Report of Findings

EMI Testing
for NAES
at Gainesville Renewable Energy Center
Gainesville, FL

Test Date: March 28, 2017

Prepared by:

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Confidential

Revision	Tested by/Date	Prepared by/Date	Reviewed by/Date	Approved by/Date
0	Dan McKim/28-Mar-17	Dan McKim/11-Apr-17	J. E. Timperley/11-Apr-17	Dan McKim/17-Apr-17

DOBLE ENGINEERING COMPANY

EMI DIAGNOSTICS REPORT
From

DOBLE ENGINEERING COMPANY
85 Walnut Street, Watertown, MA 02472

Client: NAES Gainesville Renewable Energy Center (GREC)

Client PO No.: 201700251

Test Engineer: Daniel McKim

Reference: Doble Quotation No. 84172A and Doble Siebel No. 1-23738621

Background: The following EMI Diagnostics report presents data, analysis and action items for the electrical equipment tested for NAES Gainesville Renewable Energy Center on March 28, 2017.

These tests were performed on-line in a non-intrusive manner minimizing plant impact during operation. The conclusions and recommendations by Doble Engineering provide an on-line condition assessment of the overall component and system health for NAES GREC to utilize in determining the necessity of any maintenance activities. The following color codes will be utilized in the report to aid the customer in evaluating the severity of issues found during testing and subsequent analysis.

Code	Code Description	Explanation
0	Partial Data	Indicates some data was collected but not complete or insufficient data was collected to make a good assessment.
1	Unacceptable	Strong indication that there is a serious problem. Requires attention within the next few months. Inspection and additional testing recommended for verification.
2	Questionable	Data indicates a problem is present or developing. Verification testing or inspections are needed. Requires attention within the next year.
3	Good	Data indicates there are no serious problems detected. Continue routine condition assessment testing. No maintenance can be recommended.

Date Submitted: April 11, 2017

The contents of this report, including but not limited to professional opinion, recommendations, Doble Intellectual Property, Know-How, Methodology NAES GREC reliance hereof and any liability arising hereunder, are governed by the Doble Engineering Company Condition assessment Terms and Conditions. Any additional terms and conditions are hereby expressly rejected.

1. Executive Summary

Conclusions and Recommendations

(Immediate actions required in bold)

EMI testing was performed on the generator, isolated phase bus systems and transformers. Loads greater than 70% are sufficient to detect both conductor and insulation related problems, loads less than 70% are sufficient to detect only insulation related problems.

Generator: PD, mild corona and arcing and were noted in the spectrum. High radiated EMI levels were noted at the generator connection box. Levels were highest at the generator side of the connection box. **Recommend inspecting the connections for looseness, proper assembly and torque during the next scheduled maintenance period.** Very high radiated EMI levels were noted from the lube oil piping at the turbine. Static discharges in lube oil systems can cause oxidation of the oil and result in oil breakdown and contamination. **Recommend oil analysis be conducted. If oil is darkened and breaking down the source of the static discharges should be resolved.** Recommend retesting the generator following repairs.

IPB: PD, data, FM radio signals, minor arcing and mild corona were noted at several frequencies throughout the spectrum on this bus. Radiated EMI levels were moderate throughout the bus but were higher in the vicinity of the generator connection box. Activity noted is most likely from the generator as discussed above. No corrective actions are recommend at this time. Track and trend this bus.

GSU Transformer: PD, data, AM radio, noise and mild corona were noted at several frequencies throughout the spectrum this transformer. Radiated EMI was low throughout the transformer. Levels are low and not of concern at this time. Recommend track and trend this transformer.

Station Service Transformer (SST): PD, data, AM/FM radio, noise and mild corona were noted at several frequencies throughout the spectrum this transformer. Radiated EMI was low throughout the transformer. EMI levels are low and not of concern at this time. Recommend track and trend this transformer.

It was a pleasure to be of service to NAES GREC. The assistance of the site personnel was greatly appreciated. Please contact Doble Global Power Service personnel should any questions arise. Refer to the Doble Global Power Service Contacts listed in the attached Appendix for phone numbers and email addresses.

April 11, 2017

Sincerely,

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2. Methodology

EMI testing follows the CISPR 16 standard and is a non-intrusive testing technique that is performed while the component (motor, generator, transformer, isophase bus) is on-line. EMI testing does not require installation of any permanent hardware. It also does not introduce any signals and will not cause any equipment to trip off-line. It utilizes a split ring Radio Frequency Current Transformer (RFCT) that is placed around the neutral, a safety ground or power conduit of the component being tested and measures the signals generated from the component or system defects. Each defect yields a pattern at a different frequency and amplitude allowing the EMI Engineer to identify the type of anomaly.

