APPLICATION NOTE : DIELECTRIC FAULT ANALYZER (DFA100) INSTRUMENT

IN-SERVICE TESTING OF SF_6 FILLED DEAD TANK CIRCUIT BREAKERS USING THE ACOUSTIC EMISSION DIAGNOSTIC TECHNIQUE

INTRODUCTION

The Acoustic Emission (AE) diagnostic technique is a non-intrusive in-service test used for monitoring acoustic signals produced by partial discharge and loose components. AE is effective in detecting faults in SF_6 gas insulated insulation systems, such as Gas Insulated Substations (GIS) systems and SF_6 filled dead tank breakers. AE has the ability to identify and locate the presence of Partial Discharge (PD), particles, and mechanical defects within the equipment. AE testing is non-intrusive, and can either be performed with the equipment in-service or in conjunction with an external source: a series resonance or an AC Hi-Pot. The AE diagnostic technique captures and processes AE signals primarily in the ultrasonic domain. Characteristics are extracted from the measured AE signals. This information is used to determine the nature of the AE source, which can be matched to various apparatus faults.

ACOUSTIC INSULATION ANALYZER (DFA100) INSTRUMENT

The DFA100 is a portable and battery powered instrument used for monitoring acoustic emissions. The DFA100 is specifically designed to detect faults in grounded SF_6 gas insulation systems, such as SF_6 filled dead tank circuit breakers. The DFA100 instrument can be directly applied to any grounded component that is associated with the SF_6 filled apparatus under test.

During acoustic emission measurement, the DFA100 processes the results and determines the fault. The DFA100 instrument has the ability to differentiate between PD, particles, and mechanical defects.

The DFA100 instrument provides three measuring modes: continuous, phase, and pulse.

Continuous Mode

The Continuous Mode is used for surveying the apparatus, and locating the primary source of the AE signal. The continuous measuring mode provides four scales of acoustic signal measurement: the RMS signal, peak signal, degree of modulation with fundamental, and degree of modulation with second harmonic. Figure 1 is an example of the Continuous Mode locating a PD source.

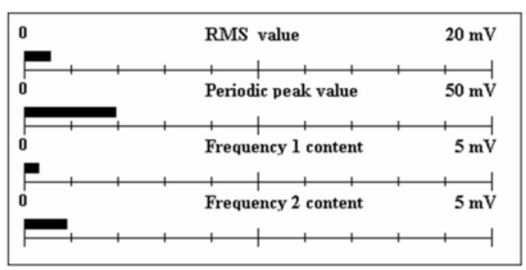


Figure 1 – Continuous Mode

Phase Mode

The Phase Mode correlates the acoustic signal and the fundamental power signal, and generates amplitude vs. phase plot. This information is used to determine the synchronizing nature of the acoustical discharges relative to the fundamental power signal. The patterns obtained are used to identify the nature of the source: PD, particles, and mechanical defects. Figure 2 illustrates mechanical vibration of a contact assembly.

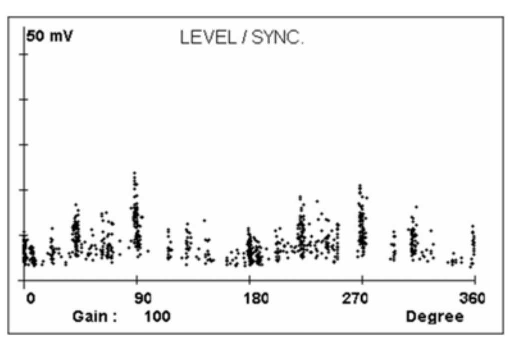


Figure 2 – Phase Mode

Pulse Mode

The Pulse Mode is primarily used for monitoring particles. Particles are dynamic and produce both electrical discharges and mechanical impacts. This dynamic behavior is best represented in the Pulse Mode in which it displays the results in amplitude vs. elevation time plot. This information can be interpreted to determine number, size, and severity of the active particles. Figure 3 illustrates the behavior of a 5mm aluminum particle.

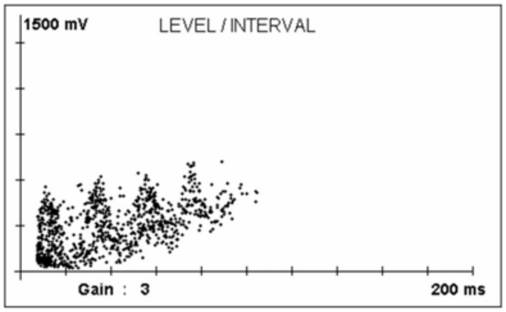


Figure 3 – Pulse Mode

FIELD TESTING OF SF_6 FILLED DEAD TANK CIRCUIT BREAKERS

The user is ultimately responsible for determining the necessary requirements for field test and maintenance justification of SF_6 filled dead tank circuit breakers. The manufacturer's recommendations, duty, number of operations, and past experience should be considered when justifying the test and maintenance requirements.

