Application of EMI Diagnostics to Diesel Generators

CATEGORIAS

* Experiencias con características de lotes de combustibles
  * Control de eficiencia de motores
  * Aliados clave para operadores de motores
  * Mejores prácticas en equipos auxiliares
  * Seguridad y Medio Ambiente

* Reporte de incidentes en equipos y soluciones implantadas
EMI Diagnostics of Air Cooled Generators
Condition Based Maintenance Goals are:

- Prevent in service failures
- Focus maintenance on equipment as needed when deterioration is indicated
- Identify where maintenance is not needed
- Not over maintain and waste resources
Numerous types of on-line diagnostic methods are applied such as Infrared & Vibration.

Two on line technologies PDA (partial discharge analysis) & EMI (electromagnetic interference) can be used to evaluate the condition of generator insulation.
Partial discharge analysis, PDA, is a time domain technique that measures and classifies electrical impulses resulting from insulation defects.
PDA was developed in Canada in the 1960’s to detect stator deterioration in large high voltage hydro generators.

Very few Diesel generators have been tested.
There is no test standard for the various PDA test instruments.

Test results depend on the device used and the year constructed.

Direct comparison of data from different generators is difficult if not impossible.
PDA “looks at” electrical discharges associated with mica based stator insulation systems.

Signals from other sources or defects are usually discarded as “noise”.

Data trending of several tests is necessary.
The second method to evaluate generators is EMI Diagnostics.
EMI

Electromagnetic Interference

The precise frequency domain measurement and identification of RF energy that results from electrical activity at defects.
EMI will detect insulation deterioration and conductor defects

Both electrical and mechanical problems can be identified.
High voltage discharges (partial discharges) and low voltage arcing generate light, chemical changes (ozone), audible noise (sound), heat and radio noise (EMI).
EMI analysis has been used for 70 years to locate defects in power lines that resulted in radio and television interference.

Application to power plant equipment started in 1980.

EMI data collection follows the international standard CISPR 16.
EMI data is collected from the temporary installation of a single split core radio frequency current transformer (RFCT) around a power conduit, on a safety ground or around a neutral lead. There are no hot connections required to any energized conductor and no interference with operation for data collection.

This one test location permits a global survey of the entire generator system.
Unlike PDA, EMI Diagnostics is a system as well as machine diagnostic technique.

More system component defects are detected than generator stator problems.

This includes many types of mechanical abnormalities.
EMI data is processed by instruments that comply with CISPR 16 standards.
Data is collected from one split core RFCT
(radio frequency current transformer)
The RFCT used has a 12 cm window. The frequency range is 0.05 to 100 MHz.
Where the RFCT is placed depends on the generator under investigation.

A safe low voltage or grounded location is selected for data collection.
Typical RFCT temporary placement at the generator stator neutral.
A power conduit is the best location to collect data from small generators.
Several radio frequency detectors are available to use.

The Peak (PK) detector is very fast and measures the maximum amplitude of a discharge.

The RMS detector is very slow and measures the power of the discharge.
The QP or Quasi Peak Detector is the one specified in the CISPR 16 standard to measure EMI.

When this international standard is followed all EMI data collected can be directly compared.
EMI Diagnostics measures and identifies the radio frequency signals resulting from high voltage PD and low voltage arcing with a QP detector.
Analyzing EMI data requires several
Radio frequency detectors
The CISPR QP is used to plot amplitudes
The AM is used to hear the discharges
The video is used to see the discharges

Frequency range of investigation 10 kHz to 100 MHz
The resulting radio frequency spectrum, or EMI Signature is unique for each physical location and type of defect present within that electrical system.
Different frequencies in the EMI Signature describe different problems. Different types of deterioration are measured at different frequencies.

- Stator slot problems
- Stator core edge problems
- Stator endwinding problems
- Bus problems
• No interference with operations
• Totally non-invasive technique
• No applied signal
• Completely passive measurements
• Maintenance recommendations can be given with the first test.

• Trending numerous tests is not necessary to analyze data.
• Over 7,000 tests conducted since 1980
• More than 500 different machine designs
  25 hp - 1,400 MW
• Fossil, hydro, geothermal, nuclear
• Over 65 types of system defects and conditions have been identified
• EMI Diagnostics is applicable to all Power Systems 25, 50, 60 Hz
• Best results 2,300 Volts ac and higher
• Some success with 250 & 600 V dc power systems
Preliminary analysis is conducted as data is collected.
• Generator: rotor & stator, insulation and conductors
• Exciter: all types
• Voltage regulator
• Bearings, shaft grounding and seals
• And other mechanical systems
Evaluation of the main generator condition is very important.

No maintenance is indicated for this generator.
Data is displayed in a log-log format to better show large and small quantities.
These examples of determining the condition of generators discusses small high speed hydro generators.

These machines are built the same as Diesel generators and develop the same problems.
Hydro Plant in Bolivia
High Speed Hydro Generators are a similar design as used for diesel driven generators.
EMI Signature with slip ring arcing and minor endwinding contamination.

**Generator 3**

- **Frequency (MHz)**
  - 0.01 to 100

**Microvolts (Quasi-Peak)**
- 0.1 to 100

- **Exciter tones**
- **Corona**
- **Slip Ring sparking**
- **Minor Endwinding Contamination**
- **Corona & PD**

**Specs:**
- 15 MVA, 500 r/min, 11 kV
- 50 Hz, Air Cooled
- General Electric Hydro Generator
A hand held EMI “Sniffer” is used to further locate each location of the EMI, slip rings, bearing stator, or power cables.
Minor dust had collected on endwindings.
Indications of shaft currents through a bearing.
A major advantage of EMI Diagnostics is the ability to compare the signatures of identical generators. This way the conditions can be ranked and the serious deterioration maintained first.
Both generators have minor endwinding corona. Minor maintenance was recommended.
This is the corona bleaching that was present after 25 years of service.
Unit 3 has more contamination than Unit 4.

