Minutes of the First ITM Working Session on Control Issues

Cadarache, 22-23 June 2009

Participants: Rui Coelho (EDRG PL), Guido Huysmans (IMP1 PL), Frederic Imbeaux (ISIP PL), Didier Mazon, Alfredo Pironti, Nathalie Ravenel, Jo Lister, Karim Besseghir, Sylvain Bremond, Anton Soppelsa, Wolfgang Zwingmann, Gael Selig, Vincent Basiuk, Jean-Francois Artaud, Tommaso Bolzonella.

Preamble: in 2009 several control oriented ITM tasks started. This called for a 2 day, face to face working session, under the framework of task EDRG-T3 "Coordination of control activities", with the specific objectives of promoting a high level of cooperation between the relevant IMPs, propagate information and competencies, elaborating a list of shared priorities and a roadmap in order to embed comprehensive plasma control capabilities within the ITM tools. As sign of close interaction with other EFDA TFs and TGs, the participation of D. Mazon and A. Pironti as representatives of the recently formed EFDA "Feedback control group" was warmly welcomed.

Agenda: To meet these objectives, the agenda was organized into three main parts:

1. general description of all the ITM activities on control represented at the meeting and of control relevant experimental activity;
2. demonstration of existing codes (outside Kepler) that already include control modules.
3. discussion on the present status of the ITM control data structure and on how to upgrade it in view of the established 2009 ITM targets.

What follows is a brief summary of presentations, relevant discussions, final decisions and actions.

Monday, June 22nd

The working session began with a brief welcoming to participants by R. Coelho on behalf of the ITM-TF TFL.

First presentation was by A. Pironti (file 20090622_Pironti.ppt) on "*EFDA "Feedback control group": general information and foreseen activities*". The main objectives of new EFDA group were presented and the possible synergies between the Control Group and the ITM TF were stressed. The part dedicated to define and comment what an integrated control is in a real tokamak in particular stimulated the first intense discussion of the working session.

Second presentation was by T. Bolzonella (file 20090622_Bolzonella.ppt) on "*Summary of existing or newly developed feedback controller(s) schemes on participating experiments*". A report on the same subject is being completed as deliverable of EDRG-T3 task 2009. The presentation summarized the methodology adopted and the most relevant points for ITM emerged from the work done. The presence of several sources of non-linearities in present controllers was highlighted; the common use of commercial tools for software generation in the experimental community was mentioned. As final point the concept of Plasma Control System (PCS) as "operation supervisor" was introduced into the discussion.

Third presentation was by R. Coelho (file 20090622_Coelho_ITMactivities.ppt) on "*Control related activities in the WP-2009*". After a general introduction on the ITM-TF present status and on the its control related wish list, the presentation moved to summarizing to the audience the 2009 control ITM related tasks: EDRG-T3: "Coordination of plasma control activities", IMP1-T2: "Free boundary equilibrium and position/shape feedback control", IMP2-T3: "RWM module", ISIP-T12: "Control Toolbox".

Forth presentation was by G. Huysmans (file 20090622_Huysmans.ppt) on "*IMP#1 task2 kick-off meeting intro*". It basically replicated, but to a different audience, a presentation with the same title given at the beginning of last March. The discussion mainly focused on part "b" of the task ("*Free boundary equilibrium and position/shape feedback control*"). Regarding its deliverables, a first document containing comments on the existing ITM data structures with respect to the requirements for feedback control already circulated; as for the other points additional work is still needed.

Fifth presentation was by N. Ravenel (file 20090622_Ravenel.ppt) on "*Development of a flight simulator for the control of plasma discharges*". It described recent efforts of the CEA group in the direction of implementing a generic framework for the development, test and qualification of advanced control algorithms in present and future devices. This advanced controller will use as much as possible ITM tools and for that reason its development is closely linked to some IPM1 and ISIP 2009 tasks. Different running modes were presented and especially their general representation stimulated questions and discussions. Of particular interest was the question about the general workflow control during such a kind of simulations; it was concluded that Kepler should lead the general workflow once all the tools will be under ITM structures. Another important point raised during the discussion was about the software to be used in the development of the controller: following ITM guidelines, free software (Scilab/Scicos) was chosen. However, it is well known (see also presentation #2) that this is seldom the case in present devices. Some points on reliability and effectiveness of translation tools such as Real Time Workshop (Matlab→C) were raised.

Sixth presentation was by K Besseghir (file 20090622_Besseghir.ppt) on "*Development DINA-CH + CRONOS. Using a full tokamak discharge simulator"*. After a brief historical introduction (given by J. Lister), the main characteristics of DINA-CH coupled with CRONOS as advanced transport solver and source profile calculator were presented. To exemplify the possibilities (and the limitations) of the code, three cases (Free boundary evolution during a VDE; Plasma control; Simulation of a full ITER discharge) were chosen and the runs were presented also as short movies. The actions towards the "keplerisation" of DINA-CH were summarized as well. The presentation resulted very informative and gave the opportunity to further discuss subject such as the relevance of Simulink environment and the different degrees of control needed in a full discharge simulation. Possible steps towards a benchmark of DINA-CH+CRONOS and ITM free boundary code(s) were discussed and could include both open loop and close loop cases (TCV simulations of close loop data could suggest a first relevant example).

