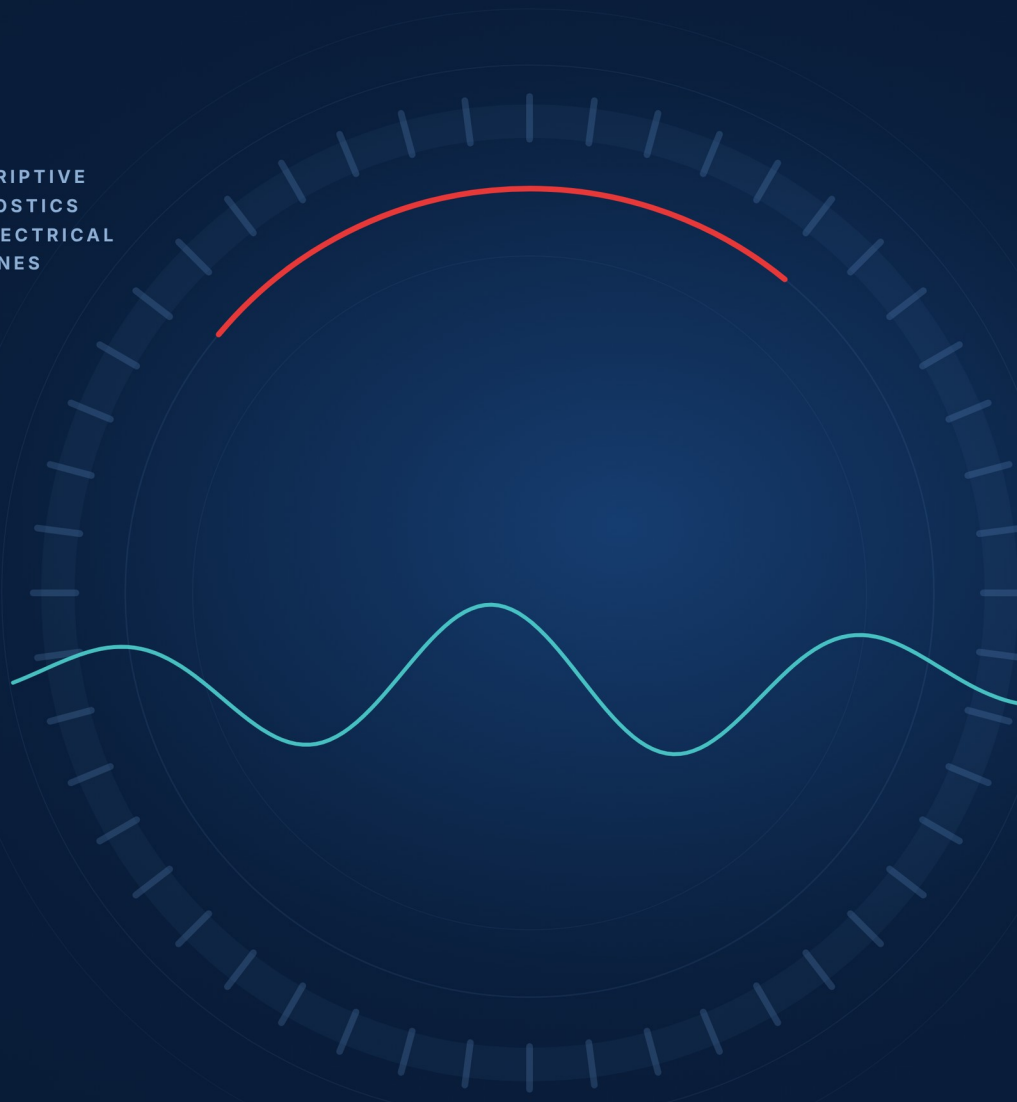
DILIGENS
REPORT

PRESCRIPTIVE
DIAGNOSTICS
FOR ELECTRICAL
MACHINES



DILIGENS DIAGNOSTIC REPORT · DGN-047/2026

Stator Winding Electrical Diagnostic

Synchronous generator GEN-15A — insulation condition, fault localisation, trend prognosis and prescriptive action plan.

15 MVA	13.8 kV	628 A	98,400 h
RATED POWER	RATED VOLTAGE	RATED CURRENT	OPERATING HOURS

86
HEALTH INDEX

OVERALL VERDICT

Sound winding — one item to act on

Fit for continuous operation. Planned end-winding intervention on phase W before Q3 2027.

Test date **14 Oct 2026**
Issued **22 Oct 2026**
Campaign **5th cycle**

Executive Summary

What the measurements say, where the risk is, and what to do about it — on one page



VERDICT

Fit for continuous operation. Planned intervention on phase W.

The groundwall insulation is **sound and dry on all three phases**. One localised mechanism — surface discharge at the slot-exit region of **phase W** — is growing at ~19% per year and is projected to reach the alert threshold in **Q4 2027**. Acting at the next planned outage removes it at a fraction of the cost of a forced one.

POLARIZATION INDEX	TAN Δ SIGNATURE	PD MAGNITUDE QM	OHMIC IMBALANCE
2.90 min	**1.04** %	**1.84** nC	**0.08** %
IEEE 43 ≥ 2.0 · all phases dry	Reference < 2.0% · low void content	Phase W · 74% of alert level	Limit 1.0% · joints healthy

01 Key Findings

- **Insulation bulk is healthy.** Resistance above 18 GΩ at 10 min on every phase (180× the IEEE 43 minimum), flat Step Voltage response and Tan δ signatures between 0.89 and 1.04% describe a dry, well-cured epoxy-mica system after 98,400 h.
- **Phase W carries the only active mechanism.** Qm of 1.84 nC (2.6× phases U and V), PDIV 1.4 kV lower, and a Tan δ tip-up of 0.42% all point to the same place: **surface discharge at the slot-exit stress-grading region**, not internal voids.
- **The trend, not the snapshot, sets the deadline.** Five campaigns show phase W PD tripling since 2018 while U and V stay flat. Projected crossing of the 2.5 nC alert level: **Q4 2027**.