EMI diagnostics measures a broad spectrum of radio frequencies to allow the EMI engineer to view various patterns at each frequency including but not limited to corona, gap discharges, and random noise and arcing. The first three are types of partial discharge each with a unique pattern resulting from the specific defect or deterioration mechanism. The fourth pattern is arcing and is not measured by PDA techniques. Arcing has current flow and by definition is not a partial discharge. Arcing is produced by many mechanical defects such as a wiped bearing, loose connections or broken rotor bars in an induction motor. Signals from radio stations and transients from power electronics are also measured and identified.

Lastly, a hand held "sniffer" is utilized in conjunction with the EMI software to further identify and pinpoint each defect location. This device measures the EMI signals radiated from each component or system defect and allows an EMI Engineer to listen to the radio noise generated from these defects.

3. Introduction

In accordance with NAES Gainesville Renewable Energy Center PO: PO-201700251 the following components were tested on March 28, 2017.

Component	Component Description	Component Serial Number
Generator	Generator	9210007.010
IPB	Isophase Bus	None
Transformer	GSU Transformer	C-07987-5-1
Transformer	Station Service Transformer	C-07992-5-1

Additional nameplate information is listed under the specific component analyzed if available. The components are listed in the order that they were analyzed.

4. Test Results and Observations

Generator

4.1 Generator

Brush Electric Generator

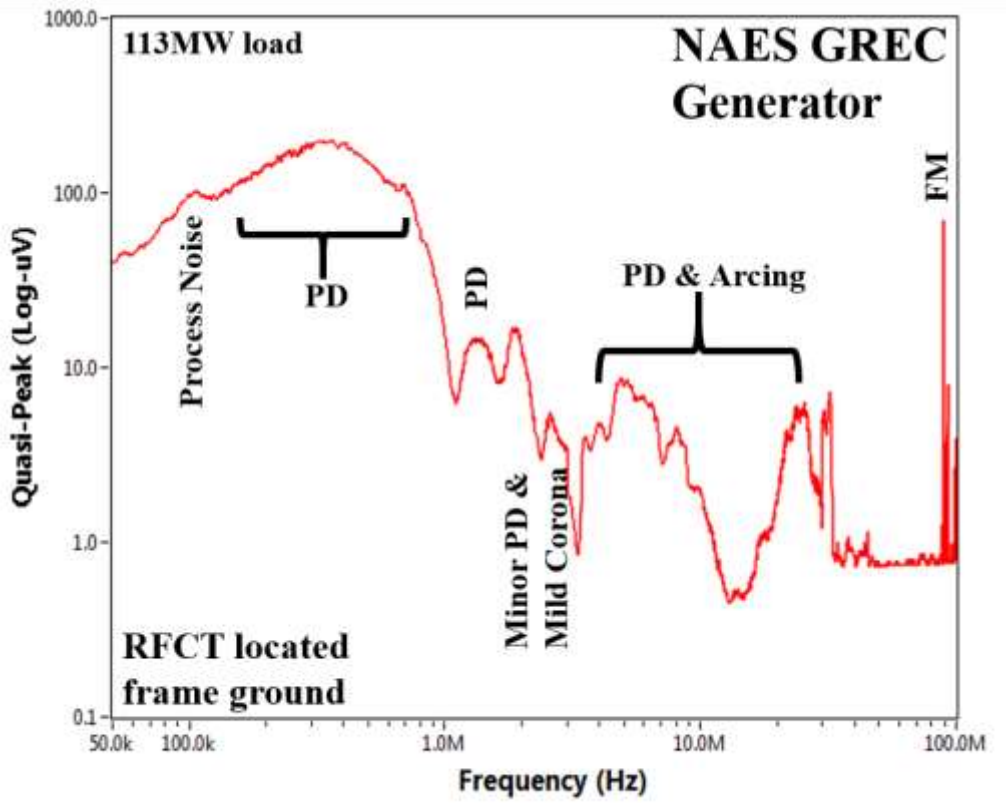

Figure 1: EMI Signature for Generator.

This was the first EMI evaluation for this Brush Electric 13.8 kV, 136 MVA, 3600 RPM, 3 PH, 60, Hz, 0.85 pf, air cooled generator, SN: 921007.010. The test was performed with EMI data collected from an RFCT (radio frequency current transformer) placed around the generator frame ground. A photograph of this location can be found at the end of this report.

The generator was loaded to 113 MW, which is sufficient to detect insulation and conductor related problems.

PD, mild corona and arcing and were noted in the spectrum. High radiated EMI levels were noted at the generator connection box. Levels were highest at the generator side of the connection box. **Recommend inspecting the cable connections for looseness, proper assembly and torque during the next scheduled maintenance period.** Very high radiated EMI levels were noted from the lube oil piping at the turbine. Static discharges in lube oil systems can cause oxidation of the oil and result in oil breakdown and contamination. **Recommend oil analysis be conducted. If oil is darkened and breaking down the source of the static discharges should be resolved.**

Recommend retesting following repairs. Track and trend this generator.

