EFDA WORKPROGRAMME 2011

Call for Participation

(Part of the EFDA WP, MHD TG)

Activities under MHD

Deadline for Responses: 4th February 2011

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This Call for Participation aims to implement the EFDA Work Programme for 2011 on MHD under a Task Agreement as foreseen in the new EFDA Article 5.

Introduction

At its meeting in Dublin on 23 June 2010, the EFDA Steering Committee approved the elements of the EFDA 2011 Work Programme, among which the MHD programme. This includes the preparation and execution of experiments performed in the Associations and the subsequent coordinated analysis of experimental data.

The 2011 Work Programme in the MHD area is based on three “cross-cutting” initiatives:

1. “MHD control and mitigation“,
2. “Three dimensional MHD and non-linear effects” and
3. “Supra-thermal particle physics”.

In particular, cross-cutting initiative 1 aims at the joint development of modern tools for real time active control of MHD stability, mitigation of MHD off-normal events and the study of the stability of high-beta regimes. Cross-cutting initiative 2 tackles the role of three-dimensional magnetic fields and flows on plasma stability; the search for advanced regimes, and addresses modelling and non-linear MHD; while cross-cutting initiative 3 deals with understanding the role of fast particles on plasma stability.

For the 2011 Work Programme the three cross-cutting initiatives will constitute the guidelines for the implementation of specific tasks, which are built around main open questions.

Resources:

Baseline Support: manpower ceiling of 26 ppy

Priority Support: ceiling of 200 kEuro EC manpower and equipment

The priority support proposals should form well defined projects, with quantitative descriptions of the work to be performed outlining the parameter range of the experimental or/and theoretical investigations, novelty compared with previous work and a detailed description of the deliverables.

1. MHD CONTROL AND MITIGATION

Task Agreement WP11-MHD-01:
MHD CONTROL AND MITIGATION

1.1 Aim of the initiative

This initiative aims at improving and expanding the knowledge base on active control of MHD stability to improve plasma performance and to access advanced scenarios, and on active prediction, detection, avoidance and mitigation of off-normal MHD events in fusion devices with particular emphasis on ITER issues. Activities are driven by the following two main questions:

a) Which are the tools to improve our understanding of disruptions and our capability to control them?

b) Which are modern and efficient paths to develop active control of MHD stability?

1.2 Objectives

This initiative is implemented with two activities.

Advancing understanding and control of disruptions and mitigation of their effects on wall and structural components

The objectives of this activity deal with modelling, design of new diagnostic and experiments in existing devices.

Modelling. The key tool for understanding disruptions is an integrated model, in particular including a full runaway description.

This activity aims at fostering the development of this integrated modelling, which includes:

- *Improved runaway modelling capability*, with particular emphasis on (i) Integration of primary and secondary generation mechanisms in a 2d runaway code, with ITER relevant parameters and with predictive capability; (ii) Ability to model runaway onset and early development in the context of evolving plasma conditions (e.g. rising loop voltage, changing profiles and shape). (iii) Prediction of runaway energy spectra at realistic plasma parameters. (iv) Initial development of a 3d runaway beam evolution code, in which full physics and inputs from other processes will be added later.
- *Full three-dimensional electromagnetic modelling* of disruptions and benchmarking against experimental data (e.g.: vertical displacement events, halo currents, sideways forces, and non-linear mode evolution). In particular, this includes: (i) a DINA replacement code as a flexible and accessible tool with a 2d model of VDE which is machine portable. (ii) The development and application of JOREK code for disruption modelling on various devices. Code

development activities should ultimately aim to provide an integrated code package comprising 3d core plasma dynamic (e.g. M3D, JOREK) and 3d wall response (e.g. CARIDDI).

New diagnostic tools. Carry out feasibility studies and proof of principle experiments for the development of *new diagnostic methods* to characterize disruption dynamics. Following previous consideration, it is clear that better experimental information on runaway electron properties is key. The assessment of the potential of methods measuring Cerenkov radiation, synchrotron radiation and X-ray emission should be carried out. Fast imaging of plasma quantities before and during disruptions is also extremely important, as well as impurity properties with high time resolution, infra-red imaging to diagnose thermal quench and runaway heat loads and bolometry.

Experiments in existing devices. Perform experiments to assess the possibility of runaway mitigation by means of three-dimensional magnetic fields and for the investigation of active termination and mitigation systems.

Modern tools for real time active control of MHD stability and mitigation of negative impact of MHD instabilities on plasma performance

The objectives of this activity concern the development and/or optimization and/or benchmarking of new integrated tools for active control of MHD stability.

Code optimization. Optimization of codes for the analysis of stability at high beta and related feedback control, including realistic plasma and conductor modelling. Integration of MHD stability codes with three-dimensional description of the magnetic front-end, sensors and actuators for feedback. Development of a closed loop simulator of the full plasma-wall-feedback system and benchmark with experimental data.

Three-dimensional boundary conditions. Investigate the influence of a three-dimensional wall and ferromagnetic inserts on plasma stability.

