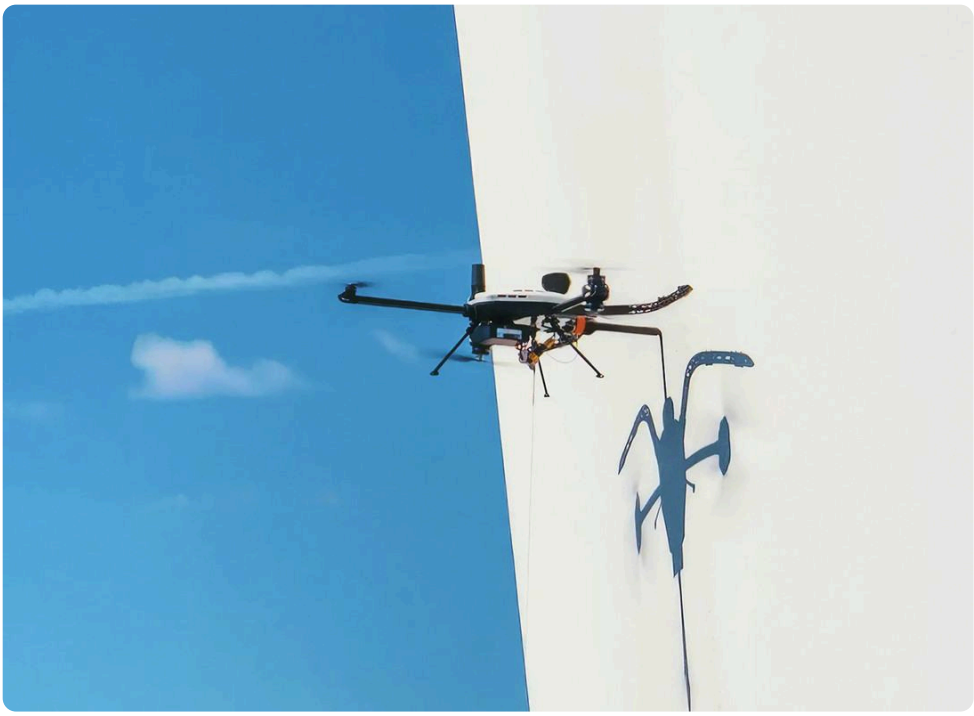
VOLIRO

Voliro T
Wind turbine LPS inspection guide



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Wind turbines can suffer damage from lightning strikes. Regular maintenance and inspections of the Lightning Protection System (LPS) are vital to ensure it continues to protect turbines effectively.

The LPS Pro tester runs 2 methods in 1 single solution: 🔵 Low Voltage (LV) resistance measurements give a precise resistance value of the LPS path. 🟠 High Voltage (HV) inspections verify continuity and provide a breakthrough voltage measurement.

You can inspect Enercon and Vestas without bridging spark gaps using the HV measurement method as well as take measurements on coated receptors.



Efficient LPS inspection data collection with minimal turbine downtime

While eliminating the need for human access to difficult-to-reach areas, Voliro drones make inspections safer, faster and more cost-effective.

Advantages of Voliro’s drone-enabled LPS inspections:

Inspect every turbine
Low Voltage (LV) + High Voltage (HV) together cover 100% of turbines, including Enercon, thick-coated Nordex and Vestas LCTU units. A tool set that complies with all manufacturer requirements.

Confidence no one else has
HV breakthrough-voltage measurement confirms real defects and rules out false positives on open-circuit readings.

10x faster inspections
Drone inspections typically take 20 to 30 minutes per turbine, reducing downtime and operational costs.

No manual bridging
HV bridges LPS spark gaps electrically, so turbines that once required a technician in the nacelle can now be inspected without anyone climbing.

Auto LV-to-HV switching
The Voliro T takes the LV reading first. If it isn’t valid, the drone switches to HV at the same receptor on its own. The mode can be turned off to prioritize one inspection type.

Small crew operation
A single pilot can run the workflow, with optional technician support.

Manufacturer and standards-compliant
Follows IEC/EN 61400-24 and meets the HV testing that manufacturers like Enercon require.