02 Prescription

01 **Online PD verification** — 0–3 MONTHS
Confirm activity under load and temperature with a short online acquisition on phase W.

02 **End-winding intervention, phase W** — BEFORE Q3 2027
Dry-ice clean, inspect and restore slot-exit stress-grading coating; re-varnish locally. 3–5 day outage.

03 **Post-repair Diligens baseline** — AFTER REPAIR
Repeat PD and Tan δ to verify the repair and reset the trend for the next cycle.

Equipment Identification & Test Conditions

Nameplate data, test scope and the environmental validity of the campaign

01 Nameplate

Equipment type	Synchronous generator, brushless
Tag	GEN-15A
Rated apparent power	15,000 kVA
Rated voltage / current	13.8 kV / 627.6 A
Power factor	0.80 lagging
Frequency / speed	60 Hz / 1,800 rpm (4 poles)
Insulation system	Epoxy-mica, global VPI
Thermal class	F (rise class B)
Cooling	TEWAC (IC8A1W7)
Year of manufacture	2011
Operating hours	98,400 h
Connection	Star, neutral via resistor

02 Test Environment

AMBIENT
26.4 °C

REL. HUMIDITY
61 %

DEW POINT
18.3 °C

WINDING TEMP.
31.5 °C

MARGIN ABOVE DEW POINT

+13.2 °C



The winding was **13.2 °C above the dew point**, well beyond the 3 °C good-practice margin. Surface condensation can be excluded as an influence on the results.

Machine state. De-energised, isolated and earthed for 4 h before testing; line and neutral connections opened so each phase was tested individually against the other two earthed.

03 Test Scope

TEST	LEVEL	STANDARD	STATUS
Polarization / Depolarization Current (PDCC)	5 kV dc	IEEE 43	DONE
Step Voltage	1–5 kV dc	IEEE 95	DONE
Dissipation factor (Tan δ) & capacitance	0.2–1.0 Un	IEC 60034-27-3	DONE
Partial discharge, offline	up to 7.97 kV	IEC 60034-27-1	DONE
Winding ohmic resistance	10 A dc	IEEE 118	DONE

04 Instrumentation

INSTRUMENT	RANGE	CALIBRATION
Insulation analyser with PDCC function	0.5–10 kV dc · 10 TΩ	VALID 03/2027
Dielectric loss and capacitance bridge	up to 15 kV ac · 10^{-5} resolution	VALID 05/2027
PD acquisition system, IEC 60270, 1 nF coupler	40–800 kHz · phase-resolved	VALID 02/2027
Micro-ohmmeter, four-wire	10 A dc · 0.1 µΩ	VALID 07/2027

Executive Reliability Overview

Condition of the five pathologies the Diligens protocol is designed to separate

STATOR INSULATION CONDITION ASSESSMENT

Each pathology is scored from the tests that are most sensitive to it, not from a single number.

01 Moisture & Contamination
PI 2.90–3.23, DD ≤ 1.3, flat Step Voltage. Dry, clean surfaces.



GOOD

02 Thermal Aging
Tan δ signature ≤ 1.04% after 98,400 h; no sign of resin depolymerisation.



GOOD

03 Voids & Delamination
Tip-up 0.25–0.42%, below the 0.5% limit; capacitance rise < 0.4%.



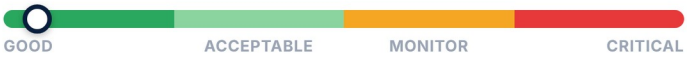
GOOD

04 End-Winding Surface Discharge
Phase W: Qm 1.84 nC, PDIV 5.6 kV, growing ~19%/yr. Slot-exit stress grading.



MONITOR

05 Connections & Joints
Ohmic imbalance 0.08% against a 1.0% limit. All brazed joints healthy.



GOOD

GOOD	ACCEPTABLE	MONITOR	CRITICAL
Low probability of defects. Normal maintenance programme.	Suitable for continuous operation. Follow normal practice.	Active mechanism. Plan action and trend at next cycle.	Operation not recommended until corrected.

How to read this page. Four green rows and one amber row are not a contradiction — they describe **different parts of the insulation system**. Tests that interrogate the **bulk of the groundwall** (IR, PI, Step Voltage, Tan δ signature) return sound results on every phase. Tests that are sensitive to **surface activity at the end winding** (PD magnitude, PDIV, tip-up) single out phase W. Separating the two is exactly what turns a pass/fail test into a **prescription**.

Overall Stator Health Assessment

A single index built from 30 measured values, and the map of where each one sits



SUB-SYSTEM SCORES

Groundwall insulation	94
Moisture & contamination	96
Dielectric losses	88
End-winding / stress grading	64
Connections & joints	99

The index is held back by a single sub-system. Restoring the phase W stress grading is expected to lift it to **≥ 93**.

01 Phase × Test Condition Map

PARAMETER	PHASE U	PHASE V	PHASE W	REFERENCE
Insulation resistance 10 min GΩ @ 40 °C · min 0.1	21.4	22.9	18.6	IEEE 43
Polarization Index min 2.0	3.14	3.23	2.90	IEEE 43
Dielectric discharge DD < 4.0	1.1	1.0	1.3	PDCC
Step Voltage drop 1→5 kV % · < 5	1.2	0.8	3.2	IEEE 95
Tan δ signature @ 0.2 Un % · < 2.0	0.92	0.89	1.04	IEC 60034-27-3
Tan δ tip-up 0.2→1.0 Un % · < 0.5	0.29	0.25	0.42	IEC 60034-27-3
Capacitance rise % · < 1.0	0.21	0.19	0.38	IEC 60034-27-3
PD magnitude Qm nC · alert 2.5	0.62	0.71	1.84	IEC 60034-27-1
PD inception voltage kV · > Uf-n 7.97	6.9	7.0	5.6	IEC 60034-27-1
Ohmic resistance mΩ @ 20 °C	18.412	18.420	18.405	IEEE 118

● Within reference ● Within limit but outlying / trending — monitor

The pattern is the diagnosis. All three amber cells sit in the same column and all three belong to tests sensitive to discharge activity. None of the bulk-insulation tests flags phase W. A single, localised mechanism — not general aging.

