Seminar

Institute for Plasma Research

Title : Studies on Quench Characteristics of Superconducting Magnets of SST-1

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Abstract:

Quench in a superconducting magnet is best described as a transition of a portion of its superconducting winding pack to normal conducting state. In case of quench in magnets like SST-1 TF coil, the joule heating in the quenched section of the magnet winding pack can lead to a very high rise in temperature as a result of the large transport current densities in the magnet and the low specific heat of material present inside the winding pack at low temperature. Such uncontrolled rise in temperature can lead to permanent damage to the conductor and insulation inside the winding pack. A properly designed quench detection and protection system detects quench at an early stage of development and extracts the magnet energy into an external resistor known as dump resistor [3.4].

Voltage measurements are commonly used to detect the superconductor to normal transition and are the fastest method of detecting quench in superconducting magnets. In tokamak magnets, such measurements are influenced by the inductive voltages arising from the current changes in the magnet itself and/or from current changes in other inductively coupled coils. Inductive voltage cancellation scheme is an important aspect of quench detection circuit design. Other important design parameters are the selection of threshold voltage and time taken to declare that the magnet has quenched, as well as to send a trigger to activate the quench protection system. Design of a fail-safe, state-of-the-art quench detection and protection system for SST-1 TF magnet system was one of the objectives of this thesis work. The quench detection and subsequent protection schemes are fully customized for SST-1 tokamak operational requirements.

Understanding the quench behaviour of CICCs is an extremely important issue for reliable superconducting magnet design and operation. The simulation of quench and its different aspects like quench initiation, quench propagation and quench protection threshold limits are crucial for magnet safety during operation. This is even

more important for large magnets for fusion machines, due to the very high energy content in them. While the analytical tools are handy for adiabatic estimations (worst case scenarios), numerical simulation becomes important for large magnets as adiabatic estimations lead to over-designed magnets and can be bulky and costly. These codes are additionally useful in analysing the reason of magnet quench. This knowledge is often useful to make required modifications in the magnet system to avoid quench. Although commercial and non-commercial codes are available for quench simulation, as each CICC has its unique characteristics depending on the intended operational scenarios, suitable input data and subroutines are required to be made to accurately model individual CICCs. Application of a commercial quench simulation code, Gandalf, towards study of quench behaviour of assembled SST-1 magnets was another motivation of this thesis work. Dedicated experiments have been carried out to determine the experimental friction factor of SST-1 CICC as a function of Reynolds number. The code was used to simulate TF coil quench observed in coil test campaigns. This code was further extended to simulate quenches observed in TF busbar sections which were extremely slow-propagating in nature. The thermo-hydraulic analyses of TF magnet system busbar and some CICC design cases have also been studied.

Quenches can also be redundantly detected by monitoring non-electrical signals like mass flow rate and pressure. Any significant change in the steady-state operational values of these signals can indicate a fault condition, like quench, inside the magnet. These are inherently slow signals and are expected to give slow response to the quench process, but can be used as secondary quench detectors. This redundancy could be very useful in case of major malfunction or failure of primary quench detector. This has been of interest to magnet designers for a very long time. However, the experimental database and guidelines to design such a system was not available and have not been reported to our knowledge. Vast databases of behaviour of these signals during quenches observed in SST-1 coil test experiments have been analysed and subsequently a guideline for detecting quenches in SST-1 TF magnets with this method has been proposed. A hardware design was also proposed for this quench detector as a part of this thesis work.