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Comprehensive Off-line Diagnostic Testing and Visual Inspections for High-Voltage Turbo Generators

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SUMMARY

Off-line electrical diagnostic testing and visual inspections play a pivotal role in ensuring the reliability and operational health of high-voltage machines. This paper presents two case studies that demonstrate the effectiveness of employing advanced off-line diagnostic methods for turbo generators, such as:

- **Insulation Resistance and Polarization Index (IR & PI) Measurements:** Assessment of the stator winding insulation for the lack of gross defects and suitability for safe high voltage (HV) testing.
- **Capacitance and Dissipation Factor Measurements:** A tool used to evaluate the condition of the winding's insulation system (voids due to ageing, delamination, etc.,).
- **Offline PD Testing:** Assessing the HV winding insulation Partial Discharge (PD) levels for comparative and trending purposes.
- **TVA Probe Survey:** Identifying localized electrical discharge sources at the slot portion of the stator winding insulation.
- **UV Corona Camera Survey:** Detecting surface electrical discharges in the generator stator end-windings.
- **DC Ramp Testing:** Evaluating the condition of the winding insulation based on the voltage withstand level and measured current monitoring during the testing.
- **ELCID Testing:** Assessing stator core inter-laminar insulation condition with low flux densities and low energy application.

These studies aim to underscore the value of integrating diverse testing and inspection methodologies to detect the stator critical components' anomalies, enabling proactive maintenance and extending equipment lifespan.

This paper will provide a detailed comparative analysis of the methods applied, showcasing their effectiveness and applicability for different generator configurations and cooling systems. The findings underline the critical role of high voltage off-line electrical diagnostic testing as an important tool in modern electrical power generating asset management strategies. In addition, on-line testing, including results, will also be discussed as a complimentary tool to off-line testing.

KEYWORDS

Diagnostic testing, off-line monitoring, rotating machines, stator winding.

1 Introduction

High-voltage turbo generators play a pivotal role in the global power generation landscape, where their efficiency and performance directly influence the overall reliability for stable and uninterrupted power demand. End users are constantly facing challenges to meet load shedding demands, which significantly stresses a generator's insulation system, leading to accelerated aging and potential failure. A failure within the turbo generator can lead to catastrophic consequences, including significant economic loss and disruptions in essential services. To mitigate risks associated with generator failures, diagnostic testing has emerged as an indispensable practice in generator maintenance. This process involves systematically evaluating the condition of turbo generators through various techniques and methods, enabling the identification of potential deficiencies before they escalate into major issues causing unforeseen outages and huge revenue loss.

The purpose and scope of these two case studies are to explore the effectiveness and implementation of diagnostic testing methodologies within the context of high-voltage turbo generators. By analyzing specific instances of diagnostic testing application, this study aims to highlight its significance in enhancing generator reliability and minimizing operational risks. This paper will focus on questions such as: What off-line diagnostic techniques are most effective in assessing the condition of turbo generators? How do these techniques contribute to improved reliability of power generation systems? What online test method complements offline test methods?

2 Off-line testing vs. on-line testing

2.1 Off-line testing

Partial Discharge (PD) testing has emerged as one of the indispensable tools in assessing stator winding insulation condition. For PD testing of most types of objects off-line method, a charge-based system, is often used. This system works in the Low Frequency (LF) range and follows IEC 60270 standards. It measures PD pulses in terms of apparent charge, expressed in picocoulombs or nanocoulombs. IEC 60270 assumes a capacitor detects the PD and the test object is mostly capacitive. But this is not true for transformer or rotating machine windings. It also requires the measurement frequency to be between 50 kHz and 1 MHz. PD detection above 1 MHz is not covered by this standard [1].

In 2016, IEC 62478 was published, a complementary document to IEC 60270, covering frequencies above those required by IEC 60270. It defines several ranges from LF (below 3 MHz) to UHF (300 to 3000 MHz).

IEC 62478 identifies several practical schemes for measuring PD above the LF range on switchgear, transformers, and stator windings. When testing a generator stator windings (for example) natural frequencies in the LF range can affect PD signals. These frequencies can amplify PD signals due to resonance. Therefore, the calibration procedure in IEC 60270 is not valid for these cases [2].

An advantage of off-line tests performed in the LF range is that there is likely to be less attenuation of PD signals. This is compared to HF, VHF, and UHF measurements. Such attenuation can be significant at higher frequencies in generator stator windings [2].

2.2 On-line testing vs. off-line PD testing

On-line PD equipment enables to monitor the PD activity of stator winding insulation systems in HV generators under operation. It aims to gather data over time to spot any changes in PD activity. This method requires sensors installed permanently in a generator, often using HFCTs or antennae-type sensors.

