IRMC 2024

Predictive Monitoring of Partial Discharges in an Electrical Generator at a Gas Plant: Supporting Decision-Making for Interventions with Minimal Impact on Plant Availability

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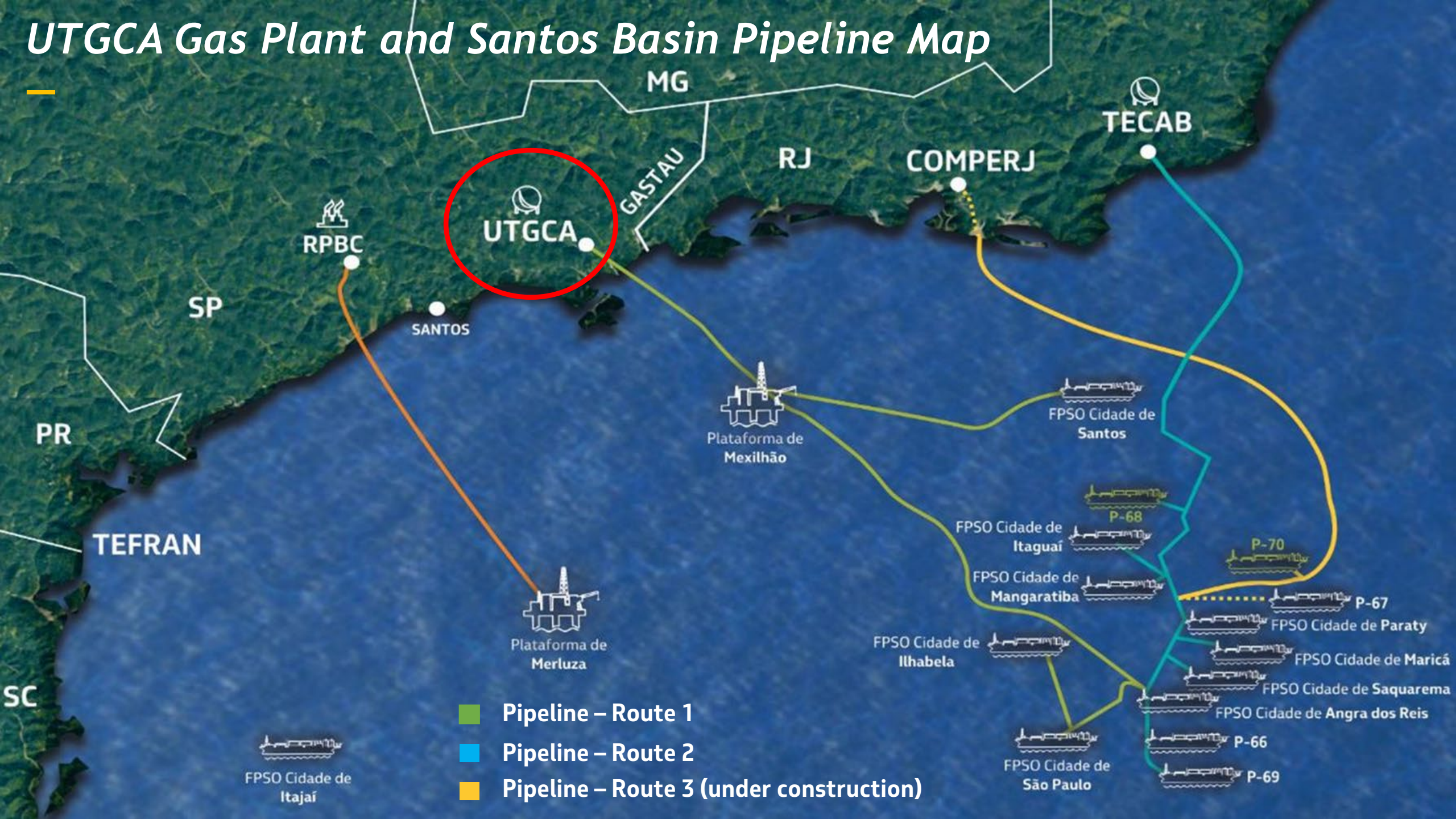
Las Vegas, NV
June/2024

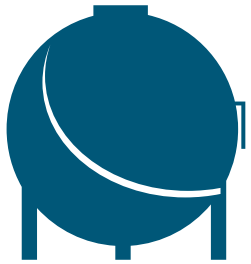
PETROBRAS

UTGCA Gas Plant and Santos Basin Pipeline Map



UTGCA (Caraguatatuba Gas Plant) Production Data

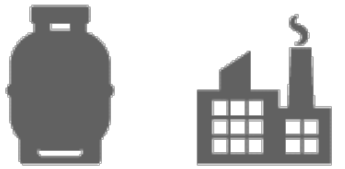
UTGCA enables approximately **11.05%**, of Brazilian oil production, by the gas processing activity.



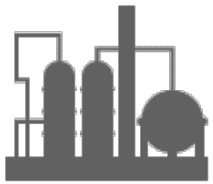
22,05% of Brazilian Natural Gas is processed at UTGCA

Natural Gas

LPG (Liquified Petroleum Gas)



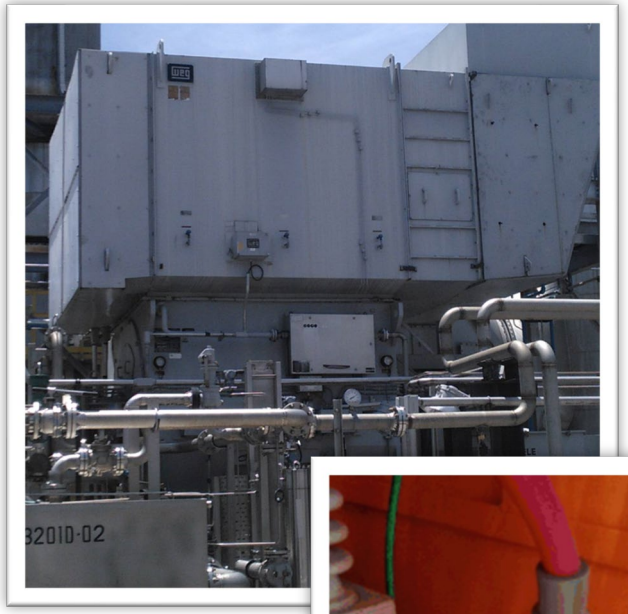
C5 +



UTGCA - High Voltage Rotating Machines (13.8kV)

Main Generators

4 Synchronous Generators 37.5 MVA driven by Aeroderivative Gas turbine



Sales Gas Compressors

5 Synchronous Motors 7.8 MW

Propane Compressors

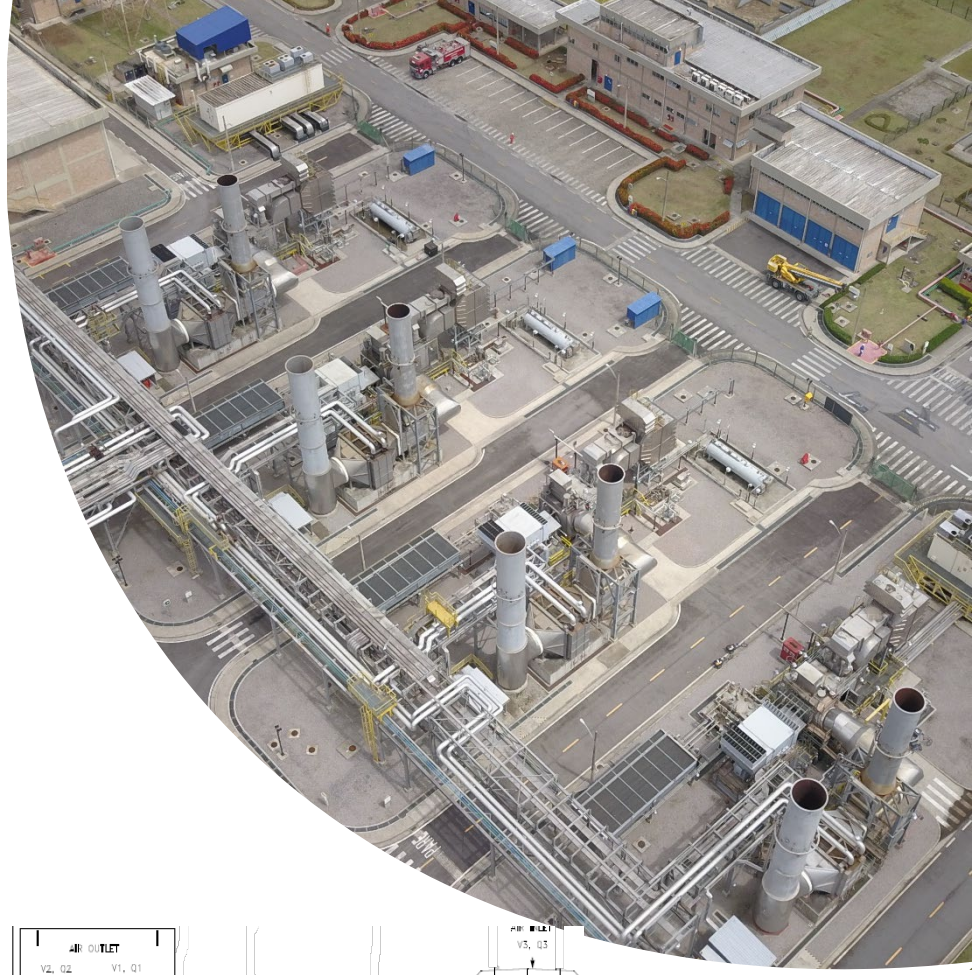
5 Induction Motors 3.4 MW – Dew Point Plant

