INTERPRETATION TECHNIQUE OF PARTIAL DISCHARGE PULSE COUNT AND SURFACE DEFECT ANALYSIS FOR EVALUATION OF COMPOSITE MATERIALS

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To my lovely parents who passed away, whose introduced me to Allah and Rasulullah and Al-Quran and gave me the endless love, trust, constant encouragement over the years during their lives, and for their prayers.

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ABSTRACT

High voltage insulation must be designed in such a way that it is very resistant to ageing including that from partial discharge (PD). Many studies were previously carried out on composites based on low density polyethylene (LDPE). However, the use of natural rubber (NR) and nanosilica (SiO_2 nanoparticle) in the LDPE-based composites are relatively new. Furthermore, the PD resistant performance of the composites is yet to be extensively researched. It is desired to know the weight percentage of each component in the LDPE-NR-SiO_2 composite, especially the nanosilica filler weight percentage, for an optimum PD resistant performance. Due to specific research requirements, a customized laboratory scale PD data acquisition system (PD-DAQS) is desired to be developed. With the availability of several parameters obtained from the PD experiment, there is another need to devise an interpretation tool that can correctly correlate all parameters to the PD resistance. This work aims to develop a new PD system for measuring, analysing and interpreting PD signals, which can then be used to determine a new nanocomposite material with high PD resistance. A new PD-DAQS comprising CIGRE Method II test cell, Picoscope interfacing device, and LabVIEW based program was successfully developed. Scanning electron as well as normal microscopes were used for composite sample's image capturing and morphological analyses. A new PD interpretation technique based on PD pulse count and its surface image analysis was obtained and successfully categorised the PD performance of a given dielectric sample on scores of 1 to 5 corresponding to very bad to very good. PD improvement index and a scoring system were also introduced and utilised for the new dielectric work. Three groups of new composites with varying compositions and nanosilica content were made and tested by applying high voltage stress using the CIGRE Method II test cell for 60 minutes. Results have shown that the addition of nanosilica filler into LDPE and LDPE-NR base polymers have increased the PD resistance of the new composites. The highest PD resistance score of 5 was achieved by the best nanocomposite sample of LDPE-SiO_2 with 4.5 weight percent of nanosilica. Even though the addition of natural rubber to LDPE matrix has caused a decrease in PD resistance, the addition of 6 weight percent of nanosilica as fillers in the LDPE-NR (80:20) composite has tremendously improved its PD resistant performance. The LDPE as well as LDPE-NR based nanocomposites can be potentially developed as a high voltage insulating material. The developed PD measuring and interpretation system can also be utilised for future PD and nanodielectric studies.

ABSTRAK

Penebatan voltan tinggi mesti direkabentuk supaya mempunyai ketahanan yang tinggi terhadap penuaan termasuk yang disebabkan oleh nyahcas separa. Banyak kajian ke atas komposit berasaskan polyethylene berketumpatan rendah (LDPE) telah dilakukan. Walau bagaimanapun, penggunaan getah asli (NR) dan nanosilika (SiO_2) di dalam komposit berasaskan LDPE masih baru. Tambahan pula, prestasi rintangan PD komposit masih perlu kajian lanjut. Ingin diketahui adalah peratus berat setiap komponen komposit LDPE-NR-SiO_2, terutama peratus pengisi nanosilika bagi prestasi PD optimum. Disebabkan oleh keperluan penyelidikan khusus, satu sistem perolehan data (PD-DAQS) berskala makmal perlu dibangunkan. Dengan adanya beberapa parameter yang diperolehi dari ujikaji PD, terdapat keperluan untuk menyediakan satu alat penafsiran yang dapat mengaitkan semua parameter dengan rintangan PD. Tujuan penyelidikan ini adalah untuk membangunkan satu sistem PD baru untuk mengukur, menganalisis dan mentafsir isyarat PD yang kemudiannya boleh digunakan untuk mendapatkan satu bahan nanokomposit baru dengan rintangan PD yang tinggi. Sebuah PD-DAQS baru yang terdiri daripada sel ujian kaedah CIGRE II, peranti antara muka Picoscope, dan program berasaskan LabVIEW berjaya dibangunkan. Mikroskop pengimbas elektron dan mikroskop biasa digunakan untuk mengambil gambar sampel komposit dan untuk analisis morfologi. Satu penafsiran PD yang baru berdasarkan hitungan denyut PD dan analisis imej permukaan telah diperolehi dan ianya berjaya mengklasifikasikan prestasi PD sampel dielektrik dengan skor 1 hingga 5, atau sangat buruk hingga sangat baik. Indeks penambahbaikan PD dan satu sistem penilaian juga diperkenal dan digunakan dalam penyelidikan dielektrik baru. Tiga kumpulan komposit baru dengan pelbagai komposisi dan kandungan nanosilika telah dibuat dan diuji menggunakan voltan tinggi dan sel ujian kaedah CIGRE II selama 60 minit. Hasil menunjukkan bahawa penambahan pengisi nanosilika ke dalam polimer asas LDPE dan LDPE-NR telah meningkatkan rintangan PD komposit baru tersebut. Skor rintangan PD tertinggi 5 dicapai oleh sampel nanokomposit terbaik iaitu LDPE-SiO_2 yang mangandungi 4.5 peratus berat nanosilika. Walaupun penambahan getah asli ke dalam LDPE telah menyebabkan penurunan rintangan PD, namun penambahan 6 peratus berat nanosilika sebagai pengisi dalam komposit LDPE-NR (80:20) telah menambahbaik rintangan PD secara mendadak. Nanokomposit berasaskan LDPE serta LDPE-NR berpotensi dibangunkan sebagai bahan penebat voltan tinggi. Sistem pengukuran PD dan sistem tafsiran yang dibangunkan juga boleh dimanfaatkan untuk kajian PD dan nanodielektrik pada masa depan.

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LIST OF ABBREVIATIONS

ADC	-	analog-digital converter
CAD	-	computer aided design
CNR	-	contrast-to-noise ratio
DAQS	-	data acquisition system
LDPE	-	low density polyethylene
GS/s	-	giga sampling per second
IEC	-	International Electrotechnical Commission
IHM	-	image histogram method
IQM	-	image quantifying method
NR	-	natural rubber
PC	-	personal computer
PD	-	partial discharge
PD-DQAS	-	partial discharge and data acquisition system
PE	-	polyethylene
PoEA	-	percentage of eroded area
PP	-	polypropylene
RGB	-	red, green and blue
SEM	-	scanning electron microscope
SiO_2	-	nanosilica
XLPE	-	cross-linked polyethylene

LIST OF SYMBOLS

S	-	standard deviation
V	-	voltage
q	-	charge
i	-	current
I	-	average discharge current
n	-	repetition rate
P	-	discharge power
y	-	filtered sequence
h	-	FIR filter coefficient

CHAPTER 1

INTRODUCTION

1.1 Preliminaries

A partial discharge (PD) is a dielectric phenomenon that occurs in solid or liquid insulating materials. It is said to have occurred when an electrical pulse or discharge partially bridges a gas void (whether they are adjacent or not). A PD is usually initiated inside voids, cracks, or inclusions within a solid dielectric or at conductor-dielectric interfaces within solid or liquid dielectrics or in bubbles within liquid dielectrics [1]. PD can also occur along the surface of solid insulating materials if the surface tangential electric field is high enough to cause a breakdown along the insulator surface. This dielectric phenomenon only partially bridges the gap between phase insulation and ground or between phase-to-phase insulation. Thus the PD phenomenon could be used as an effective assessment technique in maintenance and monitoring of electrical distribution equipment conditions [2-5].