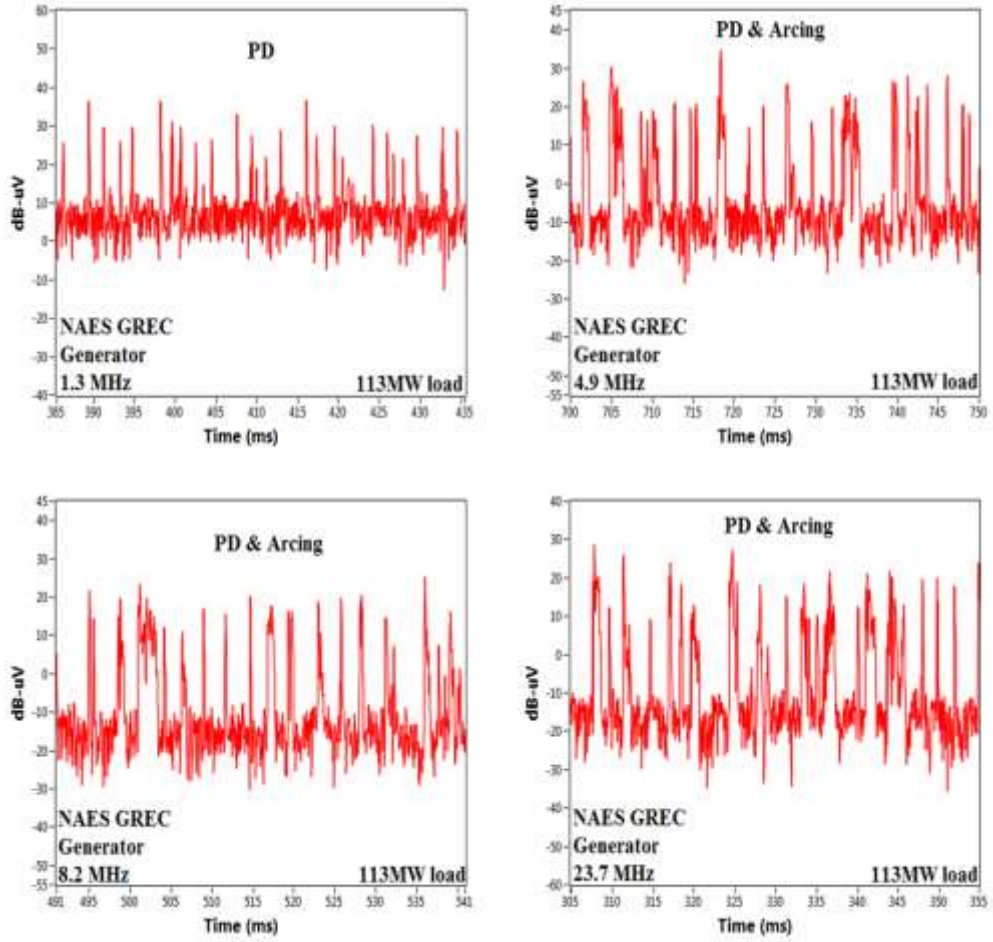

Figure 2: Generator EMI patterns in the spectrum.

Figure 2 shows PD and arcing in the spectrum. Arcing is an indication of loose connections. The source of this activity and recommended actions are discussed above.

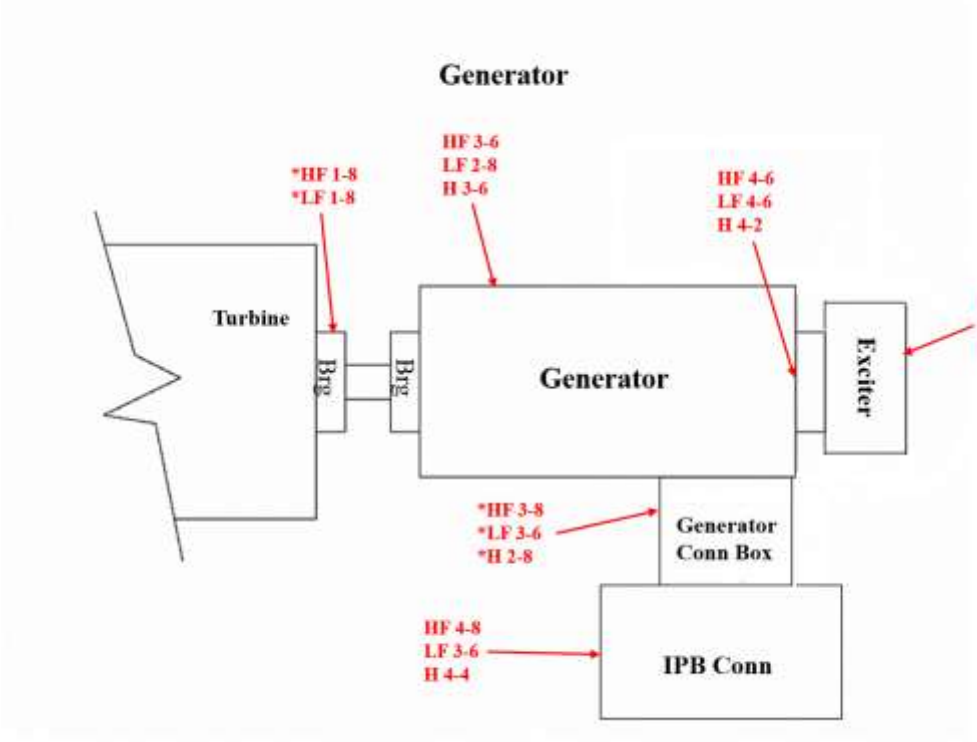

Figure 3: EMI Sniffer Evaluation for Generator

Figure 3 above shows the readings listed for the measurements taken are LF, HF and H (or a combination thereof). This is followed by a number which is the gain of the instrument. After this, the number of bars indicated the severity from 1 to 10 is shown.