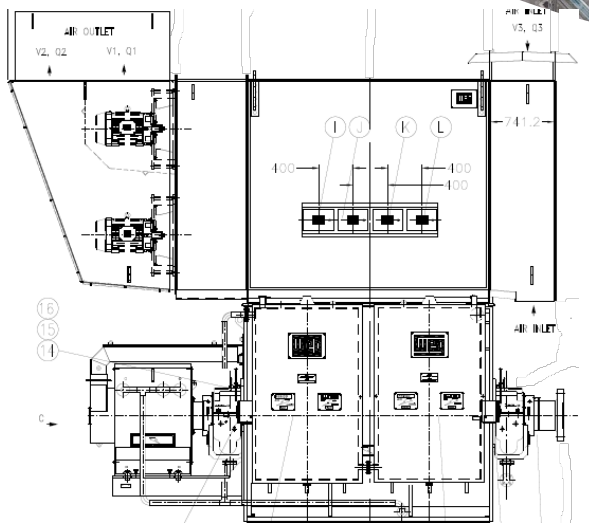
13.8kV machines with PD sensors (80 pF capacitors), installed from 2022

UTGCA - Power Generation System

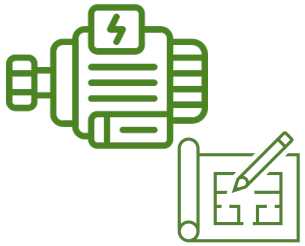
At UTGCA, all power for processing and exporting gas is produced by 04 generators (**off-grid plant**):

- Synchronous Generator, driven by Aeroderivative Gas Turbine
- Start of operation: April/2011
  - 37.5 MVA
  - 13.8 kV
  - 1800 rpm / 04 poles
  - Insulation: MICA and GVPI Impregnation
  - Class F (155°C)
  - Air cooled Generator
  - Excitation Brushless



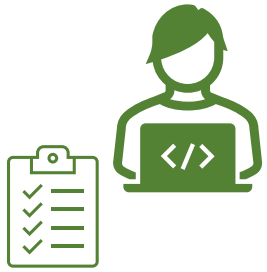


Case Study - Generator GE-513201D High Partial Discharge Levels Identification and Correction



July/2022

PD sensors were installed in UTGCA. Initial data collections on GE-513201D already indicated high Qm levels compared to other generators in the plant and the IRIS Power database.

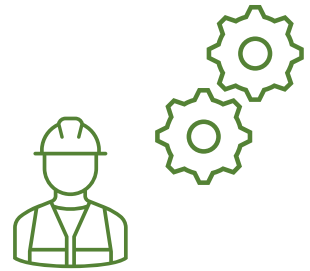


August/2022

Reduction of data collection frequency with TGA-B on Generator D, from 6 months to 15 days, for better monitoring of the machine's condition.

September/2023

Decision to perform a complete disassembly and overhaul of the generator during the Plant turnaround, scheduled for the year 2024. Work planning has been initiated.

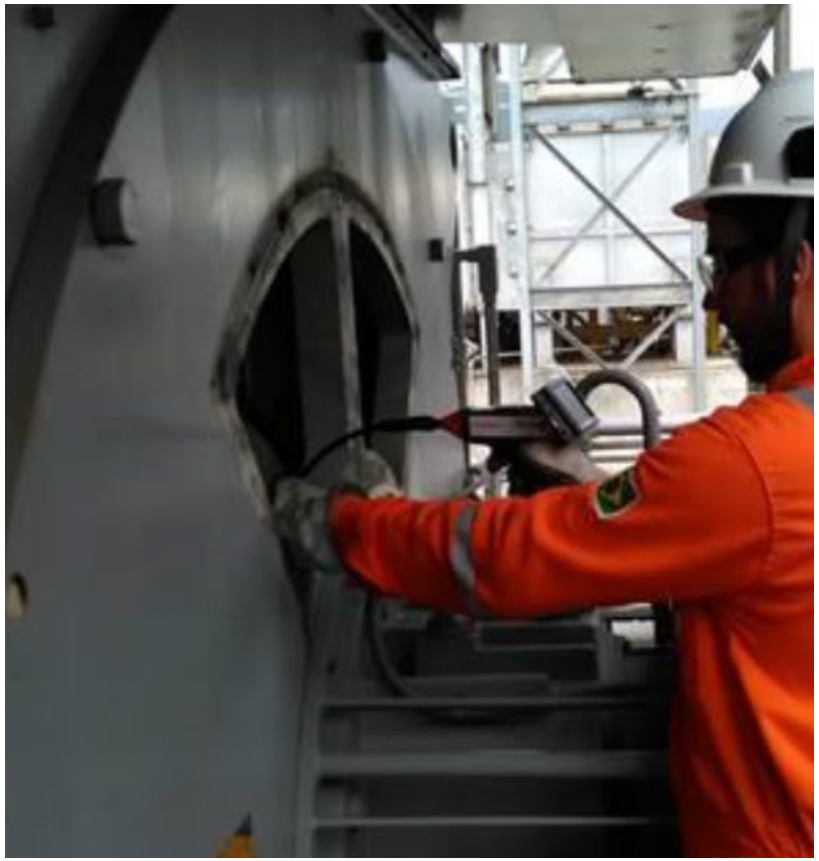


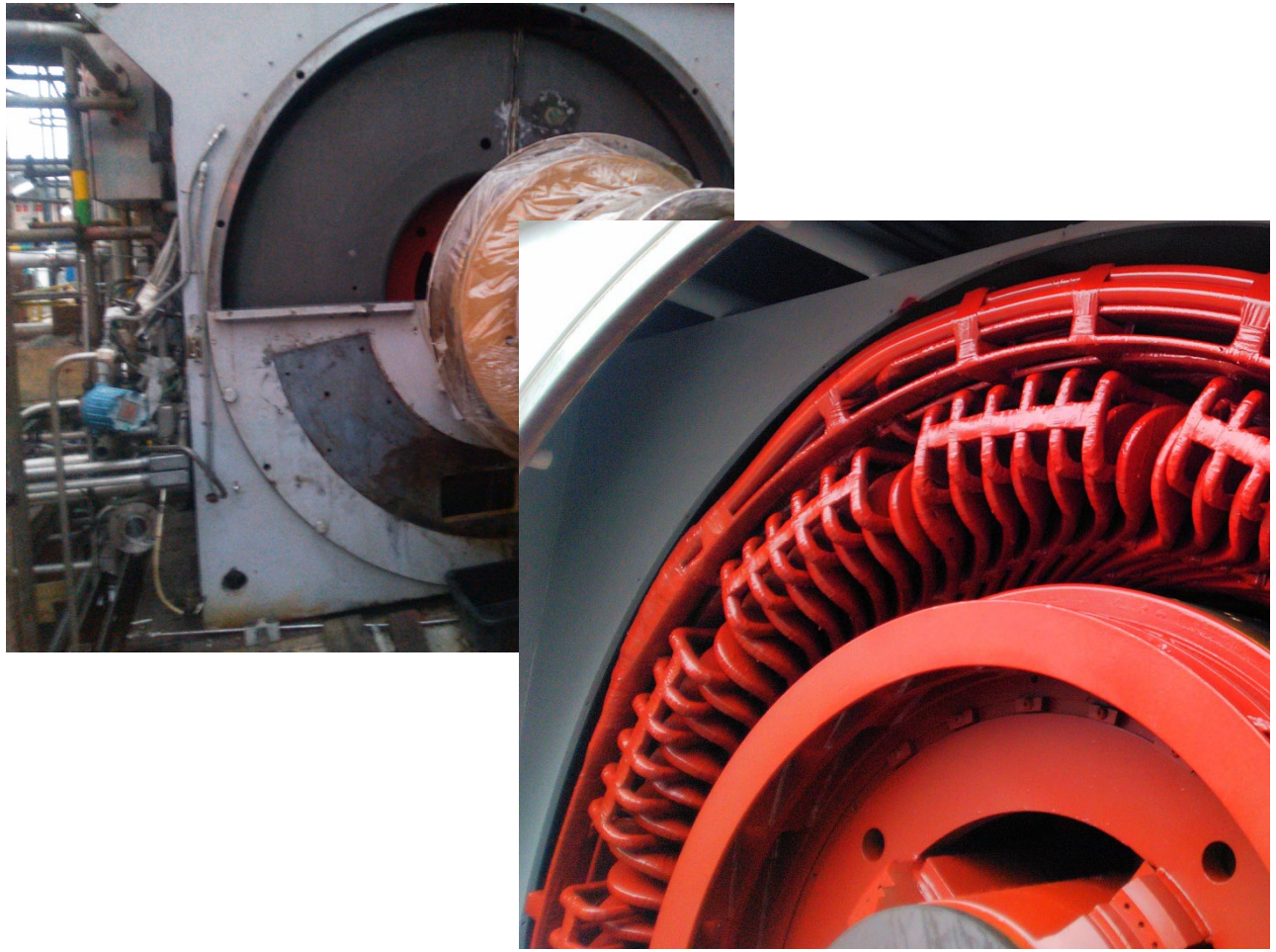
March/2024

The generator was overhauled during the plant turnaround period, and repaired PD damage findings. The maintenance was successfully completed without impacting the availability of the generation system.