Field tests can be performed either in-service or in a de-energized state. Due to the cost and inconvenience of removing equipment from service, some utilities are exclusively using in-service tests as the first line of defense. As part of a condition-based program, the in-service tests are used as indicators to initiate and warrant further investigation, which include a complete protocol of traditional off-line tests.

By using the DFA100 instrument, AE diagnostics can be non-intrusively performed while the equipment is in service. The DFA100 will provide diagnostic indicators relating to the presence of PD, particles, and mechanical defects. This information can be used by itself or in conjunction with other in-service test results to warrant further investigation and justify additional off-line tests.

Table 1, shown below, lists commonly preformed field tests. As shown in bold, the AE diagnostic technique is categorized as an in-service test.

Table 1 – Commonly Performed Field Tests on SF_6 Filled Dead Tank Circuit Breakers

State	Test	Comments
In-Service	Visual Inspection	Inspect physical condition, structure, grounding, gauges, annunciators, and on-line monitoring devices
	SF_6 Gas Analysis	SF_6 Density, SF_6 Moisture, SF_6 Decomposition
	SF_6 Leak Detection	Leaks: laser imaging, thermal conductivity, acoustics
	Infrared (IR)	Heating: temperature differential
	Acoustic Emissions	**PD, particles, mechanical defects**
	First Trip	Basic operation and timing: control circuit and main contacts, lubrication
De-Energized	Visual Inspection	Inspect physical condition, structure, grounding, gauges, annunciators, and on-line monitoring devices
	Contact Resistance	DC static and dynamic (optional)
	Insulation Integrity	Power Factor/Capacitance, insulation resistance, AC High Pot
	Timing	Timing (control circuit and main contacts), verify TRIP, CLOSE, TRIP-FREE, and RECLOSE
	Mechanism	Travel, velocity, over-travel, rebound, contact wipe
	Control Circuit	Minimum pickup, insulation resistance, operation of protective and alarm devices
	Instrument Transformers	CT saturation and CT ratio

FAILURE MODES DETECTED BY ACOUSTIC EMISSIONS

The Acoustic Emission (AE) diagnostic technique has the ability to detect a variety of failure modes, while the unit is in-service. The AE diagnostic technique focuses on failure modes associated with partial discharge, particles, and mechanical defects, such as loose components. The AE diagnostic technique only considers failure modes that are static in nature; tests are not conducted while the circuit breaker is tripping or closing. Table 2 links failure modes associated with partial discharges, particles, and mechanical defects to various circuit breaker components.

Table 2 – Failure Modes Detected by Acoustic Emissions

Partial Discharge (PD)	Particles	Mechanical Defects
Supports Structure Tracking	Static Particles - Static particles on supports structures, energized conductors, and grounded surfaces.	Contact Assemblies
Floating Electric Shields	Dynamic Particles - Moving or bouncing particles. Dynamic particles produce both mechanical and electrical burst type emissions.	Resistor Assemblies (optional)
Burning Contacts		Bushing Connection Assemblies
PD - Corona type discharges caused by protrusions, uneven surfaces, and inadequate clearances		Electric Shields
		Particle Traps
		Leaking Valves
		Mechanism
		Cabinet

It is important to note that these failure modes are induced by two energy sources: the electric field (applied system voltage) and magnetic field (load current). When comparing the failure mode type versus energy sources, partial discharges and mechanical defects are paired with electric fields and magnetic fields, respectively.

TEST PLAN

The circuit breaker size, rating, and design will determine the test plan. Generally, no more than five survey points are required for each pole. The number of survey points should be determined by the number of breaks per phase (contact assemblies), bushing connection assemblies, and insertion resistor assemblies (if applicable).

Clean silicone grease should be applied at each survey point to ensure an adequate interface. Each survey point was compared against a known baseline in the continuous mode. This baseline is provided in Figure 4, shown below. Even in a 345kV switchyard, where high external levels of corona exist, the circuit breaker internals should still produce the expected baseline. If any acoustic emissions are obtained while surveying in the Continuous Mode, determine the location of the strongest signal, and then a phase synchronized and a pulse interval recording will be collected.