On-line PD measurements usually happen in the HF, VHF, or UHF frequency ranges. This is because interference levels are lower at higher frequencies. It also allows for better interference suppression, especially in VHF and UHF ranges. The most common sensors for HV motors and generators include capacitors ranging from 80pF to 1nF [2]. High frequency current transformers (HFCTs) are also used as one of the techniques which are described in IEEE Std 1434.

During on-line PD monitoring stator PD noise is suppressed depending on the PD sensor's capacitance; however, it should be noted that for 80pF sensors, the bandwidth is 40–350 MHz [3], in the VHF. This range aids in keeping false positive rates below 1.5% [4]. However, VHF methods detect PD in only 10-15% of the winding [5]. So, sensors should be placed near the highest voltage coils or bars to catch PD effectively.

Off-line PD tests are more sensitive than on-line tests due to less interference. The main benefit of on-line testing is that it doesn't require taking the equipment off-line. This makes on-line tests more frequent and cost-effective than off-line tests.

However, comparing on-line and off-line test results can be challenging, even when done at the same voltage and with the same PD instrument due to operating conditions such as temperature, load, humidity, etc. Moreover, during operation load current may cause vibration or temperature gradients, leading to additional PD which are not accounted for during off-line measurements.

In on-line testing PD doesn't normally occur at the neutral or ground-end because the voltage is low. During an off-line test the whole stator winding, including coils at the neutral end, is energized to the test voltage. This setup can lead to more PD activity being captured, possibly more than in an on-line test.

In summary, on-line PD testing provides real-time insights under operational stresses, enabling proactive maintenance without downtime, albeit with limited spatial detection coverage. Off-line testing, while more sensitive and controlled, does not fully replicate service conditions. Both methods offer complementary advantages, yet their inherent operational and environmental divergences necessitate careful interpretation to inform asset management decisions.

2.3 Estimation on remaining life and avoiding premature failure

About 50% of machine failures are due to winding insulation issues [6]. For this reason, many tests have been developed to evaluate winding insulation. These tests include insulation resistance and polarization index, capacitance and dissipation factor, PD, corona probe (TVA), corona camera inspections, AC/DC hi-pot tests. They are detailed in various IEEE and IEC standards.

Poor winding design or manufacture can lead to early failures [7]. Issues, such as, electric stress control problems can arise from bad coatings. Moreover, windings that operate above the rated temperature rise or with elevated electric stress can also cause premature failures. Typically, it is suggested that for a 30-year life, a Class F insulation system to be operated at a Class B temperature rise [7]. If the winding operates near its rated class, its life may be short.

Since the main application for PD tests combined with other diagnostic off-line tests has been for condition assessment, using periodic onsite/off-line tests and on-line monitoring (if applicable) can aid in early discovery of root cause(s) of stator winding deficiencies. This allows sufficient time to perform repairs/maintenance at a fraction of the cost compared to the cost of a major repair or complete stator rewind in case of winding failure [2].

3 Case Studies

A comprehensive analysis of the below case studies sets the stage for a deeper investigation into the essential role of diagnostic testing in the maintenance of high voltage (turbo) generators. It seeks to emphasize the importance of advancing methodologies that can ultimately lead to enhanced operational reliability within the power generation sector.

3.1 Case Study 1: 13.8 kV Air-Cooled Turbo Generator (100 MW)

A variety of high-voltage electrical diagnostic tests on a 13.8kV air-cooled turbo generator along with the stator core low energy test (ELCID) were performed to evaluate the winding insulation as well as the core interlaminar insulation integrity, including identification and evaluation of any potential failure risks.

Insulation Resistance (IR) and Polarization Index (PI) measurement results demonstrated IR values exceeding 100 MΩ for all individual phases and PI results ranging from 3.69 to 4.70. These outcomes, compliant with IEEE Std 43, confirmed lack of gross insulation defects, acceptable insulation system's dryness and contamination levels.

Partial discharges (PD) were measured at the line and neutral end of the stator winding. A pair of 375 pF coupling capacitors were used (one at neutral and the other at line end the phase). Their outputs were connected to a 1GHz digital oscilloscope through power frequency separation filters and followed IEEE Std 1434. Each phase was tested individually, with the other phases grounded. During the test the maximum PD magnitudes at 8.0 kV, as well as the partial discharge inception (PDIV) and extinction (PDEV) voltages were recorded.

The PD test results are shown in Table 1. Moderate PD magnitudes were found on phases Y-V and Z-W. Phase X-U showed the highest PD magnitudes, reaching 116 mV. This constitutes almost double the PD readings on phase Y-V. PD patterns suggested discharges within the groundwall insulation and at semi-conductive/grading coating interfaces. Analysis of Partial Discharge Extinction Voltage (DEV) showed that 54–60% of the winding could experience PD during operation. However, PD levels and its effects may be different for in-service conditions due to various factors like, voltage distribution variances of the winding, temperature, vibration, etc.