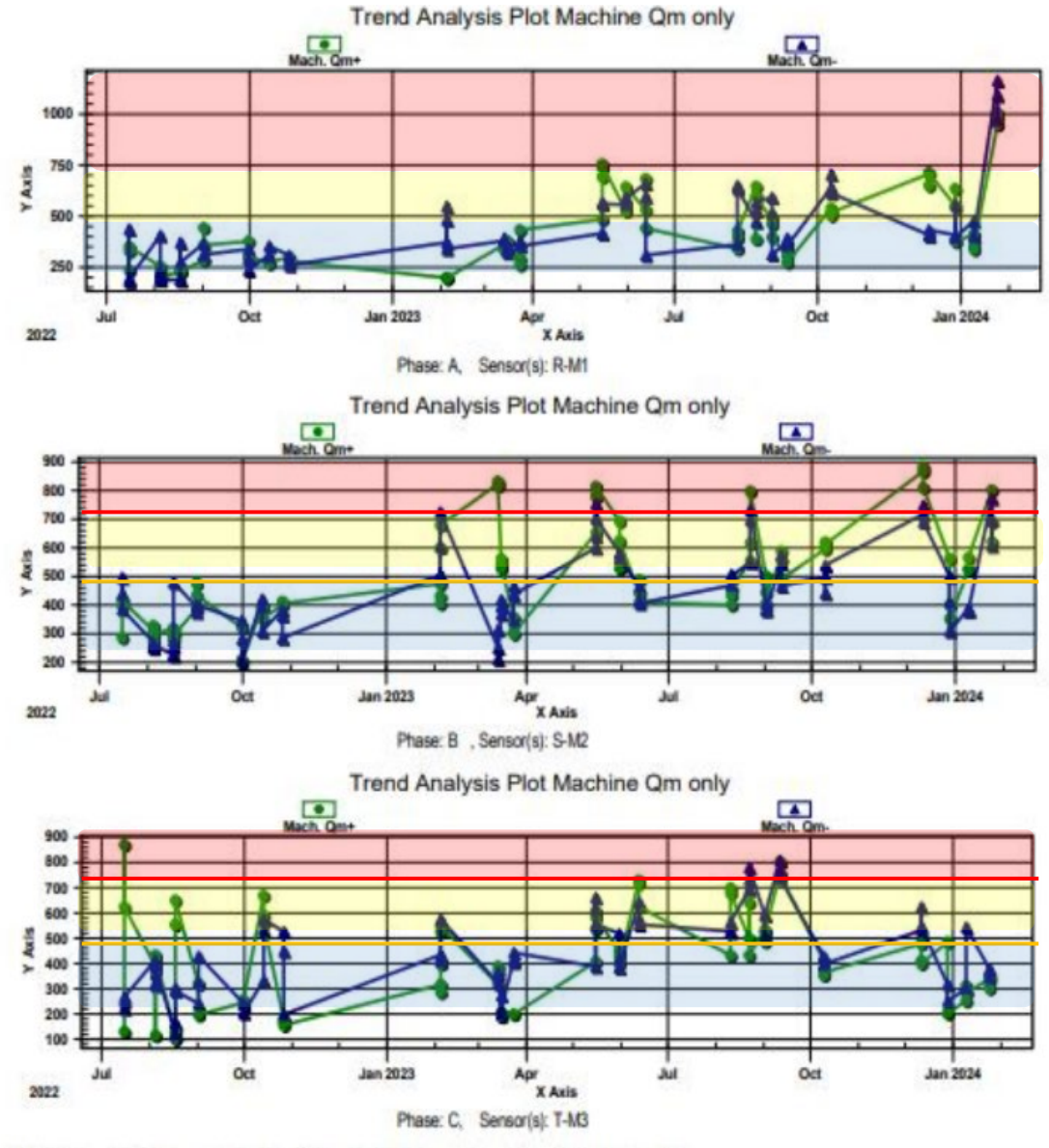
Why did we decide to inspect and overhaul the generator?

Endwinding (inner part) was not accessible for visual inspection or boroscopy, making it difficult to visualize the damage without machine disassembling





Why did we decide to inspect and overhaul the generator?



2.5 years

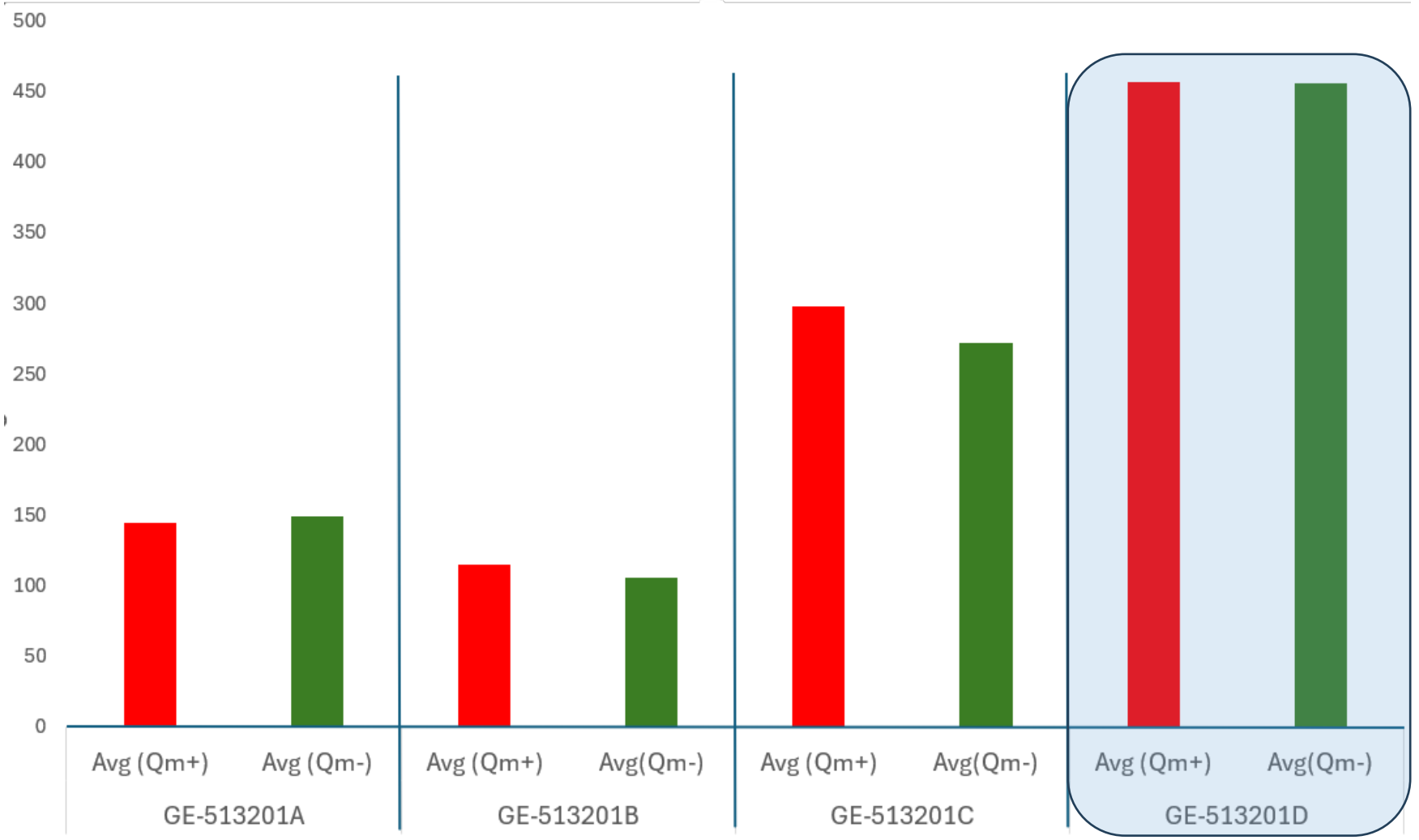
Very High (over 95% similar machines)

High (between 90% and 95%)

Moderate (between 75% and 90%)

The Qm trend plot for generator GE-513201D showed values above the moderate and high references (Iris Database). A significant increase in Qm values was also observed over the 2.5-year monitoring period.