However, despite possessing good electrical properties, polymer insulation materials have been observed to have low PD resistance. Furthermore, the voids and defects in the structure of polymer, which are usually because of imperfections in the production process, contribute to accelerating the ageing of the material. The dimension of voids could be in nanometer or micrometer size in which the gases are trapped. It is in these voids in which ionizations are most likely to start under any high electric field stress.

Partial discharge measurement is a well-known and promising method for condition assessment of insulation systems in high voltage equipment. It is used for preventive maintenance for assessing the medium voltage motors and cable joints [6-8]. The partial discharge measurements represent a universally accepted technique which gives the indication or status of the insulation. Partial discharge analysis is a noninvasive or nondestructive technique which monitors the integrity of the insulation. The discharge analysis is an efficient means used by stake holders to avoid insulation failures in electrical equipment and to reduce their maintenance costs. The analysis is used to identify deterioration mechanisms in insulation systems such as slot discharge, internal voids, wedge and winding looseness. These problems need to be monitored and corrected because their individual failures can lead to catastrophic failures of the system.

Under high voltage stress, the insulation material suffers from the electron bombardment that causes defect to the insulation surface gradually. The level of the defect depends on internal and external factors. The internal factors are such as the insulation quality and the behavior of the insulation to the high voltage stress. The external factors are like the level of the high voltage stress and the electrode shape. The size of surface damage varies in size from micrometer, centimeter, or the complete damage of the surface. By looking at the picture of the defected area, the affected area can be analyzed with image histogram analysis.

Surface defect is a common problem facing the industrial process. The defect is identified by the abnormality of texture and colour. The surface defect detection is a common process in an industrial engineering to detect the inferior product. The defect detection process can be done automatically using a high-resolution camera supported by a suitable software, but the basic defect detection is done by human visual inspection supported by image-processing software [9]. This technique was used to detect the texture defect of the surface like metal, wood, steel, wafer and even for non-flat object like fruits and aircraft surfaces [10].

Nowadays the nanofillers are gaining interest from researchers to get a better polymeric insulator due to its promising properties [11-13]. The improvement of nanofiller filled polymeric insulator is due to very small size of the filler and hence very large interfacial surface between the polymer and the filler [14-16], and the behavior of the nanocomposite molecule inside the polymer [17, 18].

Undeniably, the addition of nanofillers in polymer matrices has resulted in enhanced partial discharge resistance of the polymeric nanocomposite. It was found that the addition of silica nanofiller to the epoxy resin improved the PD resistance of the composite material [19]. It is also highlighted that epoxy/clay composite is superior in partial discharge resistance compared to base epoxy resins. The conclusion was drawn based on the evaluation on the depth of erosion. At the same time, the research on the surface discharge degradation of metal oxide nano-filled epoxy showed that nanoalumina and nanotitania filled epoxy had considerably improved its resistance to surface discharges [15]. These facts show that there are potential applications of nanocomposites in electrical insulation [20].

Although there are many experimental techniques that were used to determine partial discharge characteristics of composites, a comprehensive method to evaluate the PD resistance is still a big challenge. It is true that the PD phenomenon in composites was extensively studied and different PD models were also introduced by many researchers to understand the PD phenomenon. However, in order to choose the best performance of the composite samples, there is no evaluation technique yet proposed to rank the composite samples based on the PD data. Due to the complicated nature of composite materials, there is no single characterization method that can reveal the complete characteristics of composite materials. It is true that the breakdown test can be taken as one characteristic of the composite materials, but the information from the test is very general and cannot explain the physical characteristics or the internal structures of materials [21].

A complete and expensive partial discharge data acquisition system (PD-DAQS) is mostly used by the electrical power companies [6-8]. In contrary, only a limited number of PD-DAQS are owned by other institutions, for example, a testing laboratory. The limited market for PD-DAQS makes the price of the PD-DAQS to be relatively on the high side for laboratories that intend to purchase. A comprehensive

PD-DAQS is a basic necessity for any study on partial discharge characteristics in a laboratory environment.

Equally important for PD studies, especially when trying to determine the performance of a new composite or dielectric is the interpretation technique of the massive collected PD data. The interpretation should not be based on just PD magnitude but rather on other PD characteristics and PD related changes on the studied materials such as the morphological profiles of the materials.

1.2 Research Problem Statement

Experimental work is vital in PD studies, and hence the availability of complete experimental setups is a must for a successful research. One key setup for PD studies is the partial discharge data acquisition system (PD-DAQS). Because of specific research requirements, a customized laboratory scale PD-DAQS may incur a high procurement cost, especially when the facility itself is usually sold in a limited market. It is therefore desired to develop a custom-made PD-DAQS that suits the objectives of this research.

The partial discharge pulse count is one of PD characteristics normally measured in PD experiments and then used to reflect how resistant a material is to a PD activity, based on the correlation between the PD pulse count and the PD resistance of a given material. However, the use of just the PD pulse count to decide on the PD resistant property of a material is not sufficient. There is a need to also consider other PD characteristics apart from the PD pulse count, such as images of material surface defects caused by PD. In fact, because of the massive amount of data captured in typical PD experiments, the PD pulse count itself need to be statistically analysed to give several representative parameters before it can be used to determine the PD resistance. With the availability of several parameters obtained from the PD experiment, there is another need to devise an interpretation tool that can correctly correlate all parameters to the PD resistance. Furthermore, the tool also need to be validated. The interpretation tool is vital when designing a new dielectric material with an improved PD resistance.

Studies had been carried out to obtain new materials with high PD resistance. These materials include low density polyethylene (LDPE), natural rubber (NR), and their composites. Attempts had also been made to also include micro and nano fillers, such as nanosilica. Even though some other studies were previously carried out using LDPE-NR-SiO_2 composites, the PD resistant performance of the composites is yet to be extensively researched. In particular, it is desired to know the weight percentage of each component in the LDPE-NR-SiO_2 composite, especially the nanosilica filler weight percentage, for an optimum PD resistant performance.

1.3 Research Objectives

This research work was undertaken to address the above problem statements. It aims to provide a comprehensive PD measuring and assessment system so that a new and improved LDPE based composite material can be found. To achieve this aim the following objectives of the research are listed.

1. To develop a partial discharge data acquisition system (PD-DAQS) to acquire, store and analyze the PD data.

2. To develop and validate new partial discharge interpretation techniques based on PD pulse count and percentage of eroded area.

3. To determine a new low density polyethylene (LDPE) and natural rubber (NR) based nanocomposites with superior PD resistance performance.

1.4 Research Scopes

The study carried out in this work was limited to several scopes described below.

The partial discharge measurements were carried out using CIGRE Method II set-up which was suitable for small samples of dielectrics. Therefore all measured PD data such as PD pulse counts were based on this set-up with specified PD inception voltage levels. All other requirements of the set-up including noise elimination and equipment calibration were observed.

