Effect of state of stress on space charge accumulation in silicon rubber insulation in HVDC cables

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ABSTRACT

Silicon rubber has been used widely as the insulation material in the accessory and the terminal of HVDC cables in the last decades. Research on space charge in silicon rubber has been conducted for decades and there has already been a lot of achievements about the mechanism, the way to suppress space charge and so forth. Nevertheless, few research pays attention to the stress state of the silicon rubber material, which in practical use is under high stress in the accessory and the terminal of cables. This paper focus on the influence of the high stress state on the space charge accumulation in silicon rubber to imply whether the stress state of silicon rubber should be constrained to a certain scale around the practical value in real HVDC cables in any research concerning space charge accumulation in silicon rubber. Since controlling the stress state of silicon rubber is difficult for most of the current equipment measuring space charge accumulation like PEA(pulsed electro-acoustic) systems, this paper also proposes a new design to realize the control of the stress state of the material during measurement in PEA systems.

As the density of silicon rubber would change along with the change of the stress state, this paper analyses the research data and makes some calculation to separate the effect of the two factors on space charge accumulation, and finally the result of the research implies a relatively complicated process, not a monotonic tendency as what is expected, which can be taken into consideration in real cable design and in other research about space charge accumulation in silicon rubber.

KEYWORDS

Space charge, Stress, Silicon rubber, HVDC cable.

INTRODUCTION

Power cable is critical for the modern power grid construction, and it has been under research for decades to improve its insulation performance. In the past, researches were taken in many respects like partial discharge and electric tree aging, and the results have led to great improvement in HVAC cables, which were used for AC power transmission. Nowadays, HVDC cables have attracted more and more attention with the rapid development of DC power transmission. Due to the big difference between DC and AC power transmission, the problems that HVDC cables are facing now in practical use are quite different, especially in insulation performance. More and more researches have implied that space charge accumulation in dielectric materials in the HVDC cables is one of the main cause of insulation breakdown and the space charge has already become one of the most popular topics in the research of dielectric materials.

Former results and deductions about space charge accumulation in dielectric materials have brought out tremendous achievements, for example, the mechanism of the source, transmission and accumulation of space charge in the material [1], the way to suppress space charge like using nanoparticles grafting techniques to modify the dielectric materials, and so forth.

Nevertheless, few researches have paid attention to the state of stress of the dielectric material which may have effect on the insulation performance. The dielectric materials in the real cables are compressed tightly for practical use, especially in cable joints and terminals, to keep qualified mechanical and dielectric performance. In practical use, if the stress on the dielectric material is too high, there may cause structure distortion while too low stress on the material may cause bad surface dielectric performance [2]. Several researches have been done on that and in China, the stress on the dielectric materials are designed to be constrained between 0.1~0.3 MPa. This is crucial for the installation of cable joints

In the cable joints, there are two kinds of dielectric material for insulation, one is the XLPE and the other one is the silicon rubber for different purpose. Both of them are under a certain scale of stress and former researches have already implied that stress on the material may have effect on the insulation performance. Back to topic of research on space charge accumulation, there are several ways to measure the space charge distribution in the material like PEA method. When the material is under PEA test, it is also under the pressure from the electrode and the electrode is usually designed to be a bit heavy to ensure that there is no air gap between the electrode and the material sample. But few of the research paid attention to the stress on the material since the researcher thought it is enough to compress the material sample tightly.

Generally speaking, due to the rigidity of XLPE, the deformation of the material can be ignored when XLPE material is under PEA test. Therefore the deformation may be obvious when silicon rubber material is under test since silicon rubber is quite flexible. Deformation should be taken into consideration since PEA test needs the shape parameter of the material [3]. That is, the measurement of space charge accumulation would be influenced by the material's deformation due to the stress on that and it remains to be a problem whether the stress on the material may also influence the space charge accumulation when we manage to make the shape of the material fixed.

In conclusion, the dielectric material in real cables are under a certain scale of stress and in the PEA test the stress on the material may also influence the test results. Especially for silicon rubber which is quite flexible, the stress on that may need to be controlled. This paper is focused on the silicon rubber material and make some research about the effect of the stress on space charge accumulation. As the density of silicon rubber would change along with the change of the stress state, this