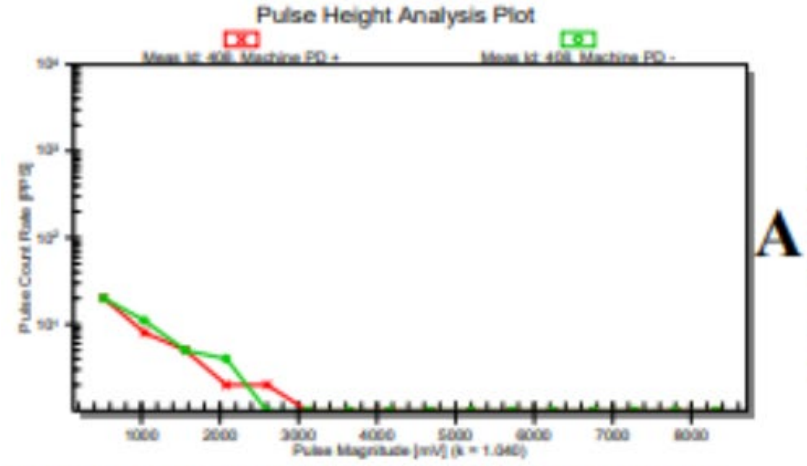
Why did we decide to inspect and overhaul the generator?



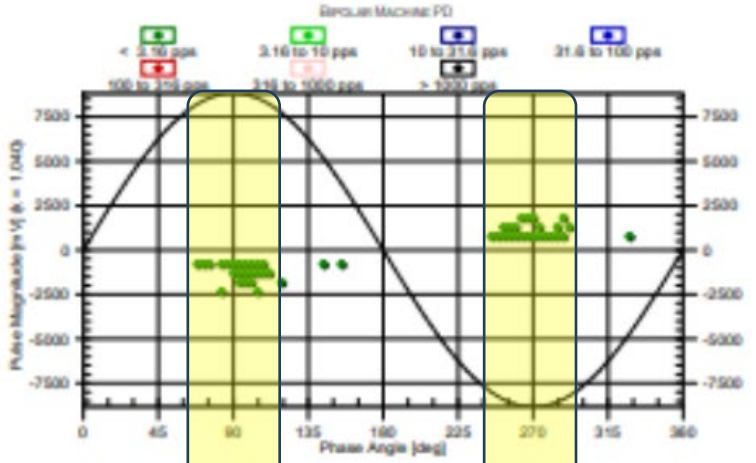
Generator C suffered water infiltration in 2021

High Average Qm levels compared to the other generators (same model and age)

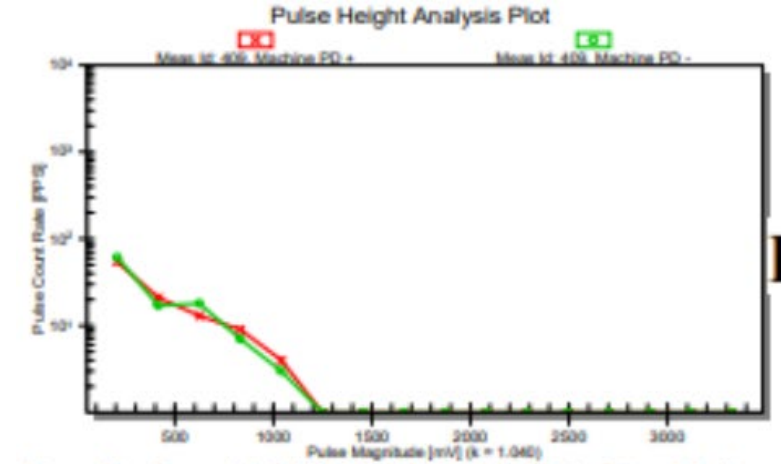
Why did we decide to inspect and overhaul the generator?



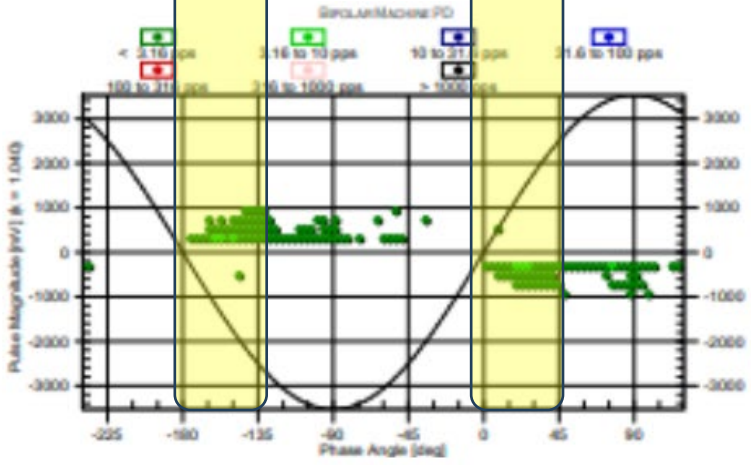
A



Phase: A, Sensor(s): R-M1, Ref. Angle: 90, Delay Time: 5 [ns]
Mach.: NQN+N/A/-N/A, Qm+948/-1165

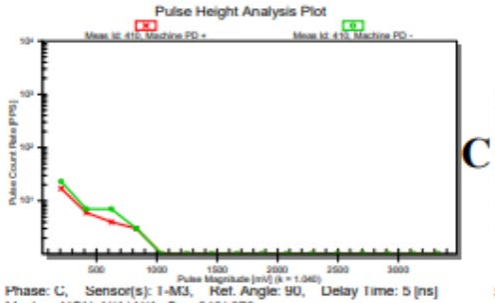


B

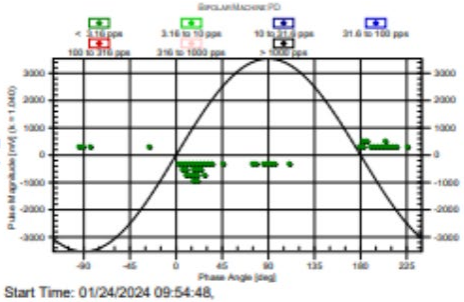


Phase: B, Sensor(s): S-M2, Ref. Angle: 90, Delay Time: 5 [ns]
Mach.: NQN+N/A/-N/A, Qm+802/-774

Opposite pulse Polarity in the two phases indicates a Phase-to-Phase PD activity (contamination, spacing issue etc)



C

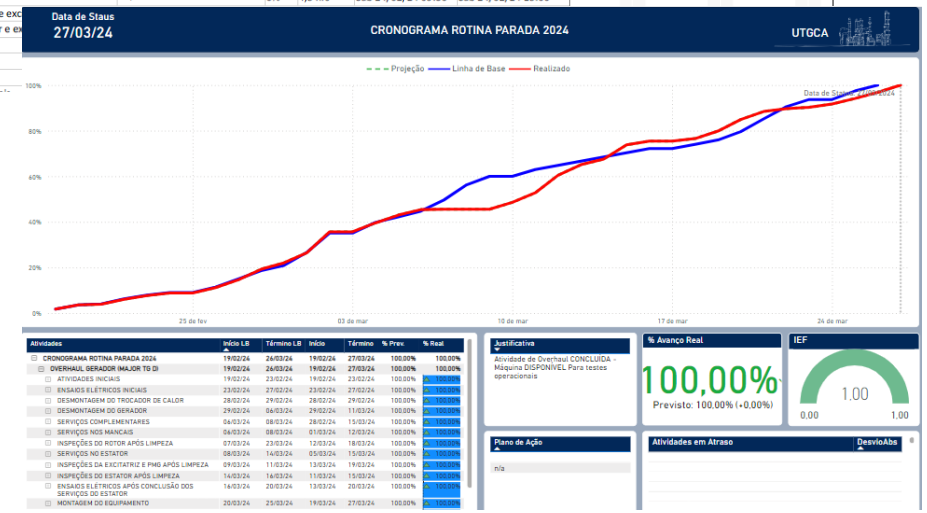


Phase: C, Sensor(s): T-M3, Ref. Angle: 90, Delay Time: 5 [ns]
Mach.: NQN+N/A/-N/A, Qm+340/-379
Start Time: 01/24/2024 09:54:48,

