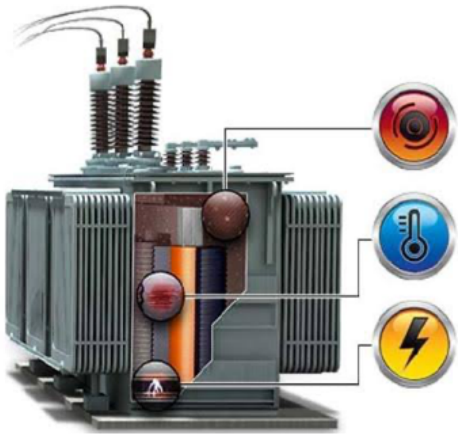
APPLICATION OF ONLINE MONITORING SYSTEM FOR POWER TRANSFORMER HEALTH ASSESSMENT

With the rapid development in the field of electronic, software and communication technology, a great transformation in power network operation and maintenance has been seen over the last decades. Traditional time-based asset maintenance predominantly relied on off-line test techniques has now been moving into condition-based maintenance aided by on-line monitoring and diagnostic techniques.



INTRODUCTION

For the purpose of on-line condition monitoring of transformers, there has been many sensors and devices introduced in the market to detect different parameters in power transformer. Other than monitoring using sensors with just 4-20 mA analog outputs, now it is more common that the modern sensors are equipped with microprocessors and various communication protocols for transferring measured data/signals which provide indications of incipient faults or faults that occurred already. As a result, optimal preventive maintenance planning, reduced transformer unavailability and increases in reliability and safety can be achieved.

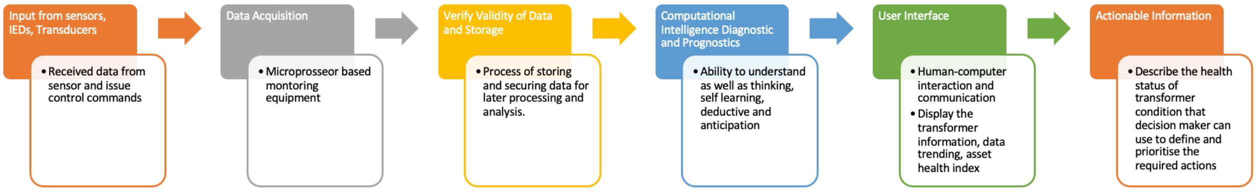
A properly implementation of online monitoring system will not only gather and present data, but should also intelligently analyze the collected data, proactively identify and diagnose pending deficiencies in the monitored parameters and giving to the users a list of possible appropriate actions. This article features the basic requirement of transformer online monitoring system and current technologies use to monitor the transformer operating parameters.

TRANSFORMER INTELLIGENT MONITORING SYSTEM

Many utilities of electrical networks are now moving into smart grid system which is a fully automated power system that can be achieved by integrating information technology, communication, control and intelligent equipment monitoring, to gain increased security of supply and better utilization of resources. It is now commonly accepted and have been demonstrated to provide critical data and information for technical and economic decision making, based on the key parameters and components of the evaluated equipment.

More specifically the technologies utilized for transformer on-line continuous monitoring have reached the point today where it is possible to access and store the most important condition and operation parameters, integrated with other historical information, periodic off- line and periodic on-line diagnostics data. These inputs once converted into useful intelligent outputs, should allow network and asset owners to make better technical and business decisions.

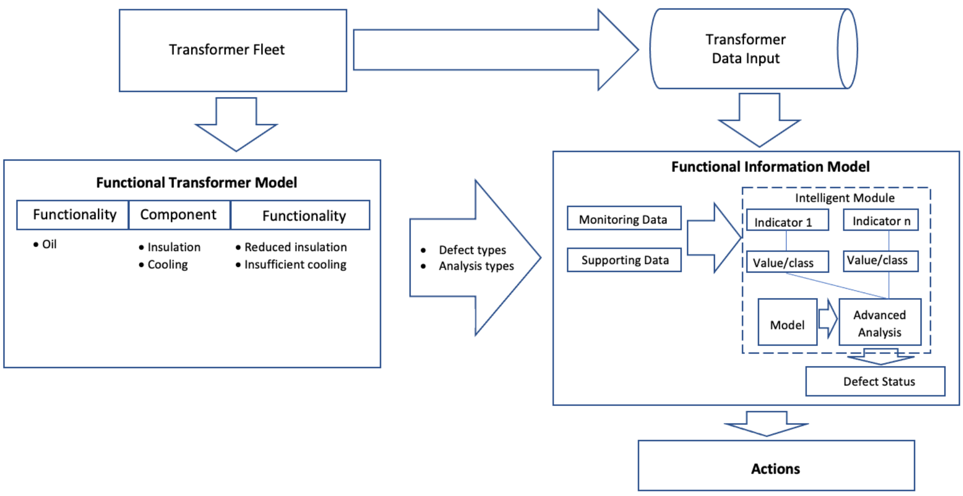
In choosing transformer online monitoring solution, some basic criteria need to be fulfilled such as the failure mode of the transformer should be identified by measured parameters, knowledge of interpreting data is available and asset owner has sufficient time to take action after incipient faults are detected. Thus, transformer intelligent monitoring system can be defined as the process of using transformer fundamental knowledge, sensing, data acquisition and processing systems to collect raw or pre-processed data and translate it to a common actionable output, that describes the transformer's condition with the use of analytical techniques.



