

# Chapter 13

## Partial Discharge Detection and Location in Transformers Using UHF Techniques

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### ABSTRACT

*Power transformers can exhibit partial discharge (PD) activity due to incipient weaknesses in the insulation system. A certain level of PD may be tolerated because corrective maintenance requires the transformer to be removed from service. However, PD cannot simply be ignored because it can provide advance warning of potentially serious faults, which in the worst cases might lead to complete failure of the transformer. Conventional monitoring based on dissolved gas analysis does not provide information on the defect location that is necessary for a complete assessment of severity. This chapter describes the use of ultra-high frequency (UHF) sensors to detect and locate sources of PD in transformers. The UHF technique was developed for gas-insulated substations in the 1990s and its application has been extended to power transformers, where time difference of arrival methods can be used to locate PD sources. This chapter outlines the basis for UHF detection of PD, describes various UHF sensors and their installation, and provides examples of successful PD location in power transformers.*

### INTRODUCTION

#### Transformer Insulation Monitoring

Transformer insulation systems are predominantly based on paper and oil. They have a history of reliable operation over long periods, often spanning many decades. However, in recent years, a

number of factors have led to an increasing use of PD monitoring as part of a more rigorous approach to health assessment so that incipient defects can be diagnosed and rectified before more serious damage occurs. These factors include:

- Growing numbers of transformers that have been in service for longer than their intended operational life.

DOI: 10.4018/978-1-4666-1921-0.ch013

- Developments in transformer design techniques and the introduction of new materials that are reducing the level of ‘over-engineering’ for new designs. In addition, there is a migration of manufacturing facilities to developing countries where demand for electrical network components is high. Both of these factors mean that new transformers may age quite differently to their predecessors.
- Requirements for more accurate data on plant health to ensure safety of personnel and security of supply.
- Regulatory penalties for interruption of supply to consumers, which might be a consequence of transformer failure.
- Increasing penetration of distributed generation and renewables, along with HVDC, which are changing the operating conditions experienced by transformer insulation systems.

Partial discharge measurements to IEC 60270 (International Electrotechnical Commission, 2000) form part of the acceptance test regime for new transformers. IEC 60270 describes test methods and defines the circuit configurations that can be used to measure a calibrated ‘apparent charge’ at the measurement terminals (e.g., at the transformer bushings). During PD measurement there is normally a schedule of overpotential testing where the transformer is subjected to voltages up to twice the normal operating level for short periods of time. During overpotential testing the measured PD levels on each phase must be below certain agreed limits (typically in the range 100 – 500 pC). The main purpose of these tests is to confirm the resilience of the insulation and thereby validate the manufacturing process.

Once a transformer has been shipped to site, installed and commissioned, it is uncommon for any further PD testing to IEC 60270 to take place. This is because of the need for a PD-free supply and a test environment with low levels

of electromagnetic interference. Without these conditions, the background noise from system transients, air corona, etc., in a substation would swamp any attempt to measure PD or distinguish between PD that originates inside the tank or externally. The only option would be to disconnect the transformer from the network and energize it from a mobile, PD-free supply. For this reason, dissolved gas analysis (Duval, 1989; Golarz, 2006; International Electrotechnical Commission, 1999) has become the main method by which PD and other degradation mechanisms are detected on in-service transformers. DGA is convenient because it only requires that a small sample of oil be taken for analysis. DGA is also a valuable diagnostic tool because, like a blood test, it enables a number of health-related parameters to be evaluated, including:

- Gases generated by partial discharges or arcing
- Moisture content of the oil
- Gases generated by thermal problems (hot spots)
- Furans, which relate to the condition of the paper insulation (Saha, 2003)

A disadvantage of periodic DGA is that the measurement reflects the accumulation of gases over a long period of time (such as a year) and only gives a snapshot of the condition at a point in time. Decisions about transformer health are usually made on the basis of trending the DGA results, although the gas levels can vary with the quality of the sampling procedure and the operating conditions at the time when the sample was taken. For these reasons, there are increasing moves towards continuous online DGA monitoring as the technology becomes more compact and cost effective.

DGA will inevitably provide baseline condition monitoring for decades to come because of its long track record and the historical databases that have been built up to help inform maintenance

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