

Advances in Condition Monitoring of Transformers: Fibre Optics Based Moisture Sensing

The presence of moisture is one of the well-known factors that can cause failure in a transformer. There are many techniques developed over the last few decades for transformer moisture measurement.

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However, accurate moisture determination in cellulose based transformer insulation is still a challenge. The advancement in optical sensing technology has the potential to provide a reliable and accurate moisture measurement directly near the hotspot location of a transformer.

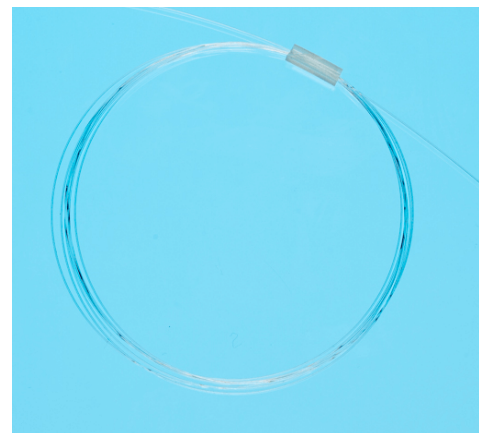
The utilities worldwide are operating in an economically constrained environment than ever before and are always keen in optimising their assets usage. Meanwhile, on the other hand, many power transformers are reaching their end of life/retirement age [1]. Therefore, it is very timely to explore new technologies that can better optimise the future usage of power transformer assets. It is well known that the life of a power transformer is determined by the condition of its paper insulation [2]. The presence of water severely reduces the insulation performance and life. The harmful effects of water have been the subject of many researches and a widely discussed topic in many international forums such as CIGRE, IEEE, and IEC.

INTRODUCTION OF ONLINE MOISTURE PROBES

Though moisture measurement techniques have significantly advanced in the last two decades, accurately measuring moisture in solid insulation is still challenging. Most of the current research is focused on improving the already developed moisture measurement techniques and their algorithms. However the inherent inaccuracies with Karl Fischer titration and dielectric based indirect techniques are difficult to eliminate [3]. Moreover, these techniques cannot capture the thermal driven moisture dynamics due to their sensitivities to temperature and other impurities. The introduction of online moisture probes based on capacitive sensor has opened new diagnostic possibilities compared with the single moisture estimation by Karl Fischer titration and dielectric based techniques. Although the moisture probe based measurement can provide an excellent online tool of measuring moisture, the probe has to install far from the active part of transformer and mathematical estimations are needed to calculate moisture at hotspots [4]. To address the shortcomings, optical fibre moisture sensors are investigated in our ARC Linkage project [5].

The advancement of optical fibre sensors and their application in civil engineering and medical equipment have proven the potential of optical Fibre Bragg grating (FBG) sensors for moisture measurements. The Bragg grating sensor is a special polymer coated fibre optic sensor that works similar to a filter. In the simplest form, the Bragg grating sensor is a reflector that reflects a particular wavelength of transmitted light and allows all other wavelengths to pass through the optical sensor core. The reflected/blocked wavelength of light

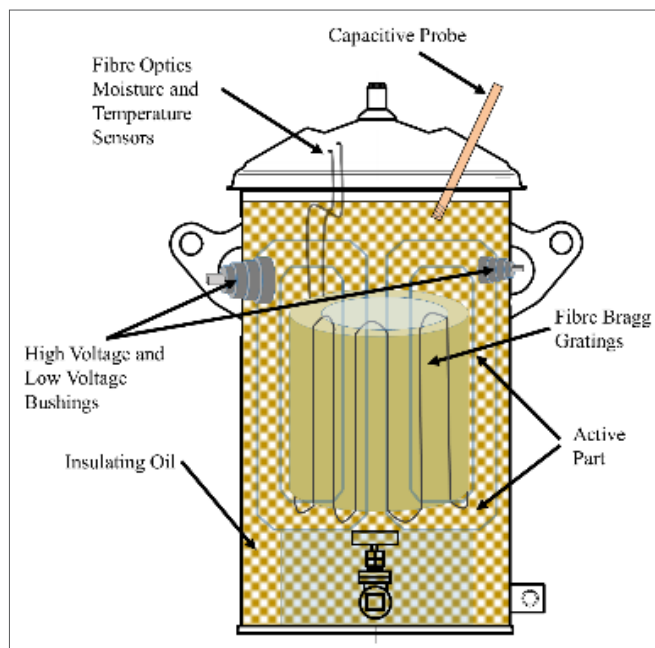
is called the “Bragg wavelength”, which depend on the moisture and temperature surrounding the sensor. The Bragg grating sensors miniature size, flexible design, and multiplexing possibility makes them an ideal sensor for power transformer application. The sensor can be easily installed near the hotspot of transformer and moisture can be measured directly. The multiplexing feature of the Bragg grating sensors allows for moisture measurement and its gradient in a large power transformer.