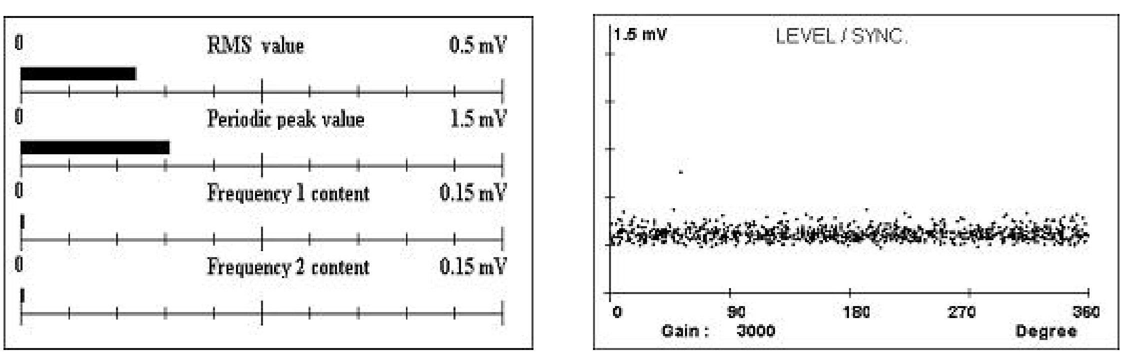
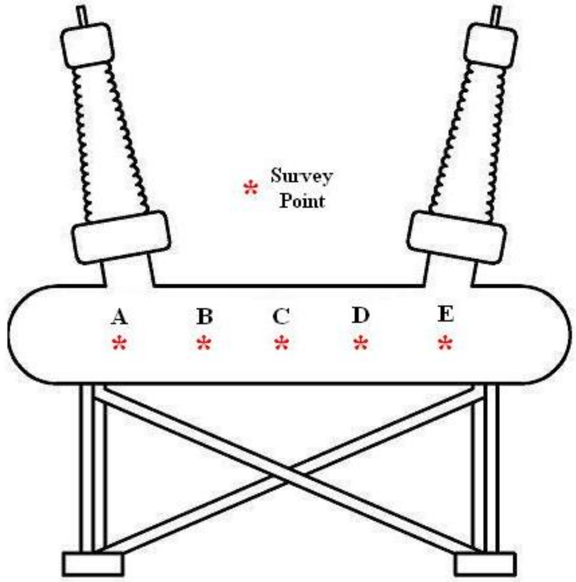


Figure 4 – Expected Baseline: No Acoustic Emissions Present

Figure 5, shown below, is an example of a test plan for a SF_6 filled dead tank circuit breaker consisting of five survey points. This particular example assumes this breaker has two breaks per phase and is equipped with insertion resistors. Five survey points are identified along with the circuit breaker's associated components.



Location ID	Associated Components
A	Mechanism, Cabinet, Shield, Bushing Connection Assembly, Supports Structure
B	Contact Assembly, Shield, Cabinet, Particle Trap
C	Contact Assembly, Shield, Particle Trap
D	Resistor Assembly (optional), Particle Trap
E	Shield, Bushing Connection Assembly, Supports Structure

Figure 5 – Survey Point Locations

NOTE: The breaker type and design will dictate the test plan. If needed, consult Doble Engineering Co. to obtain a recommended test plan.

