Application of EMI Diagnostics to Hydro Generators
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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.

PD events are sorted by +&- polarity, amplitude and frequency of occurrence as well as the power frequency phase relationship.
PDA was developed in Canada in the 1960’s to detect stator deterioration in large hydro generators. There has been wide spread application over the past 30 years to several thousand 13 kV Hydro Generators as well as numerous motors and a few Turbine Generators.
The bandwidth, sensitivity and detector time constant are not standardized for the various PDA 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 is necessary.
Several bus couplers are installed to collect data.

The high frequency system only monitors 10% of the generator stator winding.
The coupling device determines a PDA system measurement bandwidth.

Both high frequency and low frequency PDA systems are available.

All three phases must be monitored.

PDA is not successful with 4 kV machines.

A wide variety in data analysis is available.
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.
High voltage discharges (partial discharges) and low voltage arcing generate:

- Light
- Chemical changes (ozone)
- Acoustic noise (sound)
- Heat
- 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 Hydroelectric 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) on a safety ground or around the 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.
EMI Diagnostics measures and identifies the radio frequency signals resulting from high voltage PD and low voltage arcing.

Most “noise” has meaning.
The resulting radio frequency spectrum, or EMI Signature is unique for each physical location and type of defect present within that electrical system.
With EMI Diagnostics

- No design changes are needed
- 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 9,000 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
Preliminary analysis is conducted as data is collected
Generators

EMI Diagnostics Evaluates

- Generator: rotor & stator, insulation and conductors
- Exciter: all types
- Voltage regulator
- Bearings and seals
- Other mechanical defects
Hydro Plant in Bolivia
These high speed Hydro Generators had operated for 25-30 years. The OEM recommended rewinding.
EMI Signature with slip ring arcing and minor endwinding contamination.

15 MVA, 500 r/min, 11 kV
50 Hz, Air Cooled
General Electric Hydro Generator

Diagram labels:
- Exciter tones
- Corona
- Slip Ring sparking
- Minor Endwinding Contamination
- Corona & PD
Minor dust had collected on endwindings.
Indications of shaft currents through a bearing.
Both generators have minor endwinding corona.
This is the corona bleaching that was present after 25 years of service.
Unit 3 has more contamination than Unit 4.
Unit 3 had more contamination than Unit 4.
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.
Data from different conditions can be directly compared.
Minor endwinding deterioration is indicated.
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 near the GSU transformer.
The 138 kV cable grounds were loose and arcing.
Switchgear problems have also been 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.
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.
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 magnet 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
Motors

- 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
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