Effect of water adsorption at nanoparticle–oil interface on charge transport in high humidity transformer oil-based nanofluid

Yuefan Du\textsuperscript{a,c,*}, Yuzhen Lv\textsuperscript{b}, Chengrong Li\textsuperscript{a,c}, Yuxiang Zhong\textsuperscript{a,c}, Mutian Chen\textsuperscript{a,c}, Shengnan Zhang\textsuperscript{b}, You Zhou\textsuperscript{a,c}, Zhengqi Chen\textsuperscript{a,b,c}

\textsuperscript{a} Beijing Key Laboratory of High Voltage and EMC, School of Electric and Electronic Engineering, North China Electric Power University, Beijing 102206, China
\textsuperscript{b} School of Energy, Power and Mechanical Engineering, North China Electric Power University, Beijing 102206, China
\textsuperscript{c} State Key Laboratory of Alternate Electrical Power System with Renewable Energy Sources, North China Electric Power University, Beijing 102206, China

\textbf{HIGHLIGHTS}

\begin{itemize}
  \item Water molecules could be bound to the nanoparticle–oil interface.
  \item Water adsorption enhances the lateral conductive path along the interface.
  \item The change at interfaces accelerates charge hopping transport process in SNFs.
  \item Rapid transfer of charge carriers mitigates the accumulation of space charge.
\end{itemize}

\textbf{GRAPHICAL ABSTRACT}

\begin{figure}
\centering
\includegraphics[width=0.8\textwidth]{graphical摘要.png}
\caption{Graphical representation of the abstract content.}
\end{figure}

\textbf{ABSTRACT}

Transformer oil-based nanofluids (NFs) with TiO\textsubscript{2} semiconductive nanoparticles (SNFs) exhibit substantially higher AC breakdown voltage than that of pure transformer oils at variable relative humidity from 20\% to 80\%. Charge accumulation and decay characteristics of pure oils and SNFs were measured by the pulse electroacoustic technique (PEA). It reveals that SNFs have more uniform internal electric fields and higher charge decay rate compared to pure oils under high relative humidity. It is confirmed by the test results of electrophoresis and thermally stimulated current (TSC) that the nanoparticles adsorb water molecules at the nanoparticle–oil interface, giving rise to the higher shallow trap density and resulting in better charge transport in SNFs.

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1. Introduction and background

Transformer oil is one of the key insulation liquids in worldwide high-voltage transformers and its high dielectric strength provides insulation support for achieving normal operation [1]. It has been found that once the transformer oil has high relative humidity, the chance for the water molecules to form water clusters is increased, leading to more ‘weak links’ and space charge accumulation under the electrical stress which distorts the internal local electric field [2,3]. Much effort has been done to measure and understand the influences of water on breakdown performance of transformer oil as they are not only scientifically challenging but also practically important [4–6]. However, the issue of how to have a uniform internal electric field and improve the breakdown voltage of a high humidity transformer oil is still a big challenge.

\* Corresponding author at: School of Electric and Electronic Engineering, North China Electric Power University, Beijing 102206, China. Tel.: +86 010 51971611; fax: +86 010 80795842.
E-mail address: fuyangtd@163.com (Y. Du).

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