Transformer Intelligent Monitoring System

FUNCTIONAL MODEL OF TRANSFORMER INTELLIGENT MONITORING SYSTEM

Different asset maintenance strategies and practices among utilities resulted in the different complexity of systems that monitoring the parameters and delivering various diagnostic information related to the transformer's health. A systematic and structured way to select a proper data and evaluation methods to produce the required relevant information is therefore critical to develop transformer intelligent monitoring system. In general, the system should consists of functional transformer model and an information model. The functional transformer model describes how the transformer is broken down into subsystems, and defines the functionalities and failure modes of each subsystem. On the other hand, the information model which is based on functional model specifies the condition monitoring and analysis process. It serves as a framework to describe what data and information is required when and where, specifies the data processing needed to arrive at the required information and, if possible, the required action related to a specific failure mode.



Functional Model of Transformer Intelligent Monitoring System

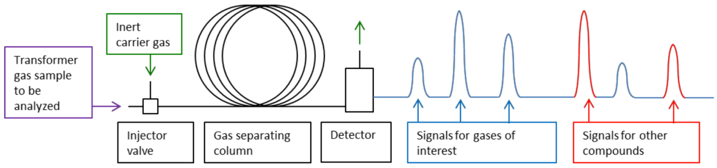
TRANSFORMER MONITORING SYSTEM

The consequences of transformer failure can be catastrophic, yet the failures are preventable by detecting and monitoring the failure symptoms. There are a wide range of transformer monitoring systems available to detect operating temperature, gases dissolved in oil, partial discharge, oil level, on-load tap changer, power factor and many more.

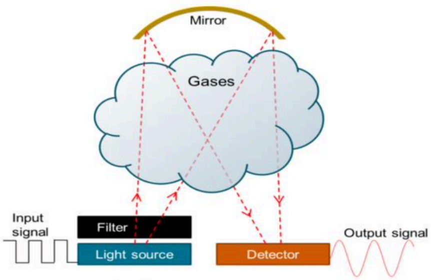
Dissolved Gases Analysis (DGA)

Faults in main tank causes decomposition of hydrocarbon oil and generates gases. Monitoring the gas concentration level is an indicator of incipient faults in power transformers. The development and advancement of sensors and microprocessor technology over the last decade has shown several online DGA monitoring devices appeared on the market, particularly hydrogen monitor and multiple gases monitor. A major advantage of on-line monitors is their capability to detect abnormal gassing and faults occurring between manual oil samplings.

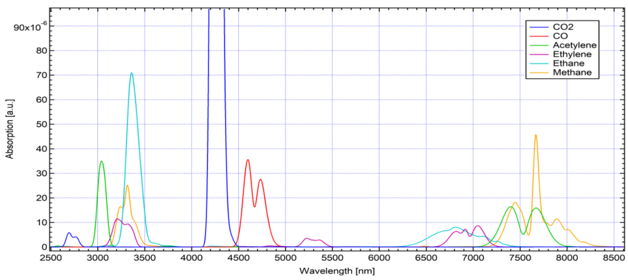
Various types of technology has been used for online gas monitor and each has its own advantages and disadvantages. Gas Chromatography (GC) method is similar to standardised laboratory gas extraction (ASTM, IEC). A sample of gas is analyzed by separating the molecular compounds and then measuring the concentration of each compound one-at-a-time. Other detection method used Infrared (IR) based gas analysis, which measured the IR wavelength of the gas absorption.



A Gas Chromatography (GC) system



Schematic of IR light gas absorption technique



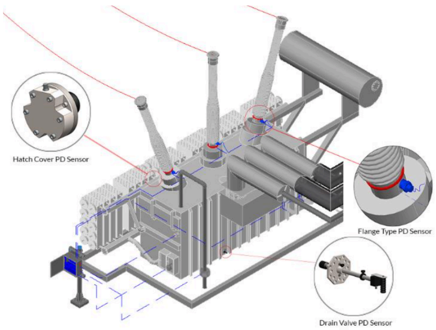
Wavelength of IR light gas absorption


Installation of online gas monitor at TNB substation

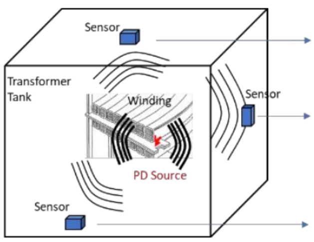
Partial Discharge Monitoring

Partial discharge occurs inside the insulation when the insulation unable to withstand the applied electric stress and finally flashover. The presence of partial discharge is an early indication of insulation failure and asset manager can monitor its activity over time and make informed strategic decisions regarding the timely repair or replacement of the transformer before an unexpected outage occurs. Typically, there are three potential sources of PD generation in a power transformer – core and coils assembly, bushing, and load-tap changer. Installation of online PD monitoring system on the respective components can avoid the potential transformer failure.

