A Study of Changes in Resistivity of the Semi-conducting Layers in High Voltage Direct Current Cables

Carl Pettersson

As the demand for clean energy rises, transporting it safely and efficiently becomes more important than ever. High voltage, HV, DC onshore and off-shore cables are essential for long-distance transmission. Understanding them, and their components, ensures a safe and efficient transition to green energy.

HV cables can be divided into two main categories, ones that are suspended above ground in overhead power lines, and ones that are submerged either underground or underwater. For power lines the surrounding air works both as a good insulator and as a cooling system. They're also easy to inspect as the insulating air is transparent. On the other hand, underground and undersea cables are safer and less prone to environmental damage. They are also able to be built over bodies of water but require a more complex design that is difficult to maintain to account for the tougher environments where they are built. Not only do they require a dedicated insulation layer, but also two semi-conducting layers to protect the insulation layer from electrical stress, discharge, and material damage. Beyond that, they also require a protective outer jacket which protects the cable from environmental damage. The voltages that these cable transmit are very high, around 525 kV which is almost 2500 times larger than the standard 220 V that can be found in most households around the world.

This thesis looked specifically at the semi-conducting material that is there to protect the insulation from electrical stress, discharge, and material damage. A picture showing a cross-sectional view of one the cables looked at can be seen in Figure 1.

Fig. 1: Cross-sectional image of an underground high voltage cable

The semi-conducting material can be seen as a thin black layer between the gray insulation and conductive copper core. It can also be seen on the other side of the insulation.

A very important aspect to the semi-conducting material is its resistivity. If the resistivity of the semi-conducting material is either too large or too small it can not protect the insulation. A too large resistivity means that the semi-conducting layers act as more insulation, resulting in the same types of damage as when no semi-conducting layer is present. A resistivity that is too small means that the semi-conducting layer acts as more conductor, leading to larger heat losses and more damage to the insulation. This thesis examined how the resistivity varied over time under different circumstances, such as at different temperatures, values of humidity, among others. One such result, showing the resistivity over time for three different temperatures can be seen in Figure 2.

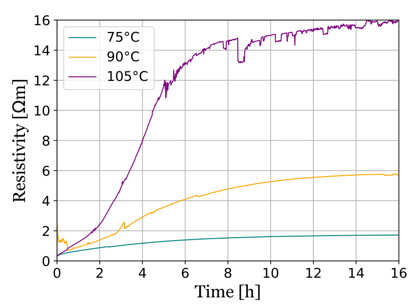

Fig. 2: The resistivity of the outer semi-conducting layer as a function of time at three different temperatures.

Figure 2 shows that the resistivity for the outer semi-conducting layer is more than 8 times larger at 105 $°C$ compared to at 75 $°C$. This is very different from other materials. Normal semi-conductors like silicon see a decrease of resistivity of approximately 20 % while metals like copper see an increase of approximately 10% over the same span of temperature.

Further analysis on similar data showed that in some cases the resistivity could increase 300 times more per degree temperature at 90 $°C$ compared to at room temperature.