A scan for radiated EMI shows activity in the turbine bearing and lube oil piping, as well as radiated EMI from the Generator Connection Box. Sparking in the lube oil system should be investigated and corrected. Discussion of the causes and recommendations is listed above.

Isophase Bus

4.2 IPB

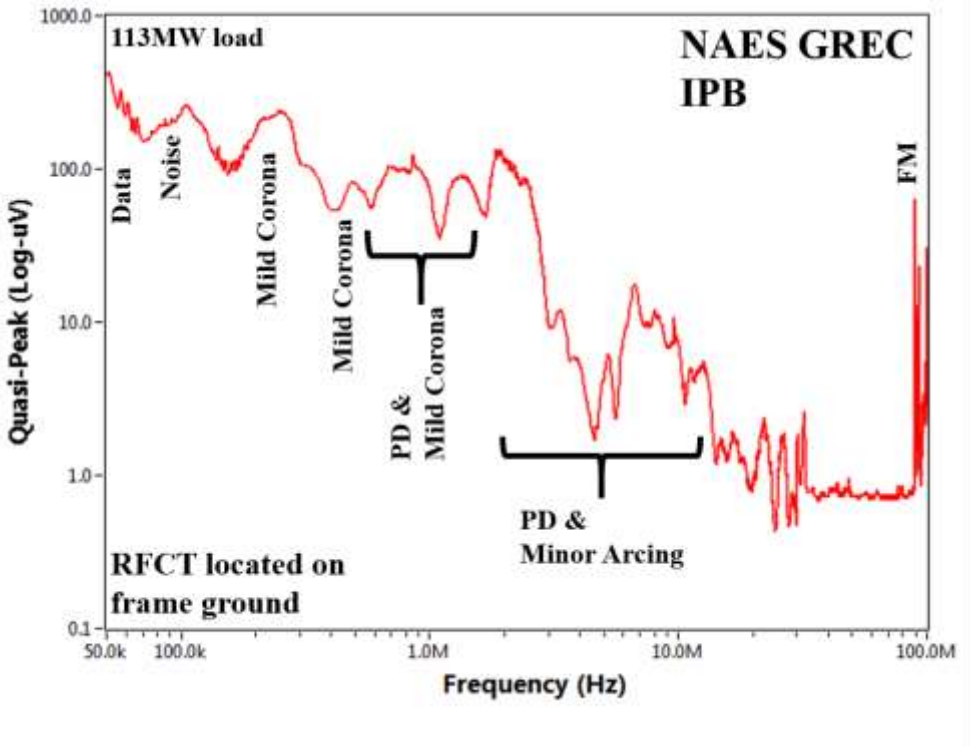

Figure 4: EMI Signature for Isolated Phase Bus.

This was the first EMI evaluation for this 13.8 kV bus system. The test was performed with EMI data collected from an RFCT (radio frequency current transformer) placed around the bus frame ground at the generator connection box. A photograph of this location can be found at the end of this report.

The bus was loaded to 113 MW, which is sufficient to detect insulation and conductor related problems.

PD, data, FM radio signals, minor arcing and mild corona were noted at several frequencies throughout the spectrum on this bus. Radiated EMI levels were moderate throughout the bus but were higher in the vicinity of the generator connection box. Activity noted is most likely from the generator as discussed above. No corrective actions are recommend at this time.

Track and trend this bus.

