Degradation rates in high voltage subsea cables with polymeric water barrier designs

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ABSTRACT

This paper presents results from numerical calculations of water ingress in a wet designed subsea XLPE cable equipped with a two-layered outer sheath, and results from water tree ageing at different relative humidity (RH) levels in an XLPE cable core. The results from the water tree ageing show that no trees appear at RH below 70 %. Low water tree density and lengths were found at RH values between 70 and 100 %. This indicates that the service lifetime can be very long for cable systems with two-layered sheaths, as it takes more than 50 years to reach 70% RH and then additional 100 years to increase the RH from 70 to 99 % in the cable insulation.

KEYWORDS

Water treeing; relative humidity; subsea cables; numerical calculations; water ingress

INTRODUCTION

Water treeing is one of the main degradation mechanisms in high voltage cross-linked polyethylene (XLPE) cables exposed to water. High voltage subsea cables are normally equipped with a metallic water barrier such as lead to keep the insulation dry. In some cases this may not be advantageous, e.g. when the cable is subjected to substantial dynamic mechanical stress. Other benefits gained from removing the metallic water barrier include reducing cable weight, which is significant during transport and lowered strain during installation of subsea cables in deep waters. The reduced cost of the cables by using polymers instead of the more expensive metallic barriers is also important.

In the absence of metallic water barriers, the moisture content in the insulation will rapidly increase as water diffuses into the system. Water tree initiation does normally not occur at relative humidity (RH) lower than approximately 70 %[1]. In addition, the water tree growth rate is likely reduced at RH levels below 100% [2]. Therefore, by limiting the diffusion rate of water by a polymeric outer sheath system, the service life of the cable can be prolonged due to reduced water tree growth. The water diffusion properties of the outer sheath system, the seawater temperature close to the cable, and the cleanliness of the insulation system are essential factors to obtain a long lifetime for such cables.

The main purpose of this paper is to show that the low RH increase and corresponding reduced water tree growth can make the lifetime of a "smart" wet designed subsea cable very long. The water transport data of the outer sheaths used during the calculations are measured on extruded cable sheaths taken from real cables.

AGEING MODEL

Water tree growth rate is affected by the availability of water in the surrounding insulation. In a cable where water diffuses into the insulation, three phases of water tree growth can be identified:

- Phase 1: RH < 70 % – Diffusion only, no water tree growth
- Phase 2: 70 % < RH < 100 % – Water tree growth at a reduced rate
- Phase 3: 100 % RH – Water tree growth at full rate

In Phase 1, the relative humidity is too low for water trees to initiate. This phase is what is usually considered relevant to the lifetime of a cable[3]. In Phase 2, the humidity is high enough for the initiation and growth of water trees. A relative humidity lower than 100 % limits the growth rate, as water trees need water in liquid form to grow[4]. The condensation of water at water soluble particles such as salts will be important in this phase. In Phase 3, the insulation is saturated with water. A high availability of water will support water tree initiation and growth.

In Fig. 1, the different phases are illustrated for water diffusion into the insulation of an XLPE insulated cable. As can be seen, the time duration of Phase 2 is much longer than Phase 1. This means that in a cable system where the relative humidity is high enough that water trees have started to grow, the growth rate will be limited for a very long time. It is therefore important to consider also the time from 70% to 100 % RH when discussing the lifetime of the cable insulation. No unacceptable reduction of the breakdown strength will likely occur during this period[5]. It is important to note that this depends on the insulation and material cleanliness of the cable core.

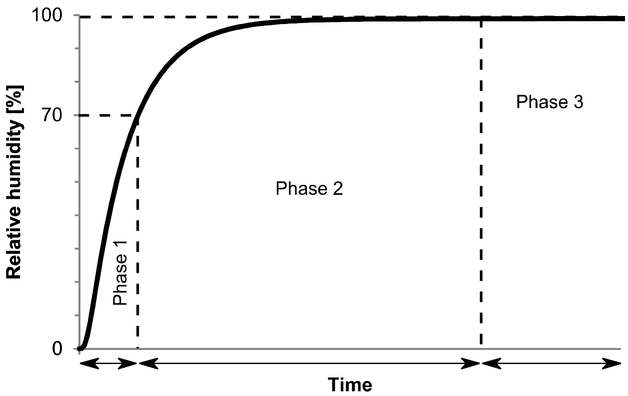

Fig. 1: Typical humidity increase in the insulation of an XLPE cable, where water absorption occurs from the outside.