Un Artículo Técnico de Aplein Ingenieros S.A.

Moisture measurments during electric substation maintenance

Electricity is generated in various ways: fossil fuel burning, hydroelectric and nuclear power stations, solar energy plants and wind farms etc. The generated electricity has to be transmitted and distributed for end usage. The transmission and distribution of electricity is completely separate from the generation operations and is carried out by different companies. Electric generators have nothing to do with the transmission and distribution of power and, in a similar fashion, the maintenance personnel at an electric substation do not have anything to do with the maintenance personnel at an electric power station. Although moisture measurement also applies to power stations (instrument air, generator cooling hydrogen etc), this document only covers applications relating to electric substations.

Substations are located all over the world and are easy to recognise. They include transformers, breakers and other electrical components. These substations can be found in all neighbourhoods, cities, towns and anywhere electricity is employed. Maintenance personnel visit the installations on a routine basis to check for correct operation of the installed electric equipment.

APPLICATIONS

There are basically four different applications for moisture measurement during substation maintenance.
These are:

1. Measurement of the moisture in sulphur hexafluoride-filled (SF6) breakers.

2. Measurement of the moisture in nitrogen-filled transformers (N2).

3. Measurement of the moisture in air and nitrogen during transformer start-up or restart-up.

4. Measurement of the moisture in oil-filled transformers.

All electrical equipment that is manipulated is filled with dome form of insulation: air, SF6, N2 or oil. These insulators must be completely dry since it is well-known that water and electricity do not mix well. The presence of moisture can cause failures, short circuits, explosions and very expensive maintenance procedures.

Moisture measurement in breakers

Substations usually employ sulphur hexafluoride (SF6) gas in: GIS (Gas Insulated Substation), breakers, insulating barriers and distribution equipment. Because of its properties, SF6 is ideal for use as an insulator in high-voltage equipment. Its main properties are:

-High dielectric strength: the breakdown voltage for is almost three times that of air at atmospheric pressure, making it an excellent insulator.
-Excellent arc-extinction properties: An electric arc is very quickly extinguished in an SF6 environment.

-Good heat transfer properties: SF6 possesses comparable or better characteristics then air under the most conditions.

-Good high-temperature thermal stability: SF6 is not inflammable and does not decompose in gas phase at temperatures below 500ºC.
-Low chemical reactivity: does not react with most other insulating or conducting materials at temperatures of up to 200ºC. It does not

produce carbon or other material deposits as the result of an electric arc.

-Relatively slightly toxic the Threshold Limit Value (TLV) for SF6 is 1,000 ppm by volume (0.1%), which is comparable with inert gases, such as argon.

-It is easily liquefied under pressure at controlled temperature: this property enables it to be compactly stored in metal cylinders.

The problem appears when there is moisture migration inside the insulation enclosure, which contaminates the SF6 and causes it to decompose and produce toxic effects.

This is where moisture measurement becomes essential and for this, the American manufacturer XENTAUR provides a portable measurement unit (XPDM) that guarantees speed of response, portability, precision and minimum gas consumption.

Moisture measurement in the transformer nitrogen blanket

The oil employed as power transformer insulator is severely affected by moisture. In order to lessen the effects of oil expansion and contraction with temperature, a nitrogen blanket is used to cover the oil. If moisture from the environment or oil comes into contact with the nitrogen blanket it could oxidise the breakers and reduce their efficiency. Maintenance personnel must perform routine checks on the moisture content of the nitrogen blanket that covers the transformer oil. Substation equipment, including breakers and transformers, is quite expensive and is the cause of power outages. One of the largest costs in supplying electric power is that produced by electric substation maintenance, with the transformer being one of the key substation components. The savings involved in correct predictive maintenance on large transformers (MVA: Megavolt-ampere) is estimated in millions of Euros.

Putting transformers into operation

When a transformer is prepared for putting into operation, the transformer vent section must be previously purged, first with air, then with nitrogen. A vacuum is applied to the transformer, typically during 24 hours.

A. Some stations measure the moisture in the vacuum current to determine the pumping time, although most vacuum pump the transformer during a predetermined time and do not bother to measure moisture at this point. There is a large surface area inside, winding insulation etc that must remain dry. This is an intermittent application, but since it is a prolonged measurement portable equipment is not that useful in these circumstances and a continuous usage measurement unit should be employed.

B. Between the windings in a transformer there is approximately 400 kg of paper that contains high levels of environmental moisture. During the drying and air evacuation process with nitrogen, some 115 litres of water is removed from the transformer. Approximately 24 hours is required to dry out the system with a further 12 for stabilisation. The transformer is therefore filled with nitrogen and allowed to stabilise. A moisture measurement is then carried out at this point (with portable equipment) in order to verify correct drying of the transformer.

c. Once the system has been evacuated, the

dew point has been verified sand stabilised at approximately -40ºC, the system is ready to be filled with oil. The transformer is then filled with new or reconditioned oil. Many stations carry out this operation in the field using a lorry fitted out with pumps, filters, heaters and measurement equipment.

Transformer oil

As previously stated, the filling of the transformer with oil, must take place after a drying purge with air and nitrogen. When this purge has been completed, the transformer is under hard-vacuum conditions and can be filled with oil. The new oil is introduced into the transformer at a rate of 75 litres per minutes and is heated to 90ºC to remove any existing gases and moisture.