The Diligens Diagnostic Ecosystem

Four families of tests, each blind to something the others see — correlated into one prescription

01 Measure
Five offline tests, phase by phase, under controlled conditions.

02 Correlate
Cross-check every finding against the tests sensitive to it.

03 Locate
Separate bulk from surface, phase from phase, joint from wall.

04 Prescribe
One action, one place, one deadline — backed by trend.

01 What Each Test Family Answers

Insulation Resistance · PI · Step Voltage
WHAT IS ON THE SURFACE?
Moisture, contamination and conductive films. Fast, sensitive, but blind to voids.

Partial Discharge
WHERE IS THE INSULATION BREAKING DOWN?
Voids, delamination, slot and end-winding discharge. Pattern locates the source.

Tan δ & Capacitance
HOW MUCH VOID VOLUME, HOW AGED?
Bulk losses and ionisation onset. The integral view of the whole groundwall.

Ohmic Resistance
ARE THE CONDUCTORS INTACT?
Brazed joints, connections and strand integrity — the copper side of reliability.

02 Sensitivity by Failure Mechanism

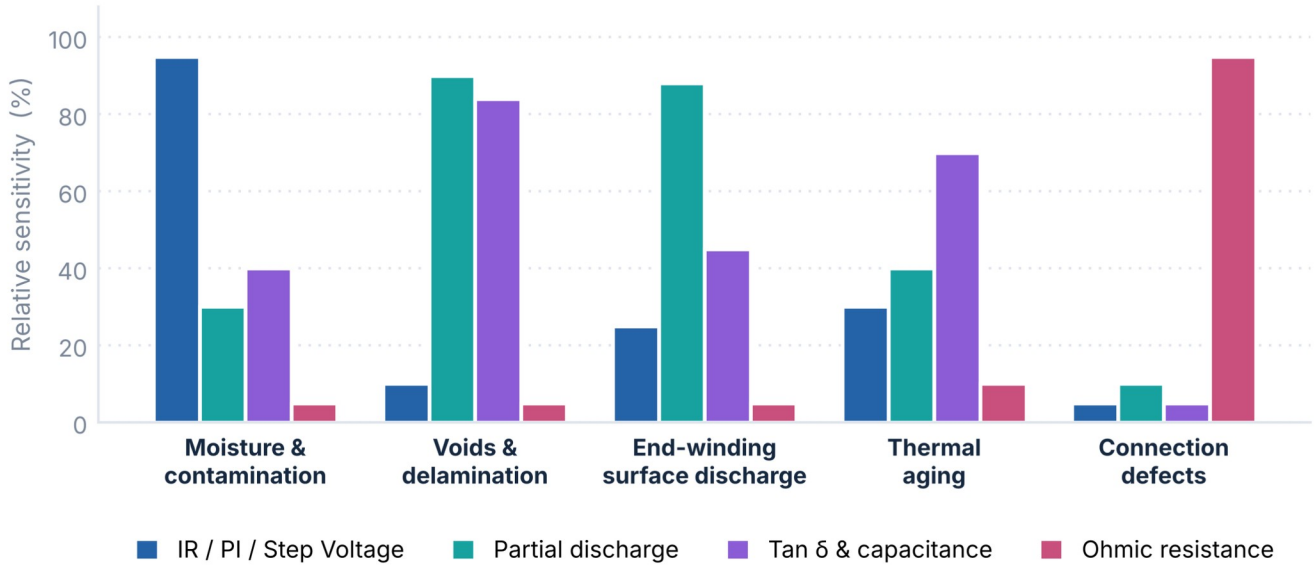


Fig. 1 — Relative sensitivity of each test family to the five failure mechanisms (schematic, after IEEE 1434 and IEC 60034-27 guidance).

Why no single test is enough. An insulation-resistance test alone would have passed this generator with a wide margin. The defect on phase W is visible only to the tests in teal and violet — and only becomes a **deadline** when their history is read together.

