Physics of Electrical Discharges is a Profound and an Extensive World

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Three topics related to the field of the technical committee on electrical discharges (TC-ED) are summarized for this special issue. First one deals with the protection against the lightning damages. As the second one, a prototype high voltage vacuum interrupter is introduced. The last one shows the problem on the electromagnetic relays.

Keywords : electrical discharges, lightning, vacuum discharge, vacuum interrupter, arc discharge, electromagnetic relay

To understand the physics of various kinds of electrical discharges is important to control and to utilize them. One of the most important problem in the field of electrical engineering is to protect damages by lightning. More than 250 years have passed since B. Franklin made the famous kite experiment. Now, everybody knows that lightning is an electrical discharge phenomenon made by the nature. But physics of lightning as an ultra-long gap discharge is not fully understood even at present days.

Lightning may cause damages not only to power transmission systems but also to structures and human beings. Last summer, many people were injured and some were killed by lightning in Japan.

As for lightning to structures, the Japanese Industrial Standard (JIS) on lightning protection systems was revised recently. Nevertheless, it is not an easy task to protect structures perfectly from lightning threat. A few years ago, the Diet Building was struck by lightning and a part of the granite wall was fallen down; though the building was protected by a lightning protection system.

In recent years, many wind turbines have been constructed all over Japan. As the number of wind turbines increases, number of damages of them by lightning increases. Though the blades of wind turbines are usually made of insulating materials such as the FRP, lightning has struck it and caused severe damages. In order to clarify the lightning striking characteristics to them, observation and model experiments have been carried out. Figure 1 shows an example of model experiments of lightning to a blade.

A lightning rod is one of practical methods to protect buildings. Novel lightning rods that claim efficient lightning interception ability have been proposed, but as has not been proved yet.

To understand lightning striking characteristics to structures such as buildings, wind turbines and the protection ability of lightning rods, extensive researches have been conducted.

New technologies are also introduced for lightning protection. Studies of laser-triggered lightning using a T₃ laser (Table Top Terawatt laser) have been done in Europe and Japan. With such a high power laser, a continuous plasma channel, which is called filament, is produced in air and it is reportedly possible to make its length more than 100 meters. Figure 2 shows a T₃ laser-guided discharge.

Fig. 1. Long gap discharge experiment using model blades

Fig. 2. Guided discharge by a T₃ laser

To utilize electrical discharge, many studies on electrical discharges in various media have been carried out. Especially, many reports on vacuum discharges are published recently. In the research field of discharges and insulation in vacuum, there are so many topics and issues:

(1) Flat display panels using different types of electron emitters, such as Surface Conduction Electron Emitter and Carbon Nanotubes etc., are under development considering their reliability and panel construction.

(2) Space related issues such as the protection of solar battery array from the charging and electrical breakdowns to ensure reliable power generation and to cope with EMC problems in the

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satellite.

(3) Future ITER (International Thermonuclear Experimental Reactor) related issue that necessitates one meter long electrical insulation in vacuum to produce high energy neutral molecular beams.

(4) Development of high voltage vacuum interrupters as an alternative to GCB that contains considerable amount of SF_6 gas, which is an excellent arc quenching and insulation medium but has an extremely high Global Warming Potential, etc..

Among these the development of high voltage vacuum interrupters is one of the vital topics for electric power engineers to cope with the Global environmental issue. The target is to achieve a rating voltage higher than 140 kV with a rating current comparable to that of GCBs, for example. The current interrupting ability of vacuum interrupter has been proved to be enough high (higher than e.g. 100 kA).

The high voltage vacuum interrupter technology in Japan attains superiority in this field:

(1) Vacuum interrupters with the rating voltage equaling to 84 kV are popular for Japanese electric power utilities and manufacturers, however, this is not the case in other countries.

(2) A vacuum interrupter with short circuit current of 40 kA at 168 kV has been developed by a Japanese manufacturer and utilized in some substations since 1979.

The 168 kV interrupter mentioned above applies two 84 kV interrupter units connected in cascade, and therefore it has two independent contacts. The current aim of the development is to realize a high voltage interrupter with single contact. Universities and electric manufacturers in Japan are collaborating on this challenging issue. Figure 3 shows a prototype high voltage interrupter with single contact developed recently.

The challenge embraces sophisticated insulation design of the vacuum valve as well as the design between the contact electrodes. The vacuum arc and its quenching mechanism, the selection of contact and valve materials are also important research subjects. Furthermore, development of the outer insulation and cooling techniques are vital to achieve the innovative high rating current.

Third topics is the Transferred Pip Grown by Arc Discharges on Surface of Electrical Contacts Mounted on Relays

A lot of electromagnetic relays are used in electrical circuits installed in cars and electric products. In facts, the production number of the relays in Japanese industry reaches one billion pieces in 2003. This is because the relays have a lot of advantages; for example, low contact resistance, high insulation resistance and low cost.

However switching a current with the contacts of the relay causes the surfaces of the contacts to be damaged. Especially, a transferred pip grows on a contact surface when the relay is operated in a direct current circuit under a certain operating condition. This phenomenon chiefly results from the dc arc formed between the contacts. In particular, the arc discharge during the contact bounce process in make operation greatly dominates this phenomenon. Figure 4 shows an example of a photograph of transferred pip grown on cathode surface after about 100,000 times make operations. The pip causes locking and sticking. In order to achieve better contact reliability and a longer lifetime of relays, many researches on the transferred pip have been carried out.

Fig. 3. 145kV prototype vacuum interrupter (Courtesy of Japan AE Power Systems)

Fig. 4. Transferred pip grown between electrical contacts mounted on a relay. The pip is on cathode. Supply voltage is 14V and termination current is 20A.

Making high performance and reliability of electromagnetic relays can contribute to achieve a high efficiency system that contains those relays.

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