reports hail as a precipitation type. Hail size distribution is on the roadmap.

RM60 Datasheet
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