***Table 1* - PD, DIV and DEV test results**

Phase	Partial Discharge at 8.0 kV		DIV (kV)	DEV (kV)
	Q_M (mV, +ve)	Q_M (mV, -ve)		
Y (LE)	*61.5*	*58.5*	*4.5*	*3.9*
V (NE)	*18.0*	*16.4*	*4.2*	*3.7*
X (LE)	*110.5*	*116.0*	*3.7*	*3.2*
U (NE)	*29.8*	*28.4*	*4.1*	*3.6*
Z (LE)	*80.5*	*85.0*	*3.8*	*3.5*
W (NE)	*25.6*	*34.4*	*4.1*	*3.7*

Capacitance and Dissipation Factor (Tan-Delta) measurements further validated insulation integrity, with capacitance change (ΔC) and dissipation factor tip-up values remaining below 1%, consistent with acceptable performance for epoxy-mica systems. However, the TVA probe survey results (Table 2) highlighted localized anomalies, with three slots (X-U: slots 9, 29 and Z-W: slot 27) exceeding the IEEE Std 1434 threshold of 20 mA. The highest reading of 26 mA occurred at slot 9 (X-U phase), around the middle of the core (lengthwise) and indicated abnormal discharge level at that area originating from the winding bar(s) of the X-U phase.

***Table 2* – TVA Probe survey results**

	Phase Y-V				Phase X-U				Phase Z-W			
Slot No.	CE (mA)	CE-M (mA)	M-OCE (mA)	OCE (mA)	CE (mA)	CE-M (mA)	M-OCE (mA)	OCE (mA)	CE (mA)	CE-M (mA)	M-OCE (mA)	OCE (mA)
1	1.2	0.4	0.4	0.4	6.0	1.6	1.4	0.8	2.0	0.4	0.4	2.0
2	0.8	0.4	0.4	0.8	1.6	1.6	1.4	1.2	1.8	0.4	1.0	1.0
3	0.8	0.4	0.4	0.4	8.0	1.4	0.8	0.8	1.0	0.4	0.8	1.2
4	0.4	0.4	0.4	0.4	13.0	2.2	1.0	0.6	2.0	0.6	1.0	3.4
5	0.4	0.4	0.4	1.2	5.5	2.5	1.4	1.4	2.8	1.2	1.2	4.0
6	0.6	0.4	0.4	0.5	1.2	2.6	1.4	3.0	5.0	1.6	1.8	2.2
7	0.4	0.4	0.4	0.5	4.4	4.8	2.2	4.0	1.4	0.8	0.4	1.2
8	0.4	0.4	0.4	0.5	8.0	7.8	4.2	2.8	0.4	0.8	0.4	0.8
9	1.2	0.6	0.6	1.4	6.0	26.0	12.0	7.6	1.0	0.4	2.4	0.6
26	0.4	0.4	0.4	0.4	0.9	2.0	2.5	1.2	8.6	15.0	15.0	6.3
27	0.4	0.4	0.4	0.4	1.8	2.0	3.4	3.4	17.0	22.0	13.0	7.5
28	0.4	0.4	0.4	0.4	6.2	9.0	15.0	20.0	3.4	3.0	2.4	2.5
29	0.4	0.4	0.4	0.4	3.4	8.4	25.0	21.0	2.8	2.0	1.8	1.4

Complementary UV corona camera survey of the end-windings pinpointed two discharge locations: weak corona activity at the top bar in slot 34 (X-U phase, OCE end) and intermediate corona activity at the top bar in at slot 50 (Z-W phase, CE end), both at semi-conductive coating interfaces, as shown in Figure 1. These findings aligned with the PD measurement results, underscoring localized degradation risks.

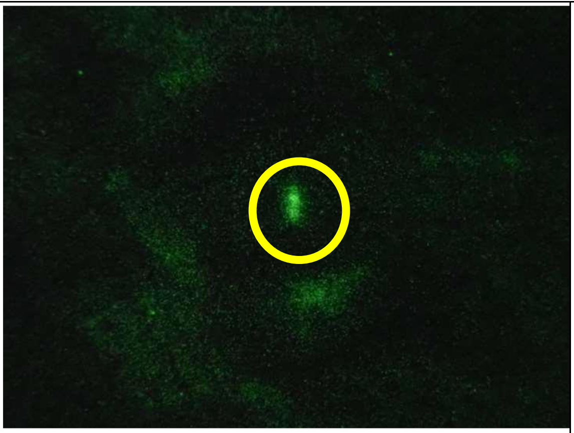
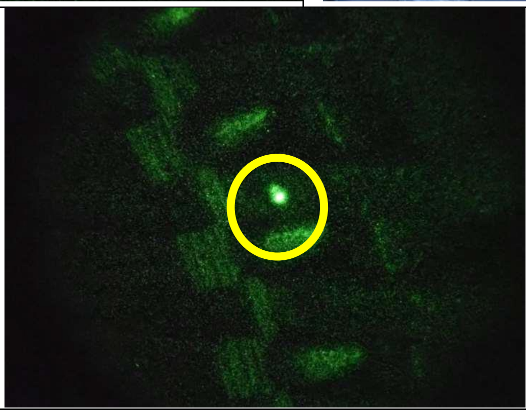
Slot 34 OCE of X-U phase	 
Slot 50 CE of Z-W phase	

