

## ABSTRACT

One of the promising topologies available for High Temperature Superconducting (HTS) synchronous machine is HTS field coils in rotor and air gap copper coils in stator. This technology can be adopted to manufacture compact, lighter and noise free machines suitable for strategic as well as critical industrial applications. It is also a step towards making more efficient electrical synchronous machines with higher power to weight ratios. Synchronous machines with larger power ratings utilising this technology will not only reduce the weight and size footprint, but also offer better operational performance as compared to their conventional counterparts.

Keeping the above-mentioned advantages of HTS machines in view, BHEL Corporate R&D, Hyderabad has taken up a technology demonstration project for developing 200 kVA (0.2 MVA), 415V, 12.5 Hz, 250 RPM HTS based synchronous machine utilizing HTS field coils in rotor and air gap copper coils in stator. One of the most vital aspects in this effort is the development of cryocooled HTS rotor encasing HTS field coils in a rotating cryostat wherein these coils cater to the field excitation requirements of synchronous machine. Hence, for realisation of HTS rotor, one of the main technological challenges is to develop and test the HTS field coil.

The main objective of this thesis work is to develop a prototype racetrack shaped double pancake HTS field coils suitable for proposed 200kVA HTS synchronous machine. This majorly involves the selection of HTS tape, winding technology and handling of the HTS tape while winding, development of cryogenic test setup at 35K, testing of developed HTS coil etc. In this regard, an electrical design of 200kVA HTS synchronous machine has been carried out with air gap winding stator and HTS coil rotor with an aim to determine the HTS field coil specifications (size, ampere turns etc.). This design has been validated through electromagnetic analysis and based on this, the specifications of HTS field coil have been finalized. The critical operating currents of HTS field coil at self-field are also estimated theoretically at 77 K and at 35 K which is the actual operating temperature of 200kVA HTS synchronous machine. The HTS tape for the field coils has been selected and procured based on its specifications and matching to the coil operating parameters. The former for winding the HTS field coil in double pancake race track shape has been designed and manufactured in-house. A special winding machine has been indigenously developed and the winding process has been established in-house to fabricate the

prototype HTS field coil. The developed HTS field coil has been tested initially at 77 K using an established liquid nitrogen bath type test setup to validate the theoretically estimated critical operating current experimentally at this temperature and self-field. Subsequently, a 35 K closed cycle cryogenic test setup has been designed and developed in-house. Using this indigenously developed cryogenic test setup, the theoretically estimated critical operating current of HTS field coil of 200kVA HTS synchronous machine at designed operating temperature of 35 K at self-field has been experimentally measured and validated. This validation confirmed the design, manufacturing and testing of racetrack shaped double pancake HTS field coil. This successful demonstration of HTS field coil has significant implications towards the development of HTS based rotor for practical realisation of 200kVA HTS synchronous machine in India. Further, this developmental work will certainly pave a way for realisation of field coils of compact HTS machines of larger power ratings in future.

**Key Words:** HTS synchronous machine, HTS field coil, HTS tape, Coil winding machine, Double pancake winding, Cryo-refrigerator, Cryogenic test setup, Critical current