Modelling and Computation of AC Fields and Losses in High Temperature Superconductors

Computational Engineering and Design Centre

Principal researcher: Mr M.D.Rotaru

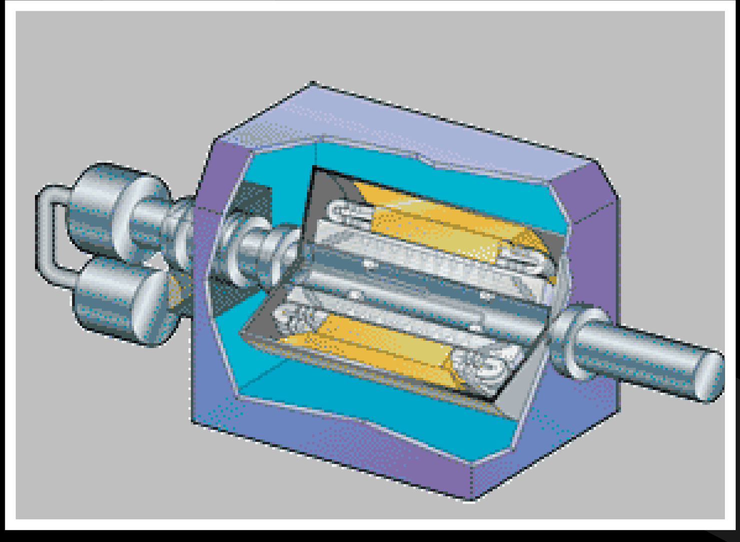
Supervisors: Prof J.K.Sykulski, Dr. R.L. Stoll

CEDC correspondence to
Prof. A. J. Keane
School of Engineering Sciences
University of Southampton
Highfield
Southampton SO17 1BJ UK
Tel: +44 (0) 23 8059 2944
Fax: +44 (0) 23 8059 3230
E-mail: ajk@soton.ac.uk

Understanding and quantifying AC losses in High Temperature Superconductors is essential in their application in power apparatus. High-T_c superconductors experience energy loss when exposed to time-varying magnetic fields or carrying alternating currents. Besides their critical current density J_c the AC loss behaviour of these materials is a crucial factor for any future power applications, and needs exploring.
High Temperature Superconductors (HTS) are used in many power aplicatons like power cables, high power electric motors, transformers or fault limiters.

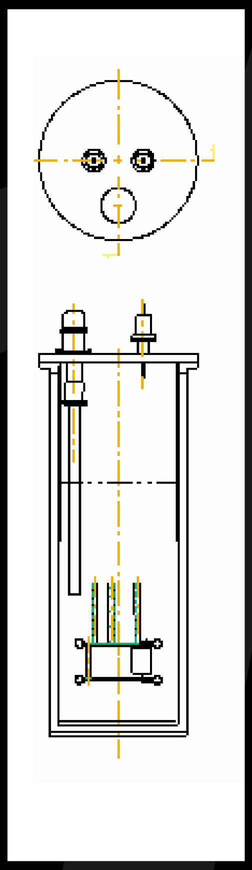
HTS Motors

HTS motors use HTS windings instead of conventional copper ones, wasting half as much energy as copper-based motors. By replacing the copper rotor winding of a conventional motor with HTS windings, higher magnetic fields will be produced with virtually no rotor losses and significantly reduced losses in the armature. All iron can be eliminated when constructing a rotor with HTS windings. The removal of the iron teeth in the armature leaves more room for armature copper, which lowers the losses and improves machine efficiency. These reductions in losses result in lower operating costs than in conventional motors.
By producing higher magnetic fields and minimizing losses, HTS motors will be the ideal choice for large motor applications over 1,000 HP.



