Technical University of Denmark

# Minimising the Usage of Superconducting Tape in Electrical Machine Applications

**Jensen, Bogi Bech; Mijatovic, Nenad; Abrahamsen, Asger Bech; Træholt, Chresten**

*Publication date:*
2011



*Citation (APA):*
Jensen, B. B., Mijatovic, N., Abrahamsen, A. B., & Træholt, C. (2011). Minimising the Usage of Superconducting Tape in Electrical Machine Applications. Abstract from 1st European Workshop SOWiT 2011, Rome, Italy.

**Topic letter and heading number: C** - HTS electric generators. 4 – Electric characteristics

**Title:** Minimising the Usage of Superconducting Tape in Electrical Machine Applications

**Authors:** Bogi B. Jensen[1], Nenad Mijatovic[1], Asger B. Abrahamsen[2], Chresten Træholt[1]

**Affiliations:** [1]Department of Electrical Engineering, Technical University of Denmark, DK-2800 Kongens Lyngby, Denmark, email: bbj@elektro.dtu.dk, telephone: +45 45253525. [2]Materials Research Division, Risø National Laboratory for Sustainable Energy, Technical University of Denmark, DK-4000 Roskilde, Denmark.

**Purpose of work:** It has become increasingly difficult to obtain planning permission for onshore wind farms in Europe. This has resulted in a trend towards larger (6-7MW) offshore wind turbines, many of which are direct drive due to reliability and the need for lower cost of energy. The trend towards larger wind turbines results in heavier generators, which are complicated to lift to the turbine tower at sea. A possible solution to this is to employ direct drive high temperature superconducting (HTS) generators, where the airgap flux density is increased by a factor of 2-3 by employing a superconducting field winding, and hence the size and weight of the generator can be reduced by this same factor.

If HTS generators are employed, it is very important to design the machine so that the HTS tape is utilised as well as possible without quenching. The reason is that HTS tape is extremely expensive and will quench if exposed to fields greater than their critical values, which are dictated by the available cooling power of the cryogenic cooling technology.

**Method of approach:** This paper proposes two methods of minimising the usage of HTS tape, both of which are based on the recognition that the flux density at the superconductor varies depending on the position of the superconductor. The first method is to supply the HTS field winding from multiple current sources, hence achieving the required airgap flux density with minimal usage of HTS tape. The second method explores where in the generator the HTS tape should be placed and how much should be used, depending on the characteristics of the individual tape.

The first method is demonstrated with an HTS machine prototype in an experimental test rig, see fig. 1. It is shown that the airgap flux density can be increased using the same amount of HTS tape, if multiple current supplies are employed compared to if all the HTS coils are connected in series, see fig. 2. [1].

The second method is simulated using an optimisation routine, where the different types of tape are 1G tape with a critical current of 80A at 77K; 1G with 160A; 2G with 80A; 2G with 120A and 2G with 140A. The estimated relative price of the tape can be seen on the legend in fig. 3, where pu stands for per unit. [2].

**Significant results:** The first method of minimising the usage of HTS tape has been demonstrated experimentally in a test rig. Although no optimisation has been employed, it was demonstrated that the airgap flux density could be increased by 12%, hence a given airgap flux density could be achieved with 12% less HTS tape if multiple current sources were employed, compared to if the tape was connected in series.

The second method focuses on optimising the usage of the HTS tape, by installing the tape in optimal regions depending on the characteristics of the individual tapes. It has been shown from simulations that the potential cost savings could be in the region of 30-50%, if this method is combined with the multiple current supply method.

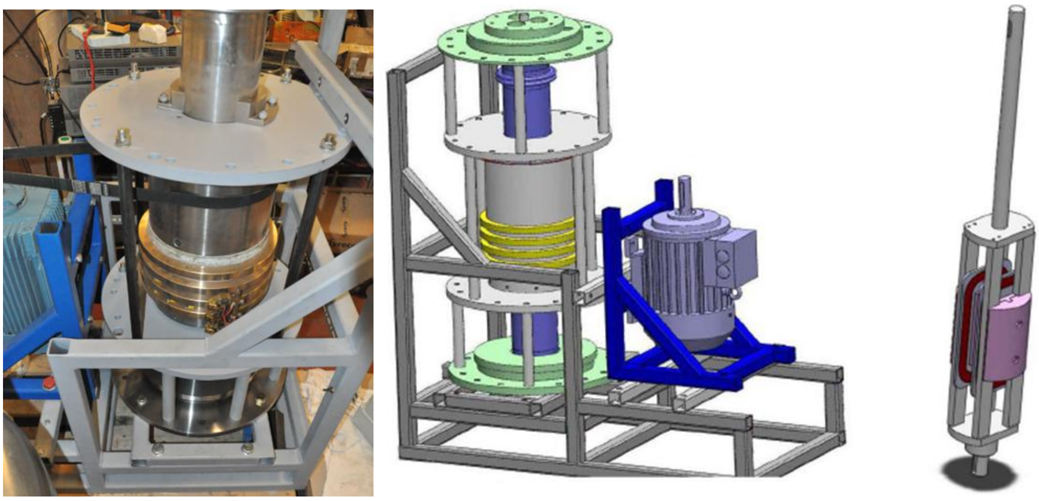

Fig. 1 – HTS machine prototype in the experimental test rig. Photo on the left and CAD drawing on the right.