The morphological analyses carried out in this work are limited by the capacity of available microscopes including the SEM. The materials used for the determination of the new dielectric are limited to LDPE and natural rubber. Only nanosilica was used as the filler material. Sample preparation and finishing techniques are as described in this thesis.

1.5 Research Contribution

Major contributions of this study are as listed below.

1. **Development of a partial discharge data acquisition system (PD-DAQS)**

   Partial discharge data acquisition (PD-DAQ) systems are available in different scales and for different purposes. However, most of them suffer from many disadvantages such as the lack of memory capacity for long data storage. In this study, a mobile, economical and customizable partial discharge data acquisition system (PD-DAQS) suitable for laboratory scale work had been successfully developed. The developed PD-DAQS successfully handled huge PD data in a much shorter time compared to the alternative MS Office Excel based system and with no memory crash problem.

2. **PD data interpreting techniques by using different methods as listed below.**

   a. **An improved PD pulse count analysis**

PD pulse count is one important property of PD characteristics and was used for a long time to justify the PD resistance of an insulation. PD pulse count represents the frequency of PD occurrence during a period of time. In the usual statistical method, the PD pulse count was mostly presented together with PD phase and PD amplitude to form the well-known PD pattern graph. In this research work, the PD pulse count was successfully evaluated using a statistical approach by taking the advantage of histogram parameters, namely, mean, standard deviation, kurtosis, and skewness. It was clearly seen that the PD pulse count for each sample was different in each interval of time reflecting the random behavior of the sample response to the electric field stress.

   b. **The surface defect analysis**

The surface image analysis using two main processing techniques called the image histogram and image quantifying methods to calculate the percentage of eroded area (PoEA) was successfully evaluated. Both methods were successfully applied to identify the percentage of the eroded area (PoEA) of the samples.

   c. **Correlation between PD pulse count and surface defects**

PD phenomenon causes defect on the insulation material including its surface. Until now, the correlation between PD events and related surface defects are still not widely discussed in depth. In this study, a correlation analysis between the PD pulse count and the corresponding surface defect had been presented. It was found that there is a strong correlation between the frequencies of the pulse count or frequency of PD, which reflects the higher value of PoEA.

d. An Improved PD resistance index (APD index)

The PD improvement (A_{PD} Index) of the composite can help the researchers to identify the contribution of nanofillers whether positive or negative compared to the base of the polymer. In this study, an improved PD resistance index (A_{PD} index) to analyze the PD resistance had been developed and proposed.

e. A Scoring System

To evaluate the performance of groups of composite samples, a comprehensive technique is needed. A scoring system was developed by considering the result of PD pulse count analysis, and combining with the results of PD pulse count and image analyses. The PD pulse count, the image histogram, and PoEA were considered to give the score for each parameter, which ranges from 1 to 5 representing qualitative values from VERY BAD to VERY GOOD. The evaluation system identified that addition of nanosilica to LDPE improved the quality of LDPE from GOOD to VERY GOOD. Also, the addition of nanosilica to LDPE-NR (80:20) composite material improved the composite quality from BAD to GOOD.

3. New composite material compositions with improved PD resistance

Additions of nanosilica filler to LDPE and to LDPE-NR composites had improved the PD resistance performance. Using the developed evaluation system, it was successfully identified that LDPE-SiO_2 composite with 4.5 wt% of nanosilica filler loading has the highest score, followed by LDPE-NR-SiO_2 composite with 6 wt% nanosilica filler.

1.6 Research Significance

The surface defect of the composite sample has a strong correlation with the PD pulse count. Smaller PD pulse count is in line with the smaller PoEA. This correlation can make the PoEA analysis as an alternative to PD pulse count analysis, or as a complement to PD pulse count analysis. In the absence of PD-DAQS, the surface defect analysis can be a good technique to classify the PD performance based on the PoEA of samples.

The PD improvement (A_{PD} Index) of the composite help the researchers to understand the contribution of nanofillers whether positive or negative compared to the base polymer. By adopting the PD resistance index to analyze the PD resistance, a new set of dielectric materials can be better understood not only for experts in this research area but also for the management team and those in common engineering.

The new compositions of composite materials have a higher PD resistance compared to their base polymers. The current proposed compositions can be a starting point for further research by doing different aspects of study in order to get a more comprehensive knowledge of these composites while looking at the opportunity to be applied as a high voltage insulating material.

1.7 Thesis Organization

Chapter 2 presents a literature review with respect to the background of composite materials, partial discharge measurements, PD data acquisitions, PD data interpretations, image processing methods to quantify the percentage of eroded area (PoEA), the evaluation system in general, and techniques used in the composite diagnosis. Chapter 3 presents the research methodology that explains the sample preparations, the experimental procedure of PD and data acquisition system, image processing method to compute the PoEA, and the evaluation procedure to select the best composite sample.

Chapter 4 presents the results and discussions of the SEM observations, the experimental results of PD pulse count, and the image processing used to count the PoEA of tested composites. The morphological characteristics of each sample are also described. The evaluation of result is also presented. Chapter 5 concludes the thesis and also presents recommendations for future work.

REFFERENCES

1. Paoletti, G. and A. Golubev. *Partial discharge theory and applications to electrical systems*. in *Pulp and Paper Industry Technical Conference , 1999. Conference Record of 1999 Annual*. 1999.
2. Wen-Yeau, C. *Partial discharge pattern recognition for cast-resin current transformer*. in *Properties and Applications of Dielectric Materials, 2009. ICPADM 2009. IEEE 9th International Conference on the*. 2009.
3. Stone, G.C. *Relevance of phase resolved PD analysis to insulation diagnosis in industrial equipment*. in *Solid Dielectrics (ICSD), 2010 10th IEEE International Conference on*. 2010.
4. Hudon, E., C.W. Reed, and J.E. Timperley. *Use of spectral analysis and phase resolved partial discharge measurements for generator testing*. in *Electrical Insulation and Dielectric Phenomena, 1994. IEEE 1994 Annual Report., Conference on*. 1994.
5. Guanjun, Z., et al. *Phase resolved analysis of PD measurements for typical discharge models of oil-immersed insulation*. in *Dielectric Liquids, 1999. (ICDL '99) Proceedings of the 1999 IEEE 13th International Conference on*. 1999.
6. Fukunaga, K., M. Tan, and H. Takehana, *New partial discharge detection method for live UHV/EHV cable joints.* Electrical Insulation, IEEE Transactions on, 1992. 27(3): p. 669-674.
7. Petzold, F., et al., *Advanced solution for on-site diagnosis of distribution power cables.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2008. 15(6): p. 1584-1589.
8. Zarim, Z.A.A. and T.M. Anthony. *The development of Condition Based Maintenance for 33kV Oil-Filled cable*. in *Condition Monitoring and Diagnosis (CMD), 2012 International Conference on*. 2012.