***Figure 1* - UV corona camera observed discharges**

The DC ramp test validated the stator winding's integrity, with all phases sustaining up to 32 kV DC. Phase Y-V demonstrated an elevated resulting current increase rate (compared to the other two phases) beyond 26 kV, likely due to age-related insulation degradation.

Subsequent ELCID testing confirmed no stator core faults, as measured signals remained below 100 mA, verifying the absence of interlaminar insulation defects.

A limited visual inspection of the stator winding revealed generally satisfactory conditions, with visible components relatively clean and of small degree of contamination. However, some abnormal localized greasing was observed in the slot regions at the wedge connections and at the end-winding support areas (Figure 2), suggesting relative movement of these components due to mechanical vibration during operation, either within the slots or at end-winding interfaces. These findings underscore adequate insulation performance but highlight areas warranting monitoring for vibration-induced wear.

To mitigate progressive degradation, the following measures were advised:

1. Planned outage actions (5–6 years): Repeat off-line diagnostics to monitor insulation trends, repair corona-affected slots (34 and 50), and conduct a full slot wedging tightness survey with rotor removal to address vibration-induced greasing.
2. Operational monitoring: Implement semi-annual on-line PD testing to dynamically track the discharge levels.
3. Long-term maintenance: Prioritize vibration mitigation during future inspections to prevent mechanical wear.

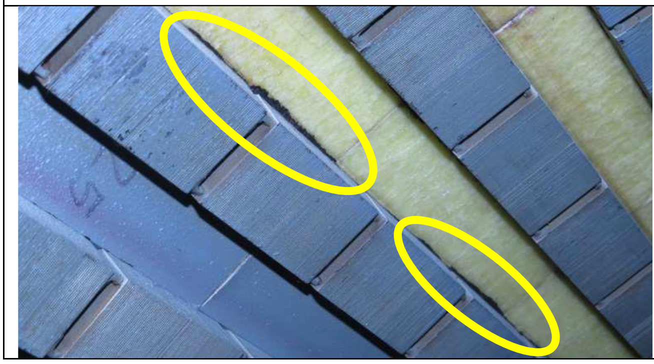
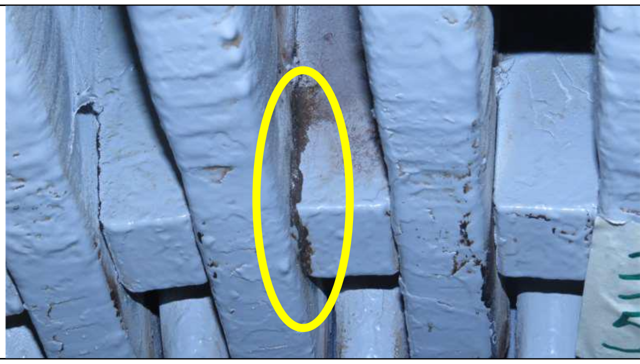
Slot region:	**End-winding region:**
	

Figure 2 ***- Signs of greasing at the slot and end-winding areas***

The diagnostic suite confirmed the stator winding and core remain functionally sound. Primary concerns included elevated PD in phase X-U, TVA probe anomalies, localized corona discharges, and mechanical greasing indicative of vibration. While these findings highlight aging-related risks, they present no imminent failure modes. Thus, adhering to these proactive strategies aim to extend operational longevity and ensure compliance with reliability standards for legacy infrastructure.

3.2 Case Study 2: 24 kV Hydrogen-Cooled Turbo Generator (540 MW)

A comprehensive series of pre-remedial and post-remedial off-line electrical diagnostic tests and inspections were performed on a 24 kV hydrogen-cooled turbo generator to evaluate the stator winding insulation integrity and identify potential failure risks of the winding and core during a planned outage. The pre-remedial (prior to maintenance work) test results were used for comparison with the post-remedial results to determine any changes to the stator winding insulation condition as a result of maintenance work being carried out as well as to provide assurance for long term reliability of the generator winding insulation system as well as the stator core.