The station regularly takes an oil sample and sends it to a laboratory (own or subcontracted) for a Karl Fischer evaluation analysis; this generally involves a problem in sending uncontaminated samples to the laboratory, so it is preferable to perform the analysis at the actual station. For this purpose liquid probes are employed to measure the moisture in the transformer oil.

The insulation oil is also used in the load regulators that are attached to the transformers. Regulator adjustment ensures correct transformer voltage. They require constant maintenance since they vent into the atmosphere. The load regulator is routinely inspected to eliminate any moisture. This is performed in the field using a filter as shown in the photo.

This measurement with a calibrated transmitter and a Karl Fischer evaluator avoids the need to take samples and send them to a laboratory

APLEIN INGENIEROS, S.A. XENTAUR SOLUTIONS

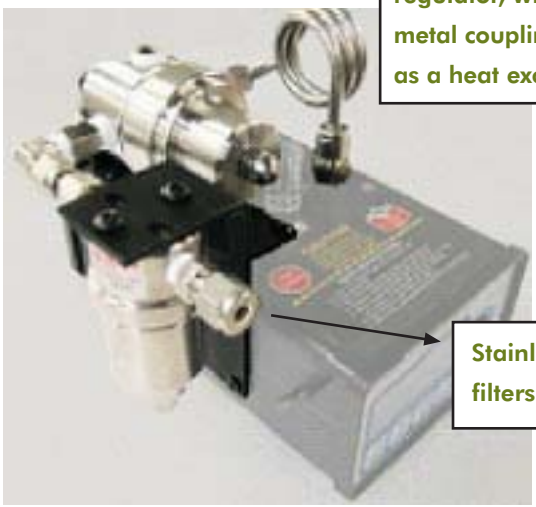
Aplein Ingenieros, S.A. and the American moisture analyser manufacturer XENTAUR have signed an exclusive distribution agreement for their equipment in Portugal and Spain. XENTAUR has proven, reliable and economic solutions available for the various described applications, which facilitate electric substation maintenance tasks.

Xentaur portable XPDM model

This is recommended for moisture measurement applications where breakers are filled with sulphur hexafluoride (SF6), in the transformer nitrogen blanket, where the operator purges a small sample of nitrogen by means of the instrument, waiting one or two minutes for stabilisation and then performing the measurement. The Xentaur XPDM model provides significant advantages over other dewpoint measuring equipment because of its response speed, portability and minimum gas consumption.

The main characteristics of this equipment are:

-Portable analyser
-The lightest and smallest analyser on the market
-Low gas sample consumption
-Response time for 10 ppmV (-60ºC dp): < 1 minute
-Robust construction
-Contamination resistant due to its internal drying chamber
-Options: Carrying case, various connectors, regulator and filter

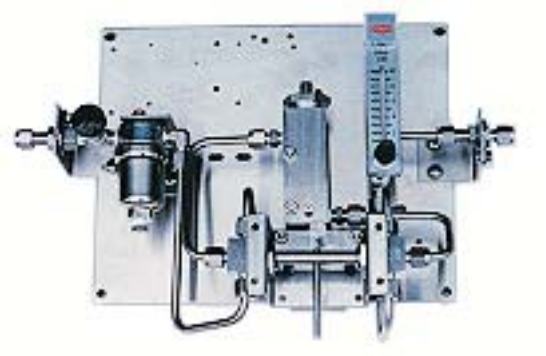


XPDM with filter and regulator option

Self-Drying ESS Xentaur Model

Recommended for transformer putting-into-operation applications.
The Sample Extraction System (SES) has a modular design and can be configured to accommodate almost any measurement requirement. It is manufactured from high quality materials and the system complies with all station standards. The system includes a moisture sensor that remains completely dry when the equipment is not actually in use. It incorporates a

desiccant cartridge that is easy to change in the field and which eliminates undesired contaminants and moisture with practically no maintenance.
The system is ideal for station or mobile applications. This system enables evacuation times to be significantly reduced, providing savings in energy and resources.
The sampling technique is unique and avoids long recovery times, drift and premature sensor failure.



Xentaur model HDT for liquids (transformer oil)
The hybrid dewpoint transmitter, model HDT, is a HART self-powered loop transmitter that can be employed in all transformer oil applications with its new sensor for liquid measurements.

The Xentaur facilities have their own liquid laboratory, which researches and develops sensors for measuring water vapour in liquids,.

The main primary standard for measuring the water vapour content in liquids is the JKarl Fischer (KF) evaluation. Aplein Ingenieros, S.A. and Xentaur also market this type of laboratory analyser.

Xentaur employs a secondary measurement method based on Al2O3 technology for mois-

ture measurements in transformer oil; these sensors measure the changes in water vapour partial pressure. Water vapour partial pressure is directly related to the concentration in parts per million by weight (ppm w) by means of the Henry non-dimensional proportionality constant. In oil transformers the Henry constant is essentially dependent on temperature. When the temperature increases, the capacity of the oil to hold water also increases, but the moisture concentration remains the same.

Other manufacturers of sensors with Al2O3 technology ignore the sensor temperature coefficient, which is a well-known problem with Al2O3 sensors, which means they have to have thorough knowledge of the temperature saturation curves in order to obtain results in ppm w. Xentaur eliminates the sensor temperature coefficient and the complex calculations by calibrating the sensors using a standard KF analyser. The HDT sensor simply monitors the water vapour pressure response and the temperature and provides moisture concentration in ppm w.

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