9. Zhao, L., et al., *Defect detection in slab surface: a novel dual Charge-coupled Device imaging-based fuzzy connectedness strategy.* Rev Sci Instrum, 2014. 85(11): p. 115004.
10. Xie, X., *A Review of Recent Advances in Surface Defect Detection using Texture analysis Techniques.* Electronic Letters on Computer Vision and Image Analysis, 2008: p. 22.
11. Singha, S. and M.J. Thomas, *Influence of filler loading on dielectric properties of epoxy-ZnO nanocomposites.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2009. 16(2): p. 531-542.
12. Ciuprina, F., et al. *Dielectric Properties of Nanodielectrics with Inorganic Fillers*. in *Electrical Insulation and Dielectric Phenomena, 2008. CEIDP 2008. Annual Report Conference on*. 2008.
13. Frechette, M.F. *Innovation in dielectric materials: from macro to nanoscales*. in *Electrical Insulation Conference, 2009. EIC 2009. IEEE*. 2009.
14. Lewis, T.J. *Interfaces and nanodielectrics are synonymous*. in *Solid Dielectrics, 2004. ICSD 2004. Proceedings of the 2004 IEEE International 3Conference on*. 2004.
15. Maity, P., et al. *Effect of particle dimensions and pre-processing of nanoparticles in improving surface degradation characteristics of nanodielectrics*. in *Electrical Insulation and Dielectric Phenomena, 2007. CEIDP 2007. Annual Report - Conference on*. 2007.
16. Raetzke, S. and J. Kindersberger, *Role of interphase on the resistance to high-voltage arcing, on tracking and erosion of silicone/SiO₂ nanocomposites.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2010. 17(2): p. 607-614.
17. Frechette, M.F. and C.W. Reed. *The role of molecular dielectrics in shaping the interface of polymer nanodielectrics*. in *Electrical Insulation and Dielectric Phenomena, 2007. CEIDP 2007. Annual Report - Conference on*. 2007.
18. Smith, R.C., et al. *Interfacial charge behavior in nanodielectrics*. in *Electrical Insulation and Dielectric Phenomena, 2009. CEIDP '09. IEEE Conference on*. 2009.
19. Frechette, M.F., et al. *Nanodielectric surface performance when submitted to partial discharges in compressed air*. in *Electrical Insulation and Dielectric Phenomena, 2005. CEIDP '05. 2005 Annual Report Conference on*. 2005.

20. Tuncer, E. and I. Sauers, *Industrial Applications Perspective of Nanodielectrics*, in *Dielectric Polymer Nanocomposites*, J.K. Nelson, Editor. 2010, Springer US. p. 321-338.
21. Castellon, J., et al., *Nanocomposite characterization and diagnostics tools.* Electrical Insulation Magazine, IEEE, 2013. 29(6): p. 37-48.
22. Chan, J.C., et al., *Partial discharge. VIII. PD testing of solid dielectric cable.* Electrical Insulation Magazine, IEEE, 1991. 7(5): p. 9-16.
23. Tanaka, T. and Y. Ikeda, *Internal Discharges in Polyethylene with an Artifical Cavity*. Power Apparatus and Systems, IEEE Transactions on, 1971. PAS-90(6): p. 2692-2702.
24. Okamoto, H., M. Kanazashi, and T. Tanaka, *Deterioration of insulating materials by internal discharge.* Power Apparatus and Systems, IEEE Transactions on, 1977. 96(1): p. 166-177.
25. Buchalla, H., T. Flohr, and W. Pfeiffer. *Digital signal processing methods for interference recognition in partial discharge measurement-a comparison*. in *Electrical Insulation, 1996., Conference Record of the 1996 IEEE International Symposium on*. 1996.
26. Krupchatnikov, B.N., V.N. Chernov, and V.A. Chechurov. *The development of a terrestrial Stirling radionuclide power set*. in *Energy Conversion Engineering Conference, 1989. IECEC-89., Proceedings of the 24th Intersociety*. 1989.
27. Van Bolhuis, J.P., et al. *Comparison of conventional and VHF partial discharge detection methods for power transformers*. in *High Voltage Engineering, 1999. Eleventh International Symposium on (Conf. Publ. No. 467)*. 1999.
28. Petchphung, P., et al. *The comparison study of PD measurement with conventional method and unconventional method*. in *Condition Monitoring and Diagnosis, 2008. CMD 2008. International Conference on*. 2008.
29. Yao, L. and Q. Su. *New partial discharge detector*. 1994. Brisbane, Aust: IEEE.
30. Kawaguchi, Y. and S. Yanabu, *Partial-Discharge Measurement on High-Voltage Power Transformers.* Power Apparatus and Systems, IEEE Transactions on, 1969. PAS-88(8): p. 1187-1194.

31. Miller, R. and I.A. Black, *Partial Discharge Energy Measurements on Electrical Machine Insulation When Energized at Frequencies between 0.1 Hz and Power Frequency.* Electrical Insulation, IEEE Transactions on, 1979. EI-14(3): p. 127-135.

32. Harrold, R.T., *Acoustical Technology Applications in Electrical Insulation and Dielectrics.* Electrical Insulation, IEEE Transactions on, 1985. EI-20(1): p. 3-19.

33. Harrold, R.T., *Acoustic Theory Applied to the Physics of Electrical Breakdown in Dielectrics.* Electrical Insulation, IEEE Transactions on, 1986. EI-21(5): p. 781-792.

34. Si, W.R., et al., *Investigation of a comprehensive identification method used in acoustic detection system for GIS.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2010. 17(3): p. 721-732.

35. Thayoob, Y.H.M., et al. *Detection of acoustic emission signals from partial discharge sources in oil-pressboard insulation system*. 2010. Kuala Lumpur.

36. Bozzo, R. and F. Guastavino, *PD detection and localization by means of acoustic measurements on hydrogenerator stator bars.* Dielectrics and Electrical Insulation, IEEE Transactions on, 1995. 2(4): p. 660-666.

37. Howells, E. and E.T. Norton, *Detection of Partial Discharges in Transformers Using Acoustic Emission Techniques.* Power Apparatus and Systems, IEEE Transactions on, 1978. PAS-97(5): p. 1538-1549.

38. Deheng, Z., T. Kexiong, and J. Xianhe. *The study of acoustic emission method for detection of partial discharge in power transformer*. in *Properties and Applications of Dielectric Materials, 1988. Proceedings., Second International Conference on Properties and Applications of*. 1988.

39. Zhao, Z.-q. and Y.-q. Yuan. *Recent study of acoustic emission locating for partial discharge in UHV transformers and shunt reactors*. 1988. Beijing, China: Publ by IEEE.

40. Eleftherion, P.M., *Partial discharge. XXI. Acoustic emission based PD source location in transformers.* Electrical Insulation Magazine, IEEE, 1995. 11(6): p. 22-26.

41. de A. Olivieri, M.M., W.A. Mannheimer, and A.P. Ripper-Neto. *On the use of acoustic signals for detection and location of partial discharges in power*

transformers. in *Electrical Insulation, 2000. Conference Record of the 2000 IEEE International Symposium on*. 2000.