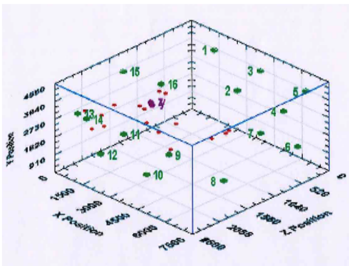
PD in transformer generate electromagnetic wave and can be detected using Ultra High Frequency (UHF) sensor. The metal surface of the tank acts as a natural Faraday-cage to filter out electrical interferences from outside the tank and give better sensitivity. Generally, three types of UHF sensor can be used for PD detection; antenna probes, hatch cover probes and flange type sensor. The UHF antenna probes are designed for use inside straight-opening oil-filling valves while hatch cover probes are designed for use inside dielectric windows custom fitted directly onto the transformer tank wall or onto the hatch cover plates. Flange-type UHF sensors are designed to fit snugly around the lower shed of the high voltage bushings.



UHF PD detection on power transformer

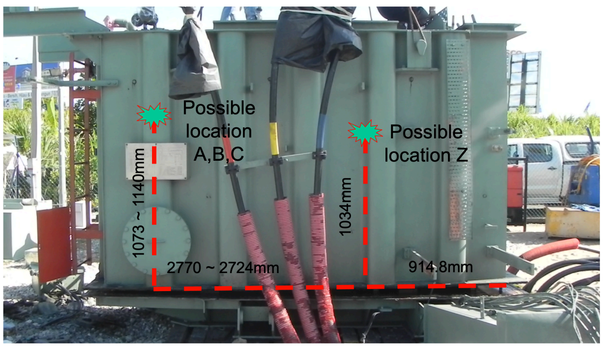


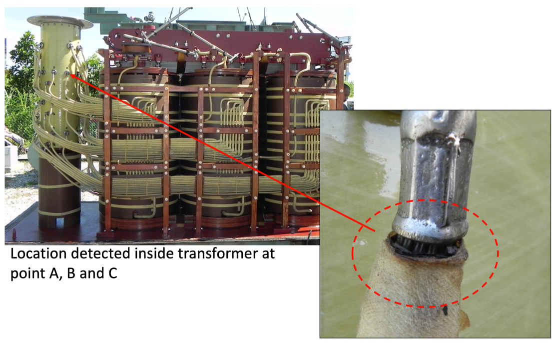
Principle of acoustic PD detection



Example of PD source detected in transformer

In addition, active PD sources also produce acoustic emission signals that propagate away from the source in all directions and eventually arrive at the transformer tank wall. Using an acoustic sensors placed at different locations on the tank wall, the different signal arrival times received by the sensors are then used to determine the position of the PD source inside the tank. Acoustic detection has several advantages; it is immune to electromagnetic interferences and experience shows it is effective to locate the PD source outside the winding, arcing or tracking of the bushing surface in oil, PD inside the tap-changer and very high intensity discharges within windings.





Overheating sign at lead terminal

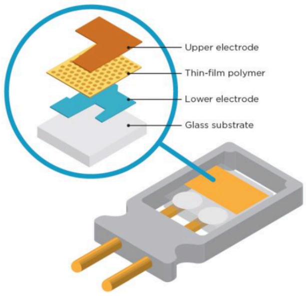
Example of field experience on acoustic PD detection and finding from internal inspection

Moisture Monitoring

Moisture is a significant concern for power transformer as excessive moisture can reduce the dielectric strength of oil and accelerate insulation ageing process. There are different sources on how moisture can exist in power transformer; depolymerisation of cellulose solid insulation generates moisture, deteriorated gasket by ageing or improper installation caused ingress of moisture from environment and exposure to atmospheric moisture during maintenance.

Therefore, management of moisture is critical to ageing, reliability, performance, and safety of in-service power transformer. Processing the oil to remove moisture and contaminants will aid in returning the oil to a higher dielectric strength for better performance. It is important to know the amount of moisture dissolved in the oil since the dielectric strength diminishes as moisture increases. A scheduled oil sample and Karl Fischer titration in a laboratory is the common practice to measure the absolute moisture content in oil and estimating the moisture level in solid paper.

The distribution of moisture in transformer is dynamic process and follow the temperature and operating condition of the transformer. Online moisture monitoring gives a true and real-time picture of the moisture levels in transformer oil in all operating conditions. The capacitive sensor is the most common technology used for online moisture monitoring. It is basically a parallel plate capacitor. At least one of the electrodes is permeable to water vapor and allows water molecules to diffuse into the dielectric polymer layer. Absorbed water molecules increase the permittivity and this can be measured as increased capacitance of the sensor element.



Capacitive thin polymer sensor

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For more detail information, please contact:
nawal.azhar@tnb.com.my / aizam.talib@tnb.com.my

Editor:

Ir. Ts. Dr. Mohd Aizam Talib
aizam.talib@tnb.com.my

TNB Labs Sdn Bhd
No.1, Lorong Ayer Hitam,
Kawasan Institusi Penyelidikan,
43000, Kajang Selangor