4.1 Polarization & Depolarization Current

PDCC at 5 kV dc, 10-minute charge — values corrected to 40 °C per IEEE 43

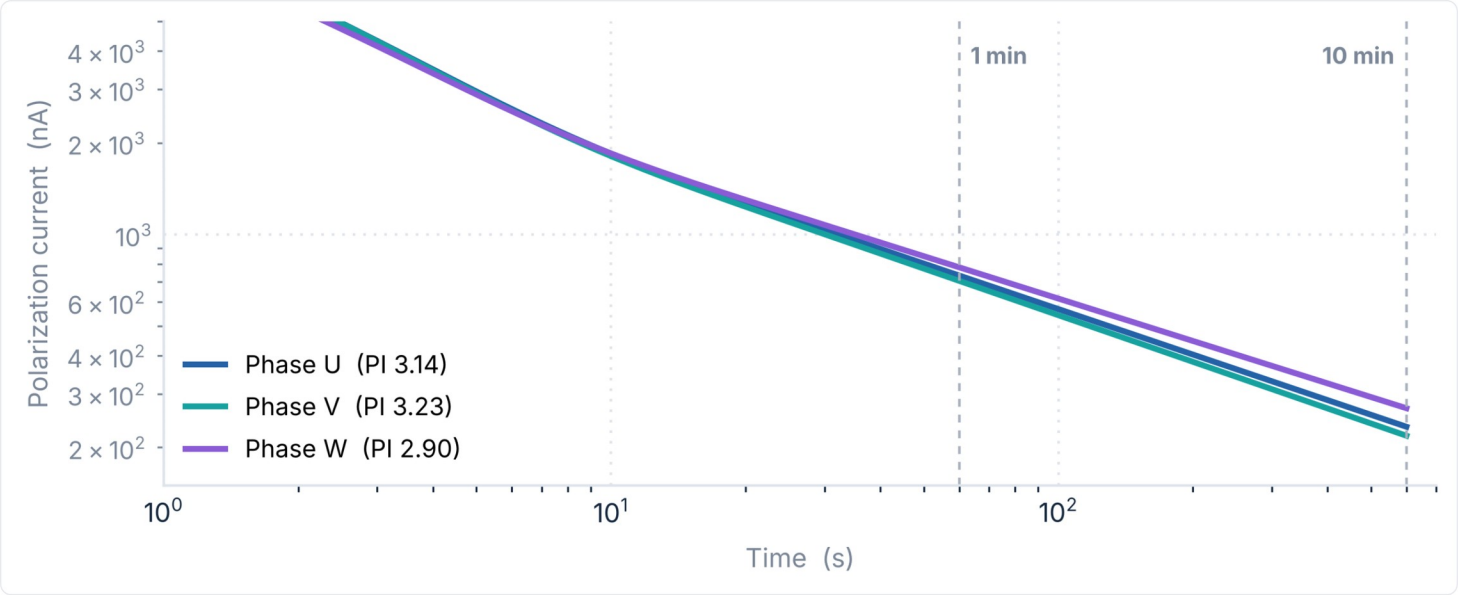


Fig. 2 — Polarization current versus time, log–log. Parallel, smoothly decaying curves are the signature of a clean, dry, homogeneous insulation.

01 Results

PHASE	R 1 MIN GΩ	R 10 MIN GΩ	PI	DAR	DD	CURVE	STATUS
Phase U	6.82	21.4	3.14	1.62	1.1	Type A	**GOOD**
Phase V	7.10	22.9	3.23	1.65	1.0	Type A	**GOOD**
Phase W	6.41	18.6	2.90	1.55	1.3	Type A	**GOOD**
Criterion	–	≥ 0.1	≥ 2.0	≥ 1.4	< 4.0	A / B	

02 Interpretation

- **All phases dry and clean.** PI between 2.90 and 3.23 and DD at or below 1.3 exclude moisture ingress and conductive contamination.
- **Curves are parallel.** The three phases share the same decay slope, so their insulation systems are aging uniformly.
- **Phase W reads slightly lower** (18.6 vs 21.4–22.9 GΩ) — still 186× the minimum. On its own this is not significant; it gains meaning only alongside the PD results in Section 4.4.

4.2 Insulation Resistance & Step Voltage

Absolute resistance, polarization index and voltage dependence from 1 to 5 kV dc

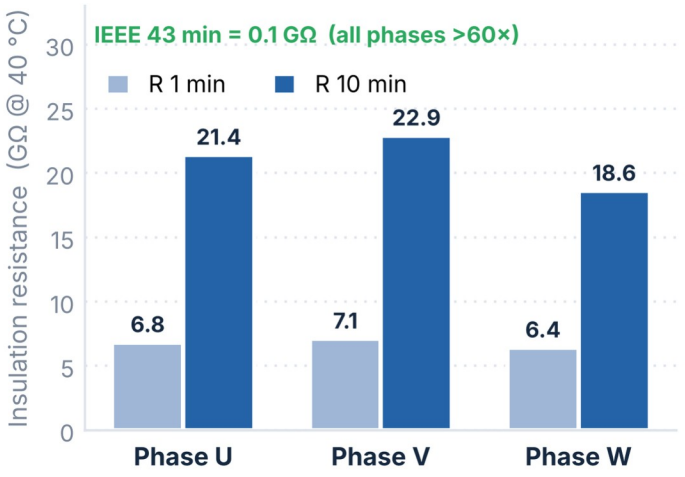


Fig. 3 — Resistance at 1 and 10 minutes.

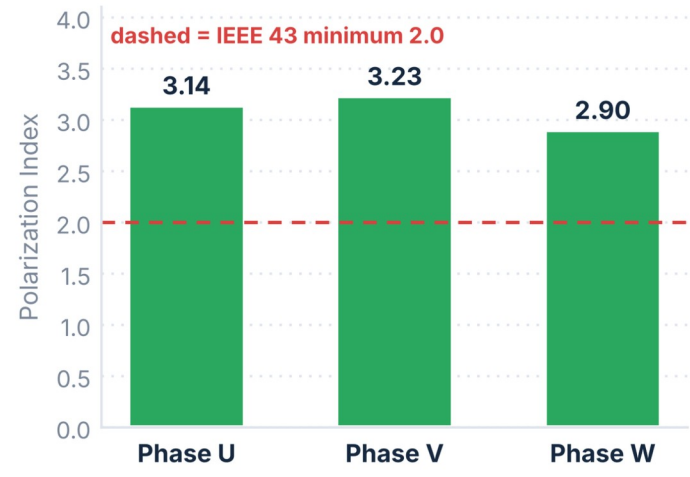


Fig. 4 — Polarization Index by phase.

01 Step Voltage

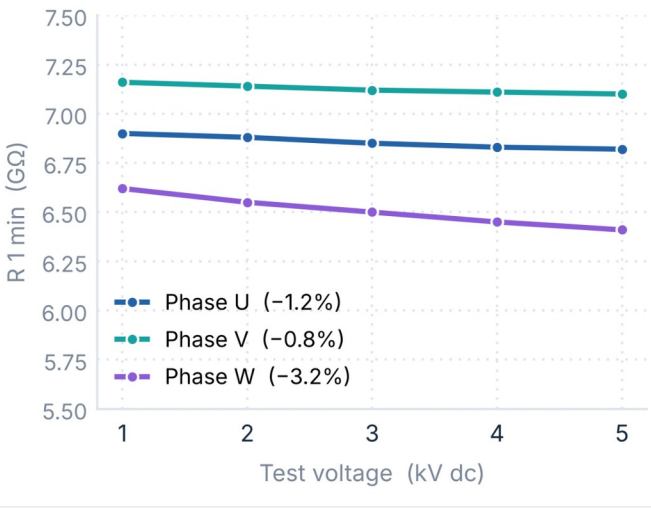


Fig. 5 — R 1 min at five voltage steps.