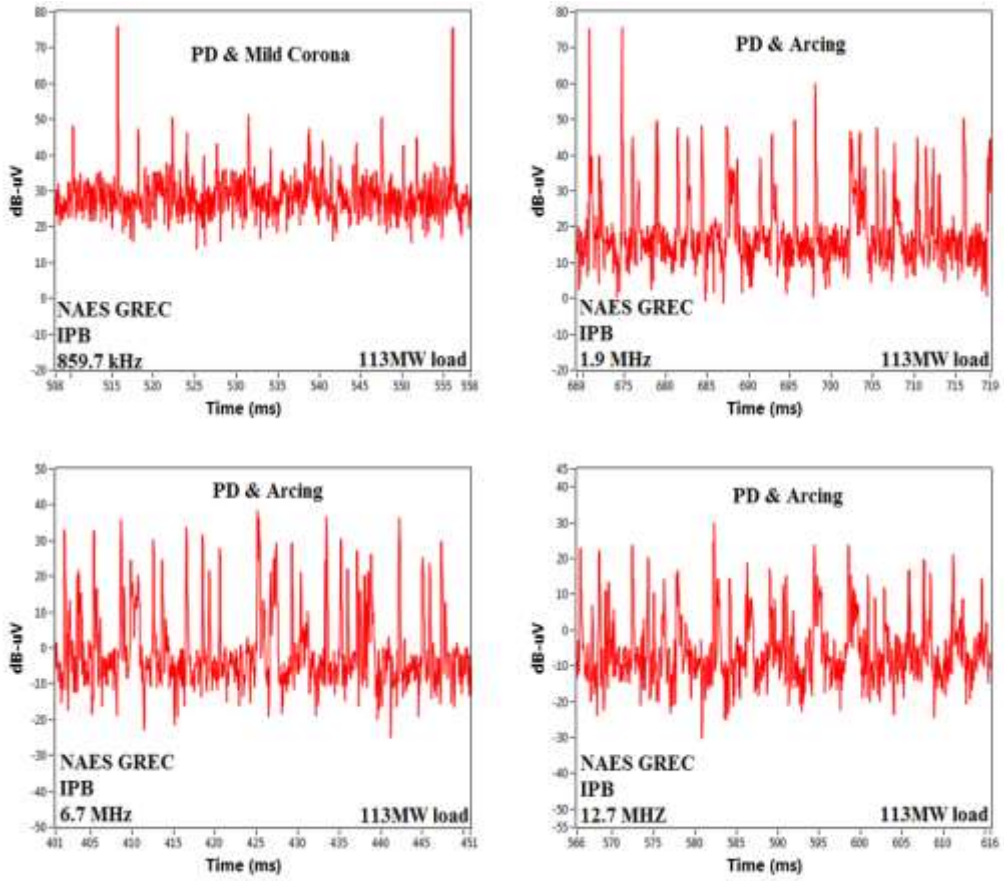

Figure 5: Isolated Phase Bus EMI patterns in the spectrum.

Figure 5 shows Arcing, mild corona and PD patterns. Arcing and PD observed in the above waveforms is likely from the generator. Those actions are addressed above.

4.3 GSU Transformer

Pennsylvania Transformer

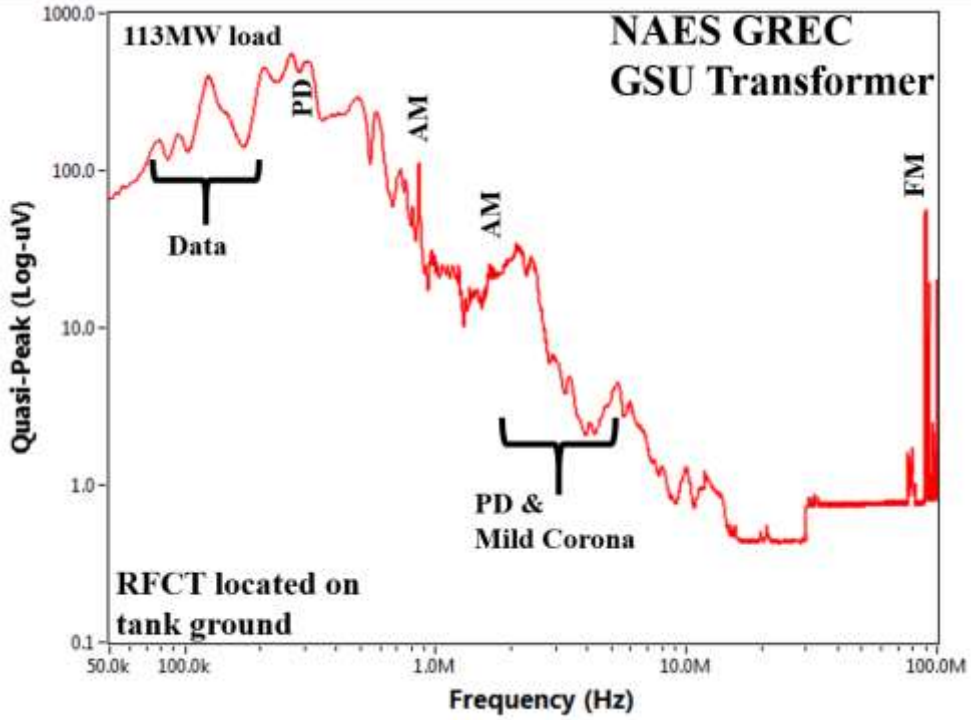

Figure 6: EMI Signature for GSU Transformer.

This was the first EMI evaluation for this Pennsylvania Transformer Co. 138/13.8 kV, 104 MVA, 3 PH, 60, Hz, transformer, SN: C-07987-5-1. The test was performed with EMI data collected from an RFCT (radio frequency current transformer) placed around the tank ground. A photograph of this location can be found at the end of this report.

