INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: **Natural Ester Oils as Liquid Insulation in HVDC Converter Transformer**

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SHORT ABSTRACT

As the world transitions to renewable energies in an effort to combat climate change, one of the greatest problems is transporting electrical energy over greater distances with minimal losses using HVDC systems. HV transformers and HV converter transformers are two critical components of HVDC transport systems. Typically, mineral oils (MO) is used for insulation and cooling however, the new technology adapts natural ester oils (NEOs) as an alternative and sustainable material, so it is vital to test the limitations of NEOs for DC voltage stresses and verify that their fundamental properties are compatible with equipment. Traditional petroleum-based transformer oils, despite their widespread use, suffer from drawbacks such as low biodegradability, limited fire resistance, and environmental concerns. NEOs, derived from renewable resources like sunflower and soybean etc., have emerged as promising alternatives. Major companies like Hitachi Energy-ABB and Siemens are already integrating NEO-based dielectric fluids into their transformer designs, reflecting a clear industry trend towards greener solutions. While the benefits of NEOs in HVAC transformers are well-documented, their application in HVDC transformers is relatively new and less explored. The unique operational stresses of HVDC systems, including high direct currents and associated electrical phenomena, necessitate a thorough understanding of how NEOs perform under these conditions. Existing

research highlights the potential of NEOs to provide superior insulation performance, enhanced breakdown strength, and better conductivity than traditional mineral oils (MOs). However, these findings primarily focus on HVAC applications, leaving a significant knowledge gap in HVDC context. The primary motivation for this thesis is to bridge this gap by extensively investigating the dielectric performance of NEOs in HVDC transformer insulation systems. This research aims to provide a comprehensive evaluation of the DC breakdown voltage (DCBDV) and DC conductivity of NEOs under various operational conditions, including thermal and oxidative ageing. The objectives of this thesis include studying the effects of oxidative ageing on the DCBDV of NEOs and comparing these results with MOs, and also analyzing the effects of accelerated thermal ageing, investigating the geometric effects on dielectric breakdown strength measurements, and evaluating the degradation of solid insulation materials aged in NEOs and MOs. This thesis also involves developing a new experimental setup for studying pre-breakdown phenomena and analyzing streamer formation in both liquid and solid insulation materials. This thesis is organized into six chapters, covering the introduction, effects of ageing on DC conductivity and DCBDV of natural ester oils, impact of electrode geometry, effects of ageing on pressboard insulation, design of experimental apparatus for pre-breakdown studies, and the conclusion with future research suggestions. By enhancing the understanding of NEOs in HVDC applications, this thesis aims to contribute to the development of more sustainable transformer technologies, promoting the reliable and widespread adoption of environmentally friendly dielectric fluids in the power industry.