ITER disruption studies including 3D volumetric blanket modules

F.Villone[1], L.Barbato[1], S.Mastrostefano[1], A.Portone[2], S.Ventre[1]

[1]DIEI, Università di Cassino e del Lazione Meridionale, Via G. Di Biasio 43, Cassino (FR), Italia
[2]Fusion for Energy, Josep Pla 2, Torres Diagonal Litoral B3, 08019 Barcelona, Spain
e-mail villone@unicas.it

Keywords: ITER, Disruptions, 3D blanket

Abstract

This paper presents the analysis of disruptions in ITER including 3D blanket modules. The plasma evolution is computed as a sequence of axisymmetric equilibria, self-consistently coupled with a 3D model of the conducting structures surrounding the plasma region. Different assumptions on the conducting structures are analyzed.

Introduction

Future magnetic confinement fusion devices, like ITER, have such high performance to require a special care in the dimensioning of various components. Disruptions are a particular concern for ITER [1]: the sudden loss of magnetic confinement, with subsequent release of plasma magnetic and thermal energy to the surrounding structures, can produce electromagnetic forces and heat loads that require careful design previsions for several components. In order to extrapolate the available experimental data to ITER, reliable and comprehensive computational tools are needed. Several modelling approaches are available for the analysis of disruptions, but none of them can be applied to all cases of interest, due to specific limitations and range of validity. For instance, [2] provides a valuable comparison of two well known axisymmetric codes for the analysis of disruptions, DINA and TSC, highlighting the effects of different assumptions and limitations. In this paper we apply the CarMa0NL code [3] to ITER in order to evaluate the 3D effects of the blanket modules on the plasma evolution during a disruption event. The CarMa0NL code has the unique capability to couple self-consistently the plasma evolution (defined by equilibrium states) to a 3D volumetric description of the surrounding plasma structures (required for a good estimate of the plasma evolution and the related electromagnetic loads).

Numerical Model

The CarMa0NL code decuples the electromagnetic interaction between plasma and surrounding conducting structures via a suitable surface. In this way, different formulations can be used to the plasma equations and structures, adopting for each region the most appropriate approach. The problem consist in solving equilibrium equations (Grad-Shafranov) in the region accessible to the plasma and eddy current equations in the 3D conductors. The two formulations are coupled via suitable coupling conditions assigned on a coupling surface located in between the two regions. As before mentioned, it is postulated that the plasma evolves through equilibrium states (quasi-static evolution). This assumption is valid if the plasma mass can be neglected and in the case in which the dynamics of the phenomena under observation are much slower than the Alfvén time scale and this is reasonable for disruptions [2].

Results

A so-called MD-UP event is analyzed [4]. It consists of a major disruption (1ms thermal quench followed by a linear thermal quench lasting less than 40 ms), causing an upward VDE (vertical displacement event). The plasma current density profile is imposed; no halo currents are considered. The first tests are made considering a 3D geometry model mimicking an axisymmetric conducting structure with no blanket in order to compare the results with available axisymmetric evolutionary equilibrium codes, both linearized (CREATE_L [5]) and non-linear (PROTEUS [6]). The results are reported in Figure.1: they are produced considering in all the codes the same mesh for the plasma region. There is a good agreement between them, but there is a significant nonlinear effect on the plasma vertical position following the thermal quench. The introduction of the blanket modules significantly affects the initial jump in the vertical position due to the thermal quench (Figure.2). Evidently, the blanket modules give a significant contribution due to the specific current loop induced in their structures. Axisymmetric codes, like DINA or TSC can account only approximately this effect, with different possible approaches [2]. It should be noticed that, differently from CarMa0NL, DINA results include halo currents which start to rise at 27 ms and completely replace the plasma core at around 45 ms.

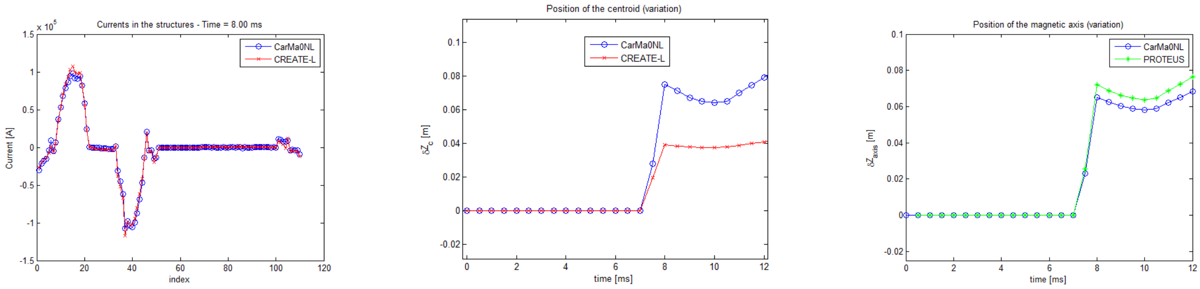

Figure.1: Comparison with axisymmetric codes: currents in the structures and time behaviour of the magnetic exis vertical position

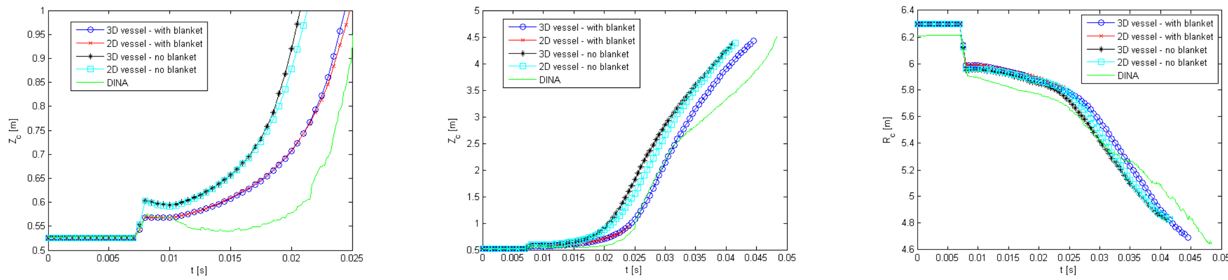

Figure.2: Time behaviour of the plasma centroid position during MD-UP disruption event.

Conclusions

We have analysed one ITER disruptive event (MD-UP) with the CarMa0NL code, including volumetric blanket modules. The results confirm the importance of a correct modelling of such conductors for an electromagnetically self-consistent plasma evolution during the event. Currently, the CarMa0NL code is being complemented with halo currents, in order to allow a more realistic description of the disruptive event. This work was supported in part by Italian MIUR under PRIN grant#2010SPS9B3.

References

[1] T. Hender et al., *Nucl. Fusion* **47** (2007) S128;
[2] S. Miyamoto et al., *Nucl. Fusion* **54** (2014) 083002
[3] F. Villone et al., *Plasma Phys. Control. Fusion* **55** (2013) 095008
[4] M. Sugihara et al., *Nucl. Fusion* **47** (2007) 337
[5] R. Albanese, F. Villone, *Nucl. Fusion* **38** (1998) 723
[6] R. Albanese, J. Blum, O. De Barbieri, *12th Conf. on Numerical Simulation of Plasmas*, San Francisco, 1987