Feedback control. Development of new tools for modelling, implementation and optimization of robust feedback schemes for coil based control systems, including optimization of sensors and actuators, interaction with the plant, controller design and tuning, mode identification, MIMO control models, inclusion of plasma response, sideband effects, advanced sensor-coil decoupling tools.

Control via RF-based systems. Optimization of detection and tracking for real-time resistive and ideal mode stabilization/destabilization. Modelling of island response to localized current drive and comparison with experimental data.

1.3 Work Description and Breakdown

WP11-MHD-01-01:

Advancing understanding and control of disruptions and of their effects

The main aim is the development of a physical model for disruption description and prediction. New diagnostic methods are required to characterise and document runaway generation and plasma profile evolution during disruptions. Active discharge termination and mitigation systems, which guarantee the least possible impact of a disruption have to be developed and tested in present devices, including in particular experiments on runaway electron control.

WP11-MHD-01-02:

Modern tools for real time active control and mitigation of MHD instabilities

This activity aims at the development and/or optimization and/or benchmarking of new integrated tools for active control of MHD stability.

1.4 Scientific and Technical Reports

Milestones and Deliverables

Milestones:

- *Mid 2011:* Activity Meetings: Collection and discussion of results obtained from the evaluation of theoretical work and experiments performed in 2010 and early 2011.
- *End second trimester 2011:* Annual meeting of the Topical Group: coordinated presentation of the results from the theoretical work and experimental campaigns in 2010.
- *December 2011:* Final report sent to EFDA-CSU.

Deliverables:

- Perform and report on the step-wise development towards integrated modelling of disruptions.
- Perform and report on feasibility studies and proof of principle experiments for the development of new diagnostic methods to characterize disruption dynamics.
- Perform and report on experiments and models to assess the possibility of runaway mitigation by means of three-dimensional magnetic field.
- Perform and report on dedicated experiments for the investigation of active termination and mitigation systems.
- Perform and report on optimization of codes for the analysis of stability at high beta and related feedback control, including integration, development of a closed loop simulator and benchmark with experimental data.

- Perform and report on further investigation of the influence of a three-dimensional wall and ferromagnetic inserts on plasma stability.
- Perform and report on the development of new tools for modelling, implementation and optimization of robust feedback schemes for coil based control systems
- Perform and report on Optimization of detection and tracking for RF-based systems for real-time resistive and ideal mode stabilization/destabilization.
- Perform and report on Modelling of island response to localized current drive.

2. THREE-DIMENSIONAL MHD AND NON-LINEAR EFFECTS:

Task Agreement WP11-MHD-02: THREE-DIMENSIONAL MHD AND NON-LINEAR EFFECTS

2.1 Aim of the initiative

This initiative aims at promoting integrated efforts to advance the knowledge in the field of non-linear MHD and of the effect of three-dimensional magnetic fields in plasma stability. The main objective of the initiative is to provide an opportunity for developing interdisciplinary tools and sharing resources for the investigation of different topics in three-dimensional MHD physics. The activities performed should aim at answering the following questions:

a) Are we able to provide a reasonable description of non-linear MHD stability?

b) Are we ready to cope with three-dimensional effects in our plasmas?

2.2 Objectives

This initiative is implemented with two activities.

Modelling and probing non-linear MHD stability

Non-linear resistive MHD simulations. The continuation of step-wise development of an advanced three-dimensional non-linear resistive MHD code for the investigation of major MHD instabilities, including NTMs, ELMs, disruptions.

NTM physics. Focused studies on critical aspects of NTM physics: triggering process, role of a primary/triggering mode, advances in scenarios, possibility of “seedless” NTMs, interaction with RWMs, non-linear coupling and the role of critical island width.

High beta regimes. Exploitation of high beta regimes promoting the understanding of MHD stability improving control capability, addressing in particular (i) the role of fast particles and flow on high beta stability, (ii) links and interactions between different modes at high beta and with other source of field errors (i.e. NTM and RWM), (iii) the issue of mode non-rigidity and (v) the imaging/reconstruction of RWM structure. Development of robust methods for probing RWM stability and benchmark of stability codes against experimental data.

New measurements. Improve understanding and the capability of imposing constraints to the codes and benchmark them, starting from experimental devices. It is therefore crucial the extension of the experimental database, in particular on imaging of the resistive instabilities dynamics, like early NTM island development and Sawtooth structure.

Role of three-dimensional magnetic fields and flows on plasma stability and their impact on the development of advanced regimes

Resonant Magnetic Perturbations. Carry out improvement of Resonant Magnetic Perturbations (RMP) as a tool for MHD event mitigation. This includes both numerical and experimental activities. Key topics are the inclusion in the RMP description of the plasma response, in particular as far as the magnetic field ergodisation for a given vacuum perturbation is concerned, and the effect of RMP on plasma rotation. These activities will be complemented with the investigation of the influence of RMP on transport and the development of zonal flows.

Three-dimensional flow. Perform modelling and experiments on rotation braking and plasma response to non-resonant magnetic perturbations. Calculation of Neoclassical Toroidal Viscosity (NTV) with plasma response, in particular, near transition between different collisionality regimes, as well as experimental measurements of the plasma electric field associated with NTV.