Initial diagnostic testing and visual inspection results revealed some contaminated sections of the IPB and prompted a remedial action. UV corona camera survey identified Stator Slot Couplers (SSC) PD sensors leads routed closely to the stator HV end-winding areas, while visual inspections showed bent stator core laminations in several areas which were rectified and confirmed acceptable after the ELCID test. Timely maintenance was performed to prevent potential cascading failures, enhancing operational efficiency and reliability.

Based on the information provided the core damage incurred during the rotor removal, a routine visual inspection of the affected stator core areas of this unit was performed as part of the pre-remedial testing program. The major findings of the inspection revealed numerous core teeth corners at the bore surface, around the middle of the core length and next to slot 30 were observed damaged (bent laminations) as shown in Figure 3.

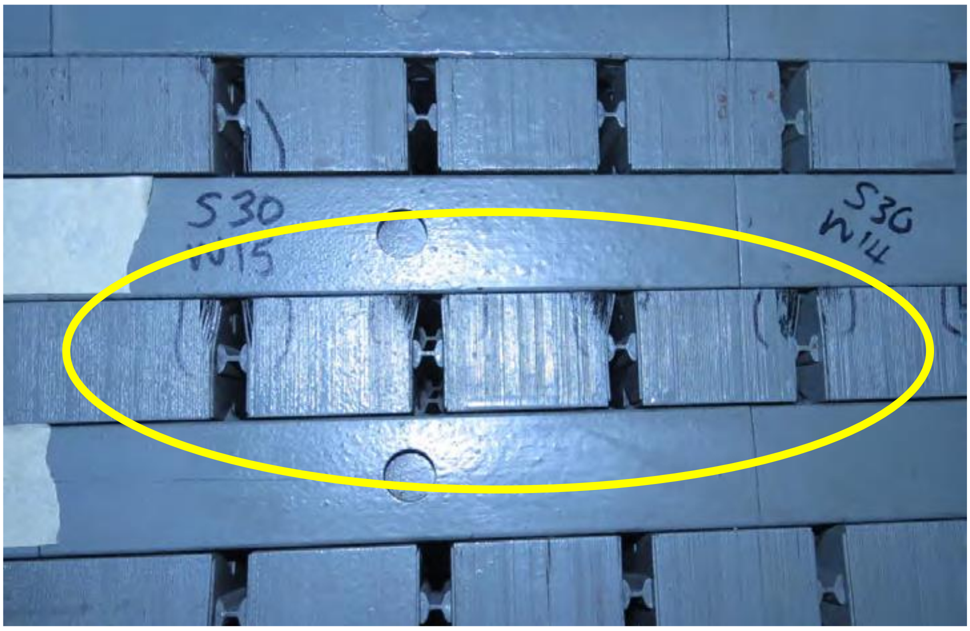


Figure 3 - Closer view of example core tooth corner damage around slot 30

The insulation resistance (IR) and polarization index (PI) measurements enabled assessment of the cleanliness and dryness of the winding insulation plus values exceeding the acceptable threshold of 100 MΩ for high voltage testing. It should be pointed out that during the post-remedial testing, the PI value for the Red phase was slightly below the recommended limit of 2.0, likely due to moisture accumulation in the inner water cooling system. Consultation with engineering teams determined that the winding condition remained acceptable for further testing.

Capacitance and Dissipation Factor (C&DF) measurements offered insight into the insulation's dielectric properties. A slight variation of capacitance and an acceptable dissipation factor indicated a stable insulation system of the winding. These measurement results complemented PD testing results to confirm whether degradation was widespread or limited to specific areas. Fortunately, the results remained within expected parameters, indicating a stable insulation condition without significant degradation compared to historical data.

Off-line Partial Discharge (PD) testing results revealed levels typical for windings of similar construction and vintage. Initially, the White phase exhibited abnormally high PD activity (over 3100 mV), which on further investigation traced to the Isolated Phase Bus (IPB) section, which was part of stator testing circuitry during the testing. Maintenance actions, including cleaning and inspection of the IPB section, helped to reduced PD levels to acceptable ranges. However, the PD levels of the White phase (with IPB isolated) recorded (around 120 mV) at the line end of the winding during the post-remedial testing that were around three (3) times higher compared to those recorded for this phase a decade earlier. Meanwhile the PD levels at the line end of the winding of the other two phases remained low (between 40 and 60 mV) and stable based on the historical records.

PD testing also helped identify localized areas of insulation deterioration, with PD patterns analyzed to determine whether discharges were occurring within the bulk insulation or at the interfaces of the conductive coatings. High PD readings were further investigated with additional tests to verify their impact.

On-line PD results (Figure 4) clearly demonstrate a reduction in PD magnitude from pre-remedial (7 mV Qm +/-) to post-remedial levels (negligible). While 7 mV may not seem as high, if referred to the Iris Power statistical PD database, consisting of >750,000 test results, 90% of the machines have PD levels of less than 6mV. In other words, this machine ranks amongst the top 10% of the worst machines compared to similar machines of its voltage class, cooling method, and sensor type [8] and hence a significant difference.

