CABLE REJUVENATION – PAST, PRESENT AND FUTURE

William STAGI, UtilX Corporation (USA), rstagi@Utilx.com
Wayne CHATTERTON, UtilX Corporation (USA), wchatterton@Utilx.com

ABSTRACT

This paper discusses the basic theory behind the functionality of phenylmethyldimethoxysilane as a water tree retardant when injected into a power distribution cable with extruded dielectric insulation. Also discussed is a new class of fluids; dialkyldialkoxysilanes, that continue to show promise as next generation fluids.

KEYWORDS

Cable Injection Technology, phenylmethyldimethoxysilane dimethyldimethoxysilane water tree cable aging insulation.

CABLE REJUVENATION - THE PAST

Cable injection technology and cable rejuvenation are two terms commonly used to describe the introduction of engineered materials into an aged but still operational cable with the intent of counteracting the effects of cable insulation aging. The ultimate objective is to significantly extend the economically useful lifespan of an underground power distribution cable, deferring by decades the cost of cable replacement. Early attempts at cable rejuvenation included the introduction of a continuous stream of dry gas or alternatively a plasticizer such as acetophenone through the cable conductor's interstitial spaces [1], [2]. The introduction of dry gas was an attempt to alter the equilibrium water content of a cables insulation. Plasticizers were injected with the hope that they would diffuse into the cables insulation and swell the insulating material collapsing the voids and imperfections which seed water tree growth.
These approaches provided promising results [3] but they both shared the same weakness that would have to be overcome before cable rejuvenation was to become economically attractive. For these materials to have an affect on a cable's insulation they needed to diffuse into the material fairly quickly. The same property that allowed them to enter the insulation material quickly however, also allowed them to pass through and out of the cable in similar fashion. They needed to be constantly replenished in order for their affects to be maintained. It did not take long for the maintenance and material costs to undermine their up front economics.

CABLE REJUVENATION - THE PRESENT

Dow Corning Corporation overcame the weakness noted in the earlier materials by employing materials which could diffuse quickly into a cable's insulation but which, once there, would undergo oligomerization rendering them much less mobile. The earliest material successfully employed using this strategy was Phenylmethyldimethoxysilane (PMDMS). This material is still in use today. Under some conditions it is still used as a standalone injection material. In most cases it has been blended with other materials for enhanced functionality. An understanding of its' effects on cable ageing provides a basis for understanding the formulations of this material that are currently being employed today, as well as the material advancements on the horizon.

Phenylmethyldimethoxysilane(PMDMS) functionality

To understand how this class of materials function one needs some background in the very broad topic of water tree growth, which is the primary aging mechanism of medium voltage cables employing extruded dielectric insulating materials.

Water Tree Growth

An understanding of the process by which water trees grow and degrade a cable's insulation was required before tree-resistant materials could be incorporated into newly manufactured cables. Certainly, this understanding was required before cable rejuvenation materials intended for use in existing field aged cables could be investigated. The subject of water tree growth has consequently been researched [4], [5] and reported on [6] in great depth. This paper discusses only those parts of the topic necessary for a cohesive treatment of the functionality of cable rejuvenation materials. It is known that water trees are imperfections in a cable insulation characterized by their polar hydrophilic nature. That is in contrast to perfectly crystalline polyethylene which is non-polar and hydrophobic. The polar nature of those imperfections attracts water and ionic impurities. Once there and under the influence of the cable's electrical field, water can be disassociated into damaging radicals. Equations (1) and (2) are examples.

$$OH^- \text{ (from water)} \rightarrow OH \text{ (hydroxyl group)} + e^- \quad (1)$$

$$2H_2O \rightarrow H_2O_2 \text{ (hydrogen peroxide)} + 2H^+ + 2e^- \quad (2)$$

The result is that the interfaces between the polar amorphous regions, and the non-polar crystalline regions of the insulating material are oxidized. The oxidation furthers the polarization propagating water tree growth. This explanation of water tree propagation requires the presence of: polar imperfections or voids in the dielectric structure; a sufficiently strong ac electrical field and of course, water.