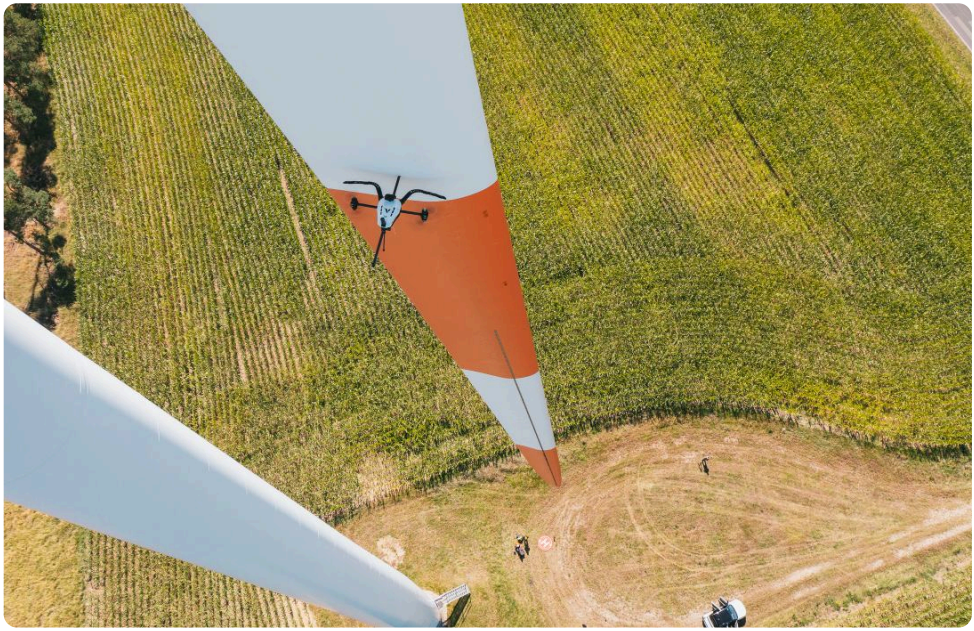


Voliro LPS inspection solution

- LV 4-wire resistance measurement and HV breakthrough-voltage measurement.
- One-person operation with optional technician support.
- Single and multi rotor stop supported.*
- No access to the hub or nacelle required with LPS Pro. **Including turbines that previously needed manual spark-gap / LCTU bridging, can now be bridged electrically by HV.****
- Two methods, one system. **LV and HV run from the same ground station.** HV is part of the LPS Pro upgrade any Voliro T operator can unlock when they need it.

* Depending on wind speed the most efficient method is chosen — see "LPS inspection mission variables" on page 24.

** Requirements must be discussed with the asset owner. Spark gap bridging might still be required.



Low voltage (LV) vs high voltage (HV)

The LV measurement is the 4-wire resistance inspection. The ground station's microohmmeter pushes 300 mA through the LPS and measures resistance down to milliohms — a direct, precise reading of the conductor's health. Take LV whenever possible; it gives the clearest quantitative result.

Not all LPS have a continuous path by design. That's why Voliro provides HV. Instead of measuring resistance, the system ramps voltage (from ~50 V up to a target of ~15 kV) until spark gaps or discontinuities are bridged and current flows. The result is a breakthrough voltage, not a resistance. High voltage can also be used, when agreed with the asset owner, to avoid spark gap bridging — this makes missions drastically more efficient.

	Low Voltage (LV)	High Voltage (HV)
Question answered	How good is the path?	Is the path there, and at what voltage does it conduct?
Result type	Resistance (Ω)	Breakthrough voltage (V)
Tool	4-wire microohmmeter	High-voltage continuity tester
Best for	Coating-pierceable receptors, continuous LPS designs	Thick coatings, spark gaps, discontinuous LPS designs

LV tells you how good the path is. HV tells you whether the path is there, and at what voltage it starts conducting.

The three inspection modes

🔵 Low Voltage only (LV)

A 4-wire resistance measurement at every receptor, so the reading reflects only the LPS path.

🔵🔴 Auto LPS mode (LV + HV)

The drone takes an LV measurement first. If the LV result isn't valid, the Voliro T automatically switches to HV at the same receptor.

🔴 High Voltage only (HV)

The whole mission runs on high voltage. Choose this when the turbine has discontinuities in its LPS, or when a spark gap must be bridged and running HV throughout is faster than bridging manually.

Note: Agree with the customer upfront
Whether HV continuity measurements are satisfactory for all receptors, or whether HV should only be used where LV measurements are not satisfactory.

Wind turbines and conditions unlocked by HV LPS

HV unlocks turbines that LV alone cannot serve.

Turbine / condition	● Why HV is needed
Enercon	Requires HV; LV does not work — discontinuities are built into the blades
Coated receptors	Thick blade coatings make LV readings hard; HV gets a reading anyway
Vestas (LCTU)	The LCTU often needs to be bridged in the nacelle; HV enables inspection without a technician in the nacelle
Open circuits	When the microohmmeter reads no value, HV confirms whether the defect is real — ruling out false positives

Voliro equipment

1. Voliro T

Wind resistance	8 m/s / 17 mph for contact, 12 m/s / 26 mph for free flight
Temperature	−10 to 40 °C / 14 to 104 °F
Precipitation	Dry weather operation only; no rain, no snowfall
Fog	No operation in fog
Payload	Needle probe payload

2. Needle probe payload

3. LPS Ground Station

Tether length	180 m / 590 ft, optionally 250 m / 820 ft
Grounding cable	50 m / 164 ft
Resistance Measurement Unit	
Method	4-wire measurement
Measurement current	0.30 A (for resistances < 20 Ω)
Measurement range	0.001 Ω to 1000 Ω
Resolution	0.01 mΩ
Voltage range	0 V to 26 V
Compliant with	IEC/EN 61400-24 standards
Continuity Measurement Unit	
Method	High-voltage breakthrough
Use case	Discontinuities, LCTU, Enercon
Voltage range	0 V to 15,000 V

1.



