Abstract

For an efficient yet effective mode of electric power transmission and distribution across kilometers of length, high temperature superconducting (HTS) power cable is the most suitable alternative. This cable can be opted in the future transmission and distribution network because of its advantages of huge power carrying capacity at minimum transmission losses in compact size. Over past few decades, researches are being carried out on its design and development worldwide, to realize this technology most suitable for its application in real grid.

The design procedure of this cable mainly involves an understating of three different aspects other than electrical one e.g., structural aspect (the electro-mechanical behavior of HTS tape and cable), hydraulic aspect (obtaining reduced pressure drop for liquid nitrogen flow along the length of cable and thereby establishing less pumping power requirement) and thermal aspect (convective heat transfer analysis of liquid nitrogen flow).

The HTS tape is helically wound around a circular former and undergoes different types of mechanical loading conditions during the cable production (helical winding of HTS tape around copper former), transportation as well as installation processes (bending and tensile load on cable). A finite element analysis is carried out to investigate the electro-mechanical behavior of 2G HTS tape during its production and post-production processes with five different winding pitches and four different cable bending radii with YBCO layer in the downward position. From this analysis, a minimum winding pitch is obtained above which critical current degradation is not observed.

The pressure drop is an important parameter in the cable design, as it decides the length of the cable. Liquid nitrogen flows through an annulus having two different walls (inner smooth and outer corrugated one) within the cable. Therefore, the friction factor of the flow should be estimated considering the contribution of both the walls. The corrugation geometries (i.e., corrugation pitch and depth) and shapes in the outer wall of the annulus affects the friction factor of the flow. A numerical analysis is performed with nine different pitch and depth combinations, to realize the effect of corrugation geometry on friction factor and also to suggest a suitable combination having minimum pressure drop.

In HTS power cable, the liquid nitrogen flow through a bilaterally heated annulus having two different walls is exposed to uniform but unequal heat fluxes. The corrugations in the outer wall of the annulus increases the heat transfer area and the corrugations shape has an effect on the convective heat transfer. To realize the effect of corrugation shape on both hydraulic as well as heat transfer performances a detailed CFD investigation is carried out with four corrugation shapes at a constant pitch and depth, for the turbulent liquid nitrogen flow within the concentric annulus. Further, it is also necessary to establish a comprehensive performance of heat transfer enhancement with pumping power penalty, while designing the cable. Therefore, a performance evaluation criterion (PEC) is introduced to take both heat transfer enhancement as well as pressure drop into account.

In this dissertation, a 22kV/3kA HTS cable is designed based on the Indian power grid scenario, considering all the afore-mentioned design aspects and safety measures into account.