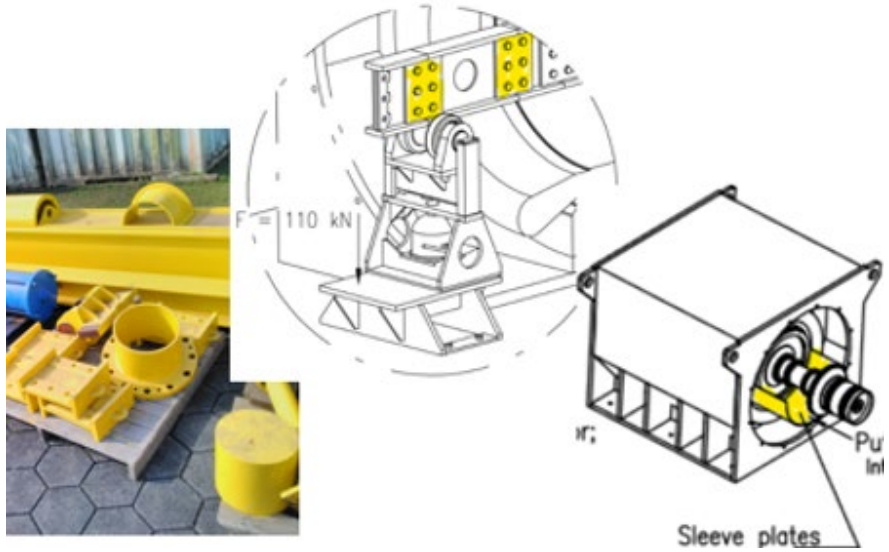
Overhaul Planning

Insight Energy — CRO.1993.010-R00 - Major (Campo) TG-D - UTGCA — PETROBRAS

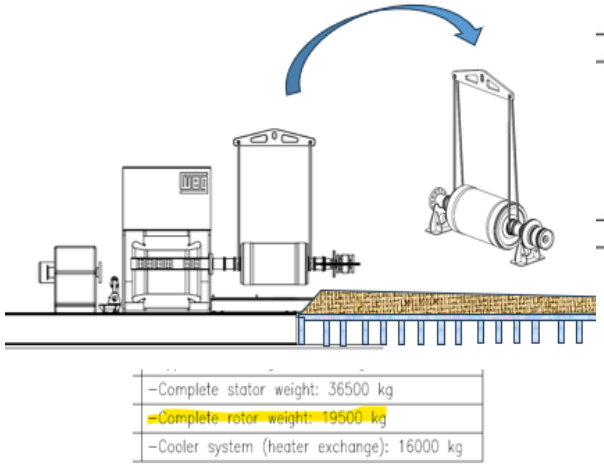
Id	Nome da Tarefa	RECURSOS	% concluída	Duração	Início	Término
1	1 CRO.1993.010-R00 - Major (Campo) TG-D - UTGCA		0%	32,17 dias	Ter 20/02/24 07:30	Sáb 23/03/24 12:00
2	1.1 MAJOR OVERHAUL (VALIDAÇÃO DAS INFORMAÇÕES APÓS VISITA AGENDADA)		0%	25,17 dias	Ter 20/02/24 07:30	Sáb 16/03/24 16:00
3	1.1.1 Início dos serviços		0%	1,5 dias	Ter 20/02/24 07:30	Qua 21/02/24 12:00
4	1.1.1.1 Mobilização da equipe (Chegada da equipe)		0%	3 hrs	Ter 20/02/24 07:30	Ter 20/02/24 10:30
5	1.1.1.2 Preparativos da área de trabalho		0%	2 hrs	Ter 20/02/24 10:30	Ter 20/02/24 13:30
6	1.1.1.3 Verificações de bloqueios de segurança		0%	2 hrs	Ter 20/02/24 13:30	Ter 20/02/24 15:30
7	1.1.1.4 Abertura das tampas das caixas de ligação	Munck	0%	2 hrs	Ter 20/02/24 15:30	Ter 20/02/24 17:30
8	1.1.1.5 Ensaios elétricos iniciais		0%	0,5 dias	Qua 21/02/24 07:30	Qua 21/02/24 12:00
9	1.1.1.5.1 Resistência ôhmica (Estator, rotor e excitatriz)		0%	2 hrs	Qua 21/02/24 07:30	Qua 21/02/24 09:30
10	1.1.1.5.2 Resistência de isolamento (Estator, rotor e excitatriz)		0%	2 hrs	Qua 21/02/24 09:30	Qua 21/02/24 11:30
11	1.1.1.5.3 Verificar sistemas de aterramento		0%	0,5 hrs	Qua 21/02/24 11:30	Qua 21/02/24 12:00
12	1.1.2 Desmontagem do equipamento		0%	5 dias	Qua 21/02/24 13:00	Seg 26/02/24 16:00
13	1.1.2.1 Montagem de estrutura de Tubo roll	Equipe de Tubo roll	0%	4 hrs	Qua 21/02/24 13:00	Qua 21/02/24 17:00
14	1.1.2.2 Desmontagem dos equipamento de excitação	Munck	0%	2 hrs	Qua 21/02/24 17:00	Qui 22/02/24 09:00
15	1.1.2.3 Desconexões elétricas e hidráulicas	Munck	0%	4 hrs	Qui 22/02/24 09:00	Qui 22/02/24 14:00
16	1.1.2.4 Desacoplamento do rotor (Verificar alinhamento)	Munck	0%	4 hrs	Qui 22/02/24 14:00	Sex 23/02/24 08:00
17	1.1.2.5 Desmontagem dos radiadores	Munck	0%	9 hrs	Qui 22/02/24 14:00	Sex 23/02/24 14:00
18	1.1.2.6 Desmontagem dos mancais	Munck	0%	9 hrs	Qui 22/02/24 14:00	Sex 23/02/24 14:00
19	1.1.2.7 Desmontagem das tampas principais	Munck	0%	9 hrs	Sex 23/02/24 14:00	Sáb 24/02/24 15:00
20	1.1.2.8 Montagem dos dispositivos de remoção do rotor	Munck; Dispositivos do rotor	0%	4,5 hrs	Sex 23/02/24 14:00	Sáb 24/02/24 09:30
21	1.1.2.9 Remoção do rotor	Dispositivos do rotor	0%	4,5 hrs	Sáb 24/02/24 09:30	Sáb 24/02/24 15:00
22	1.1.2.10 Inspeção visual do estator, rotor e exc					
23	1.1.2.11 Ensaios elétricos do estator, rotor e ex					
24	1.1.3 Serviços nos mancais					
25	1.1.3.1 Limpeza dos mancais					
26	1.1.3.2 Inspeções dos mancais					

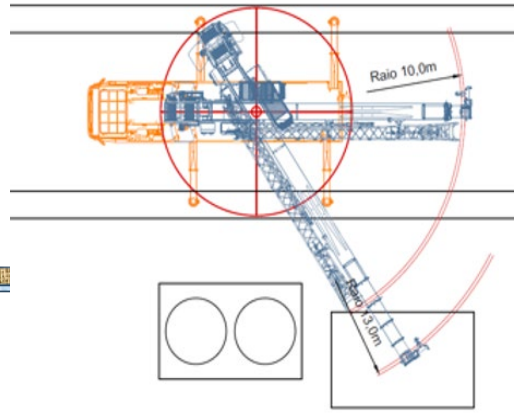


Planning made with the premise of execution within 35 days (plant turnaround period)



The preparation, conditioning and testing of special tools for extracting the rotor was part of the planning.