2.



3.



Inspection workflow

Step 1: Equipment and wind turbine setup

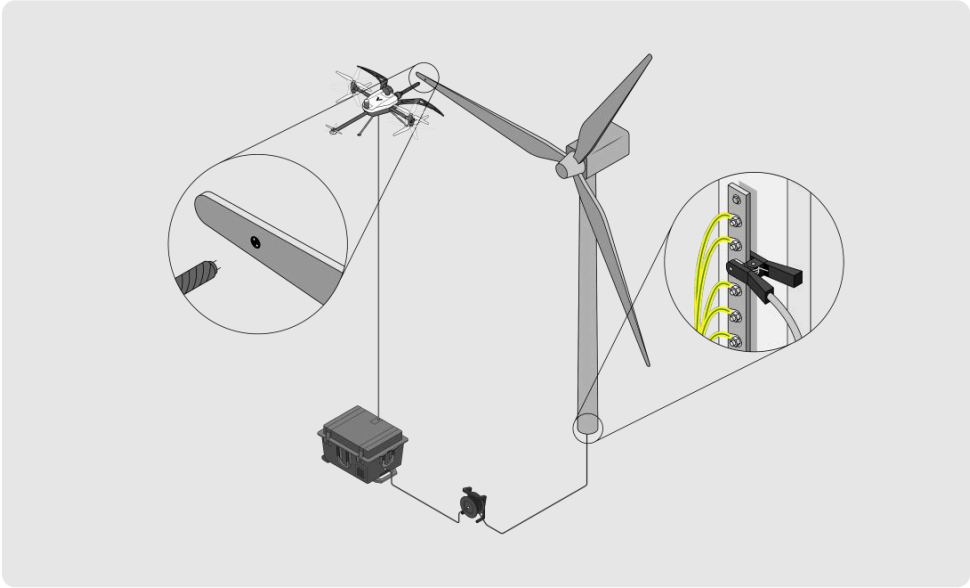
Step 2: Inspect

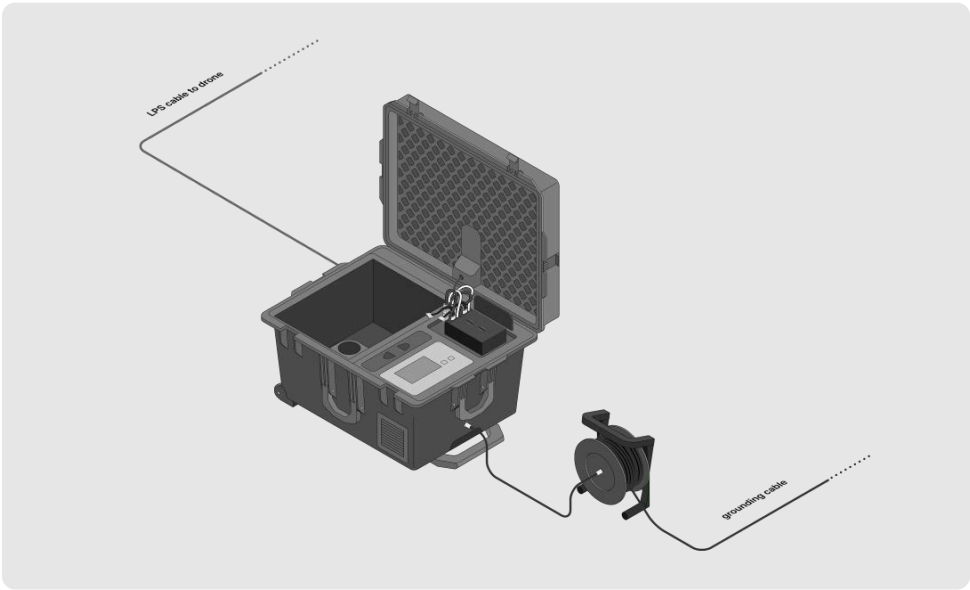
Step 3: Report

Step 1: Equipment and wind turbine setup

Equipment setup

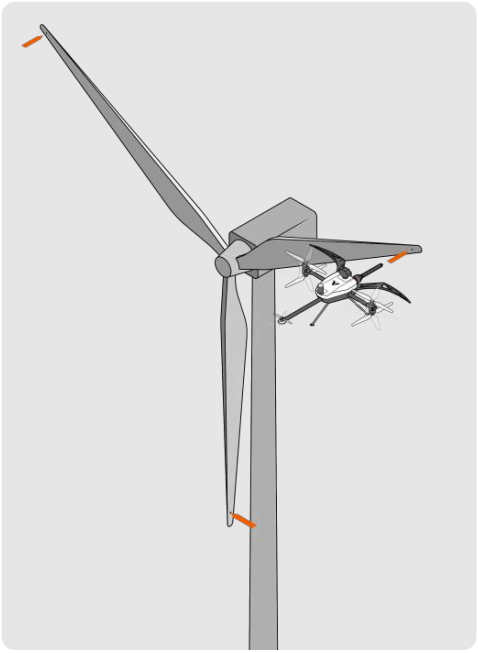
- Place the LPS Ground Station 20–30 m (65–98 ft) in front of the turbine tower.
- Connect the grounding cable to a grounded point at the turbine base.
- Connect the grounding cable to the Ground Station.
- Assemble the Voliro T and attach the LPS payload and cable to the drone.
- The Ground Station runs on Voliro T batteries. One set usually lasts a full day of inspections.
- HV is built into this same ground station; no additional hardware is required when HV is unlocked.





Above: Complete turbine setup showing grounding and drone connections.
Below: Detail of the LPS Ground Station and cable connections.

Wind turbine setup



A: One-stop inspection:
Rotor in the Y position; blades not in the 6 or 12 o'clock position are pitched to 0°. At low wind speeds (below 6 m/s) this is the fastest mode — the drone inspects all blades in a single flight.



