Activities of Laboratories

Research in High Voltage and Electrical Insulation Laboratory at Tianjin University

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1. Introduction

High Voltage and Electrical Insulation Laboratory (HVEIL) at Tianjin University was founded originally to serve as a test site for college students of the department of electrical engineering who wanted to learn knowledge about high voltage test skills for power equipment. In 1990s', the HVEIL was open to scientific research and some of the hot topics, such as partial discharge measurement for high voltage transformer, were immediately involved at that time. The development of the HVEIL became even faster after the year 2002 in which Prof. Du joined in the laboratory and served as a leader. With the active work of Prof. Du and our staffs, we have developed scientific researches in many fields, including tracking behavior of polymer insulating materials, condition monitoring and diagnosis for power equipment, plasma discharge and its application, etc. Our work covers the fundamental study for insulating material and also the industry application to local power system in China. Over 220 scientific papers have been published by our staffs both in Journals and Conference Proceedings, which earns us a worldwide academic reputation and encourages us to further discover the unknown firmly.

At present, we have one full professor, one associate professor, two lecturers and three engineers in the HVEIL. Three Ph. D. candidates and eighteen postgraduate students are pursuing their degrees here, and more than twenty undergraduate students work in the laboratory for their Bachelor Degree Thesis every year. Our research projects have attracted over 2 million RMB as financial support from Chinese government, ministry of education and companies, and we would like to show the research activities in the HVEIL in the following sections.

Figure 1: A picture from Prof. Du's Laboratory

2. Research Activities in the HVEIL

In the HVEIL, two main issues are currently performed, namely tracking behavior of polymer insulating material and condition monitoring and diagnosis for power equipment. A brief introduction of the research progress will be shown below in detail.

A. Tracking Behavior of Polymer Insulating Materials

Polymer insulating materials have been widely used in electrical and electronic industry for over 50 years. The safe use of the material is very important for the reliability of the electrical and electronic devices. One particular phenomenon that occurs on the surface of polymer is tracking failure. The tracking is essentially a surface breakdown phenomenon which is characterized by the formation of carbonized conductive path that bridges the electrodes. This is considered as an important reason for short-circuit and even fire of the polymers. With the purpose of understanding the tracking behavior clearly, systematic works have been carried out since 1990s'. The influence of concerned factors, such as ambient temperature, pressure, additives, waveform of applied voltage and frequency, on the tracking behavior has been investigated, and the results obtained containing valuable information for understanding the nature of

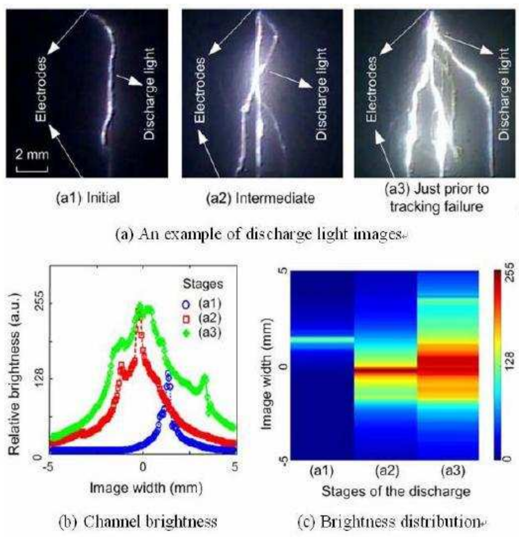

Figure 2: A discharge light distribution based method to feature the tracking failure

tracking phenomenon have been published both in IEEE Transactions and Conference Proceedings.

Recently, we start to focus on the radiation effect on the tracking behavior of polymers. Radiation environment can be found in nuclear power stations, space equipment and scientific facility. A highly energetic radiation ray, for example gamma-ray, can have a significant influence on the ageing process of insulating material, and thereby influence the safe use of the equipment. We have set up a test system to investigate the tracking behavior of gamma-ray irradiated polymers, including polyethylene, epoxy resin and polybutylene polymers. It has been preliminarily concluded that a cross-linking type material is more sustained in the resistance to tracking than a degradation type material after gamma-ray irradiation. This information may help to choose the proper material used as insulation in radioactive environment. Moreover, we currently adopt epoxy based nano-composite as test sample to study the tracking behavior so as to find a new way to improve the resistance to tracking for polymer by nano-particle doping.

Besides the tracking phenomenon, we are also interested in another attractive and important phenomenon-surface charging and charge decay. The surface charge accumulation has been found a critical problem that rules the withstand voltage of the insulation surface. A considerable number of researchers have engaged in the work of clarifying the mechanisms of surface charging and charge decay, and it is generally established that surface charge dynamics is deeply related to the characteristics of localized surface states and is influenced by surface property, permittivity, surface as well as bulk resistivity, temperature, relative humidity and so on. The very issue we concerned is the radiation effect on surface charge dynamics of insulating polymers, and we have found that the charge behavior for both polyethylene and epoxy resin is evidently changed as the material is exposed to gamma-ray irradiation. We are now trying to reveal the mechanism for the results obtained, and such information will be helpful in determining the safe use of polymer in radiation environment.

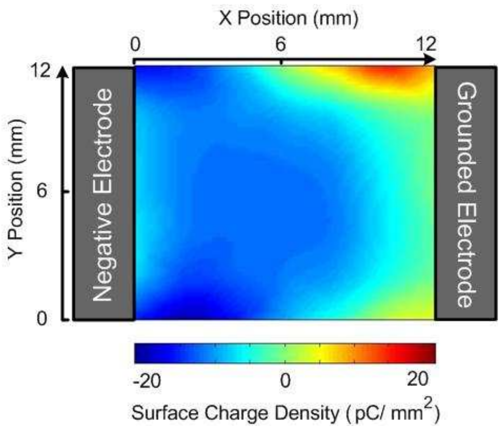

Figure 3: Surface charge image of polyethylene after charging by negative bias voltage (obtained in the HVEIL by using a self-designed electrostatic probe).

