Development of a Test System to Study the Bubble Formation in Transformer Winding Insulation Systems

C. Pößniker[1], S.Y. Matharage[1], Z.D. Wang[1*]
[1]Centre for Smart Grid, Department of Engineering, University of Exeter, Exeter, EX4 4PY, UK
[*]E-mail: zhongdong.wang@exeter.ac.uk

***Abstract*— Bubble formation in transformers could result in severe consequences leading to power outages and huge financial losses. There is an increased risk of bubble formation in the future due to increasing load demand and much higher loading fluctuations. The bubble formation process in transformer insulation has been studied for decades and the water content in the paper has been addressed as the most influential impact parameter. However, results from the most common insulating material combination of Kraft paper and mineral oil vary widely and a meaningful comparison for other parameters or insulating material combinations is challenging. This work is introducing the development and verification process of a simple test setup that can be used to study various impact factors on the bubble formation process with a high degree of confidence.**

Background & Test system Development

Transformers are an essential part of the electricity network and the system's reliability is strongly connected to their dependable operation. Failures could be catastrophic and severely affect the network reliability resulting in huge financial losses. Bubble formation from winding insulation is one of the transformer failure mechanisms, which is related to a rapid temperature-rise due to severe short-term over-loading conditions. These bubbles, if moved into an area of a high electric field, can cause transformer failure through flashover. Therefore, the risk of bubble formation is one of the main loading constraints for transformers and understanding the fundamentals behind bubble formation mechanisms will help to utilise short-term overloading of transformers, if necessary, with minimum risks.

For several decades, researchers have been studying the bubble inception phenomenon from liquid-paper insulation systems of transformers. Most of these studies have been performed with the most common insulating material combination of non-thermally upgraded Kraft paper and mineral oil. However, even for this material combination and test conditions which are claimed to be similar, the obtained results vary widely and a comparison or the proposal of a meaningful conclusion is challenging, apart from the general agreement that the water content in paper seems to be the main influence factor on the bubble formation temperature. In addition, the various test setups and measurement methods make it challenging to draw a distinct conclusion on single impact parameters. Therefore, a coherent study performed with one test setup would allow to obtain comparable results to study the impact of individual parameters.

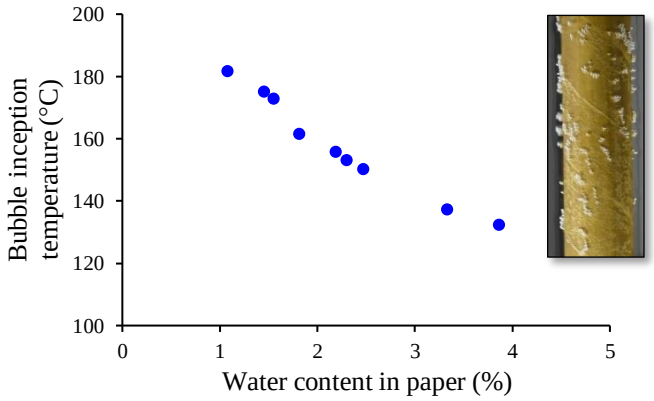

Fig. 1: Obtained result for the bubble inception temperature in non-thermally upgraded Kraft paper and mineral oil according to the water content in paper, including a photo of the observed bubble formation.

Based on a thorough study of thermal and moisture dynamics, a test system and method has been developed [1, 2], which allows the study of different impact parameters on bubble formation from transformer winding insulation with one test setup to obtain comparable results. Preliminary tests have shown the suitability of the test setup for such a study to obtain results with a high degree of confidence (Fig. 1).

Conclusion

The available studies on bubble formation from transformer winding insulation show a wide range of their results and lack of comparability. These variations could be caused by multiple impact factors such as the test system or material parameters. Therefore, this work introduces a developed test setup to determine the impact of different parameters on the bubble formation from transformer winding insulation systems. The developed test system is based on a thorough analysis of temperature and moisture dynamics, and the obtained results from preliminary tests indicated that the developed system can be used to study the bubble formation process in insulation systems.

References

[1] C. Pößniker, S.Y. Matharage, Z.D. Wang, D. Walker, C. Krause, and A. Hilker, "Development of an experimental setup to study the bubble formation of transformer insulation systems," *in IEEE Conference on Electrical Insulation and Dielectric Phenomena (CEIDP)*, 12-15. December, Vancouver, BC, Canada, pp. 147-150, 2021.

[2] C. Pößniker, S.Y. Matharage, Z.D. Wang, D. Walker, C. Krause, and A. Hilker, Muhammad Daghrah, "Evaluation of Bubble Formation in Transformer Insulation Systems - a Step Forward," *in 2022 IEEE 21st International Conference on Dielectric Liquids (ICDL)*, 29 May -02 June, Sevilla, Spain, pp. 1-4, 2022.