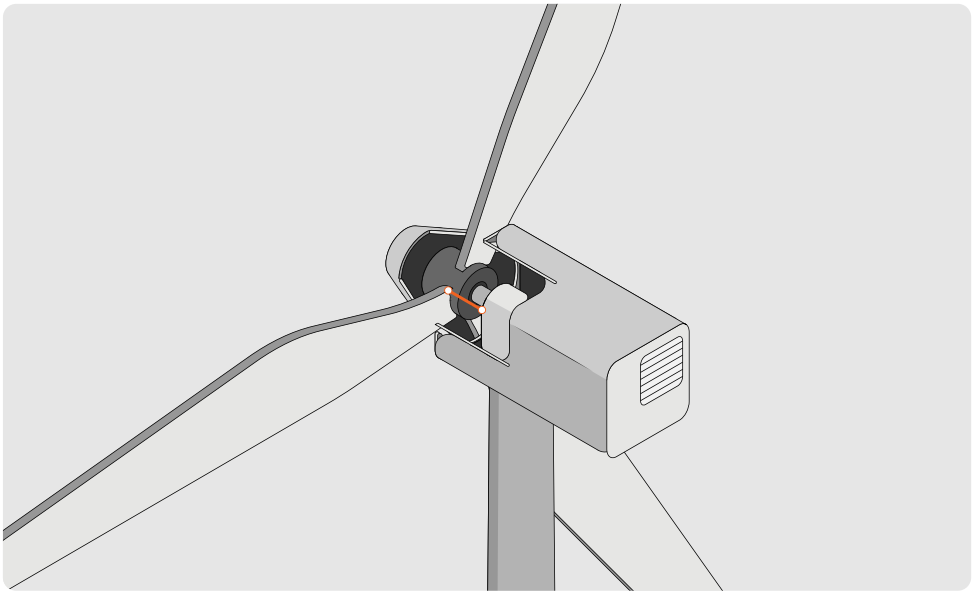
B: Three-stop inspection:
Inspect each blade in the 6 o'clock position, keeping the rotor facing the wind (keep the yaw angle). Safer at higher wind speeds; blades are repositioned twice, no blade pitching required.

Note: Which mode?
Depending on wind speed the most efficient method is chosen. See "LPS inspection mission variables" on page 24 for the full complexity picture.

Spark gap bridging

LV inspection requires continuity of the LPS from the blade to the bottom of the tower. Some turbines have a discontinuity where the hub meets the nacelle.

Manual jumper cable (● Low Voltage – LV)
A technician accesses the hub and installs a jumper cable between an accessible LPS point on the blade and one in the hub or nacelle, usually one blade at a time. Resistance measurements are only possible once the gap is bridged this way. Typically each blade is bridged in the 6 o'clock position; use 3 or 9 o'clock if the turbine design requires it.



