Contribution ID: **243** Type: **Poster**

Challenges and Solutions in the Design of RFX-Mod2, a Multi Configuration Magnetic Confinement Experimental Device

Friday, 26 October 2018 14:00 (20 minutes)

The RFX toroidal device (R –major radius=2.0 m, a - plasma minor radius=0.457 m, b - shell minor radius=0.535 m; in operation 1992-1999) was designed to be operated in Reversed Field Pinch (RFP) configuration with a plasma current up to 2 MA. RFX-mod (R=2.0 m, a=0.459 m, b=0.512 m; in operation 2004-2015) was then equipped with 192 independently driven full coverage saddle coils to achieve the full control of RWM modes and a significant mitigation of tearing modes. The mode and plasma equilibrium control innovations allowed to effectively reach the 2 MA current goal and led to the experimental confirmation of the single helical axis equilibrium of the RFP. Operation in ultra low-q (Ulq) pinch gave new insights on fundamental plasma properties. Experiments performed in circular and shaped tokamak configurations led to the first active stabilization at $q(a) \leq 2$ and recently an H-mode by electrode biasing.
Such results suggested the two future main goals of RFX-mod2 (R=2.0 m, a=0.490 m, b=0.512 m), the upgrade of RFX-mod: improvement of the RFP confinement and knowledge expansion on a broad spectrum of plasma physics in regimes otherwise not accessible on other devices.
The key ingredient of the new design is the enhancement of the shell-plasma proximity (b/a=1.04), expected to provide a significant reduction of the amplitude of RFP tearing modes. This reduction would lead to the positive cascade effects of magnetic chaos mitigation with confinement improvement, reduced plasma wall interaction and better mode control capability. This choice implied challenging major modifications on the components of the machine close to the plasma: removal of the present vacuum vessel and placement of the existing conducting shell in vacuum as close as possible to the plasma; the vacuum barrier would be then provided by the properly modified toroidal support structure. Innovative solutions have been conceived to fulfill vacuum and electrical requirements of the in-vessel components.
Furthermore a number of corollary modifications are foreseen, aimed at widening the operational space in terms of controlled density, magnetic field topology and the diagnostic capability, in all three different magnetic configurations in the foreseen range of plasma currents: 100 kA - 2 MA RFP, 40 - 180 kA tokamak, 20 - 800 kA Ulq.

Country or International Organization

Italy

Paper Number

EX/P8-7

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Session Classification: P8 Posters