42. Akumu, A.O., et al. *A study of partial discharge acoustic signal propagation in a model transformer*. in *Electrical Insulating Materials, 2001. (ISEIM 2001). Proceedings of 2001 International Symposium on*. 2001.
43. Raja, K. and T. Floribert. *Comparative investigations on UHF and acoustic PD detection sensitivity in transformers*. in *Electrical Insulation, 2002. Conference Record of the 2002 IEEE International Symposium on*. 2002.
44. Min, L., Z. Hong, and Z. Jian. *Fiber Fabry-Perot Sensors Based Acoustic Detection of Partial Discharges in Power Transformers*. in *Properties and applications of Dielectric Materials, 2006. 8th International Conference on*. 2006.
45. Wang, X., et al., *Acousto-optical PD detection for transformers.* IEEE Transactions on Power Delivery, 2006. 21(3): p. 1068-1073.
46. Xiaodong, W., et al., *Acousto-optical PD detection for transformers.* Power Delivery, IEEE Transactions on, 2006. 21(3): p. 1068-1073.
47. RamÃ-rez-NiÃ±o, J. and A. Pascacio, *Acoustic measuring of partial discharge in power transformers.* Measurement Science and Technology, 2009. 20(11).
48. Wotzka, D. *Partial discharge simulation in an acoustic model of a power transformer*. in *Electrodynamic and Mechatronics, 2009. SCE 11 '09. 2nd International Students Conference on*. 2009.
49. Lima, S.E.U., et al. *Acoustic source location of partial discharges in transformers*. 2010. Porto.
50. Yamamoto, T., et al., *Studies on acoustic emission signals detected in an oil-immersed pole transformer.* IEEJ Transactions on Fundamentals and Materials, 2010. 130(11): p. 1031-1036.
51. Cosgrave, J.A., et al. *Non-invasive optical fibre acoustic monitoring of partial discharges within GIS*. in *Dielectric Materials, Measurements and Applications, 1992., Sixth International Conference on*. 1992.
52. Haque, E., et al. *Application of acoustic sensing and signal processing for PD detection in GIS*. in *Information, Communications and Signal Processing, 1997. ICICS., Proceedings of 1997 International Conference on*. 1997.

53. Schoffner, G. *The acoustic method for PD-measurements in N₂-SF₆ gas mixtures*. in *Electrical Insulation and Dielectric Phenomena, 2000 Annual Report Conference on*. 2000.

54. Phil Soo, Y., F. Campbell, and A.H. Eltom. *The diagnostic analysis of partial discharge with acoustic monitoring in GIS equipment*. in *Power Engineering Society Summer Meeting, 2002 IEEE*. 2002.

55. Suwarno, P. Caesario, and P. Anita. *Partial discharge diagnosis of Gas Insulated Station (GIS) using acoustic method*. in *Electrical Engineering and Informatics, 2009. ICEEI '09. International Conference on*. 2009.

56. Algeelani, N.A., et al. *Optical detection and evaluation of partial discharge on glass insulator*. in *Power Engineering and Optimization Conference (PEOCO), 2013 IEEE 7th International*. 2013.

57. Deng, J., et al., *Optical fiber sensor-based detection of partial discharges in power transformers.* Optics & Laser Technology, 2001. 33(5): p. 305-311.

58. Özen, I., G. Yilmaz, and S.E. Karlik. *Determination of fabry-perot spacing in optical fiber acoustic pressure sensors*. in *Optik fiberli akustik basinç sensörlerinde fabry-perot boşluğunun belirlenmesi*. 2010. Bursa.

59. Lima, S.E.U., et al., *Mandrel-Based Fiber-Optic Sensors for Acoustic Detection of Partial Discharges—a Proof of Concept.* Power Delivery, IEEE Transactions on, 2010. 25(4): p. 2526-2534.

60. Hashmi, G.M. and M. Lehtonen. *On-line PD detection for condition monitoring of covered-conductor overhead distribution networks - A literature survey*. 2008. Lahore.

61. Hashmi, G.M., M. Lehtonen, and M. Nordman, *Calibration of on-line partial discharge measuring system using Rogowski coil in covered-conductor overhead distribution networks.* Iet Science Measurement & Technology, 2011. 5(1): p. 5-13.

62. Zhang, Z.S., D.M. Xiao, and Y. Li, *Rogowski air coil sensor technique for on-line partial discharge measurement of power cables.* Science, Measurement & Technology, IET, 2009. 3(3): p. 187-196.

63. Mariscotti, A. and L. Vaccaro, *A Rogowski coil for high voltage applications.* 2008 Ieee Instrumentation and Measurement Technology Conference, Vols 1-5, 2008: p. 1069-1073.

64. Hikita, M., et al., *Measurements of partial discharges by computer and analysis of partial discharge distribution by the Monte Carlo method.* Electrical Insulation, IEEE Transactions on, 1990. 25(3): p. 453-468.

65. Mota, H.O. and F.H. Vasconcelos. *A partial discharge data acquisition system based on programmable digital oscilloscopes*. in *Instrumentation and Measurement Technology Conference, 2001. IMTC 2001. Proceedings of the 18th IEEE*. 2001.

66. Fawcett, T., et al., *Experience in PD site location in XLPE cables.* Electrical Insulation Magazine, IEEE, 2000. 16(5): p. 8-12.

67. Xiang, Y., et al., *Design and Application of High Potential Acquisition System for Corona Current Measurement.* Energy and Power Technology, Pts 1 and 2, 2013. 805-806: p. 915-919.

68. Barry H. Ward, *Digital techniques for partial discharge measurements*, in *Power Delivery, IEEE Transactions on*, W.G. on and D.A.o.P. Discharges, Editors. 1992. p. 469-479.

69. Aksyonov, Y., et al. *Partial discharge measurements on medium voltage motors*. in *Electrical Insulation Conference and Electrical Manufacturing & Coil Winding Conference, 1999. Proceedings*. 1999.

70. Fromm, U., *Interpretation of partial discharges at dc voltages.* Dielectrics and Electrical Insulation, IEEE Transactions on, 1995. 2(5): p. 761-770.

71. Kuwahara, H., et al., *Partial Discharge Characteristics of Silicone Liquids.* Electrical Insulation, IEEE Transactions on, 1976. EI-11(3): p. 86-91.

72. Tani, Y., et al. *PD patterns for LDPE with needle-plane electrode*. in *Conference on Electrical Insulation and Dielectric Phenomena (CEIDP), Annual Report*. 2001. Kitchener, ON.

73. Song, I.-K., K.-S. Suh, and H.-R. Kwak. *Characteristics of partial discharge in various polyethylenes*. in *Proceedings of the Electrical/Electronics Insulation Conference*. 1997. Rosemont, IL, USA: IEEE.

74. Zhang, X.H., et al., *Characteristics of electrical breakdown and partial discharge of polyethylene/montmorillonite nano-composites.* Gaodianya Jishu/High Voltage Engineering, 2008. 34(10): p. 2124-2128.

75. Mizutani, T., T. Kondo, and K. Nakao. *Change in partial discharge properties of a void in LDPE*. in *Conference on Electrical Insulation and Dielectric Phenomena (CEIDP), Annual Report*. 1999. Austin, TX, USA: IEEE.