Bridged electrically — no climb (● High Voltage – HV)
HV bridges the spark gap electrically, so no technician enters the nacelle. Use it for turbines that can't be bridged, or when faster operation is prioritised. Running HV removes the manual climb entirely.

Step 2: Inspect

Flight and alignment

- Fly in Visual Line of Sight (VLOS) until near the turbine blade.
- The Ground Station automatically reels the tether in and out, keeping it taut.
- Switch to FPV camera for the final approach; built-in sensors assist alignment.
- Use autonomous interaction mode (AIM) to establish and hold contact with the LPS receptor.



AIM - Autonomous Interaction Mode

Autonomous Interaction Mode (AIM) lets the Voliro T automatically detect, track, and make contact with wind turbine LPS receptors through its computer vision camera — without the operator manually steering the final approach.The operator flies the drone to the general area of the target; when they activate AIM, the drone takes over the precision approach and contact.

AIM is designed to make precise receptor contact faster and more repeatable. It lowers the skill required to reliably hit small LPS targets in challenging conditions (wind, distance, lighting), reduces re-flights from missed contact points, and produces more consistent inspection data.

The operator always stays in command: AIM only runs while the interaction button is held, and releasing it or any other pilot stick input immediately stops all autonomous motion.



LV measurement — resistance

- Both the grounding cable and drone tether carry 2 phases, enabling a 4-wire resistance measurement (IEC 61400-24 compliant).
- This captures only the resistance from the contact point on the blade to the grounding clamp at the tower base.
- A certified third-party ohmmeter pushes 300 mA and measures the resistance.
- Data is sent to the drone and stored on the on-board computer and redundantly on the ohmmeter; each measurement is linked to the correct receptor through Voliro's mission plan.
- Measurements can be verified in real time on the control tablets.

HV measurement — breakthrough voltage

The Voliro GS ramps the test voltage from ~50 V upward and records the **breakthrough voltage**, the point where current begins to flow.

- Use HV where LV can't read: discontinuities, spark gaps, thick coatings, or to confirm an open circuit.
- In Auto LPS mode the drone switches to HV automatically while in contact — no repositioning. Fully integrated in the Voliro system, fuses in the report together with LV measurements
- The energy released is very low and won't damage turbine electronics.

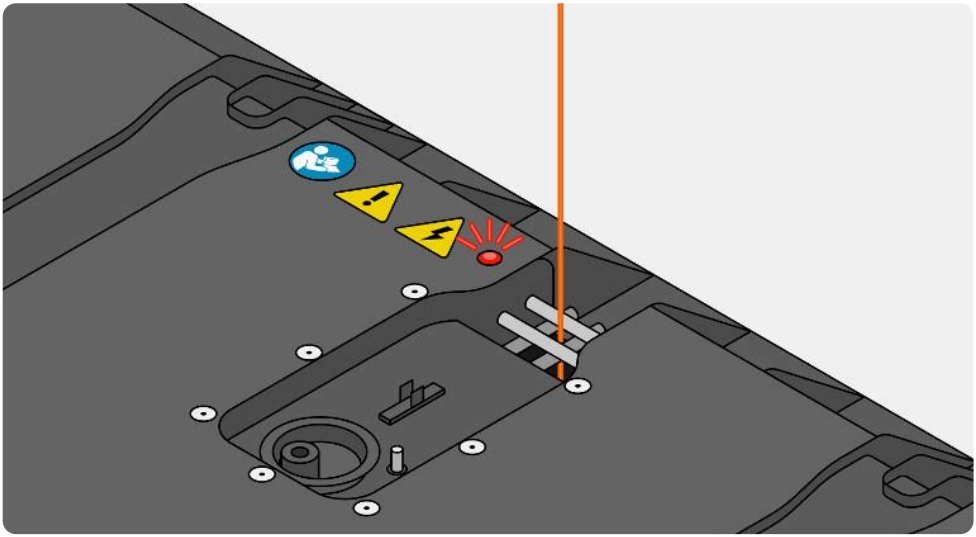
Safety considerations

Although 15 kV sounds dangerous, it is inherently safe in this system. The LPS Ground Station cannot deliver high current, so the released energy remains low.

Stored energy stays around 0.12 J at 15 kV, well below the 0.2 J UNECE threshold for what counts as non-hazardous to touch. Continuous current is below 200 µA, under the human perception threshold (IEC 60479-1).

Nevertheless, **the operator must not touch the high-voltage power source during operation.** Safety layers help prevent this:

- The control app shows an on-screen warning during the HV measurement.
- An LED on the box lid blinks when the line is live. It is hardwired to trip above 50 V.
- HV only runs with the lid closed and the drone armed, and the system self-discharges in under 3 seconds.