ANALYSIS OF MEASUREMENTS AND FAILURE MODES

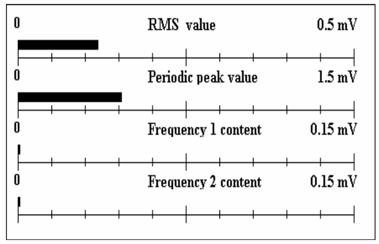
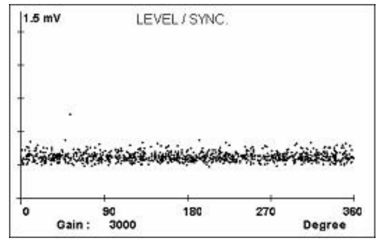
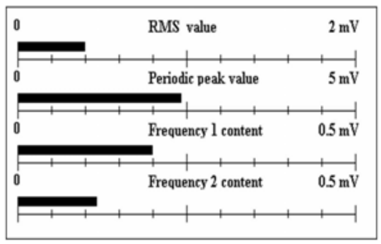
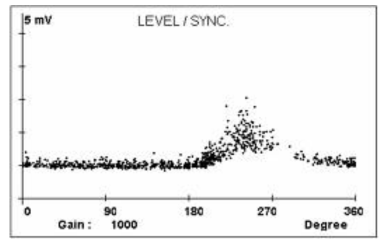
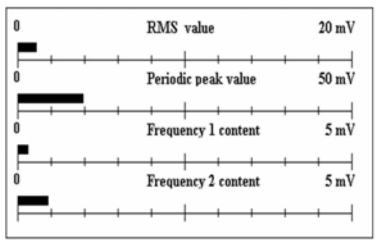
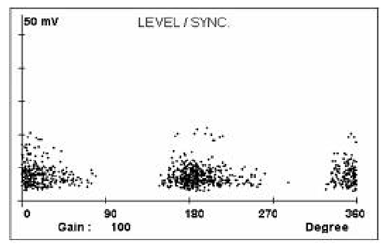
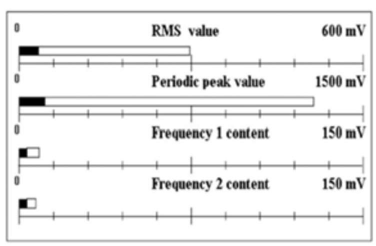
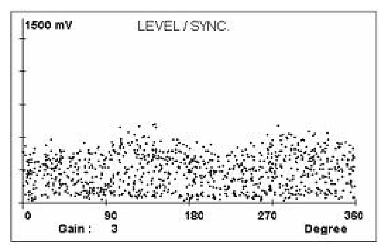
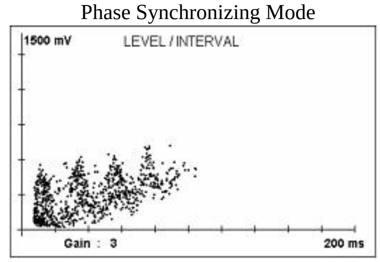
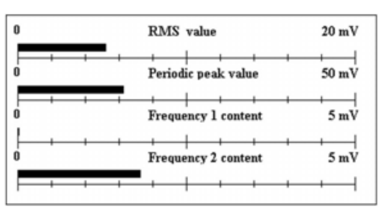
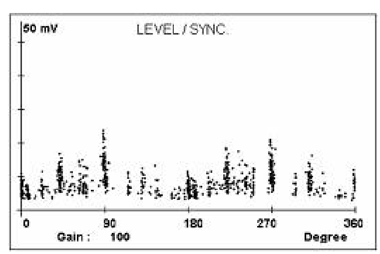
Noticeable acoustic emissions detected during the measurements warrant further investigation to determine the nature of the source. Properly analyzing the results will provide information such as:

- Source Type: Partial Discharge, Particles, and/or Mechanical Defects
- Source Location
- Relative Strength of the Failure Mode
- Risk: Severity of the Failure Mode

Characteristics such as amplitude, amplitude scatter, periodic modulation (60Hz/120Hz), crest factor, and pulse shape are used in conducting the analysis. These characteristics will be matched to source type and then the failure mode will be determined by comparing the source type and general location of the source. All of this information in conjunction with the relative signal strength will be used to estimate risk.

Table 3 illustrates the analysis fundamentals, based on knowledge of the features of the various sources generated within SF_6 filled dead tank circuit breaker, to recognize the different types of defects.

Table 3 – Analysis Features Versus Failure Modes

<u>Baseline</u>: The expected meaurement reported by the DFA100 instrument in the absence of acoustic emissions. Most favorable measuresents will produce similar results.	 Continuous Mode "Survey"	 Phase Synchronizing Mode
<u>Partial Discharge (PD)</u>: PD caused by protursuions and tracking produce results that are generally low in magnitude, while favoring the Frequency 1 modulation content.	 Continuous Mode "Survey"	 Phase Synchronizing Mode
<u>Electrically Floating Shields:</u> Floating Shields produce results generally higher in magnitude while favoring the Frequency 2 modulation content. The phase plot produces dual clouds, as shown.	 Continuous Mode "Survey"	 Phase Synchronizing Mode
<u>Particles:</u> The main indication of particles is the fluctuating periodic peak signal. Furthermore, the signal level is typically several decades higher than that with partial discharges and corona. Particles are generally not phase synchronized and appear random. Particles, also, produce a unique pulse mode pattern, as shown. The magnitude of mV and time are used to determine the severity and size of the particle contamination.	 Continuous Mode "Survey"	 Phase Synchronizing Mode  Pulse Mode
<u>Mechanical Defect:</u> Loose components produce results generally higher in magnitude having a dominate Frequency 2 modulation content. The phase plot produces a mirror image, as shown.	 Continuous Mode "Survey"	 Phase Synchronizing Mode