76. Mizutani, T. and T. Kondo. *PD patterns and PD current shapes of a void in LDPE*. in *Proceedings of the IEEE International Conference on Properties and Applications of Dielectric Materials*. 2000. Xi'an, China: IEEE.
77. Tiemblo, P., et al., *The development of electrical treeing in LDPE and its nanocomposites with spherical silica and fibrous and laminar silicates.* Journal of Physics D-Applied Physics, 2008. 41(12).
78. Kim, C.S., T. Hirase, and T. Mizutani. *PD frequency characteristics for a void bounded with LDPE*. in *Conference on Electrical Insulation and Dielectric Phenomena (CEIDP), Annual Report*. 2002. Cancun.
79. Guastavino, F., et al. *Resistance to surface partial discharges of LDPE nanocomposites*. in *Annual Report - Conference on Electrical Insulation and Dielectric Phenomena, CEIDP*. 2007. Vancouver, BC.
80. Lapp, A. and H.G. Kranz, *The use of the CIGRE data format for PD diagnosis applications.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2000. 7(1): p. 102-112.
81. Kranz, H.G., *Partial Discharge Evaluation of Polyethylene Cable-Material by Phase Angle Analysis.* Ieee Transactions on Electrical Insulation, 1981. EI-17(2): p. 151-155.
82. Paoletti, G. and A. Golubev, *Partial discharge theory and applications to electrical systems.* IEEE Conference Record of Annual Pulp and Paper Industry Technical Conference, 1999: p. 124-138.
83. Paoletti, G.J. and A. Golubev, *Partial discharge theory and technologies related to medium-voltage electrical equipment.* Industry Applications, IEEE Transactions on, 2001. 37(1): p. 90-103.
84. Nagamani, H.N. and S.N. Moorching. *A study on the influence of partial discharges on the performance of solid dielectrics*. in *Conduction and Breakdown in Solid Dielectrics, 1998. ICSD '98. Proceedings of the 1998 IEEE 6th International Conference on*. 1998.
85. Paoletti, G. and A. Golubev. *Partial discharge theory and technologies related to traditional testing methods of large rotating apparatus*. 1999. Phoenix, AZ, USA: IEEE.
86. Huang, L.W., D.J. He, and S.X. Yang, *Segmentation on Ripe Fuji Apple with Fuzzy 2d Entropy Based on 2d Histogram and Ga Optimization.* Intelligent Automation and Soft Computing, 2013. 19(3): p. 239-251.

87. Chang, Y.C. and J.F. Reid, *RGB calibration for colour image analysis in machine vision.* IEEE Trans Image Process, 1996. 5(10): p. 1414-22.

88. Tobias, O.J. and R. Seara, *Image segmentation by histogram thresholding using fuzzy sets.* IEEE Trans Image Process, 2002. 11(12): p. 1457-65.

89. Wang, H.M. and J. Na, *Texture Image Segmentation using Spectral Histogram and Skeleton Extracting.* Icect: 2009 International Conference on Electronic Computer Technology, Proceedings, 2009: p. 349-352.

90. Ngan, H.Y.T., et al., *Wavelet based methods on patterned fabric defect detection.* Pattern Recognition, 2005. 38(4): p. 559-576.

91. Mak, K.L., P. Peng, and K.F.C. Yiu, *Fabric defect detection using morphological filters.* Image and Vision Computing, 2009. 27(10): p. 1585-1592.

92. Morshuis, P.H.F., *Degradation of solid dielectrics due to internal partial discharge: some thoughts on progress made and where to go now.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2005. 12(5): p. 905-913.

93. Guastavino, F., et al. *Resistance to surface partial discharges of LDPE nanocomposites*. in *Electrical Insulation and Dielectric Phenomena, 2007. CEIDP 2007. Annual Report - Conference on*. 2007.

94. Yalman, Y., *A Histogram based Image Quality Index.* Przeglad Elektrotechniczny, 2012. 88(7A): p. 126-129.

95. Baydush, A.H. and C.E. Floyd, Jr., *Improved image quality in digital mammography with image processing.* Med Phys, 2000. 27(7): p. 1503-8.

96. Grundland, M. and N.A. Dodgson, *Automatic contrast enhancement by histogram warping.* Computer Vision and Graphics, 2006. 32: p. 293-300.

97. Killing, J., B.W. Surgenor, and C.K. Mechefske, *A machine vision system for the detection of missing fasteners on steel stampings.* International Journal of Advanced Manufacturing Technology, 2009. 41(7-8): p. 808-819.

98. Jiang, L.X., et al., *Automatic Detection System of Shaft Part Surface Defect Based on Machine Vision.* Automated Visual Inspection and Machine Vision, 2015. 9530.

99. Abdullah, M.Z.F.-S., A. S. Mohd-Azemi, B. M. N., *Automated inspection system for colour and shape grading of starfruit (Averrhoa carambola L.) using machine vision sensor.* Transactions of the Institute of Measurement and Control, 2005. 27(2): p. 65-87.

100. Ding, Z.Q., R.Y. Zhang, and Z. Kan, *Quality and Safety Inspection of Food and Agricultural Products by LabVIEW IMAQ Vision.* Food Analytical Methods, 2015. 8(2): p. 290-301.

101. Yamashina, H. and S. Okumura, *A machine vision system for measuring wear and chipping of drilling tools.* Journal of Intelligent Manufacturing, 1996. 7(4): p. 319-327.

102. Huang, J.C., et al., *Performance analysis of the vision measuring machine for spindle motor.* 2006 IEEE Instrumentation and Measurement Technology Conference Proceedings, Vols 1-5, 2006: p. 568-572.

103. Tsai, D.M., J.J. Chen, and J.F. Chen, *A vision system for surface roughness assessment using neural networks.* International Journal of Advanced Manufacturing Technology, 1998. 14(6): p. 412-422.

104. Boby, R.A., et al., *Identification of defects on highly reflective ring components and analysis using machine vision.* International Journal of Advanced Manufacturing Technology, 2011. 52(1-4): p. 217-233.

105. Bradley, C. and S. Kurada, *Machine vision monitoring for automated surface finishing.* Journal of Manufacturing Science and Engineering-Transactions of the Asme, 1999. 121(3): p. 457-465.

106. Abdul-Malek, Z., A. Abdul-Rahman, and Aulia. *Development of severity index in medium voltage underground cable using partial discharge mapping*. in *Electrical Engineering and Informatics (ICEEI), 2011 International Conference on*. 2011.

107. Cavallini, A., et al. *Indexes for the recognition of insulation system defects derived from partial discharge measurements*. in *Electrical Insulation, 2002. Conference Record of the 2002 IEEE International Symposium on*. 2002.

108. Cavallini, A., et al. *Searching for PD-based indexes able to infer the location of internal defects in insulation*. in *Electrical Insulation and Dielectric Phenomena, 2002 Annual Report Conference on*. 2002.

109. Smit, J.J., O.M. Piepers, and E. Gulski. *Diagnostic decision support system with condition indexing for asset managers of electrical infrastructures*. in *Systems, Man and Cybernetics, 2007. ISIC. IEEE International Conference on*. 2007.

110. Jie, J. and X. Bo. *Towards the Automatically Semantic Scoring in Language Proficiency Evaluation*. in *Advanced Learning Technologies, 2008. ICALT '08. Eighth IEEE International Conference on*. 2008.

111. Anil S. Jadhav, R.M.S., *Evaluating and selecting software packages: A review*. Information and Software Technology, 2009: p. 9.