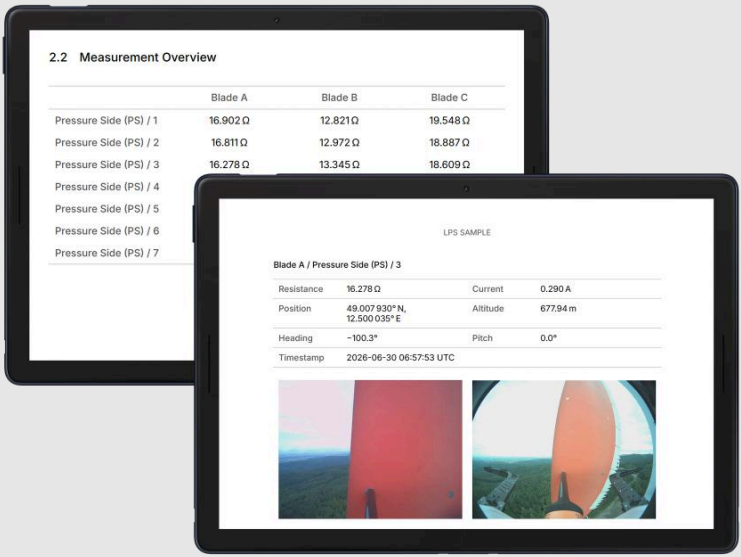
An LED on the box lid blinks when the line is live.

Step 3: Report

- Mission data is automatically uploaded to the Voliro Cloud through 5G, WiFi, or through an SD card if necessary.
- Data can be cleaned up in the cloud if necessary and a report can be auto generated.
- Alternatively, export as CSV and JSON for third-party tools or custom reports.

LV + HV results

Preferred values: lowest valid resistance for LV; lowest breakthrough voltage for HV. The HV value only becomes the headline number when no valid LV measurement exists for that point.

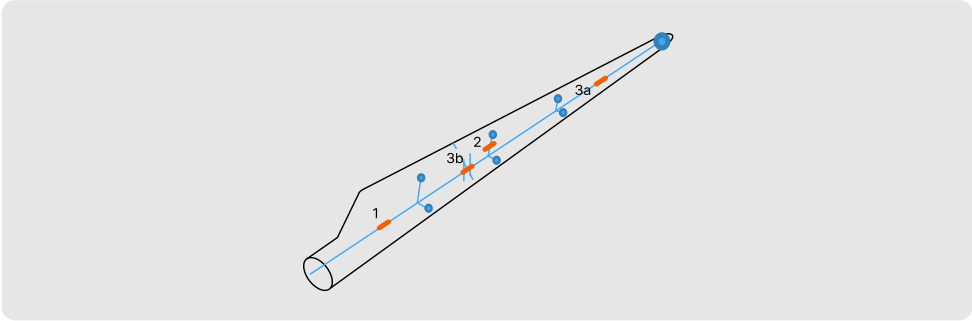


Preview of the auto-generated PDF inspection report. Both views are included in one single report.

Data interpretation

Receptor states reveal LPS integrity. Different defect patterns point to different failure modes.

Result	Interpretation
All receptors disconnected on one blade	Defect at the blade root, or in the hub / nacelle
A single receptor disconnected	That individual receptor is disconnected
Multiple receptors disconnected	Damage within the down conductor — e.g. between receptor pairs, or at the joint of two blade parts



LV resistance interpretation

Resistance interpretation should be defined by the manufacturer. If unavailable the German Bundesverband WindEnergie provides the following guidelines:

Result	Interpretation
0–1 Ω	LPS is in a good state
1–10 Ω	LPS needs to be monitored
>10 Ω or no connection / open circuit	Followup inspection recommended

This table applies to LV results only. HV reports a breakthrough voltage, not a resistance.

LPS inspection mission variables

The following table categorizes the complexity of missions undertaken with the Voliro T drone for Lightning Protection System (LPS) inspections of wind turbines. The complexity is determined by several factors, including nacelle access requirements, wind speed, turbine location, number of receptors, and receptor type. This criteria should influence how to quote inspection services.

Factor	Low	Medium	High
Nacelle access / bridging	LV: not required HV: bridged automatically	LV: bridging required	LV: bridging required
Wind speed	<5 m/s	5-8 m/s	8 m/s, gusty
Number of receptors per blade	2	4-6*	8-16*
Location	Onshore		Offshore
Receptor type	Metal tip	Standard receptor plug	Bulb, Tip winglet
Team	Highly experienced pilot + assistant	Medium experienced pilot	Low experienced pilot

* Optionally, if agreed upon with the customer, inspect the 2 receptors closest to the tip, and only inspect the rest if defects are found on those 2, as defined by the OEM.

Mission examples

Representative mission examples from actual Voliro T operations. Illustrative only; they do not represent the full operational capacity of the technology.

