



شبكة المعلومات الجامعية  
التوثيق الإلكتروني والميكروفيلم

# بسم الله الرحمن الرحيم



**MONA MAGHRABY**



شبكة المعلومات الجامعية  
التوثيق الإلكتروني والميكروفيلم



# شبكة المعلومات الجامعية التوثيق الإلكتروني والميكروفيلم



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# جامعة عين شمس

## التوثيق الإلكتروني والميكروفيلم

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# **Transformer Insulation Deterioration as Influenced by Various Voltage Stresses and Effects of Using Nanofluids**

A Thesis

Submitted in Partial Fulfillment for the Requirement of the  
Degree of **Doctor of Philosophy** in Electrical Engineering

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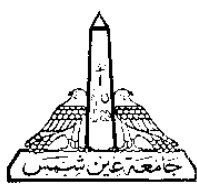
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2020



AIN SHAMS UNIVERSITY  
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# **Transformer Insulation Deterioration as Influenced by Various Voltage Stresses and Effects of Using Nanofluids**

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## **Dedication**

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***To all who has been a great support for me,  
I dedicate this work***

# Statement

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This thesis is submitted to Ain Shams University in partial fulfillment of the requirements for the award of Doctor of Philosophy degree in Electrical Engineering.

The author declares that no part of the work included in this thesis has been submitted to any other university / scientific entity for the award of any Degree or Diploma.

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## Acknowledgements

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In the name of Allah, the Beneficent, the Merciful .

Praises be to **Allah** for giving me the efforts, patience, and success to complete this PhD thesis. Without his infinite mercy and grace, I would never be able to reach at this stage.

I have the great honor to express my appreciations and thanks to my committee for their continuous support and guidance throughout this work. Special thanks go to my first supervisor **Prof. Dr. Soliman M. Eldebeiky** for his continuous guidance, helpful support and suggestions which kept me on track throughout my study. His endless drive for better results is highly appreciated. Deep thanks to **Prof. Dr. Loai S. Nasrat** for dedicating so much of his time to aid me and guide me throughout the period of the work. I wish also to express my appreciation to **Dr. Ahmed H. Gad** for his attention and suggestions .

Sincere thanks are extended to the staff and technicians of the Extra High Voltage Research Centre (EHVRC) Laboratory especially, Eng. Mohamed Selim for their contribution during carrying out this research work. Appreciation goes also to all the staff in the Nano Technology Research Center (NTRC), Department of Electrical Engineering, Faculty of Energy Engineering for their assistance during my sample synthesis in that laboratory.

Finally, I would like to express my heart-felt gratitude to my family and friends, for their encouragement and companionship when encountering difficulties. I never would have made it this far without their constant love and support. I am grateful for everyone believed in me and supported me throughout my educational experience.

# Abstract

With the tendency of the power system to increase the generating capacities and transmission voltage levels to meet the rapidly growing worldwide energy demands, associated problems with additional stresses on conventional insulation systems of high voltage equipment such as power transformer insulations have become an expected concern. Additional stresses will affect the lifetime of transformer insulations. Consequently, there is a critical need to develop new reliable transformer insulation materials to meet these worldwide challenges and resist the faster the deterioration effect.

As nanotechnology moves forward, nanofluids represent very promising fluids for applications as transformer insulating liquids, from the viewpoint of their excellent dielectric and thermal properties. Where there are many research papers stated that nanofluids provide better heat transfer and dielectric properties than those of base liquids. Nevertheless, it is still a significant step to move these fluids from the lab domain to high voltage power transformers. This step still requires more comprehensive studies of dielectric performance of nanofluids.

In this thesis, the dielectric performance of the transformer mineral oil (MO) based on these nanofluids developed using conductive Zinc Oxide (ZnO), semi-conductive Titanium Dioxide (TiO<sub>2</sub>) and Insulating Silicon Oxide (SiO<sub>2</sub>) nanoparticles have been researched. Nanofluids (NFs) were prepared with various concentrations ranging from 0.01 to 0.1 wt. %. The experiments have been designed and performed on prepared samples for study of: AC breakdown voltage, relative permittivity, DC conductivity, lightning impulse breakdown voltage, acceleration voltage and breakdown time. Studies on the analysis of the dissolved gas in the presence of nanoparticles under impulse faults have also been put forward. The experimental results demonstrated improvement of the AC breakdown strength with ~30 % enhancement for ZnO concentration of 0.06 wt. %, ~22 % for TiO<sub>2</sub> concentration of 0.1 wt. % and ~15% for SiO<sub>2</sub> at relatively low concentration of 0.01 wt. %. Positive effects on relative permittivity and the opposite ones on DC conductivity have been obtained for

tested nanofluids. For positive impulse voltage, the breakdown voltage of ZnO nanofluid achieved ~9% enhancement under quasi-uniform field and ~32% under non-uniform field. For negative impulse voltage, ZnO nanofluid achieved slight worsening of breakdown voltage by ~9%. Potential mechanisms behind nanoparticle influence on the dielectric properties of nanofluid have been discussed and analyzed by using thermally stimulated current technique.

Moreover, the deterioration behavior of nanofluid in combination with cellulose insulation has been investigated and compared with that of mineral oil-cellulose system. Accelerated thermal aging experiments of cellulosic insulations impregnated in nanofluid and mineral oil were conducted under laboratory conditions at 120°C for aging period up to 20 days. Different aging properties such as tensile strength, breakdown voltage, and dielectric dissipation factor of impregnated paper/pressboards were monitored and analyzed throughout the aging period. In addition, properties of oils related deterioration rate such as breakdown voltage, acidity value, interfacial tension, viscosity and color are thoroughly investigated in this research work to assess the degree of deterioration of both nanofluid and mineral oil. It is found that paper/pressboards aged in nanofluid possessed higher mechanical and dielectric properties than those in mineral oil. Regarding aged oils, nanofluid exhibited higher values of aging indicators such as interfacial tension, acidity and viscosity than mineral oil. The breakdown voltage of nanofluid was superior to that of mineral oil in the initial aging period, thereafter, showed a lesser reduction tendency with increasing age.

**Keywords:** Power transformer, Mineral oil, Nanofluid, lightning impulse voltage, Aging.

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