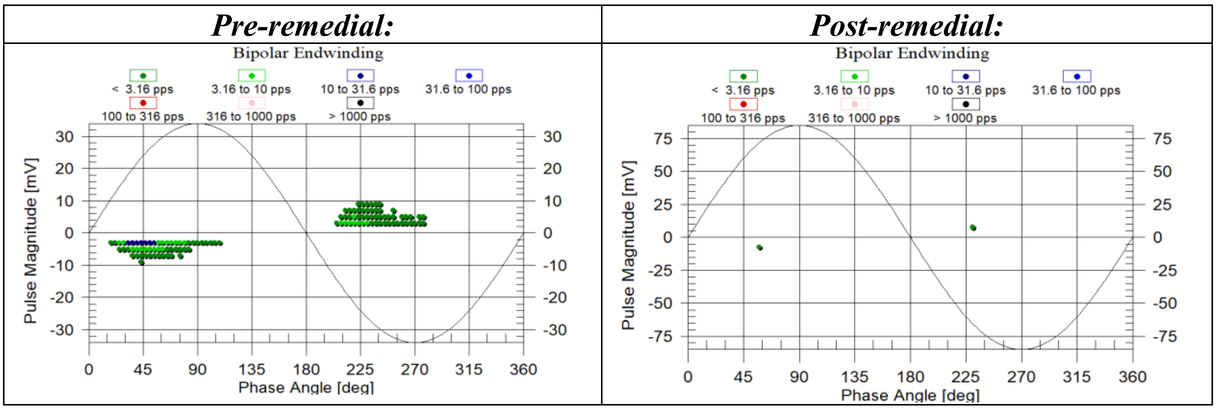


***Figure 4** – Typical PRPD plot for a PD test on an operating stator winding on slot 6 SSC leads – White phase (T2). The colored dots indicate the pulse repetition rate per second.*

The TVA probe survey was utilized to scan for PD activity along the stator slots and some of the results are shown in the example for the Red phase in Table 3. This technique pinpointed specific locations/slots with above-the-threshold discharge activity of the winding throughout the length of the stator core, allowing for targeted corrective measures and future trending monitoring of the discharges. The TVA probe survey identified moderately high and high PD readings in specific slots, mainly in the Red phase, with values exceeding the IEEE Std 1434 recommended threshold of 20 mA. Moderately high PD activity was also observed across some of the slots in the remaining two phases. As a corrective measure, close future monitoring combined with some limited corrective actions were recommended.

Table 3 - TVA Probe survey results (RED phase)

Slot No.	Red Phase				Measured Values in (mA)							
	T1-1	T1-2	T1-1a	T1-2a	CE		CE to Middle		Middle to TE		TE	
					Pre-Remedial	Post-Remedial	Pre-Remedial	Post-Remedial	Pre-Remedial	Post-Remedial	Pre-Remedial	Post-Remedial
1	22 T			12 B	7.0		4.2		4.2		5.0	
2	20 T				25		12		6.6		4.5	
3	18 T				8.2		4.8		2.5		3.5	
4	16 T				5.2		3.2		3.0		3.4	
5	14 T				17		15		5.9		5.0	
14	23 B				7.2		6.8		3.4		5.0	
15	21 B				12		5.8		6.4		5.0	
16	19 B				11		7.8		5.0		6.0	
17	17 B				11		9.4		5.8		6.5	
18	15 B	1 T			12		12		7.4		7.0	
19	13 B	3 T			29		17		10		16	
20		5 T			66	90	52	72	32	34	40	48
21		7 T			24		21		9.0		12	
22		9 T			17		13		6.7		6.0	
23		11 T			19		11		9.4		12	
32		2 B			11		9.0		5.7		3.3	
33		4 B			26		24		24		13	
34		6 B			11		16		21		4.0	
35		8 B			10		7.8		5.5		41	
36		10 B	24 T		11		13		5.5		5.5	
37		12 B	22 T		21		9.8		14		12	
38			20 T		44	72	38	42	25	29	8.0	20
39			18 T		17		8.0		6.7		3.4	
40			16 T		18		15		3.1		4.0	
41			14 T		15		8.6		4.2		9.0	
50			23 B		30	25	17	17	12	12	7.0	7.0
51			21 B		61	60	32	38	27	32	22	27
52			19 B		29		19		23		8.5	
53			17 B		14		4.0		6.7		7.0	
54			15 B	1 T	13		8.2		8.0		7.5	
55			13 B	3 T	21		25		18		24	
56				5 T	28		31		32		27	
57				7 T	16		17		35		12	
58				9 T	8.4		7.0		5.8		8.2	
59				11 T	15		6.8		6.8		7.8	
68				2 B	6.2		4.0		3.4		2.3	
69				4 B	9.6		7.8		6.4		4.5	
70				6 B	7.4		9.8		9.4		14	
71				8 B	3.2		3.8		4.5		4.2	
72	24 T			10 B	13		11		8.0		7.8	