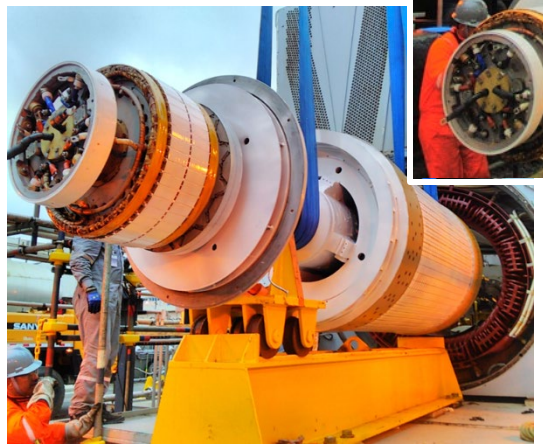
Load lifting planning

Overhaul Execution: Generator disassembly

Partial disassembly of the heat exchanger

KG

22 TONS



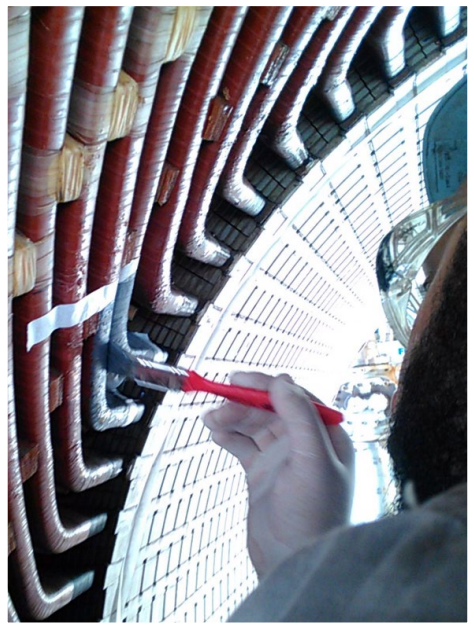
Rotor extraction and lifting

Structure to accommodate and cover the rotor

Generator Overhaul Workscope in site

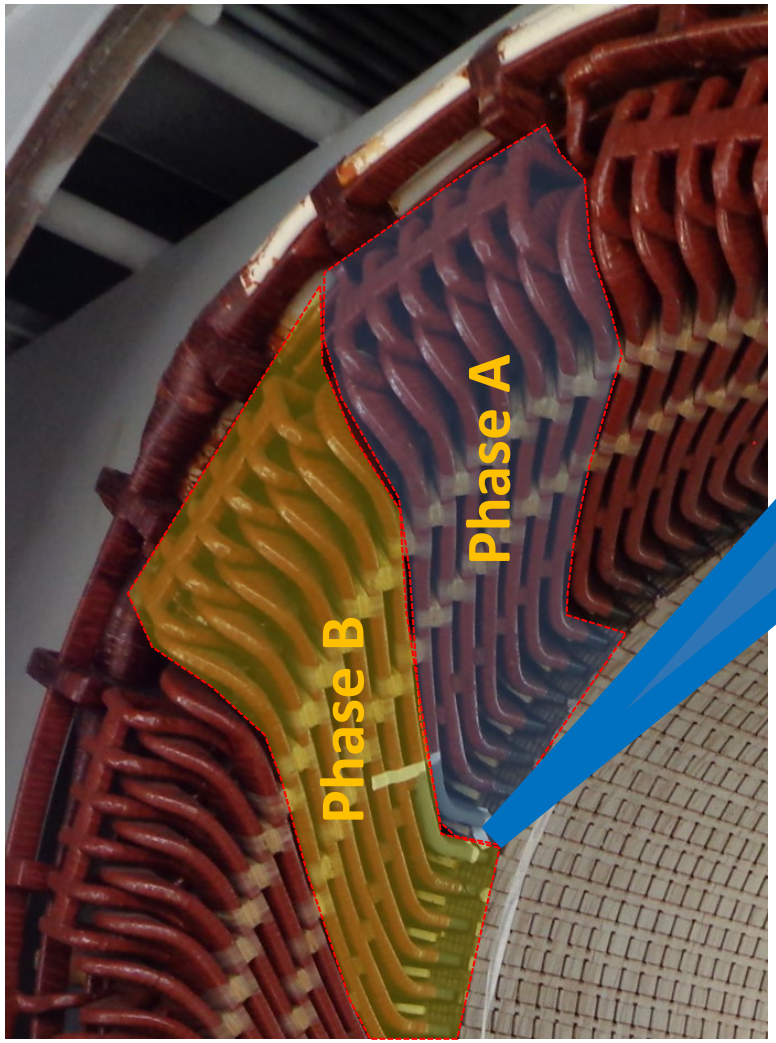
Electrical and Mechanical complete inspection. Bearing replacement (pitting corrosion found)

