HTS cables open the window for large-scale renewables

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Abstract. In a realistic approach to future energy consumption, the effects of sustainable power sources and the effects of growing welfare with increased use of electricity need to be considered. These factors lead to an increased transfer of electric energy over the networks. A dominant part of the energy need will come from expanded large-scale renewable sources. To use them efficiently over Europe, large energy transits between different countries are required. Bottlenecks in the existing infrastructure will be avoided by strengthening the network. For environmental reasons more infrastructure will be built underground. Nuon is studying the HTS technology as a component to solve these challenges. This technology offers a tremendously large power transport capacity as well as the possibility to reduce short circuit currents, making integration of renewables easier. Furthermore, power transport will be possible at lower voltage levels, giving the opportunity to upgrade the existing network while re-using it. This will result in large cost savings while reaching the future energy challenges. In a 6 km backbone structure in Amsterdam Nuon wants to install a 50 kV HTS Triax cable for a significant increase of the transport capacity, while developing its capabilities. Nevertheless several barriers have to be overcome.

1. Introduction

In the last years, superconducting technology has taken enormous steps forward and is becoming very attractive for real applications in electricity networks. The latest advances in HTS cables make it possible to use them to efficiently solve the challenges of a fast-growing society with increasing electricity consumption and use of large-scale renewable sources.

Some of the advantages HTS technology has to offer are low energy losses, large power transport capacity, short-circuit-limiting properties and negligible electromagnetic emissions and heat transfer to the environment. Nevertheless there are still several barriers to overcome before all these benefits can be addressed. That is why the utility Nuon is carrying out a pilot project in the downtown of Amsterdam. A 6 km long 50 kV HTS cable will be installed in the backbone network of this city. During this project the capabilities that make this technology suitable for use in real applications in electricity networks and integration of renewables will be developed.

Details of this project and the application of the HTS technology to integrate large-scale renewables will be discussed in this paper.
2. Challenges for the future

In a realistic approach to future energy consumption, several factors will lead to an increased transfer of electric energy over the networks. We live in a fast changing world with crescent prosperity and improved living standards. The use of more and more computers, air conditioning and heat pumps and electric and hybrid cars increases the dominance of electricity as an energy carrier. Even if small-scale distributed energy sources will contribute to an increasing fraction of the energy need, a dominant part will come from expanded large-scale renewable sources such as hydro power, wind parks, bio-mass, geo-thermal plants, blue energy and wave energy (Figure 1). These sources have to be integrated in a grid with traditional infrastructure and traditional energy sources.

![Figure 1. Large-scale renewable sources to be integrated in electricity networks](image)

To integrate and use these renewables in an efficient way over Europe, country borders have to be crossed. This implies large energy transits over long distances. To avoid the appearance of bottlenecks in the existing infrastructure as a result of this large energy transport the network will have to be strengthened. A conventional way to do this is to install overhead lines at high voltage levels. Nevertheless for environmental reasons the acceptance of overhead lines is decreasing. Requirements regarding emission of electromagnetic fields are becoming more and more rigid and the allowed limits lower. The visual effect of overhead lines in landscapes and built-up areas is not being tolerated anymore. Consequently, more infrastructure will be built underground (Figure 2).
3. HTS: Technology for the future
There are many reasons why HTS technology is ideal to reach the challenges of the future in electricity networks and integrate large-scale renewable sources. Compared with the traditional technology it has big technical and environmental advantages (Figure 3).

3.1.1. Technical advantages. An important property of HTS cables is their large transport capacity at low voltage levels. HTS cables can transport up to 10 times more power than conventional cables with a much lower amount of energy losses. Furthermore these cables have no thermal influence on other infrastructures. There is no heat transfer to the environment that could result in a reduction of the transport capacity of other infrastructure. In networks with mixed loads and generation, voltage fluctuations are a problem. The low impedance of HTS cables not only reduces the energy losses but also contributes to a stable voltage profile in the network. All these characteristics give the opportunity to upgrade existing high and medium voltage networks while re-using them and allow the integration of power sources like large-scale renewables in a more efficient, easy and flexible way. At this respect HTS technology has another important advantage: the possibility to reduce short circuit currents. Integrating this current limiting property in the cable will make other measures to limit the short-circuit contribution of renewable power sources in many cases unnecessary.

3.1.2. Environmental friendly. The well-known property of superconducting materials of having very low energy losses is not only economically and technically attractive but also contributes to spare the environment. The most recent three-phase HTS cable design of nkt cables barely emits any electromagnetic fields to the outside. It is the so-called Triax cable where the three phases and the screen are coaxially aligned. Additionally and contrary to overhead lines there is no visual impact on landscapes and built-up areas.

Figure 2. Overhead lines in landscapes and built-up areas

Figure 3. Technology for the future. HTS cables in the grids of tomorrow
4. Pilot project in downtown Amsterdam: The breakthrough

Until now, all HTS cables used in current projects are limited to 200-600 m. But to give this technology a significant use in HV-networks and reach all the challenges in the grids of tomorrow, their length has to be increased to several kilometers.

The utility Nuon has identified a suitable first installation site in downtown Amsterdam (Figure 4) where a 6 km long 50 kV HTS cable is intended to be installed for a significant increase of the transport capacity. In the chosen location there is an important 150 kV substation fed by three gas-pressure (GP) cables. The HTS cable, with more than twice the power carrying capacity, will replace one of these cables (Figure 5).

Due to its very large power handling capacity in a small diameter the HTS cable is the ideal solution for a crowded city like Amsterdam, where reusing the existing steel conduit avoids many civil issues. For this purpose nkt’s Triax design will be used. Due to the concentric alignment of the three phases, it is a very compact cable. After pulling the GP cable out of the steel pipe, the Triax cable will be pulled into it (Figure 6). To fit in the steel pipe this cable will be provided with both inside and outside cooling channels.

In order to get the benefits of the HTS technology, an efficient cooling system is needed. Due to limited space and other practical issues in the city of Amsterdam, several cooling systems along the cable are not allowed. Therefore, only two cooling systems (one at each end) will be used. These two systems have also to be optimized to get a compact construction at both substations. This will be achieved by an efficient array of the system’s components.

A very revolutionary idea that also makes it possible to have only cooling systems at each end of the cable is the splitting of the cooling for the cable and the terminations. A serious part of the energy losses is due to the temperature gradients in the terminations. Using a separate loop to cool them will allow the cooling loop of the cables to keep its temperature stable.
5. Conclusion
Installing a 6 km long HTS cable in the city of Amsterdam is a very ambitious project and represents a very big challenge in HTS technology. Nevertheless none of the technical feasibility studies until so far give indication of any insurmountable obstacle. By using a compact cable design and a very efficient cooling system and reusing existing infrastructure it will be possible to enjoy all the advantages HTS technology has to offer.

This project is the beginning of a breakthrough in HTS technology and will give the chance to develop its capabilities. It will prove that HTS technology is the answer we are waiting for to meet the challenges of the future in a continuous and fast changing world with increasing electricity consumption and use of large-scale renewable sources.

The window for large-scale renewables will be opened.

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