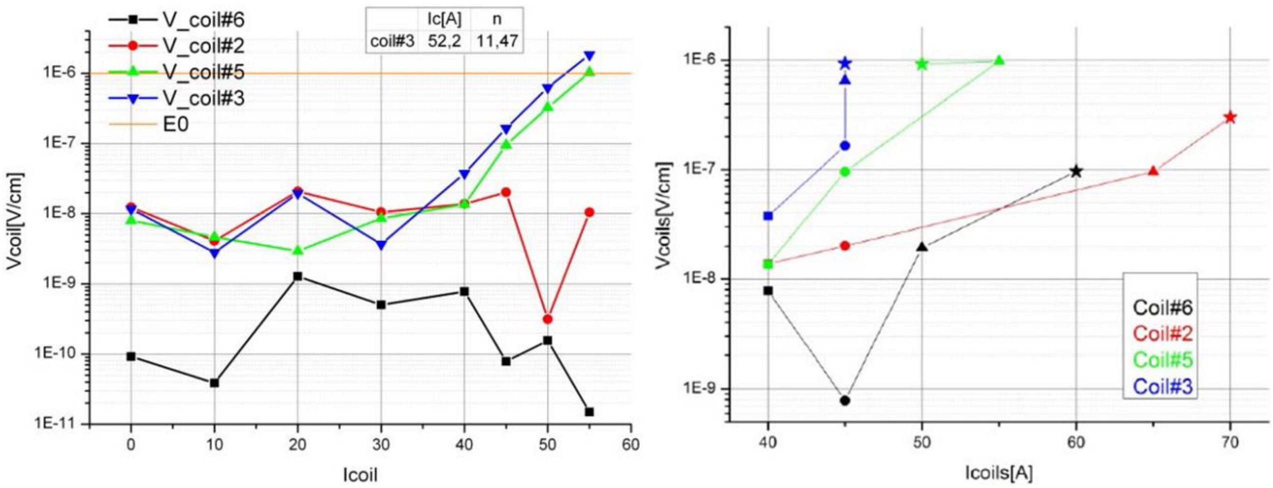


Fig. 2 – Experimental IV curves with multiple current supplies on the right and series connected coils on the left.

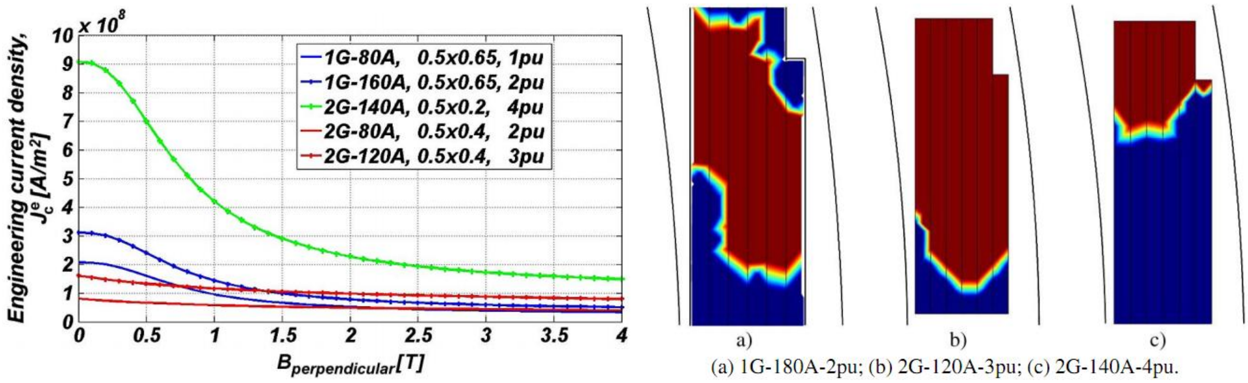


Fig. 3 – Left: estimated engineering current densities. Right: Position of tapes, where the red region is where the tape should be installed and the blue region is where no tape should be installed.

[1] N. Mijatovic, *et al*., "High Temperature Superconductor Machine Prototype", ICEMS 2011.

[2] N. Mijatovic *et al*., "Coil Optimization for High Temperature Superconductor Machines", IEEE transactions on superconductivity Vol. 21, No. 3, pp. 1136-1140, 2011.