Progress in optical PD detection for translucent and transparent HV cable accessories with improved fluorescent optical fibres

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ABSTRACT

In [1] we introduced sensitive and interference-immune optical PD measurements on HV cable accessories and presented first results. Since then, our investigations tried to cover all important aspects that lead to further improved sensitivity for optical PD detection and to applicability under harsh service conditions. In this paper, we report on the design of fluorescent optical fibres made of transparent silicone elastomers, which can withstand the electrical, thermal and mechanical stress within HV cable accessories in operation. Until now, stress cones can be made of qualified translucent silicone elastomers. To improve transmittance, however, new silicone elastomers with high transparency were investigated with respect to their characteristic properties, e.g. AC withstand voltage, electrical treeing behaviour, thermal ageing, mechanical capabilities.

Sensitive optical PD detection proved also very useful for HVDC cable systems, where immunity to electromagnetic interference allows unambiguous PD observations.

Besides, we will report on a new fibre-acoustic PD sensor that showed high sensitivity for PD detection and can be used in case of nontransparent insulation materials.

KEYWORDS

Partial Discharge, PD, PD measurement, cable accessories, translucent, transparent, high transmission, optical, fibre-acoustic, FOF, F-POF, fluorescent optical fibre, silicone, elastomer, interference, HVAC, HVDC

INTRODUCTION

Targeting on interference-immune partial discharges (PD) measurement techniques for HV/XLPE cable systems, we began to study optical methods. We applied fluorescent polymer optical fibres (F-POF) as distributed light sensors. The F-POF-based optical PD measurement on HV cable accessories made of translucent silicone rubber showed already its general feasibility and delivered promising detection sensitivity compared to conventional PD measurements according to IEC 60270 [1]. Nevertheless, our previous investigations pointed to several details which left room for further improvements.

First of all, we focussed on high transparent silicone elastomers to obtain the best-possible transmittance compared to the translucent silicone rubber used before. Though translucent silicone rubber is a well-proven insulation material for making stress cone elements, it is certainly not the best solution for high-sensitive optical PD detection. Of course, transparency is only one of the material properties to be taken into account when it comes to HV applications. Electrical properties (e.g. breakdown strength, dielectric constant, dielectric losses, resistance against electrical treeing), mechanical properties (e.g. shore hardness, tensile strength, elongation at break, tear strength), thermal properties (e.g. continuous operating temperature, coefficient of thermal expansion) and chemical properties (e.g. material compatibility, aging) all have to fulfil application requirements.

The F-POF we used as distributed light sensors were easily commercially available and were made of Polymethylmethacrylate (PMMA). This worked well for room temperature. However, F-POF made of PMMA have a too low heat resistance to withstand thermal stress in cable accessories during load cycling. Furthermore, the elasticity of PMMA is not sufficient to follow the thermal-mechanical expansion/contradiction of components made of silicone rubber. The dielectric constant of PMMA is different from silicone elastomers, requiring special attention when placing PMMA-F-POF into regions of high electric field stress. In fact, the best would be to make F-POF out of transparent silicone rubber. In the meantime, this became possible and first results showed promising properties.

Besides our investigations on optical PD measurements, we looked into optical detection methods applicable to opaque (nontransparent) insulation materials. One possible approach is to use fibre-acoustic sensors. Fibre-acoustic sensors are immune to electromagnetic interference, but the signal-to-noise ratio is affected by ambient acoustic noise and by the acoustic damping properties of the insulation material in between the possibly PD defect and the sensor site. From our point of view, the advantages of fibre-acoustic PD detection compared to electromagnetic PD detection are still sufficient to investigate this technique in more detail.