Reading the curve

A healthy winding shows resistance that is essentially **independent of voltage**. A fall of more than ~5% from the first to the last step signals cracks, tracking paths or contamination that conduct more as the field rises.

All three phases stay flat. Phase W shows the largest fall (**3.2%**) — inside the limit and consistent with the mild surface activity identified later.

PHASE	1 KV	2 KV	3 KV	4 KV	5 KV	DROP	STATUS
Phase U	6.90	6.88	6.85	6.83	6.82	**1.2%**	**FLAT**
Phase V	7.16	7.14	7.12	7.11	7.10	**0.8%**	**FLAT**
Phase W	6.62	6.55	6.50	6.45	6.41	**3.2%**	**FLAT**

Values in GΩ at 1 minute, corrected to 40 °C.

4.3 Dissipation Factor & Capacitance

Tan δ and C measured at five voltage steps from 0.2 to 1.0 Un (2.76 to 13.8 kV ac)

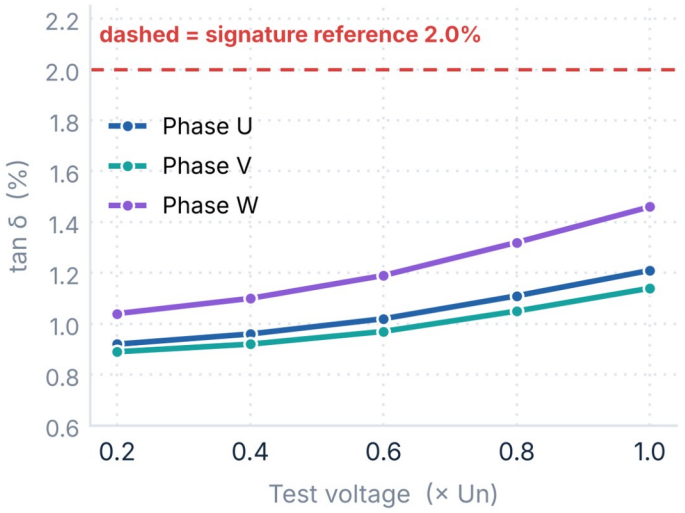


Fig. 6 — Tan δ versus test voltage.

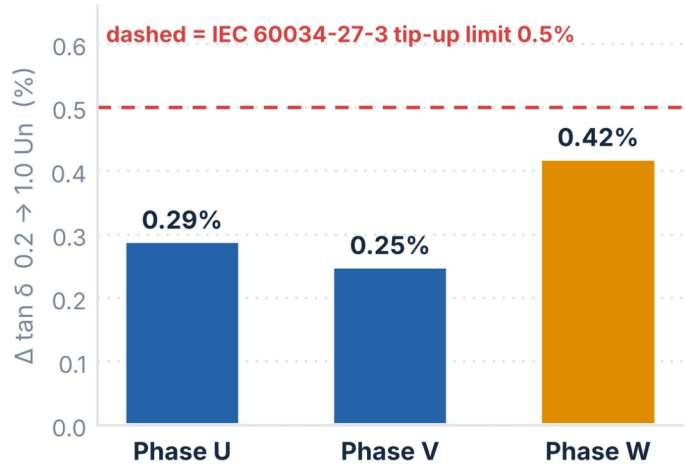


Fig. 7 — Tip-up, 0.2 to 1.0 Un.

PHASE	0.2 UN	0.4 UN	0.6 UN	0.8 UN	1.0 UN	TIP-UP	C_0 NF	ΔC %
Phase U	0.92	0.96	1.02	1.11	1.21	0.29	118.4	0.21
Phase V	0.89	0.92	0.97	1.05	1.14	0.25	118.9	0.19
Phase W	**1.04**	**1.10**	**1.19**	**1.32**	**1.46**	**0.42**	**119.6**	**0.38**

Tan δ in %. Criteria: signature < 2.0%, tip-up < 0.5%, ΔC < 1.0% (IEC 60034-27-3).

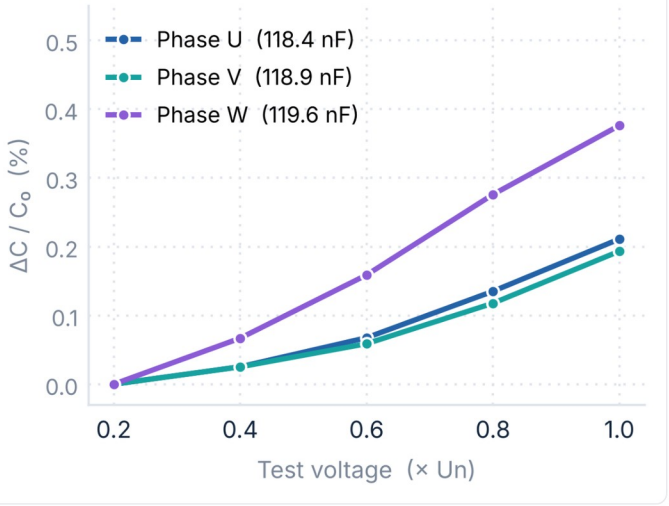


Fig. 8 — Capacitance rise with voltage.