Complete cleaning and painting stator/rotor

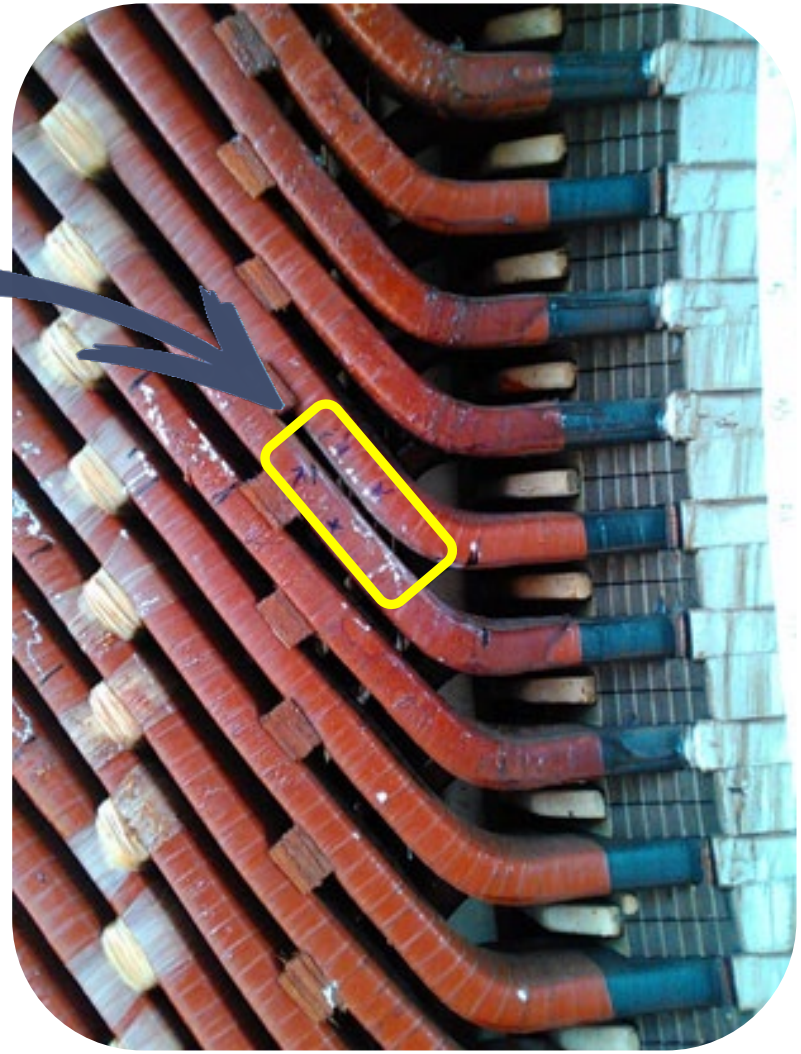


Repair of damaged insulation surface

Findings

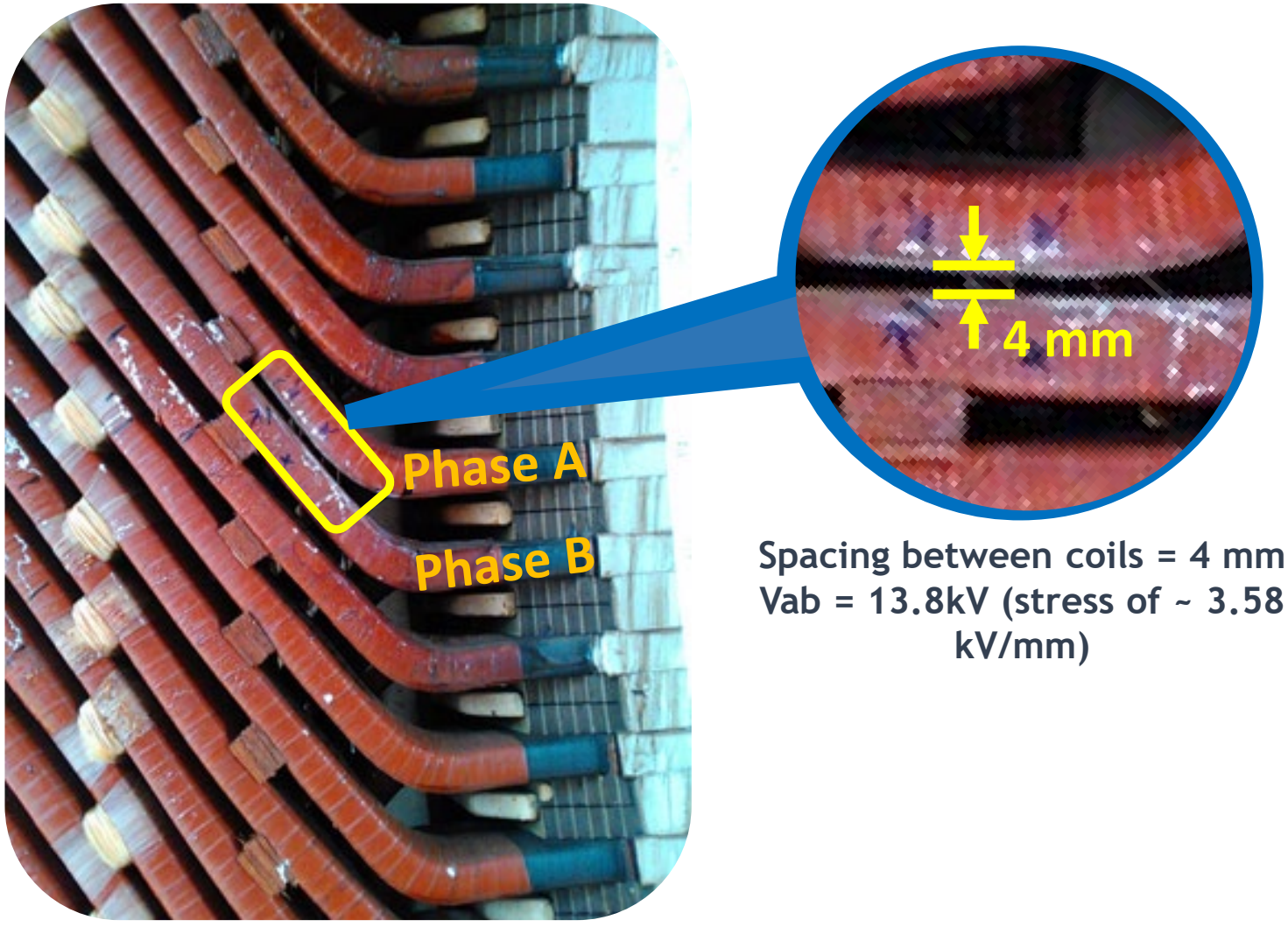


PD occurring between high voltage coils in two different phases



Two coils in different phases that were installed too close to one-another

Repairing End-winding surface damaged

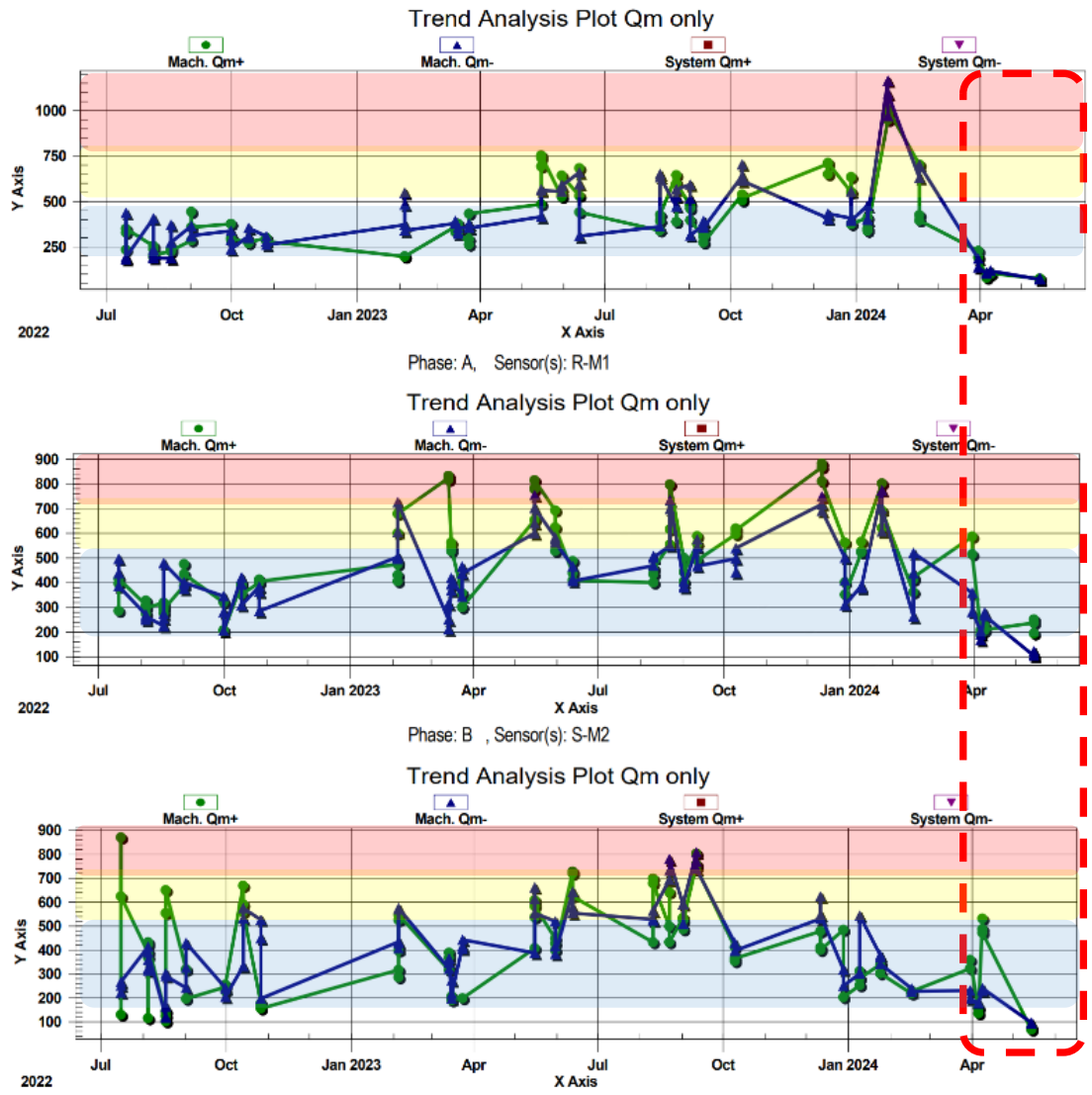


Spacing between coils = 4 mm
Vab = 13.8kV (stress of ~ 3.58 kV/mm)

Repair and Remedy:
a. Sanding and cleaning the surface damaged
b. Reapplication of semiconductive coating
c. Injection of Silicon rubber (Higher dielectric strength than air)

Dow Corning® brand Product	Room Temperature Cure Time[2]	Heat Cure Time[2], minutes	Dielectric Strength	
			volts/mil	kV/mm
Standard Gels				
527 Dielectric Gel	24 hr/>1 week	30/200 @ 100°C 20/75 @ 125°C 10/35 @ 150°C	385	15.1

Post Overhaul Results (online IRIS PD Data)

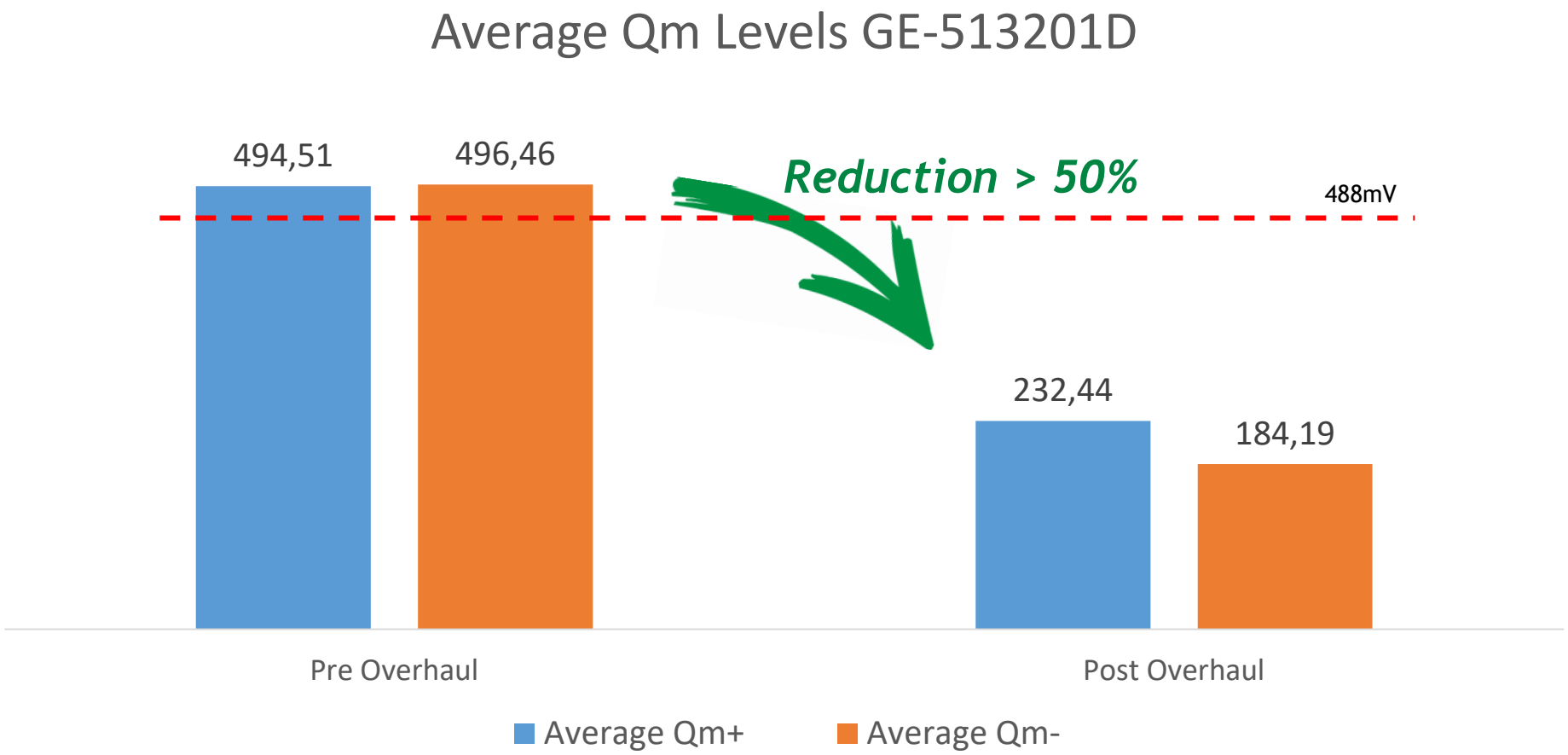


Post Overhaul

Trend plot shows a significant reduction in Qm values after Overhaul, being close to typical values compared to stators of similar machines.