112. Lautié, E., et al., *Selection methodology with scoring system: Application to Mexican plants producing podophyllotoxin related lignans.* Journal of Ethnopharmacology, 2008. 120(3): p. 402-412.

113. Houghton, D.J., *An evaluation of the Bishop scoring system in relation to a method of induction of labour by intra-vaginal prostaglandin.* Postgrad Med J, 1982. 58(681): p. 403-7.

114. Pedersen, S.J., et al., *The FAt Spondyloarthritis Spine Score (FASSS): development and validation of a new scoring method for the evaluation of fat lesions in the spine of patients with axial spondyloarthritis.* Arthritis Res Ther, 2013. 15(6): p. R216.

115. Popovic, V., *Product Evaluation Methods and Their Applications*, in *IEA 97 Congress*, P. Seppala, et al., Editors. 1997: Tampere, Finland. p. 165-168.

116. Cui-yun, M., M. Qiang, and M. Zhi-qiang. *A New Method for Information System Selection*. in *Future Information Technology and Management Engineering, 2009. FITME '09. Second International Conference on*. 2009.

117. Snyder, R.L., et al., *Chronic intracochlear electrical stimulation in the neonatally deafened cat. II: Temporal properties of neurons in the inferior colliculus.* Hearing Research, 1991. 56(1-2): p. 246-264.

118. Ahmadi, S. and A.S. Spenias. *Sinusoidal speech coding at 2.4 kbps using an improved phase matching algorithm*. in *Signals, Systems & Computers, 1997. Conference Record of the Thirty-First Asilomar Conference on*. 1997.

119. Brown, S., *Standardized Technology Evaluation Process (STEP) User's Guide and Methodology for Evaluation Teams*, MITRE, Editor. 2007: Massachusets, USA. p. 51.

120. Iyer, G., et al. *Evaluation of epoxy based nanodielectrics for high voltage outdoor insulation*. in *Electrical Insulation (ISEI), Conference Record of the 2010 IEEE International Symposium on*. 2010.

121. Tanaka, T., et al. *PD Resistance Evaluation of LDPE/MgO Nanocomposite by a Rod-to-Plane Electrode System*. in *Properties and applications of Dielectric Materials, 2006. 8th International Conference on*. 2006.

122. Arfin, T., A. Falch, and R.J. Kriek, *Evaluation of charge density and the theory for calculating membrane potential for a nano-composite nylon-6,6 nickel phosphate membrane.* Physical Chemistry Chemical Physics, 2012. 14(48): p. 16760-16769.

123. Mortezaei, M., et al., *Evaluation of Interfacial Layer Properties in the Polystyrene/Silica Nanocomposite.* Journal of Applied Polymer Science, 2011. 119(4): p. 2039-2047.

124. A Merrick, J.R.W., D. A Morrice, and J.C. A Butler, *Using multiattribute utility theory to avoid bad outcomes by focusing on the best systems in ranking and selection.* J of Sim, 2015. 9(3).

125. Butler, J., D.J. Morrice, and P.W. Mullarkey, *A Multiple Attribute Utility Theory Approach to Ranking and Selection.* Manage. Sci., 2001. 47(6): p. 800-816.

126. Douglas J. Morrice, John Butler, and Peter W. Mullarkey, *An Approach to Rangking and Selection for Multiple Performance Measures*, in *Winter Simulation Conference*, E.F.W. D.J. Medeiros, J.S. Carson and M.S. Manivannan, Editor. 1998. p. 7.

127. Karimzadeh, F., S. Ziaei-Rad, and S. Adibi, *Modeling considerations and material properties evaluation in analysis of carbon nano-tubes composite.* Metallurgical and Materials Transactions B-Process Metallurgy and Materials Processing Science, 2007. 38(4): p. 695-705.

128. Lupo, G., et al. *Partial discharge diagnostics on a HV superconducting model cable*. in *Electrical Insulation and Dielectric Phenomena, 1997. IEEE 1997 Annual Report., Conference on*. 1997.

129. Kemp, I.J. *Developments in partial discharge plant-monitoring technology*. in *Partial Discharge, 1993., International Conference on*. 1993.

130. Van Brunt, R.J., P. von Glahn, and T. Las. *Nonstationary behavior of partial discharge during insulation aging*. in *Partial Discharge, 1993., International Conference on*. 1993.

131. Van Brunt, R.J., P. von Glahn, and T. Las. *Partial discharged-induced aging of cast epoxies and related nonstationary behavior of the discharge statistics*.

in *Electrical Insulation and Dielectric Phenomena, 1993. Annual Report., Conference on*. 1993.

132. Kirkici, H., M. Serkan, and K. Koppisetty, *Nano-dielectric materials in electrical insulation application.* Iecon 2005: Thirty-First Annual Conference of the Ieee Industrial Electronics Society, Vols 1-3, 2005: p. 2395-2399.

133. Tanaka, T., *Dielectric nanocomposites with insulating properties.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2005. 12(5): p. 914-928.

134. Abdelmouleh, M., et al., *Short natural-fibre reinforced polyethylene and natural rubber composites: Effect of silane coupling agents and fibres loading.* Composites Science and Technology, 2007. 67(7-8): p. 1627-1639.

135. Altpeter, F. and R. Perez, *Relevant topics in wire electrical discharge machining control.* Journal of Materials Processing Technology, 2004. 149(1-3): p. 147-151.

136. Piah, M.A.M., A. Darus, and A. Hassan, *Electrical tracking performance of LLDPE-natural rubber blends by employing combination of leakage current level and rate of carbon track propagation.* Ieee Transactions on Dielectrics and Electrical Insulation, 2005. 12(6): p. 1259-1265.

137. Lewis, T.J., *Interfaces are the dominant feature of dielectrics at the nanometric level.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2004. 11(5): p. 739-753.

138. Tanaka, T. *Multi-core model for nanodielectrics as fine structures of interaction zones*. in *Electrical Insulation and Dielectric Phenomena, 2005. CEIDP '05. 2005 Annual Report Conference on*. 2005.

139. Lewis, T.J., *Charge transport in polyethylene nano dielectrics.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2014. 21(2): p. 497-502.

140. Shengtao, L., et al., *Short-term breakdown and long-term failure in nanodielectrics: a review.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2010. 17(5): p. 1523-1535.

141. Thabet, A. and Y.A. Mobarak. *Dielectric characteristics of new nano-composite industrial materials*. in *High Voltage Engineering and Application (ICHVE), 2010 International Conference on*. 2010.

142. A.THABET, Y.A.M., and M. BAKRY *A Review of Nano-fillers Effect on Industrial Polymers and Their Characterisitics.* Journal of Engineering Sciences, 2011. 39(2): p. 27.

143. Katiyar, N. and K. Balasubramanian, *Nano-heat-sink thin film composite of PC/three-dimensional networked nano-fumed silica with exquisite hydrophobicity*. Rsc Advances, 2015. 5(6): p. 4376-4384.

144. Vrsaljko, D., D. Macut, and V. Kovacevic, *Potential Role of Nanofillers as Compatibilizers in Immiscible PLA/LDPE Blends.* Journal of Applied Polymer Science, 2015. 132(6).