The transformer was loaded to 113 MW, which is sufficient to detect insulation and conductor related problems.

PD, data, AM radio, noise and mild corona were noted at several frequencies throughout the spectrum this transformer. Radiated EMI was low throughout the transformer. Levels are low and not of concern at this time.

Recommend track and trend this transformer. Continue schedule oil analysis.

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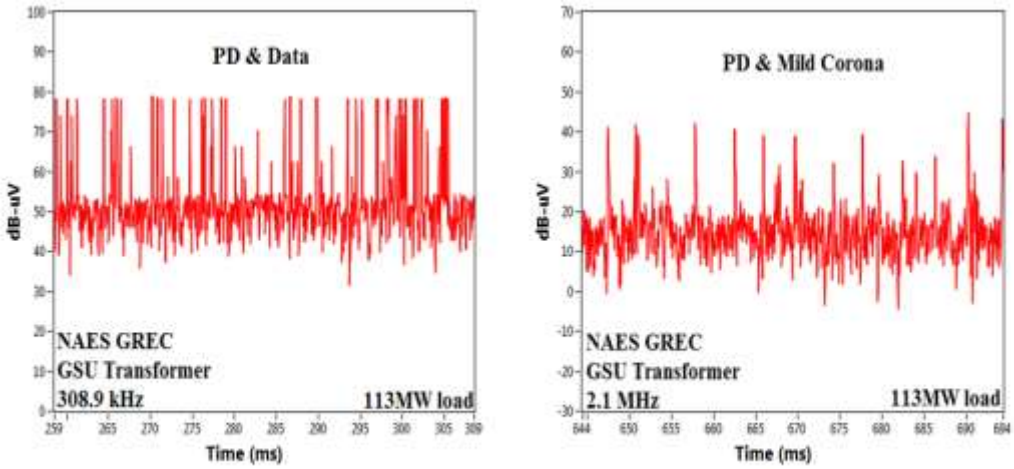

Figure 7: GSU Transformer EMI patterns in the spectrum.

Figure 5 shows data, mild corona and PD patterns. This activity may be external to the transformer.

4.4 Station Service Transformer

Pennsylvania Transformer

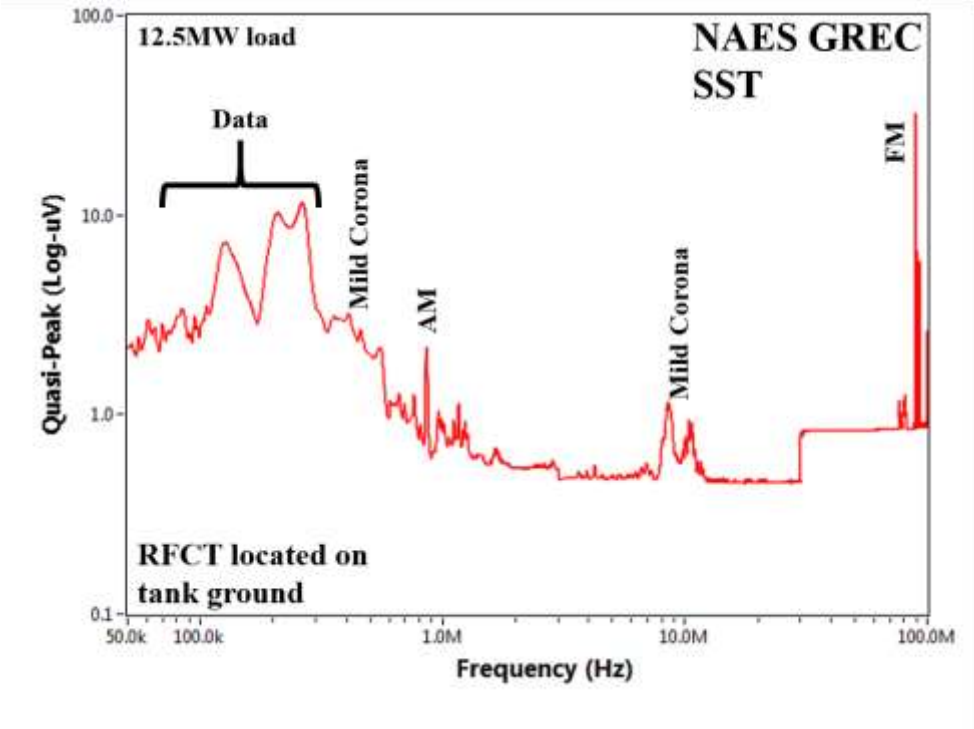

Figure 8: EMI Signature for Station Service Transformer.

This was the first EMI evaluation for this Pennsylvania Transformer Co. 138/4 kV, 1800 KVA, 101 amps at 138KV, 3 PH, 60, Hz, transformer, SN: C-07992-5-1. The test was performed with EMI data collected from an RFCT (radio frequency current transformer) placed around the tank ground. A photograph of this location can be found at the end of this report.