- **Low signature, low losses.** Tan δ at 0.2 Un of 0.89–1.04% is typical of a well-impregnated VPI system in mid-life.
- **Phase W ionises earlier.** Its curve bends upward from 0.6 Un and its tip-up (0.42%) is 50% higher than U and V — the dielectric fingerprint of discharge activity starting below rated voltage.
- **No bulk void growth.** Capacitance rises less than 0.4% on every phase, so the extra loss comes from a **surface** process, not from delamination.

4.4 Partial Discharge

Offline PD, IEC 60270 acquisition, applied voltage up to Uf-n = 7.97 kV, 60 Hz

01 Phase-Resolved PD Patterns

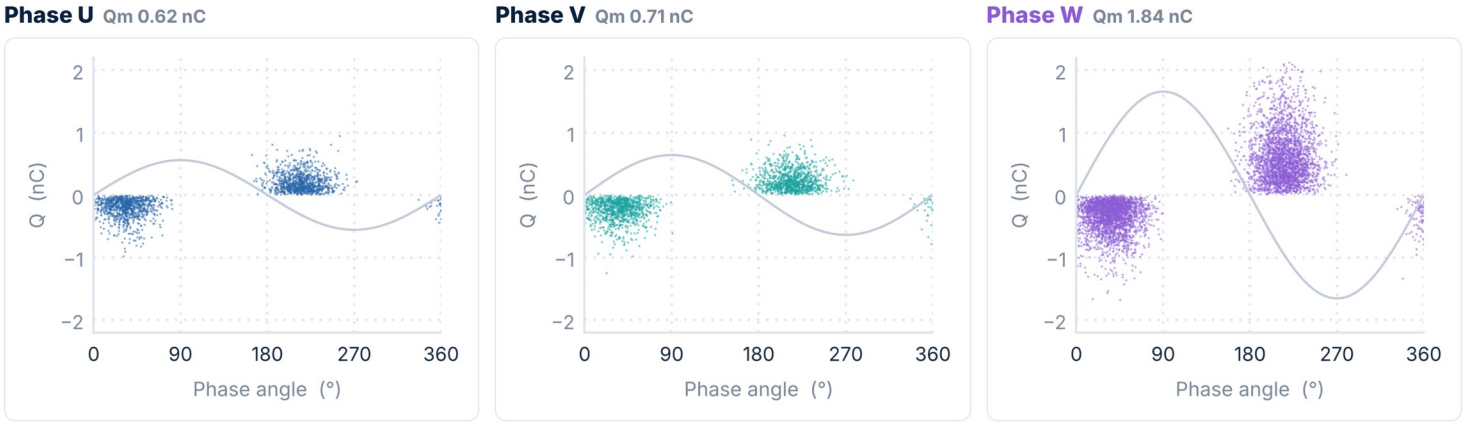


Fig. 9 — Phase-resolved PD maps at Uf-n. Same vertical scale on all three. Phase W shows denser, larger pulses with a marked half-cycle asymmetry.

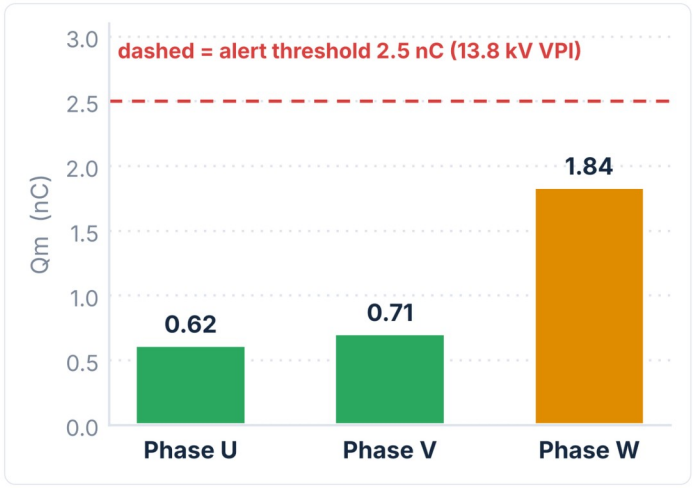


Fig. 10 — Peak repetitive PD magnitude.

What the pattern tells us

- **Location: slot exit.** Pulses cluster near the zero crossings with larger positive-cycle magnitude — the classic pattern of surface discharge at a degraded stress-grading interface.
- **Not internal voids.** Void discharge would be symmetric and would raise capacitance; it does neither.
- **Inception below operating voltage.** PDIV of 5.6 kV is under Uf-n, so the activity runs continuously in service.

PHASE	QM NC	PDIV KV	PDEV KV	PATTERN
Phase U	0.62	6.9	6.2	Symmetric, low — normal background
Phase V	0.71	7.0	6.4	Symmetric, low — normal background
Phase W	**1.84**	**5.6**	**4.9**	**Asymmetric, positive-dominant — surface discharge**

4.5 Winding Ohmic Resistance

Four-wire measurement at 10 A dc, corrected to 20 °C

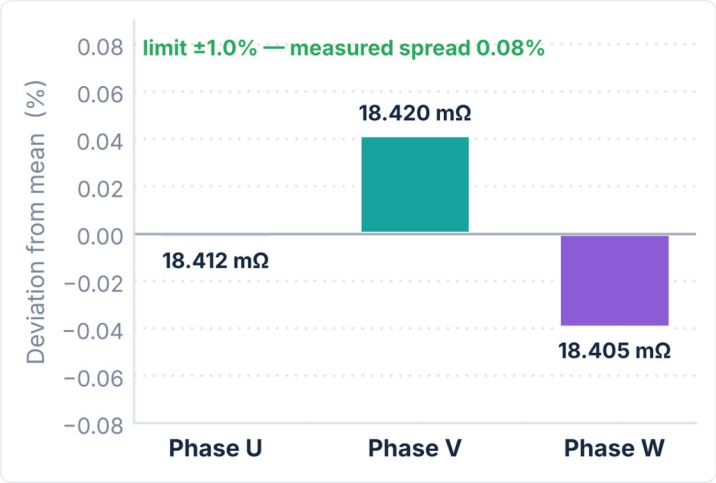


Fig. 11 — Deviation of each phase from the three-phase mean.