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B. Condition Monitoring and Diagnosis for Power Equipment

Ageing of insulating material acts as a decisive factor that influences the life-time of power equipment. Knowing the insulation status is a key point for understanding how risky the equipment is. A traditional method for getting insulation status of power equipment is often off-line and periodical test based. Such method is likely to send information deficient to make a decision that if the insulation is in danger or not, because the information is of course less accurate comparing with that obtained from on-line test which can reflect the real manner of insulation when it is in real operation. On-line measurement of insulation status then becomes the state of the art and condition monitoring and diagnosis (CMD) is likely to play a dominant role in power management system in the future.

Figure 4: Devices for research of partial discharge measurement for XLPE power cable.

We noticed that the CMD would facilitate to know insulation status of power equipment in early 1990s', and the interesting topic we concerned was partial discharge detection. By developing very high frequency sensors, ultra-acoustic sensor and optical sensor, we successfully captured partial discharge signal in the HVEIL by employing insulation models that are extracted from high voltage transformer and XLPE cable. We also make efforts to develop new methods based on wavelet analysis to separate the real partial discharge signal from the data measured. Currently, we are trying to put the above ideas into real industry application. For instance, with the help of Tianjin Electric Power Corporation, we are establishing an on-line partial discharge monitoring system for a 220 kV XLPE cable route located in Tianjin Binhai New Area by using both high frequency current transformer and capacitive coupler sensor assembled at the cable accessories. Such a monitoring system may benefit from the sensor arrangement so that the location of partial discharge is feasible.

For supporting the CMD research work, we have carried out a series of fundamental investigations in order to gain a good understanding of the ageing mechanism of

Figure 5: PD detecting sensor assembling and laboratory PD test for 110 kV XLPE cable (supported by Tianjin Electric Power Corporation).

polymer insulating materials. What we have concerned with includes electrical treeing as well as water treeing phenomenon, space charge measurement technique and its application in detecting space charge within real XLPE cable, interface breakdown behavior occurred at cable joint between XLPE and silicone rubber, effect of cross-linking byproducts on the insulation performance of XLPE.

Furthermore, we engage in the work of leakage current measurement and analysis by using a novel data processing method called "recurrent plot". This method is proved to be available for identifying the process of surface discharge on outdoor insulator. It will provide useful information for estimating the insulation status of outdoor SIR insulator.

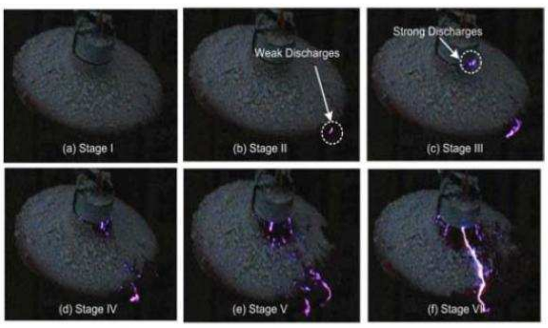

Figure 6: Monitoring on process of rime-ice flashover of outdoor SIR insulator.

The researches presented in this section are mainly supported in finance by local electric power corporation in China, and we find that such cooperation between the HVEIL and the company can benefit both the participants.

3. Academic Exchange and Cooperation

With the financial support of the HVEIL, we have frequent international academic exchanges and cooperation. We have sent our staffs to attend international conference and symposiums, such as CEIDP, ICSD, CMD, ICPADM, etc. We have also invited active researchers to visit us and make academic exchange. We are pleased to share the experience and facility in the HVEIL with researchers in the community of electrical engineering, high voltage/electrical insulation and applied physics, and we sincerely invite specialists from all over the world to visit the HVEIL and make cooperation together.

4. Acknowledgement

The authors wish to thank Prof. Toshikatsu Tanaka, Waseda University, for kindly offering the opportunity to us to introduce the research progress in the HVEIL at Tianjin University.

5. Biography

Prof. B. X. Du received the M.E. degree in electrical engineering from Ibaraki University in 1993 and Ph.D. degree from Tokyo University of Agriculture and Technology in 1996. He was with Niigata College of Technology, Japan and was an Associated Professor. Now, he is a Professor at the Department of Electrical Engineering, School of Electrical Engineering and Automation, Tianjin University, China. His main research interests are dielectric failure mechanisms of polymer insulating materials, electrical insulation technology and partial discharge measurements. He is a member of IEEJ, senior member of IEEE and CSEE.

Dr. Y. Gao was born in Liaoning Province, China. He received the M. E. degree and Ph.D. degree from the School of Electrical Engineering and Automation in Tianjin University, China, in 2006 and 2009 respectively, after which he joined the HVEIL at Department of Electrical Engineering in the same school in Tianjin University and served as a lecturer. His main research interests include surface charge dynamics of polymers, dielectric performance of polymer under radioactive environment and partial discharge measurement in XLPE power cable.

Dr. Y. Liu was born in Tangshan, China. He received the M.E. and Ph.D. degrees in Electrical Engineering from Tianjin University, China, in 2006 and 2009 respectively. He is currently working as a lecturer at School of Electrical Engineering and Automation in Tianjin University. His main research interests are dielectric breakdown mechanisms of polymeric insulating materials and monitoring of polymer insulators under multi-effect environments.