Frequency (MHz)

Microvolts (Quasi-Peak)

22.5 MVA, 750 r/min
10.5 kV, 50 Hz, air cooled
Mitsubishi Hydro Generators

Generator 3

Endwinding Corona & PD from dirt

Generator 4
Unit 3 had more contamination than Unit 4.

Dirt on Endwindings

Dust on High Voltage Coils
EMI Diagnostics permits this ranking of contamination to better plan maintenance.

The generators that need cleaning can be scheduled first.

Cleaning of other stators can be postponed.
The generators with no problems can continue to operate without unnecessary down time.
Testing of emergency generators is one area where there is usually very little activity.
Typical large emergency generator
Diesel generator shafts are ungrounded. Most low frequency EMI is from the exciter.

Emergency Diesel Generator Div 2 vs Div 1

![Graph showing EMI levels for Div 2 and Div 1 generators.]

- **Exciter noise**
- **Noise spike**
- **Random noise**

Microvolts (Quasi-Peak)

**Div 2 Diesel Gen.**
- 11-10-04

**Div 1 Diesel Gen.**
- 09-08-04

**Frequency (MHz)**
- 0.01
- 0.1
- 1
- 10
If there were stator deterioration it would be seen at frequencies above 1 MHz as with the following two generators.
Unit 1 has stator serious deterioration.

Emergency Generator Comparison

1875 kW, 1800 r/min, air cooled
4160 V, 60 Hz
Diesel Driven Generators
Both generators have stator problems. A stator rewind for Unit 1 was recommended. The Unit 2 generator had already failed.
This plant had suffered several generator connection failures
Crimp connections should never be used on large machines.
No loose connections were detected.
No generator maintenance was needed.
The OEM had recommended all 5 generators be opened and the rotors removed.

Since no deterioration was indicated it was recommended this activity could be postponed with minimum risk.
An EMI Diagnostic also provides information on the condition of the GSU and AUX transformers. Switchyard defects are often detected.
At this location arcing was detected when testing the GSU transformer.
The 138 kV yard was searched for the source of the arcing EMI.
A problem was located at both ends of the 138 kV power cables.
The 138 kV cable grounds were loose and arcing.
Switchgear problems have also be detected.

At this location in Oklahoma a strong EMI source was detected in the 6.9 kV switchgear room.
A switchgear defect location can be determined without opening the cubicles.
The highest EMI activity was at the top of the third cabinet.
A potential transformer in cubical 3 was found to have a loose high voltage connection to the 6.9kV bus.

It was repaired during the next short outage.
With most equipment

80% no maintenance
15% some level of concern
5% need attention soon
Identification of that 80% is very important for the allocation of resources to the 5% that do need attention.
Summary

EMI Diagnostics can provide information for condition based maintenance of systems with detectable deterioration.

Data is collected without effecting operations. No design changes are necessary. Inherently safe technology.
Air Cooled Generator Conditions
Detected with EMI Diagnostics
1. Slot discharges due to side packing deterioration
2. Slot discharged resulting from stator bar coating deterioration
3. Loose endwindings (broken ties)
4. Loose stator bars (loose wedging)
5. Loose phase rings (circuit rings)
6. Verify maintenance corrected all winding defects
7. Foreign metal objects on endwindings
8. Shaft oil seal rub
9. Arcing shaft grounding brush
10. Shaft currents through bearings
11. Contamination on windings (dirt, water & oil) cleaning recommended
12. No contamination present (no maintenance necessary)
13. Arcing exciter commutator or main field slip-rings
14. Defective exciter diodes present
15. Loose brushless exciter components
16. Loose static exciter power circuits
17. Open exciter diode fuses
18. Defective voltage regulator components and / or control settings
19. Loose breaker parts
20. Foreign object on rotor
21. Loose surge capacitor connections
Additional Defects Found, Motors

- Dirty stator windings
- Loose windings in slots and end-arms
- Broken rotor bars
- Synchronous motor field ground
- Rotor not set on magnetic center
- Frame had loose foundation (soft foot)
- Wiped bearings
- Defective outboard bearing insulation (or insulation shorted)
- Bearing oil seal rub
- Exciter drive shaft weather seal rub
- Coupling mis-alignment with driven gear box, pump, fan
- Defective or missing coupling insulation
- Circulating currents in driven pumps, coal mills, gearboxes, fans
- Magnetized gear box shafts / gears
• Loose crimp / bolted line connections
• Coupling mis-alignment with driven gear box, pump, fan
• Defective or missing coupling insulation
• Circulating currents in driven pumps, coal mills, gearboxes, fans
• Magnetized gear box shafts / gears
• Loose neutral connections
• Loose surge / power factor capacitor connections
• Abrasive erosion of stator windings
• Defective motor lead insulation
• Detect wet power cables
• Detect 13 kV cable stress cone deterioration
• Verify correct maintenance was or was not performed
Bus & Sub Station Conditions Identified

- Loose & broken support insulators
- Contaminated insulators (dirt, cement dust, water)
- Loose and corroded generator iso-bus hardware
- Stray circulating currents outside iso-bus enclosures
- Defective iso-bus enclosure insulation
- Foreign metal objects inside bus enclosure
- Defective bus potential transformer connections
- Open PT high voltage fuses * Loose AUX transformer connections
- Loose GSU transformer shield ground * Defective surge capacitor connections
- Loose disconnect switch components, Defective lightning arrestor
- Loose safety ground on unused 230 kV line
- Verify correct maintenance was / was not performed
- Verify no bus, transformer maintenance was necessary
Are there any questions?
Thank you for listening to the presentation