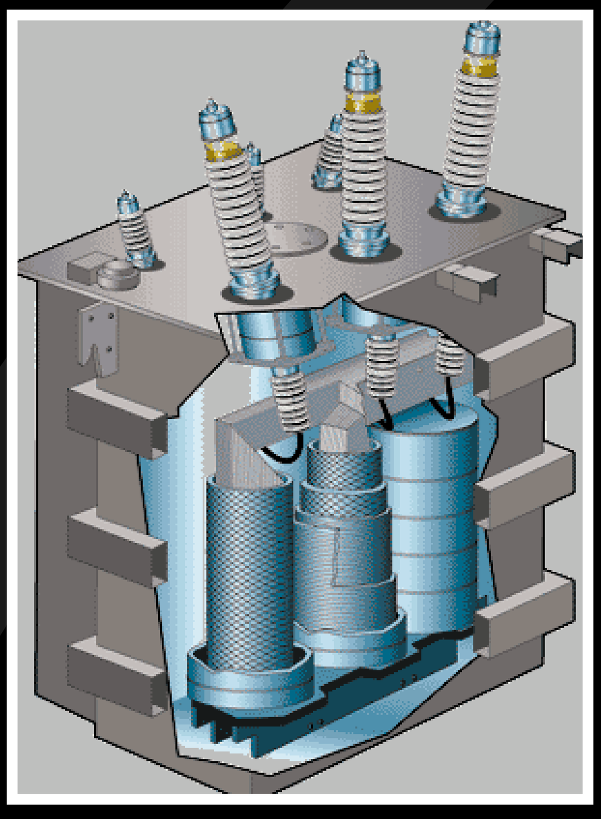
HTS Fault Current Limiters

A current limiter is designed to react to and absorb unanticipated power disturbances in the utility grid, preventing loss of power to customers or damage to utility grid equipment. Conventional copper-based equipment conducts electricity but inherently has energy losses associated with (joule) heating. Fault current limiters would be installed in transmission and distribution systems, especially for electric utilities and large energy users in high-growth, high density areas.

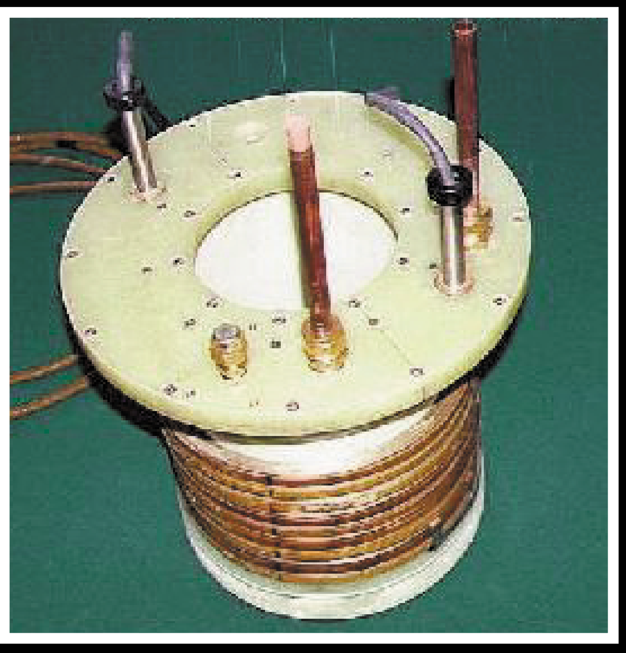


HTS Transformers

HTS step-up transformers will be used by power generators to increase their overall efficiency and competitive advantage. Small, quiet, lightweight and efficient HTS step-down transformers will be used by distribution utilities. Environmentally friendly and oil-free, they will be particularly useful where conventional transformers previously could not easily be sited, such as in high density urban areas. Unprecedented fault current limiting functionality, which is expected to protect and reduce the cost of utility system components.