Mission Complexity	Low	Medium	High
Country	United States	Austria	Germany
Turbine model	GE 2.82-127	V150/4200	SWT-6.0-154
Nacelle access/ bridging	Not required	LV: required HV: not required	Not required
Wind speed	5 m/s	6 m/s	7-8 m/s
Numbers of receptors per blade	2	8	10
Location	Onshore	Onshore	Offshore
Receptor type	Standard receptor plug	Standard receptor plug	Standard receptor plug
Time per turbine incl. setup	20-30 min	30-60 min	60 min +
Team	Highly experienced pilot	Medium experienced pilot	Highly experienced pilot + assistant

* Inspection speed is reduced if defects in the LPS are found, and if the mission is a proof of concept or product demonstration.

Inspected wind turbines models

The following list provides an overview of wind turbine models that have been successfully inspected using the Voliro T for Lightning Protection System (LPS) assessments. The model list is not exhaustive — inspection can be extended to additional models on request.

- ● Low Voltage (LV)
- ●* Low Voltage (LV) + spark gap bridging required
- ●** Low Voltage (LV), coated receptors might not be possible
- ● High Voltage (HV)

Acciona ●
AW-1500/77
AW-1500/82
AW-3000/116
AW-3000/125
AW-3150/125

Alstom ●
ECO 86
ECO 122

Bonus ●
B62/1300

DeWind ●
D6/1250

Enercon ●
E-40/500
E-40/600
E-48/800
E-53/800
E-58/1000
E-66/1800
E-70/2000
E-70/2300
E-82/2000
E-82/2300
E-92/2350
E-101/3050
E-103/2350
E-115/3000
E-115/3170
E-138/4200
E-141/4200
E-175/7000

Fuhrländer ●
FL 2500/90

Gamesa ●* ●
G52/850
G80/2000
G87/2000
G90/2000
G114/2000
G114/2500
G132/3450

GE Vernova ●
GE 1.5sle
GE 1.6-100
GE 1.7-100
GE 1.85-87
GE 2.3-116
GE 2.5-116
GE 2.5-120
GE 2.5-127
GE 2.52-116
GE 2.7-116
GE 2.72-116
GE 2.75-120
GE 2.8-127
GE 3.2-103
GE 3.4-137
GE 3.4-140
GE 3.6-137
GE 4.0-137
GE 4.8-158
GE 5.3-158
GE 5.5-158
Haliade-X 12MW

HSW ●
HSW 1000

IMPSA ●
IV-77/1500

NEG Micon ●
NM52/900
NM54/950
NM64c/1500
NM72/1500
NM82/1500

Nordex ●** ●
N60/1300
N90/2300
N90/2500

N100/2500
N117/2400
N117/3000
N117/3600
N131/3000
N131/3600
N133/4800
N149/4000
N149/4500
N149/4800
N155/4500
N155/4800
N163/5900
N163/6250
N163/6800

Samsung ●
Samsung 25x

Senvion ●
MD77/1500
MM82/2050
MM92/2050
MM100/2000
3.0M122
3.2M114
3.4M104
3.4M114
6.2M126

Siemens / Siemens Gamesa ●
SWT-2.3-93
SWT-2.3-101
SWT-2.3-108
SWT-2.3-113
SWT-2.5-108
SWT-2.6-120
SWT-3.0-101
SWT-3.2-113
SWT-3.6-107
SWT-6.0-154
SG 2.0-114
SG 2.1-114
SG 2.6-114
SG 2.625-120
SG 2.9-129
SG 4.8-145
SG 6.2-170

