TOROIDAL HIGH TEMPERATURE SUPERCONDUCTOR COILS FOR ISTTOK

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High Temperature Superconductors (HTS) are very attractive to be used in fusion devices mainly because of its lower operations costs. The HTS technology has reached a point where the construction of toroidal field coils for a tokamak is possible. The feasibility of a tokamak operating with HTS is extremely relevant and ISTTOK is the ideal candidate for a meaningful test in this sense, due to its small size and therefore lower cost.
ISTTOK have performed one of the early experiments of AC discharges showing that long discharges could be produced merely with inductive operation. But due to the characteristics of the toroidal coils, the data acquisition system, limiter refrigeration and power supplies, a limit of 250 ms (six times the nominal forward current duration) is imposed at present. One of the possibilities to overcome successfully a steady-state operation on ISTTOK would be the use of high temperature superconducting (HTS) coils. Most of the other obstacles are being removed as new power supplies are being assembled, a new ATCA enduring controller have been commissioned and refrigerated limiters are being tested, eventually with liquid metals (Ga). Moreover, the technical diagnostics to operate the machine have been moved for a real-time philosophy, allowing a continuous monitoring of the plasma.
In the paper, a conceptual study of the ISTTOK upgrade to a superconducting device is presented, along with the relevant boundary conditions to achieve a permanent toroidal field with HTS.
We show that the actual state of the art in HTS allows to design the toroidal field coil capable of generating the proper field on plasma axis, providing a reasonable upgrade of ISTTOK confinement magnetic field while respecting the structural specification of the machine. Based on the actual properties of a commercially available HTS conductor of the 2nd generation, the amount of tape necessary for the complete replacement of all the toroidal coils has been calculated. It is found that the operation at liquid nitrogen (LN2) boiling and atmospheric pressure (i.e. the temperature of coils is 77 K) with 0.5 Tesla field on plasma axis would require 17 km of tape 12 mm wide. It is also possible to consider a cooling of the coils to 65 K still using LN2, generating slightly over 1 T. As a first step, the enhancement of the actual toroidal magnetic system by the partial substitution of copper coils by HTS modules operating at LN2 temperatures will be presented and discussed, including the influence of the coil geometrical configurations on the toroidal field. Taking into account the continuous improvement of the HTS properties, the present results should be considered a conservative estimation.