	Readings below 10 mA
	Readings between 10 to 15 mA
	Readings between 16 to 19 mA
	Readings of 20 mA and above

The UV corona camera inspections revealed certain areas of low-level visible discharge activity at the end-windings during pre-remedial testing at the SSC coupler leads at slot 6 (White phase) particularly at the grading coatings of the stator bars. These leads were routed closely to the stator end-winding bottom bars at the collector end and were fully exposed in air (not encapsulated). Post-remedial observations, after the re-routing the SSC coupler leads, showed a noticeable reduction in corona activity. Very low-intensity corona activities were observed during post-remedial inspection at the SSC coupler leads at slot 42 (White phase), where the leads were previously routed closely to the stator end-winding bottom bars and possibly exposed in air (not fully encapsulated prior to the maintenance activity). This demonstrates the effectiveness of the maintenance interventions (as shown in Figure 5). These findings corresponded with PD reinforcing identified areas of concern.

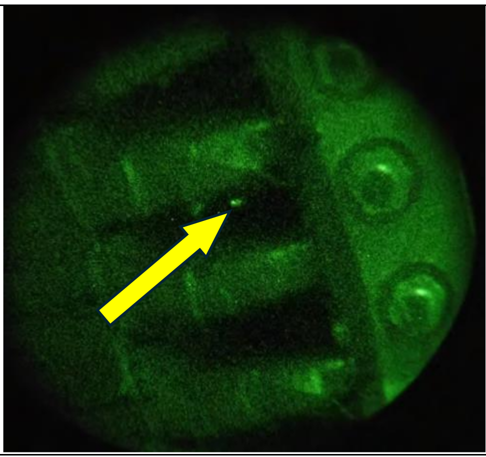
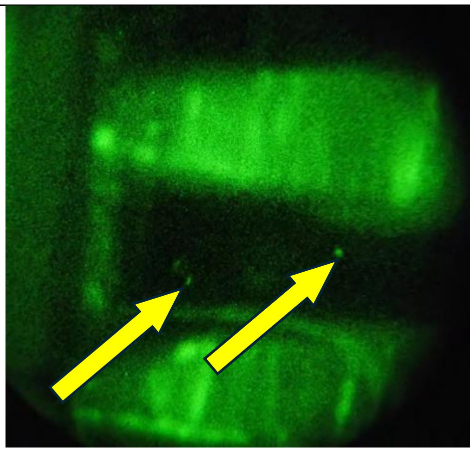
Slot 6 SSC leads – (pre-remedial) White phase (T2)	Slot 42 SSC leads – (post-remedial) White phase (T2)
	

Figure 5 ***- Corona activity on slots 6 and 42 SSC leads***

The DC ramp test applied a controlled increase in voltage to evaluate the insulation's ability to withstand electrical stress, providing secondary validation of insulation strength and helping to confirm whether the readings of the other tests of the program were indicative of actual insulation weakness. This test confirmed the integrity of all three phases, with each phase withstanding the applied voltage and exhibiting the resulting currents ranging from 19 µA to 29 µA.

Finally, the ELCID test was used to evaluate the stator core's interlaminar insulation condition. The results further confirmed that quadrature signal readings were well below the significance threshold of 100 mA, indicating that the stator core’s inter-laminar insulation remained in good condition and thus complementing the other tests by ensuring that core-related faults were not contributing to insulation issues. Figures 6 and 7 present the pre- and post-remedial quadrature signal distribution graphs, respectively.