- Very High (over 95% similar machines)
- High (between 90% and 95%)
- Moderate (between 75% and 90%)

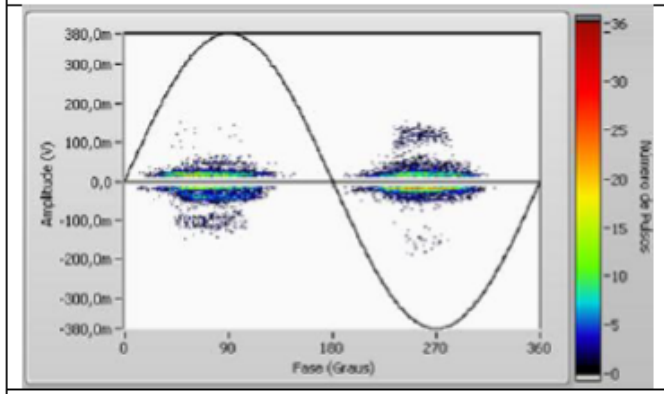
Post Overhaul Results (online IRIS PD Data)



Average Qm values for GE-513201D shows a significant reduction in DP activity

Post Overhaul Results - Offline Test (PD measurement system by another manufacturer)

ØU x ØV+ ØW + Massa – 8 kV



Amplitude Máxima Pos (V)	156,47m
Amplitude Máxima Neg (V)	189,29m
Amplitude Persistente Pos (V)	133,59m
Amplitude Persistente Neg (V)	130,62m
NQN Pos	61,93
NQN Neg	62,33
Amplitude Máxima Persistente Pos (V)	72,78m
Amplitude Máxima Persistente Neg (V)	51m

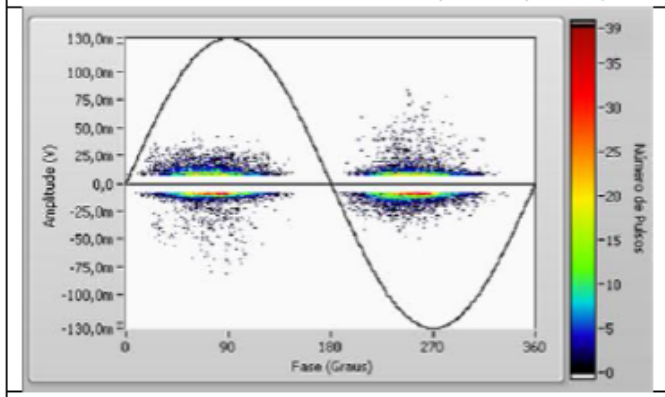
Amp. Positiva (Persistente)	133,59 mV
Amp. Negativa (Persistente)	130,62 mV

Pre-Overhaul

Offline PD readings obtained before the overhaul appeared satisfactory. This test is not impacted by load, temperature, vibration, and uses single-phase voltage, rendering it inadequate for detecting spacing issues between end-windings of distinct phases.

nearly three-fold decline in offline PD

ØU x ØV+ ØW + Massa – 8 kV

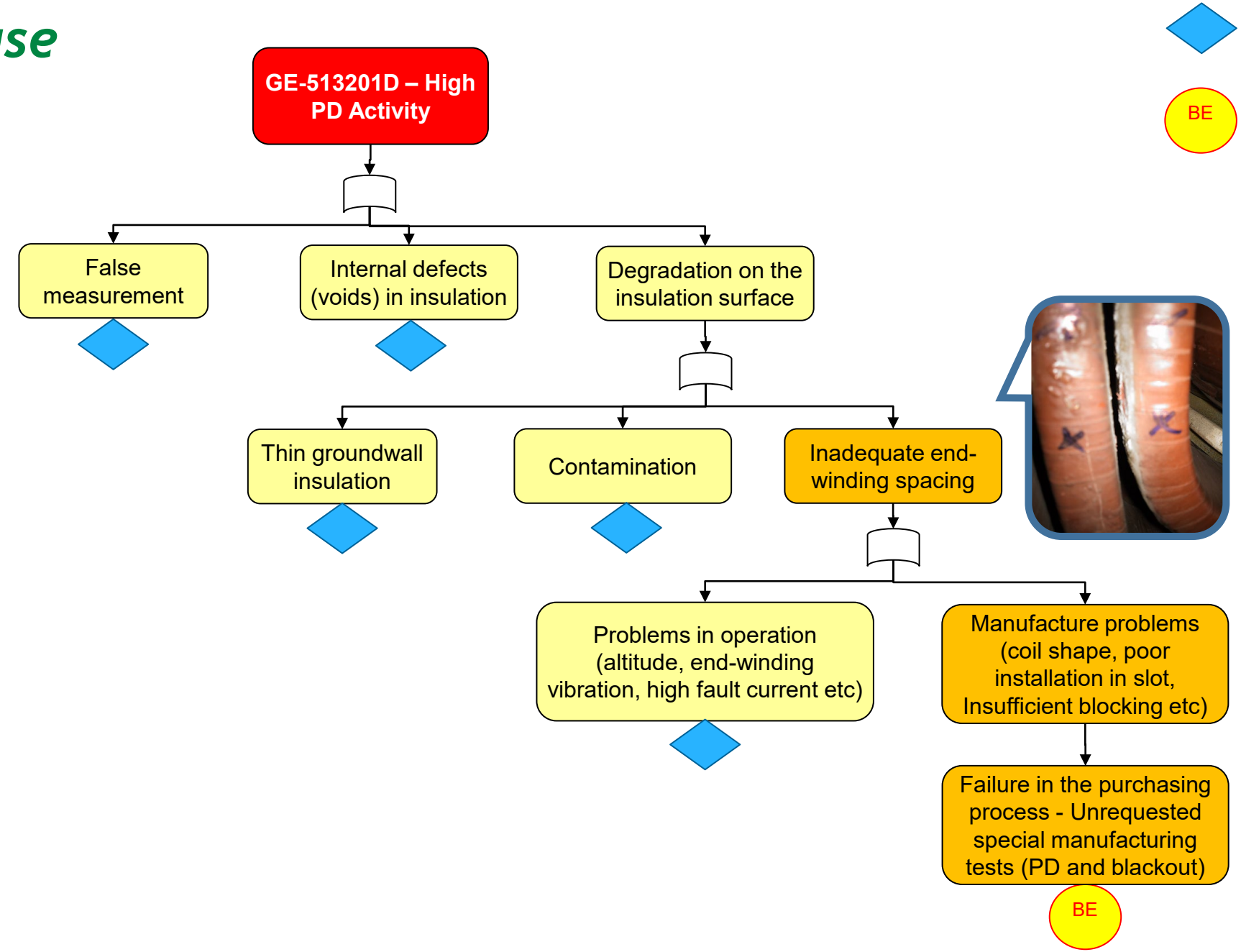


Amplitude Máxima Pos (V)	84,12m
Amplitude Máxima Neg (V)	81,06m
Amplitude Persistente Pos (V)	42,66m
Amplitude Persistente Neg (V)	42,66m
NQN Pos	251,53
NQN Neg	126,72
Amplitude Máxima Persistente Pos (V)	25,13m
Amplitude Máxima Persistente Neg (V)	22,21m

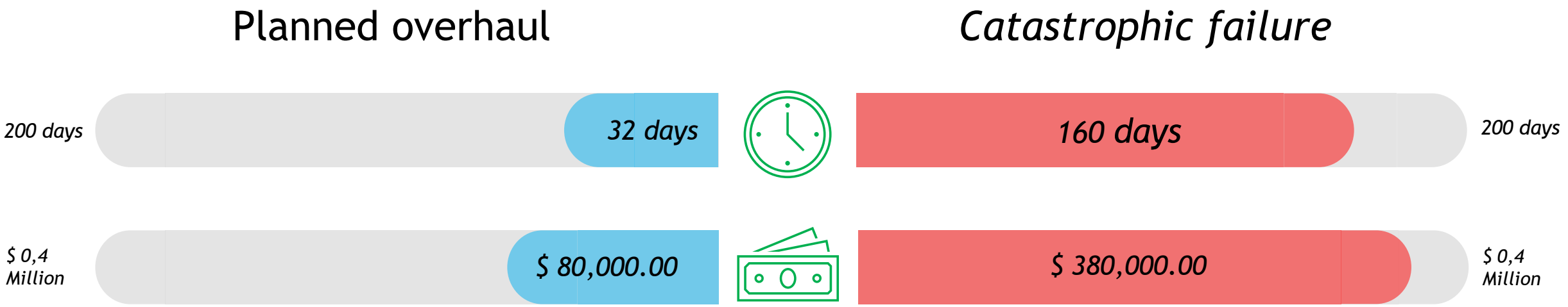
Amp. Positiva (Persistente)	42,66 mV
Amp. Negativa (Persistente)	42,66 mV

Post-Overhaul

Root Cause



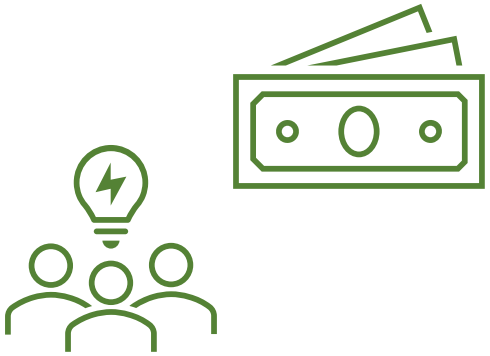
Cost and Downtime Comparison



The planned overhaul, when compared to corrective maintenance of a potential catastrophic failure, allows for a significant reduction in costs and downtime, of about 5 times less.

Conclusions

Condition-based PD monitoring is effective in identifying and keeping under surveillance insulation failures. Furthermore, maintenance outages can be planned in advance (The time to failure is usually 5 years or more).



The PD monitoring enabled the decision to intervene during plant turnaround, ensuring that the machine downtime did not impact production. Additionally, performing this type of intervention during plant turnaround allows for cost reduction through resource sharing, such as cranes and labor.

The early execution of the generator overhaul avoided the risk of coil failure, which would have had a COST and OUTAGE TIME 5 times higher compared to the planned corrective action.

Conclusions

Intervention decision-making should involve analyzing the trend and comparing PD values with other machines of the same model. Additionally, understanding the operational history of the machines is crucial.

Controlling the PD level in air-cooled machines reduces the creation of ozone, which is important to prevent accelerated insulation degradation.

Partial Discharge test and black-out test must be requested for new machines to prevent problems with inadequate end-winding spacing.

Thank You!

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