The transformer was loaded to 12.5 MW, which is sufficient to detect insulation and conductor related problems.

PD, data, AM/FM radio, noise and mild corona were noted at several frequencies throughout the spectrum this transformer. Radiated EMI was low near the transformer. EMI levels are low and not of concern at this time.

Recommend track and trend this transformer.

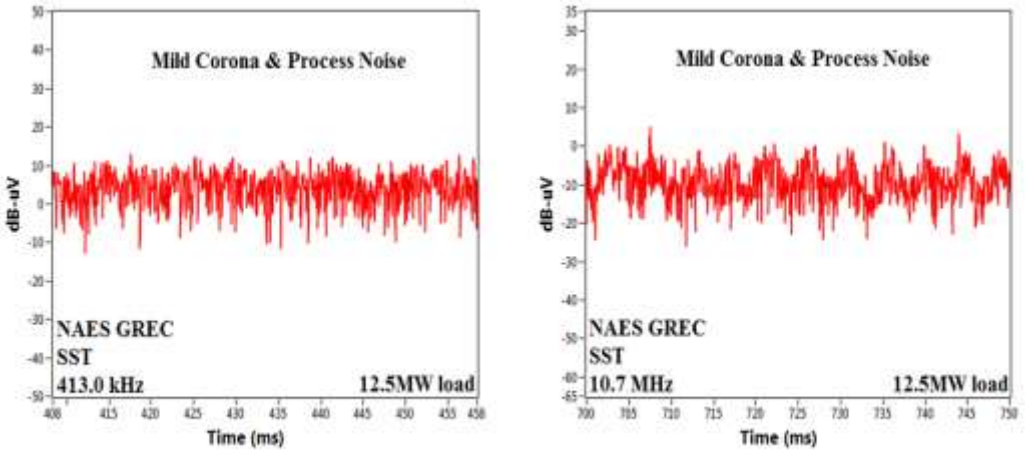

Figure 9: Station Service Transformer EMI patterns in the spectrum.

Figure 9 shows process noise and mild corona. These levels are very low and not of concern at this time.

5. Photographs

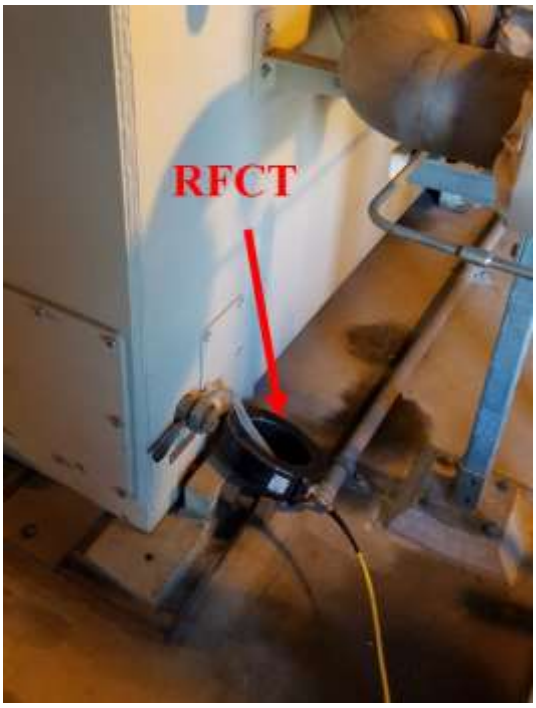

Photo 1: RFCT location for Generator.

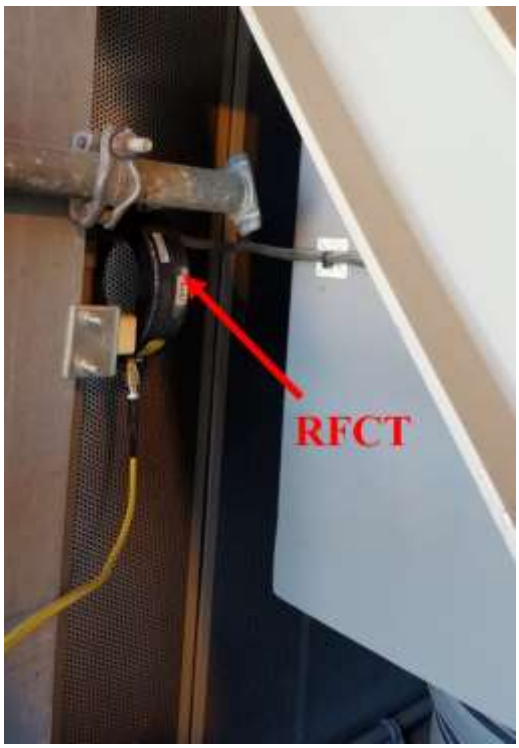

Photo 2: RFCT location for IPB.

Photo 3: RFCT location for GSU.

Photo 4: RFCT location for SST.

Photo 5: Generator Connection Box Sniffer Results.