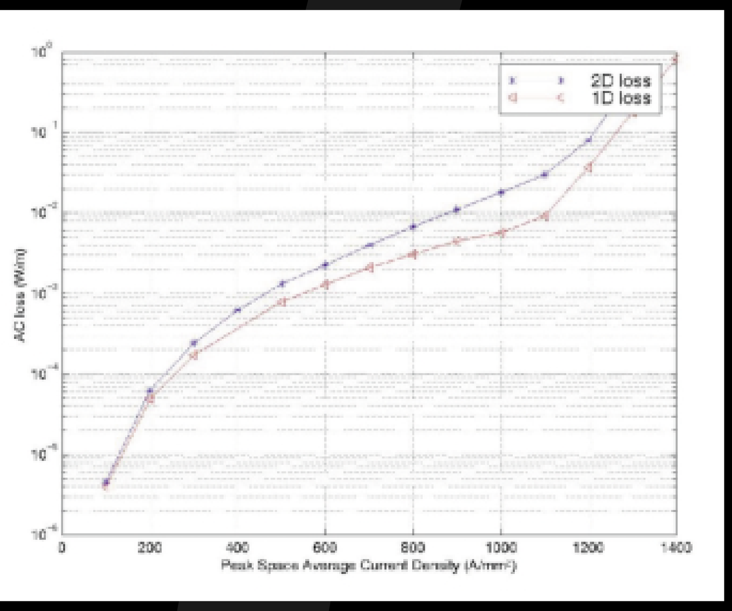


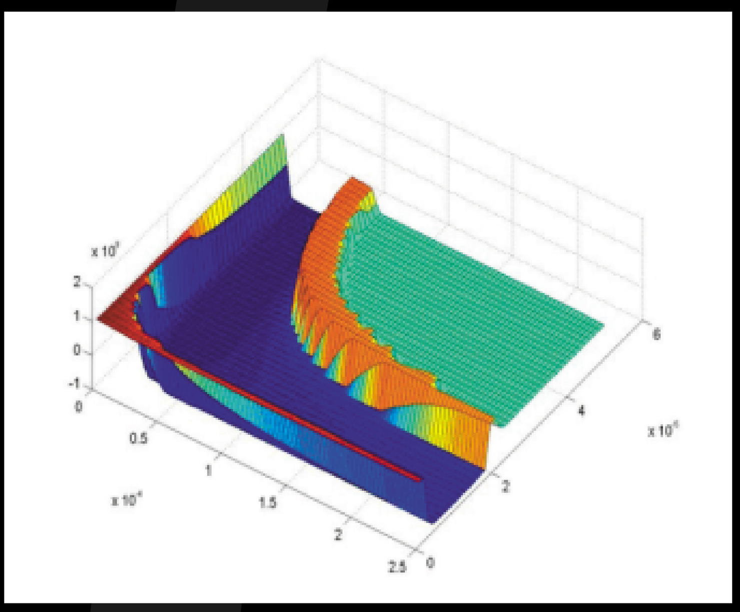
Reduced operating impedance, which will improve network voltage regulation. Significantly lower energy losses through improved efficiency of electric delivery, resulting in reduced greenhouse emissions from fossil generation. Size and weight reduced by a factor of two, which will increase existing substation capacity, reduce land area needed for new substations, and greatly relieve transportation challenges. Increased safety from elimination of fire and spill risks associated with oil dielectrics by replacing the oil used in conventional transformers with low-cost, environmentally-friendly liquid nitrogen.



HTS Coil

The above figure presents a HTS coil which was built at University of Southampton in the Cryogenics department in collaboration with the Electrical Engineering department. The coil was used in demonstrator transformer for measuring the AC losses which occurs when the transformer is used.
One possibility, recently examined, is to treat the superconductor as a highly non-linear conductor. In this case a non-linear diffusion equation has to be solved. The models developed are 1-D and 2-D diffusion models based on the power law E-J characteristic given by Ryner.
In general, two cases of AC loss (the self-field and the external field) have been considered, with more emphasis on the self-field case.
The models have benefited from the introduction of the Ryner power law E-J characteristic, as it is simpler, quicker to implement and can be ajusted by varying both alpha and J_c.
This research tries to increase the understanding of AC loss mechanisms and tries to develop theoretical models and computation techniques. In order to achieve these two aims the first step is to move into an implicit time-stepping algorithm and secondly replacing the iteration with some form of sub-domain decomposition technique so that advantage could be taken of the power of parallel processing.





University of Southampton