Fibre Bragg Grating Sensor



Sensors Testing in Humidity Chamber with Mineral Oil

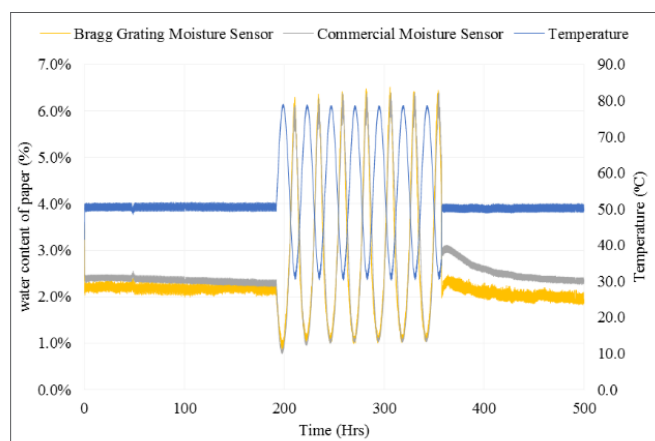


Sensors Testing in Prototype Test Transformer

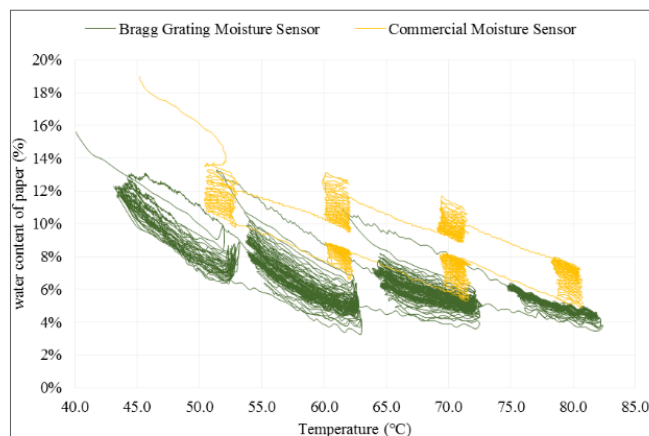
RESULTS

In our research conducted at the Australasian Transformer Innovation Centre (TIC) laboratory at the University of Queensland, we investigated, in detail, the application of Bragg grating sensors for Transformers. First, the Bragg grating sensors were tested in a controlled environment and their calibrations were performed. Then, the calibrated sensors were tested in specially designed prototype transformers. Ten distributed moisture sensors were installed around the active part of the transformers and tested to measure the thermal moisture dynamics during different loading conditions of transformers. The moisture dynamics and moisture hysteresis loops were investigated at different locations of transformers. The sensors were also tested for different accelerated ageing experiments at high temperature of 110°C, over longer durations. All the testings were performed in cellulose based insulation with mineral and vegetable oils. The sensors were tested for their stability, repeatability, precision, and reliability. The Bragg grating sensors were found to be stable and reliable during the experiments and showed superior advantages to the current moisture estimation techniques [6]–[8]. Two experimental results against a commercial moisture sensor is shown in figure below.

The research investigations showed that the polyimide coated Bragg grating sensors can provide a true real-time picture of the



Moisture Measured by a FBG and Commercial Sensor during Cyclic Loading




Moisture Hysteresis Measured by a FBG Sensor and Commercial Sensor during Cyclic Loading

moisture level and its distribution in all operating conditions. The sensor data can be easily integrated with any online monitoring and diagnostics system. Different algorithms can be used to alert the transformer asset owner for any contingency event and downtime can be minimised. The next stage of research can be the development of suitable spacers for Bragg grating sensor, so they can be safely installed in field transformers for field measurements.

References:

- [1] CIGRE Working Group A2.37, "Transformer Reliability Survey (TB#642)," 2015.
- [2] CIGRE Working Group D1.53, "Ageing of Liquid Impregnated Cellulose For Power Transformers (TB#738)," 2018.
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- [5] "Sustainable operation of transformers with better understanding of technical and economic constraints, ARC Linkage Projects (CI: Tapan Saha & Chandima Ekanayake)."
- [6] M. A. Ansari, D. Martin, and T. K. Saha, "Investigation of Distributed Moisture and Temperature Measurements in Transformers Using Fiber Optics Sensors," *IEEE Trans. Power Deliv.*, vol. 34, no. 4, pp. 1776–1784, Aug. 2019.
- [7] M. A. Ansari, D. Martin, and T. K. Saha, "Advanced Online Moisture Measurements in Transformer Insulation using Optical Sensors," *Accept. IEEE Trans Dielectri. Electr. Insul.*, no. February, 2020.
- [8] M. A. H. Ansari, C. Ekanayake, T. K. Saha, and H. Ma, "Examining the Performance and Stability of Fibre Optics Moisture Sensors near Hotspot Temperatures of Transformer," *Submitt. to IEEE Trans. Power Deliv.*, 2020.