PHASE	R MΩ	DEVIATION
Phase U	18.412	-0.002%
Phase V	18.420	+0.042%
Phase W	18.405	-0.040%

Imbalance 0.08% against a 1.0% limit. No high-resistance brazed joint, no broken strand, no loose connection. The copper side of the winding is in excellent condition.

01 Electrical Diagnostic Summary

TEST	CRITERION	RESULT (RANGE OF 3 PHASES)	STATUS
Insulation resistance	≥ 0.1 GΩ	18.6 – 22.9 GΩ	GOOD
Polarization Index	≥ 2.0	2.90 – 3.23	GOOD
Step Voltage	drop < 5%	0.8 – 3.2%	GOOD
Tan δ signature	< 2.0%	0.89 – 1.04%	GOOD
Tan δ tip-up	< 0.5%	0.25 – 0.42%	MONITOR W
Capacitance rise	< 1.0%	0.19 – 0.38%	GOOD
PD magnitude Qm	< 2.5 nC	0.62 – 1.84 nC	MONITOR W
Ohmic imbalance	< 1.0%	0.08%	GOOD

6/8

criteria fully green on every phase

The two that are not belong to the same phase and the same mechanism. Both are still inside their limits today — the reason to act is their **rate of change**, shown on the next page.

Trend Analysis & Prognosis

Five Diligens campaigns, 2018–2026 — the history that turns a reading into a deadline

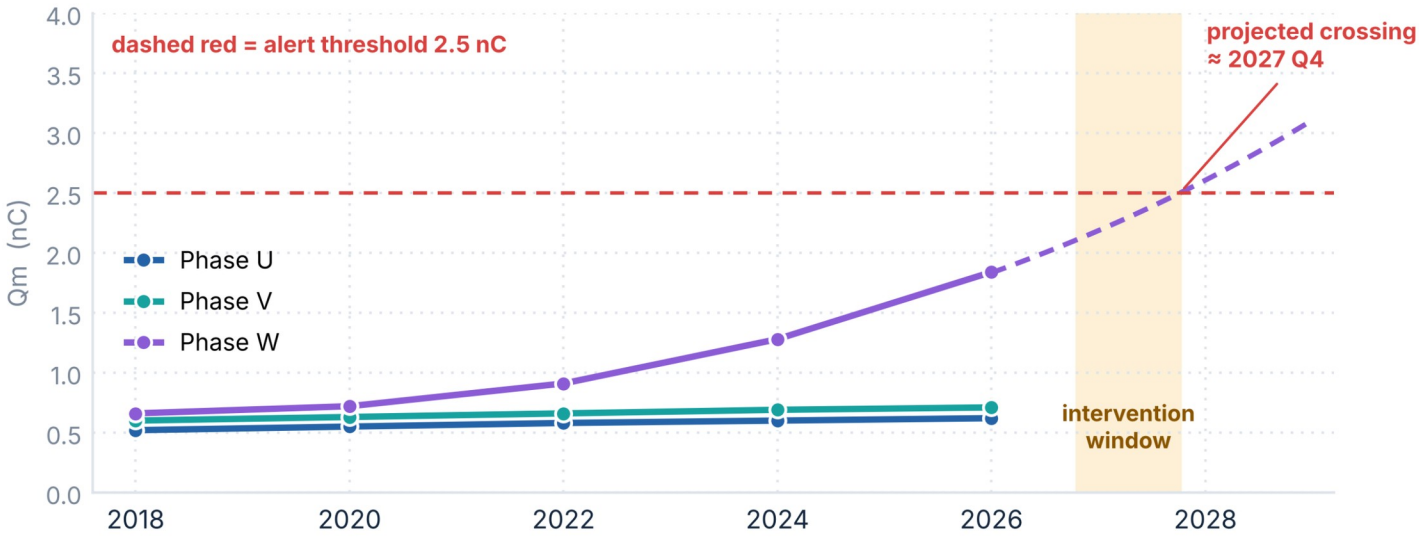


Fig. 12 — Peak PD magnitude per campaign. Dashed violet: exponential fit to the last three campaigns of phase W, projected forward.

PHASE W GROWTH
+19%/yr
compounding since 2022

PHASES U & V
+2%/yr
normal aging

ALERT CROSSING
Q4 2027
at 2.5 nC

WINDOW TO ACT
~11 mo
from this report

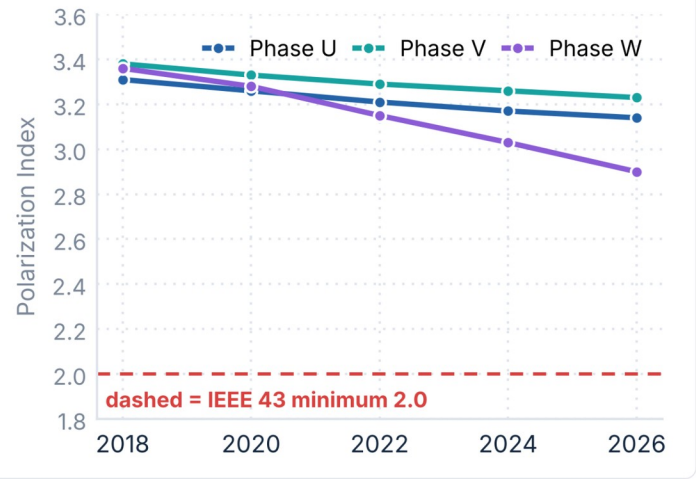


Fig. 13 — Polarization Index history.