Südwind ●
S70/1500

Suzlon ●
S88/2100

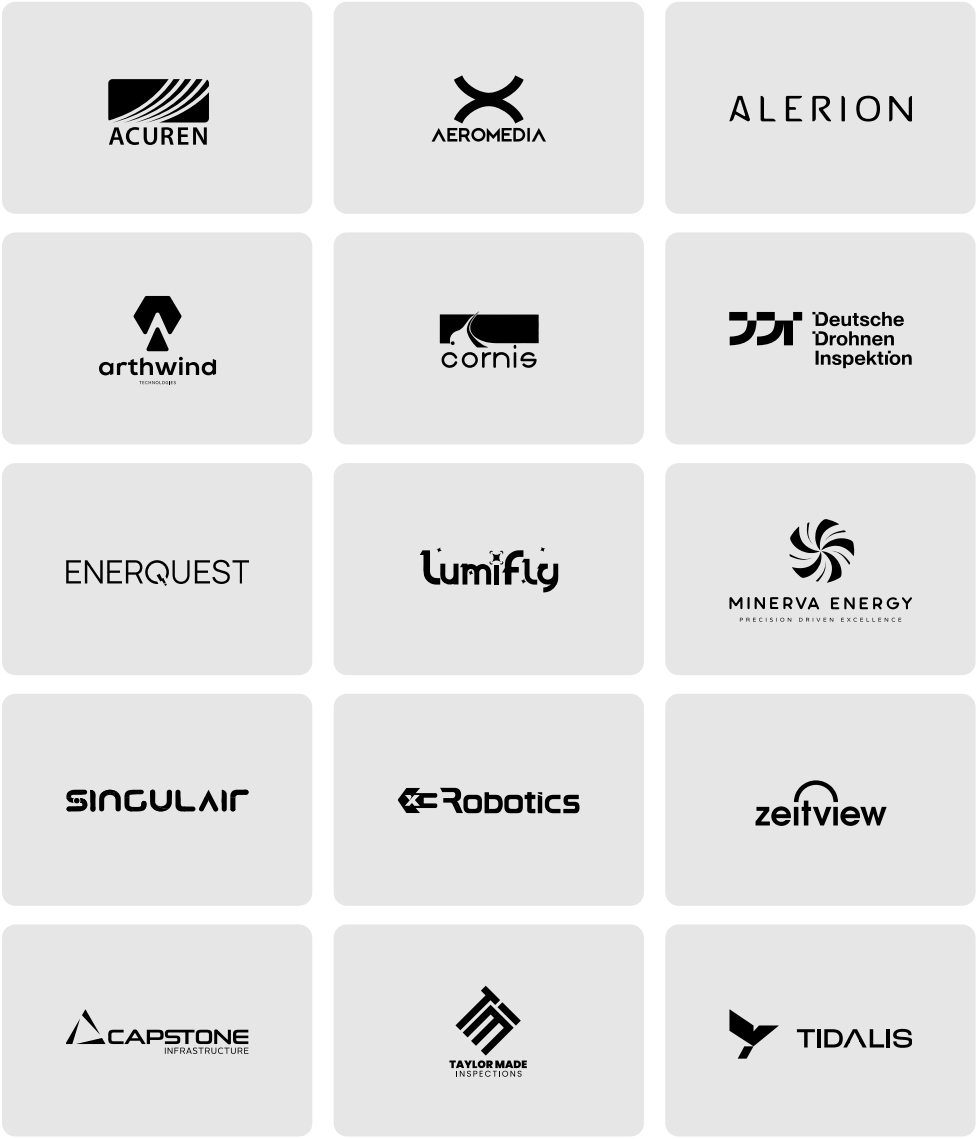
Tacke ●
TW600

Vensys ●
77/1500

Vestas ●* ●
V47/660
V52/850
V80/1800
V80/2000
V90/2000
V90/3000
V100/1800
V100/2000
V100/2200
V110/2000
V110/2200
V112/3000
V112/3300
V112/3450
V117/3300
V117/3450
V117/3600
V117/4300
V120/2200
V126/3300
V126/3450
V126/3800
V136/3450
V136/3700
V136/4200
V150/4000
V150/4200
V150/4300
V150/4500
V162/6000
V162/6200
V163/4500

WEG ●
AGW 110/2.1
AGW 147/4.2

Trusted by leading companies



LPS inspections done by the Voliro T around the world



Argentina
Australia
Austria
Belgium
Brazil
Canada
Chile
Croatia
Denmark
England
Finland
France
Germany
Indonesia
Ireland
Italy
Luxemburg
Netherlands
Norway
Poland
Portugal
Romania
Scotland
Spain
Sweden
Switzerland
Thailand
United Kingdom
United States
Uruguay
Wales

Operator discovery questions for Voliro LPS inspections

1. Turbine specifications

- Turbine OEM and model?
- Is there continuity of the LPS inside the wind turbine or is there a spark gap inside the hub or nacelle which needs to be bridged? If so is high voltage an option?
- What is the number of LPS receptors per blade?
  - Shall every receptor be inspected or inspect the tip ones and only in case of detected defects inspect all receptors?
  - Do the blades have any non standard receptor types?
  - Are any LPS receptors painted / coated?

2. Operating procedure

- Turbine control
  - Can each blade be pitched separately?
  - What is the technician availability from the client during the inspection to control the turbine?
- Shall the ground wire for the measurement be connected to a specific grounded point in the base of the turbine or any grounded point?

3. Measurement interpretation

- Any specific requirements from the turbine OEM?
- Shall the recommendation from the German Bundesverband Windenergie (BWE) be used?
- Are HV measurements acceptable to avoid bridging?

The German Bundesverband WindEnergie guidelines state:

Result	Interpretation
0–1 Ω	LPS is in a good state
1–10 Ω	LPS needs to be monitored
>10 Ω or no connection / open circuit	Followup inspection recommended



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