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Continuing and Professional Development (CPD) Course Update

Recent Advanced CPD Course Completed Power Transformer Condition Monitoring and Asset Management

This was the eleventh course of a series being delivered at the Australasian Transformer Innovation Centre (TIC). Twelve industry and academic presenters delivered the online course providing practical information on the latest advances in condition monitoring, and innovation methods in asset management to reduce the whole of life costings of transformer fleet.

We would like to acknowledge the contributions of our speakers who are highly regarded in their fields:

- - Dr Hui Ma, The University of Queensland
- - Amra Alibegovic -Memsevic, Powerlink Queensland
- - Tuan Vu, Powerlink Queensland
- - Carlos Gamez, Western Power
- - Chris Beckett, United Energy
- - Rob Milledge, Hitachi ABB Power Grids Australia
- - Bhaba Das, Hitachi ABB Power Grids Singapore
- - Brian Sparling, Dynamic Ratings Canada
- - Alexei Babizki, Maschinenfabrik Reinhausen Germany
- - Barry Myburgh, Reinhausen Australia
- - Dr Attila Gyore M&I Materials MIDEL
- - James Reid M&I Materials MIDEL

DELEGATES

65 delegates were from generation, transmission and distribution companies, mining, heavy engineering, renewables, consulting groups, services companies and power transformer manufacturers and transformer components.

*95% of delegates said they would recommend this course to others.
90% of delegates rated the course "Excellent".*

TIC EDUCATION PROGRAM FOR 2021

Our first series of zoom webinars will start in February 2021. These webinars will typically be 1hr long, and offer great learning outcomes at low cost:

- o +\$60 (incl GST) for Non TIC member (+1 hr course.)
- o Free for TIC members

Advanced Webinar SVCs and Statcoms:

- The design and operation
- Key components.
- Key areas to consider for purchasers/operators/maintenance/testing/spares

Presenter Alwyn Janke - Power Sector Services

**Date 3rd February 2021 3.00pm to 4.00pm Brisbane Time (AEST)*

Advanced Webinar Phase Shifting Transformers

- The purpose of a phase shifting transformer
- Standards
- Types of Phase Shifting Transformers - Single Core versus Dual Core, Symmetric versus Asymmetric versus
- Important Parameters and their impact on the design
- Design Considerations
- Manufacturing challenges/testing

Presenter Iain Mackay GE Grid Solutions

**Date 10th February 2021 3.00pm to 4.00pm Brisbane Time (AEST)*

Advanced Webinar Generator Transformers

- Key design parameters for generator transformers
- Differences between generator transformer and other power transformers

- How to deal with stray flux in windings, core/clamping, tank and turrets
 - Special cooling considerations and ratings
 - Induced Core circulation Currents
 - Special Aspects of Dual LV's for Renewables Applications
 - Circulating Currents in windings
 - Special Considerations for Short Circuit Withstand
- Presenter Rob Milledge Hitachi ABB Power Grids*
**Date 18th February 2021 2.00pm to 4.00pm Brisbane Time (AEST)PD*


Advanced Webinar Final Acceptance Testing: Scope, Techniques, and Result Assessment for Power Transformers Pt1 & Pt2

- Scope and Classification of Tests
- Lightning Impulse requirements, Test Equipment and results assessment
- Other Dielectric Tests and their Applicability, Purpose & Assessment
- Loss Measurements (No Load & Load) Test techniques, expected results and assessment
- Test Circuits for Routine Tests and requirements of the Standards
- Useful rules to assess test results
- Temperature Rise tests techniques and thermal theory to understand the results
- Sound Level Measurement and theory including Sound Pressure vs Sound power
- Understanding Zero Sequence Impedance and its testing

Presenter Rob Milledge Hitachi ABB Power Grids

**Part 1: Date 25th February 2021 2.00pm to 4.00pm Brisbane Time (AEST)*

**Part 2: Date 4th March 2021 2.00pm to 4.00pm Brisbane Time (AEST)*

Note: Dates/timing to be confirmed. 

The TIC management team wishes to thank APT Publications for all their marketing activities for technical papers and CPD courses in 2020. Thanks to Tyrone, Martine, Lawrie and the team from the TIC team.



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The details of TIC education program will be posted on our website: <http://www.itee.uq.edu.au/tic-cpd> or to register your interest contact Ray Holzheimer, Manager, Australasian Transformer Innovation Centre, University of Queensland - E: r.holzheimer@uq.edu.au M: 0417 629 684

If you want to learn more about TIC and the benefits of becoming a member, visit: <http://www.itee.uq.edu.au/tic> or contact: Prof Tapan Saha, Director, Australasian Transformer Innovation Centre, University of Queensland E: saha@itee.uq.edu.au M: 0422 001 378