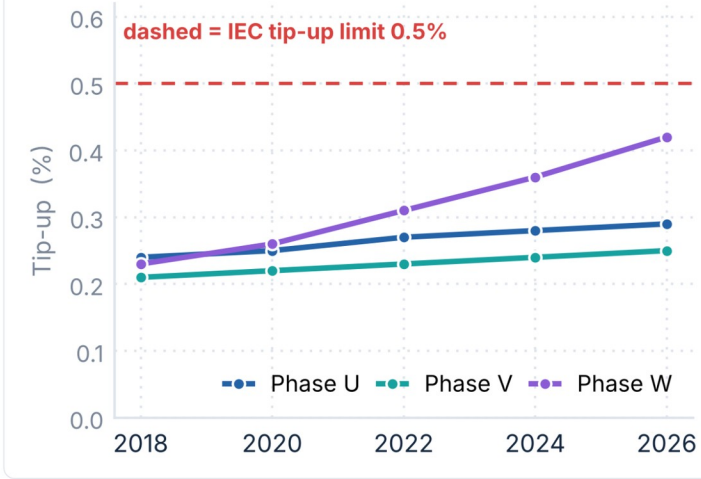
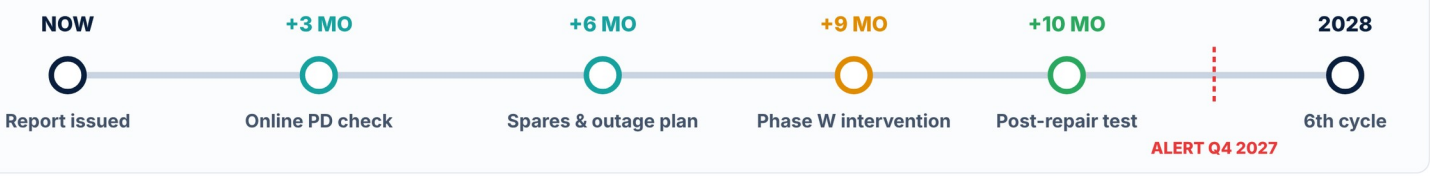


Fig. 14 — Tan δ tip-up history.

Three independent indicators, one direction. PD magnitude, tip-up and PI of phase W have all moved away from U and V since 2022, at a consistent rate. Phases U and V age in parallel and slowly. The convergence of three unrelated measurements on one phase is what gives this prognosis its confidence.

Prescriptive Action Plan

What to do, where, and by when — sequenced to stay ahead of the projected alert crossing



#	ACTION	WHEN	OUTCOME	PRIORITY
01	**Online PD acquisition on phase W under full load and operating temperature**	0–3 months	Confirms the offline finding in service conditions	HIGH
02	**Order stress-grading coating, end-winding varnish and dry-ice cleaning service**	0–6 months	Removes lead time from the critical path	HIGH
03	**Planned outage: clean, inspect and restore phase W slot-exit stress grading; inspect U and V**	Before Q3 2027	Removes the active mechanism before alert level	CRITICAL PATH
04	**Post-repair PD and Tan δ baseline**	At return to service	Verifies repair; resets trend	HIGH
05	**Sixth Diligens campaign, full protocol**	2028	Keeps the 2-year trend unbroken	ROUTINE

01 Planned versus Forced

ACT NOW — PLANNED

3–5 days outage

- Local cleaning and stress-grading restoration
- Scheduled with production, spares on site
- Winding returns with health index ≥ 93

WAIT — RISK OF FORCED OUTAGE

16–24 weeks

- Discharge erodes groundwall at the slot exit
- Possible phase-to-ground fault, partial or full rewind
- Unscheduled loss of 15 MVA generation

02 Expected Outcome



Back to the U–V baseline

Expected Qm on phase W below **0.8 nC**, PDIV above **Uf-n** and tip-up aligned with phases U and V. The post-repair campaign closes the loop and verifies it with measurements, not assumptions.

References & Approval

Standards applied, acceptance criteria and sign-off

01 Normative References

IEEE 43-2013	Recommended Practice for Testing Insulation Resistance of Electric Machinery
IEEE 95-2002	Recommended Practice for Insulation Testing of AC Electric Machinery with High Direct Voltage
IEEE 118-1949 (R)	Standard Test Code for Resistance Measurement
IEEE 1434-2014	Guide for the Measurement of Partial Discharges in AC Electric Machinery
IEC 60034-27-1:2017	Off-line partial discharge measurements on the winding insulation
IEC 60034-27-3:2015	Dielectric dissipation factor measurement on stator winding insulation
IEC 60270:2000	High-voltage test techniques — Partial discharge measurements

02 Acceptance Criteria Applied

PARAMETER	CRITERION	SOURCE
Minimum insulation resistance	≥ 100 MΩ at 40 °C	IEEE 43
Polarization Index	≥ 2.0 (class F)	IEEE 43
Dielectric discharge DD	< 4.0 mA/(V·F)	PDCC practice
Tan δ signature / tip-up	< 2.0% / < 0.5%	IEC 60034-27-3
PD alert level, 13.8 kV VPI	Qm 2.5 nC (site trend-based)	IEEE 1434 / Diligens database
Test validity	Winding ≥ 3 °C above dew point	Good practice
Ohmic imbalance	< 1.0%	IEEE 118 practice

03 Sign-off

Field Test Engineer
Data acquisition · 14 Oct 2026

Diagnostic Specialist
Analysis & prescription

Technical Approval
Issued 22 Oct 2026

Illustrative sample. This report demonstrates the Diligens methodology and format. The machine, the measurements, the history and the conclusions are fictitious and do not refer to any real equipment or client.

DILIGENS REPORT

PRESCRIPTIVE DIAGNOSTICS FOR ELECTRICAL MACHINES

We do not stop at the measurement.
We tell you **where**, **why** and **by when**.

Measure
Five-test offline protocol, phase by phase.

Correlate
Every finding cross-checked by an independent test.

Locate
Bulk versus surface, phase versus phase.

Prescribe
One action, one place, one deadline.

ILLUSTRATIVE SAMPLE REPORT · ALL DATA ARE FICTITIOUS