145. Hidayah, I.N., et al., *Electrical Properties of LLDPE/SR with Nano-Silica and Nano-Boron Nitride.* Frontiers in Materials and Minerals Engineering, 2014. 858: p. 80-87.

146. Abd Jamil, A.A., et al., *Short-term Breakdown in Silicone Rubber Based Nanocomposites Caused by Electrical Treeing.* Materials, Industrial, and Manufacturing Engineering Research Advances 1.1, 2014. 845: p. 482-486.

147. Arief, Y.Z., et al. *Effects of nanosilica and nanotitania on partial discharge characteristics of natural rubber-lldpe blends as high voltage insulation material*. in *Electrical Insulating Materials (ISEIM), Proceedings of 2014 International Symposium on*. 2014.

148. Jarnthong, M., et al., *Influence of Surface Modification and Content of Nanosilica on Dynamic Mechanical Properties of Epoxidized Natural Rubber Nanocomposites.* Advances in Rubber, 2014. 844: p. 289-292.

149. Pustak, A., et al., *Interfacial and mechanical properties of polypropylene/silica nano- and microcomposites.* Journal of Reinforced Plastics and Composites, 2014. 33(9): p. 851-861.

150. Veena, M.G., et al., *Tribological and Electrical Properties of Silica-Filled Epoxy Nanocomposites.* Polymer Composites, 2011. 32(12): p. 2038-2050.

151. Tanaka, T., et al., *Dielectric properties of XLPE/Sio2 nanocomposites based on CIGRE WG D1.24 cooperative test results.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2011. 18(5): p. 1482-1517.

152. On, N.K., et al., *Thermal and mechanical behavior of natural rubber latex-silica aerogel film.* Journal of Applied Polymer Science, 2011: p. n/a-n/a.

153. Lai, S.-M., et al., *Preparation and properties of melt-mixed metallocene polyethylene/silica nanocomposites.* Polymer Engineering & Science, 2011. 51(3): p. 434-444.

154. Zilg, C., et al. *Electrical properties of polymer nanocomposites based upon organophilic layered silicates*. in *Electrical Insulation and Dielectric Phenomena, 2003. Annual Report. Conference on*. 2003.

155. Wilder, A.T. and R.S. Neves, *Fillers in insulation for rotating electrical machines.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2010. 17(5): p. 1357-1363.

156. Kozako, M., et al., *Surface degradation of polyamide nanocomposites caused by partial discharges using IEC (b) electrodes.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2004. 11(5): p. 833-839.

157. Wan, Y., et al. *High Reliable Partial Discharge Online Monitoring System of Hydro-generator*. in *Measuring Technology and Mechatronics Automation (ICMTMA), 2011 Third International Conference on*. 2011.

158. Liu, M., et al. *Online UHF PD monitoring for transformers: Pulses knowledge acquisition*. 2010. Minneapolis, MN.

159. Illias, H., G. Chen, and P.L. Lewin, *Modeling of partial discharge activity in spherical cavities within a dielectric material.* Electrical Insulation Magazine, IEEE, 2011. 27(1): p. 38-45.

160. Ghani, A.B.A., et al. *Diagnostic criteria based on the correlation of the measurement of DGA, moisture contents with PD & tan d in MV oil-filled underground cable*. in *Dielectric Liquids (ICDL), 2011 IEEE International Conference on*. 2011.

161. Chen, Y., et al., *Development of 100 MS/s intelligent unit for partial discharge on-line monitoring.* Gaodianya Jishu/High Voltage Engineering, 2008. 34(11): p. 2368-2373.

162. Zhou, X., et al. *Optimal sampling rate for wavelet-based denoising in PD measurement*. in *Electrical Insulation, 2004. Conference Record of the 2004 IEEE International Symposium on*. 2004.

163. Picotech. *Picoscope 5203 series* 2014 [cited 2014 5/2/2014]; Available from: http://www.picotech.com/discontinued/Picoscope5203.html. .

164. Sahoo, N.C., M.M.A. Salama, and R. Bartnikas, *Trends in partial discharge pattern classification: a survey.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2005. 12(2): p. 248-264.

165. Hoof, M., B. Freisleben, and R. Patsch, *PD source identification with novel discharge parameters using counterpropagation neural networks.* Dielectrics and Electrical Insulation, IEEE Transactions on, 1997. 4(1): p. 17-32.

166. Firstner, S., et al. *Resonant Stirling engines*. in *Exploitation of Renewable Energy Sources (EXPRES), 2011 IEEE 3rd International Symposium on*. 2011.

167. Tanaka, T. *PD pulse distribution pattern analysis*. in *Properties and Applications of Dielectric Materials, 1994., Proceedings of the 4th International Conference on*. 1994.

168. DeCarlo, L.T., *On the Meaning and Use of Kurtosis* Psychological Methods, 1997. 2(3): p. 16.

169. Corporation, N.I. *NI Vision for LabVIEWTM User Manual*. 2005. 149.

170. Di Lorenzo del Casale, M., R. Schifani, and J.T. Holboll, *Partial discharge tests using CIGRE method II.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2000. 7(1): p. 133-140.

171. Di Lorenzo del Casale, M., et al. *Partial Discharge Tests Using CIGRE Method II Upon Nanocomposite Epoxy Resins*. in *Solid Dielectrics, 2007. ICSD '07. IEEE International Conference on*. 2007.

172. Xiangrong, C., et al., *Effect of tree channel conductivity on electrical tree shape and breakdown in XLPE cable insulation samples.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2011. 18(3): p. 847-860.

173. Yu, C., et al., *Tree initiation phenomena in nanostructured epoxy composites.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2010. 17(5): p. 1509-1515.

174. Hao, L., P.L. Lewin, and S G Swingler, *Improving detection sensitivity for partial discharge monitoring of high voltage equipment.* 17th International Conference on Electricity Distribution, , 2003.

175. Soraghan, M.H.F.J.J. and W.H.S.J.S. Pearson, *Remote Control Partial Discharge Acquisition Unit.* 17th International Conference on Electricity Distribution, 2003.

176. Rahim, M.A.A., I. Elamvazuthi, and N.H.H.B.M. Hanif. *Online monitoring of palm oil mill effluent*. 2009. Serdang.

177. Stone, G.C., *Partial discharge part XXV: Calibration of PD measurements for motor and generator windings - Why it can't be done.* Ieee Electrical Insulation Magazine, 1998. 14(1): p. 9-12.

178. Na, L., L. Zhi, and Q. Zheng, *Study on the calibration of partial discharge calibrator*. 2008 Conference on Precision Electromagnetic Measurements Digest, 2008: p. 232-233.

179. Mentlik, V., et al. *Partial discharges of solid insulation in different insulating fluids*. in *Solid Dielectrics (ICSD), 2010 10th IEEE International Conference on*. 2010.

180. L. Elias, F.F., J.-C. Majeste, and P.C. G. Martin, *Migration of Nanosilica Particles in Polymer Blends.* Journal of Polymer Science Part B: Polymer Physics, 2008. 48(18).

181. Fenouillot, F., P. Cassagnau, and J.C. Majeste, *Uneven distribution of nanoparticles in immiscible fluids: Morphology development in polymer blends.* Polymer, 2009. 50(6): p. 1333-1350.