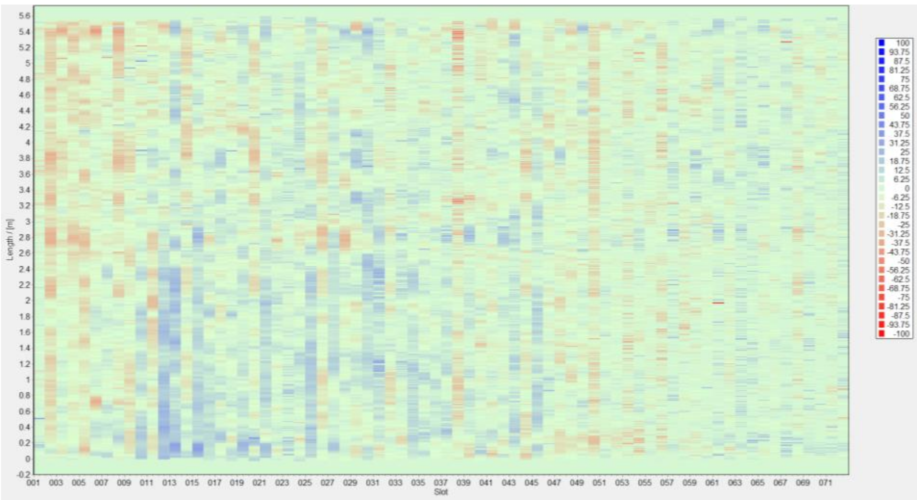


Figure 6 ***- Visual Quad signal distribution (mA) – pre-remedial test***

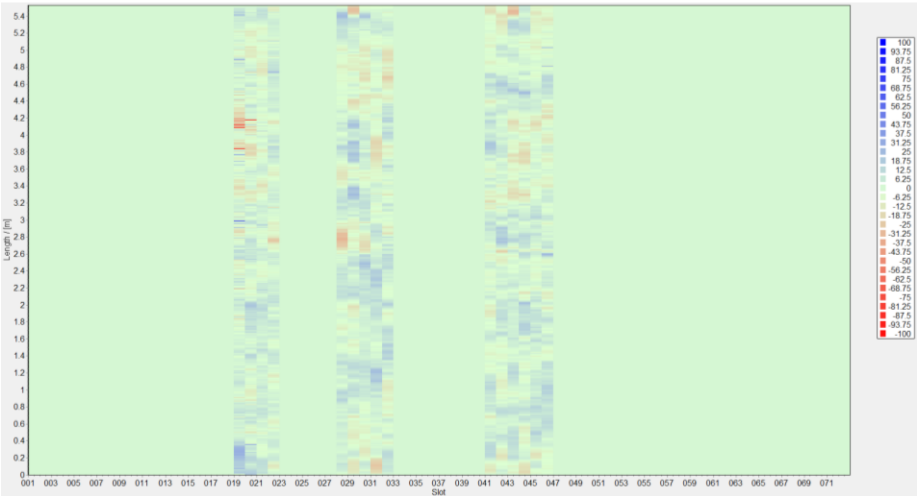


Figure 7 - ***Visual Quad signal distribution (mA) – post-remedial test***

The assessment confirmed that the generator stator winding and core are in satisfactory condition for continued operation. High partial discharge (PD) activity detected during pre-remedial testing was successfully addressed, with post-remedial tests verifying the effectiveness of corrective actions. No immediate concerns were identified regarding the insulation system's integrity. To ensure long-term reliability and optimal performance, ongoing monitoring, periodic testing, and targeted maintenance are essential.

4 Conclusions

Off-line diagnostic testing and inspections combined with on-line monitoring have proven as one of the invaluable tools for assessing and maintaining the integrity of generator stator windings and cores, as demonstrated in both case studies. In the 13.8 kV air-cooled turbo generator, comprehensive tests identified insulation risks, localized corona discharges, and mechanical wear, enabling targeted maintenance for the life extension. Similarly, the 24 kV hydrogen-cooled turbo generator benefited from pre- and post-remedial testing, effectively detecting and mitigating high PD activity and insulation anomalies. Employing advanced off-line diagnostic methods provides a holistic assessment, allowing proactive identification and remediation of issues to minimize a risk of catastrophic failures. This approach extends operational lifespan, reduces downtime, and enhances the reliability of critical power generation assets.

Bibliography

[1] G.C. Stone, H.G. Sedding, C. Chan, C. Wendel, Comparison of Low Frequency and High Frequency PD Measurements on Rotating Machine Stator Windings, IEEE, 2018.

[2] G.C. Stone, Andrea Cavallini, Glenn Behrmann, et al. Practical Partial Discharge Measurement on Electrical Equipment, Hoboken NJ: Wiley, 2023.

[3] Saeed Ul Haq, Ashish Trivedi, Steve Rochon, Madu TS Moorthy, Alternative Methods of Machine Online Condition Monitoring, IEEE, 2023.

[4] Sunny Gaidhu, Christa Fitzpatrick, Vicki Warren, Greg Stone, ANALYSIS OF A PARTIAL DISCHARGE DATABASE TO DETERMINE WHEN STATOR WINDING INSULATION MAINTENANCE IS NEEDED, IEEE, 2023.

[5] M. Henriksen et al, "Propagation of PD and Noise Pulses in Turbine Generators", IEEE Trans EC, Sept 1986, pp161-166.

[6] G.C. Stone, I. Culbert. Prediction of Stator Winding Remaining Life From Diagnostic Measurements, IEEE, 2010.

[7] G.C. Stone, M. Sasic, D. Dunn, I. Culburt, Motor and Generator Windings, IEEE Industry Application Magazine, Nov | Dec 2011.

[8] Warren, Vicki, PARTIAL DISCHARGE TESTING: A PROGRESS REPORT, Iris Rotating Machine Conference 2022, 2022.