6. Listing of EMI Detectable conditions

The following is a list of the various conditions that have been detected and identified with EMI Diagnostics. Since both partial discharges from insulation defects and arcing from conductor/mechanical defects are measured the entire system is analyzed during the EMI evaluation.

Generator Conditions Detected with EMI Diagnostics

STG, Hydro, CTG, Air, Water, H_2 Cooled

1. Slot discharges resulting from side pack deterioration
2. Slot discharged resulting from stator bar coating deterioration
3. Stator bar vibration sparking
4. Loose end windings (broken ties)
5. Loose stator bars / coils (loose wedging)
6. Loose phase rings (circuit rings)
7. Verify maintenance corrected specific winding defects
8. Loose flux shield ground
9. Broken/shorted stator bar sub-conductors (strands)
10. Foreign metal objects on end windings
11. Shaft oil/hydrogen seal rub
12. Arcing shaft grounding brush
13. Shaft currents through bearings
14. Verify shaft grounding maintenance eliminated bearing currents
15. Contamination on windings (dirt, water, break dust & oil) cleaning recommended
16. Contamination in insulation (wet stator bar insulation)
17. No contamination present (no maintenance necessary)
18. Arcing on alternator exciter or main field slip-rings
19. Verify field ground was/was not present
20. Rotor fan blade corona
21. Foreign object on rotor
22. Defective alternator exciter diodes present
23. Loose brushless exciter components
24. Loose static exciter power circuits
25. Open exciter diode fuses
26. Defective voltage regulator components and / or control settings
27. Incorrect dc exciter brush adjustment
28. High dc exciter commutator segment
29. Loose generator breaker parts
30. Loose neutral grounding resistor connection

Induction & Synchronous Motor Conditions Detected with EMI Diagnostics

1. Dirty stator windings
2. Loose windings in slots and end-arms
3. Broken rotor bars
4. Synchronous motor field ground
5. Rotor not set on magnetic center
6. Frame had loose foundation (soft foot)
7. Wiped bearings
8. Shaft currents present, shaft grounding needed
9. Defective outboard bearing insulation (or insulation shorted)
10. Bearing, oil seal rub,
11. Exciter drive shaft weather seal rub
12. Coupling mis-alignment with driven gear box, pump, fan
13. Defective or missing coupling insulation
14. Circulating currents in driven pumps, coal mills, gearboxes, fans
15. Magnetized gear box shafts / gears
16. Loose neutral connections
17. Loose crimp / bolted line connections
18. Loose surge / power factor capacitor connections
19. Abrasive erosion of stator windings
20. Defective motor lead insulation
21. Detect wet power cables
22. Detect sea water in terminal box
23. Detect 13 kV cable stress cone deterioration
24. Verify correct maintenance was or was not performed

Isolated Phase Bus, AUX Bus and Substation Conditions Detected with EMI Diagnostics

1. Loose support insulators
2. Broken support insulators
3. Contaminated insulators (dirt, cement dust, water)
4. Loose generator isolated phase bus hardware
5. Corroded isolated phase bus hardware
6. Stray circulating currents outside isolated phase bus
7. Defective isolated phase bus enclosure insulation
8. Foreign metal objects inside bus enclosure
9. Defective bus potential transformer connections
10. Open PT high voltage fuses
11. Loose AUX transformer connections
12. Loose GSU transformer shield ground
13. Defective surge capacitor connections
14. Defective load tap changer
15. Loose disconnect switch components
16. Defective lightning arrester
17. Loose safety ground on unused 230 kV line
18. Verify correct maintenance was / was not performed
19. Verify no bus, transformer maintenance was necessary

7. Glossary of EMI Terms

Term	Description
AM	Amplitude modulation-radio broadcast stations from 550 kHz to 1605 kHz.
Arcing	A strong EMI source that results from loose or broken conductors. Arcing is also produced by defective shaft grounding and slip ring brushes.
Bus Noise	A mixture of power electronics signals and other common EMI sources in the modern industrial environment.
CISPR 16	International standard for the collection of EMI data.
Data/Process Noise	Transmitters used to carry information within a plant or process control power electronic switching.
FM	Frequency modulation typically found in broadcast transmitters between 88 to 108 MHz.
PLC	Power line carrier transmitters used by utilities for telemetry data between 30 kHz and 500 kHz.
PD	Partial discharges resulting from insulation defects.
QP	Quasi-peak noise detector used for partial discharge detection from 9 kHz to 1 GHz.
SCR	Silicon controlled rectifier- Solid-state switch found in inverters, voltage regulators and exciters. IGBT and other power electronics are also sources of EMI.
Sniffer	Hand held radiated EMI detector used to locate defects.
Sniffer LF Scale	Low frequency electric fields (50kHz to 5MHz)
Sniffer HF Scale	High frequency electric fields (2Mz to 30MHz)
Sniffer H Scale	Low frequency magnetic fields (under 1MHz)
SW	Short wave –International broadcast stations in the frequency range from 3 MHz to 30 MHz.

8. Appendix

Doble Global Power Service Contacts List

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