Public Report Project Supernet NL

1- **Project information**
Project number: DEI1150006
Project Title: Supernet NL
Applicants (Penvoerder en medeaanvragers): TenneT TSO, IWO Project, TU Delft, University of Twente, HAN, RH Marine
Project timeline: 01 July 2015 – 30 June 2019

In 2015 the project Supernet NL was started to integrate a High Temperature Superconducting (HTS) cable system into the Dutch high voltage power network. The project Supernet NL was designated as a demonstration project to illustrate the applicability of a HTS cable system in an operational high voltage network and open the application of superconductivity in other sectors and in particular the maritime sector where a large added economic value was expected. It was not a project target as such, but the aimed cable was expected to be the longest in service HTS cable at high voltage (HV) worldwide (approximately 3.4 km circuit length). Six institutes, namely; TU Delft, University of Twente, HAN, IWO Project, RH Marine and TenneT TSO, participated in the project based on the expertise they could offer to the project. The project had seven work packages (WP) focusing on finding an adequate demonstration site, on electrotechnical design of the HTS cable system, on its reliability, on diagnostics, on the specifications and tender, on realisation of the project and on the demonstration. With an increased renewable energy, new technologies are needed to transmit the energy more efficiently. HTS cable has larger capacity and can transmit more power compared to its equivalent conventional cable systems. Further, the society demands more underground transmission systems than overhead line systems. However, in urban area, this is/can be problematic due to limited available free underground space as cable systems occupy certain space deviating from which will have adverse operational impact. There shall be certain distance between the cables within one circuits as well as certain distance between the cable circuit and other underground infrastructure to function reliably and efficiently (e.g. to release the heat production to the soil). HTS cable system, has a closed cooling system which minimizes the influence of the other infrastructure on it almost to zero level. Based on the knowledge derived from the technical aspects, the application of the HTS cable system in the High Voltage grid is possible. The HTS cable also aimed at having near zero electromagnetic (EM) emission at ground level (i.e. < 0.4 microT). Regarding the reliability aspect, HTS technology has been used for several years in other industries. As for cable systems, there are several pilot projects as well as commercial projects that prove the HTS cable system is a reasonable technology, and the reliability of the grid could be made sufficient by means of redundant subsystems provided as part of the cable system. To assure that a system is technically and financially feasible to be incorporated to the high voltage grid, it is important to consider a worst case scenario where a system is failed and needs to be restored in a short period of time i.e. a scenario where the out of service time is minimized. To start a repair of a HTS cables system, the cable system needs to be warmed up without damaging any (sub-)component prior to start the repair and it needs to be cooled down again to the cryogenic temperature without damaging the (sub-)components after the repair is finished. This can be time consuming process as the warming up and cooling down with a wrong rate can damage the cable

system. Under this research, it was shown that by applying a special method of warming up and cooling down, this rate can be improved considerably and hence the restoration time after failure can be minimized.

Within the research framework, it was shown that the HTS cable system is technically a potential replacement for conventional cable systems i.e. XLPE, gas-pressurized and fluid-filled cable systems. However, the project is still considerably more expensive to realize compared to its equivalent conventional cable system. The dominant cost factors are the cost of HTS tapes and the cooling system including cryostat. Hence, at this stage applying a HTS cable system in a high voltage network was concluded not to be economically competitive to conventional cable.

List of publications:

1. "Supernet project overview", Johan Smit (TUD/IWO), Uitgever: TU Delft, 2015
2. "Superconductivity in Transmission Grid", G. Aanhaanen, Uitgever: TU Delft, 2015
3. "Supernet NL - A superconducting power transmission cable in the Netherlands", R. Ross, EMS symposium; Uitgever: UTwente, 2015
4. "Nederlands krijgt 's werelds langste supergeleidende hoogspanninskabel", http://www.engineersonline.nl/nieuws/id25765-nederland-krijgt-s-werelds-langste-supergeleidende-hoogspanningskabel.html, engineersonline 2015
5. " TenneT selecteert Enschede voor wereldprimeur met 'ijskoude' superkabel" https://www.tennet.eu/nl/nieuws/nieuws/tennet-selecteert-enschede-voor-wereldprimeur-met-ijskoude-superkabel/, TenneT TSO, 2016
6. "Supernet NL - Feasibility and demonstration of a superconductive HV cablein the transmission grid", R. Ross, Cigré D1.34 Workshop, 2016
7. "Supernet NL - De eerste supergeleidende hoogspanningskabel in Nederland", R. Ross; Uitgever: HAN, 2016
8. "Supergeleiding in magneten voor windturbines, kernfusie en deeltjesversnellers", H. ten Kate, Uitgever: HAN, 2016
9. "Praktische Aspecten van Betrouwbaarheid en Beschikbaarheid voor Supernet NL"; Report number IP15P0202, IWO Projects, 2016
10. "Statistische Betrouwbaarheid en Beschikbaarheid voor Supernet NL"; Report number IP15P0201, IWO Projects, 2016
11. "Lezing: Supernet NL - A 3.4 km superconducting power transmission cable in Enschede", University Twente: EMS - Super Act Symposium, 2016."Lezing: Supernet NL - A Superconductive High Voltage Cable System for the Netherlands", Elektro-Technische Vereniging TU Delft, 2016.
12. "Jaarverslag 2015, Online Monitor Jaarcijfers Superkabel", 2016
13. Gholizad, B., Ghaffarian Niasar, M., Ross, R., Ter Brake, M., Smit, J., "Technical and Economical Evaluation of High Temperature Superconductivity Solutions in High Voltage and Extra High Voltage Transmission", the 13th European Conference on Applied Superconductivity (EUCAS), Switzerland, 2017.
14. "The Supernet NL Project: The Netherlands High Voltage HTS Cable Project", the 13th European Conference on Applied Superconductivity (EUCAS), Switzerland, 2017.
15. Ross, R. et al, "Insulation Reliability of Superconductive Cables", 1st Inter. Conf. on Electrical Material and Power Equipment, Xi'an, China, 2017.

16. "Modeling cool down characteristics of a 3.4 km long superconducting cable using FEM analysis", Stagiair rapportage, TenneT TSO & University Twente, 2017.
17. "Supernet NL program: 3.4 km 110 kV underground superconducting cable in the Dutch grid", IWC-HTS 2017
18. "Efficienter stroomtransport dankzij supergeleiding en vloeibare stikstof", Kijkarticel, 2017
19. "Supergeleiding, een koud kunstje", presentatie Dutch Power, 2018
20. Gholizad, B. et al, "Reliability Considerations of Electrical Insulation Systems in Superconducting Cables", 2nd Inter. Conf. on Electrical Material and Power Equipment, Xi'an, China, 2018.
21. "Rapid cooling down of superconducting power cables", Hunik, R., Ter Brake, M., Ross, R., 2018

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