Three-dimensional equilibria and shaping. Perform modelling and experiments on the effect of three-dimensional shaping on plasma performance and on MHD behaviour in various plasma configurations.

2.3 Work Description and Breakdown

WP11-MHD-02-01:

Modelling and probing of non-linear MHD stability

Development and optimization of an advanced three-dimensional non-linear resistive MHD code for the investigation of major MHD instabilities. Development on new tools for imaging of the resistive instabilities dynamics. Optimization of our capability of controlling MHD phenomena in fusion plasmas, both in terms of experiments and the *design* of control tools.

WP11-MHD-02-02:

The role of three-dimensional magnetic fields and flows on plasma stability and their impact on the development of advanced regimes

The project aims at fostering the organization of an inter-configuration knowledge basis on the influence of three-dimensional magnetic field and flows on plasma MHD stability, in particular for their exploitation in advanced regimes.

2.4 Scientific and Technical Reports

Milestones and Deliverables

Milestones:

- *Mid 2011 Activity Meetings:* Collection and discussion of results obtained from the evaluation of theoretical work and experiments performed in 2010 and early 2011.
- *End second trimester 2011:* Annual meeting of the Topical Group: coordinated presentation of the results from the theoretical work and experimental campaigns in 2010.
- *December 2011:* Final report sent to EFDA-CSU.

Deliverables:

"Modelling and probing non-linear MHD stability"

- Continuation of step-wise development of an advanced three-dimensional non-linear resistive MHD code.
- Report on studies on critical aspects of NTM physics.
- Report on extension of the experimental NTM database.
- Report on MHD stability in high beta regimes and the capability of controlling it.
- Report on development of robust methods for probing RWM stability and benchmark of stability codes against experimental data.
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"The role of three-dimensional magnetic fields and flows on plasma stability and their impact on the development of advanced regimes"

- Report on studies of Resonant Magnetic Perturbation as a tool for active ELM control.
- Report on the role of three-dimensional flow on the dynamics of MHD instabilities.
- Report on Modelling and experiments on rotation braking and plasma response to non-resonant magnetic perturbations.
- Report on modelling and experiments on the effect of three-dimensional shaping on plasma performance and on MHD behaviour in various plasma configurations.

3. SUPRATHERMAL PARTICLE PHYSICS:

Task Agreement WP11-MHD-03: SUPRATHERMAL PARTICLE PHYSICS

3.1 Aim of the initiative

This initiative aims at promoting activities to enhance knowledge on the behaviour of the population of fast particles (ions in particular) and its influence on MHD on the path towards burning plasmas.

The aims of the initiative are:

1. *To confidently predict fast particle stability boundaries in future devices, including ITER.*

2. *To understand the influence of fast particle populations upon macroscopic MHD modes such as sawteeth and RWMs.*

3.2 Objectives

This initiative is implemented with two activities.

Alfvénic modes.

This aims at improving confidence in predicting fast particle stability boundaries in ITER through experimental validation of models.

Influence of fast ions on resistive and resistive-wall modes.

This activity aims at providing a better description of the role of a population of fast ions on the stability of sawteeth and resistive wall modes and control strategies to destabilize sawteeth.

3.3 Work Description and Breakdown

<u>WP11-MHD-03-01:</u>

Alfvénic modes

Perform further Alfven Eigenmodes damping measurements, with improved hardware if required, and continue development of modelling capabilities.

Perform further code-code and code-experiment comparisons regarding the properties of Alfvénic modes in tokamaks.

<u>WP11-MHD-03-02</u>:

Influence of fast ions on sawteeth and resistive-wall modes

Perform modelling and experiments aiming at a more complete description of the role of fast ions on the stability of sawtooth and resistive wall modes.

Perform experiments aiming at the verification off the possibility for RF schemes (ECRF and ICRF) to destabilize sawteeth in the presence of a significant population of fast ions.

JET related activities

Damping measurements of Alfvénic modes are possible at JET during the Ohmic and L-mode phases of the ILW operation in 2011. Sawtooth control experiments in the presence of a significant population of fast particles on JET are currently not foreseen until C30 (2012).

3.4 Scientific and Technical Reports

Milestones and Deliverables

Milestones:

- *Mid 2011 Activity Meetings:* Collection and discussion of results obtained from the evaluation of theoretical work and experiments performed in 2010 and early 2011.
- *End second trimester 2011:* Annual meeting of the Topical Group: coordinated presentation of the results from the theoretical work and experimental campaigns in 2011.
- *December 2011*: Final report sent to EFDA-CSU.

Deliverables:

- Report on further Alfven Eigenmodes damping measurements, with improved hardware if required.
- Report on further code-code and code-experiment comparison regarding the properties of Alfvénic modes in tokamaks.
- Report on modelling and experiments aiming at the description of the role of a population of fast ions on the stability of sawtooth and resistive wall modes.
- Report on experiments aiming at the verification off the possibility for ECCD to destabilize sawteeth in presence of a significant population of fast ions.