A general discussion at the end of the day fixed some clear points:

- Three different control implementations in Kepler were distinguished:
  - standard controller (such as a simple PID);
  - more sophisticated codes with control modules (independent Kepler actors);
  - Discharge supervisor.
- Importance of clearly defining how to lead the general workflow when dealing with full discharge evolution;
- Relevance of the discussion on commercial softwares when a comparison with experimental experience is relevant.
- Importance of the development of adequate diagnostic modeling for real time simulations.

Tuesday, June 23rd

The last half day of the working session was essentially dedicated to discuss how to proceed towards the implementation of control capabilities in the ITM tools.

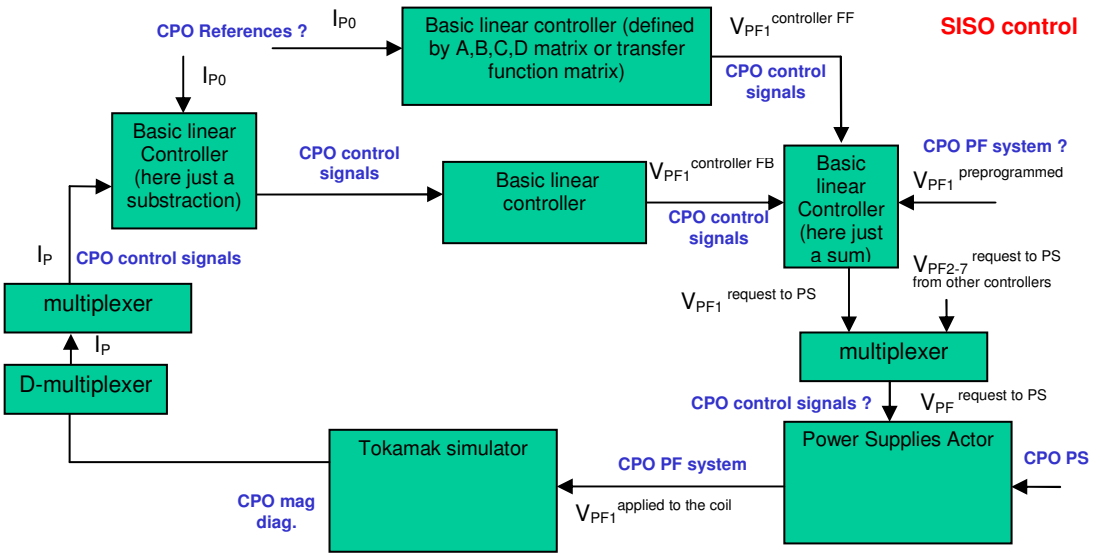
First presentation was by A. Pironti on behalf of several CREATE colleagues (file 20090623_Pironti.ppt) on "*CREATE-NL axysimmetric equilibrium code. Closed loop simulations and integration with transport codes".* The presentation ideally followed the last presentation of the day before, giving an additional example of an existing code already containing control modules. The general architecture of closed loop runs was discussed and some recent developments on coupling with transport were shown. It is probably useful to remember that also CREATE-NL works in a commercial software environment.

Final Discussion and Summary of actions

The final discussion of the meeting was stimulated by a short presentation by F. Imbeaux, (file 20090623_Imbeaux.ppt). A possible workflow example was proposed, the role of references was discussed (stressing the difference between feedback references, feed forward terms and plain open loop control), and, finally, some functionalities of a controller CPO were presented.
A frank and open discussion addressed the previous issues with the intention of deciding a list of shared short term actions.
It was agreed that 2009 activities should start from the implementation of the first type of controller (simple "standard" controller).
Still, even for the simpler case, different possible architectures were discussed, in particular regarding the input structure ("what a controller should know") and the chain of control actions. It was argued that the controller block in Kepler should be a pure control object and somewhat detached of the physics properties, i.e. the usual physics CPOs. This would allow a mathematical treatment of individual signals, as in usual control toolboxes such a Simulink. Therefore it is needed to have a de-multiplexer actor that would extract from a CPO structure a certain number of individual signals. These signals would be transferred to the control by a generic "signal" CPO, containing the description of signals and their values. Signal CPOs can be combined in multiple de-multiplexer actors in order to combine signals from multiple CPOs. This gives the input to the controller. The controller output is also a

signal CPO, which content is then re-distributed by a multiplexer actor in the usual physics CPOs.
This scheme ("signal" CPO + de-multiplexer) requires a development from ISIP/T12 and could be used for any operation requiring to work on individual signals while ignoring the physical context, such as visualisation..

A possible workflow under the KEPLER environment (all boxes are actors) for closed loop simulations was elaborated (see figure below by S. Bremond) in order to stimulate and guide further discussions. The case chosen is relative to a plasma (total) current control simulation. Note that all controllers should also receive the CPO control (that contains in particular the values of the A,B,C,D matrix).



Note that in this view (i.e. in the ITM view) the overall orchestration should be done by Kepler and not by other high level softwares such as Simulink. Discharge PCS will appear then as a "controller of the controllers" inside Kepler.

It was finally agreed to organize a second meeting (with remote participation) shortly before or after the summer break to keep the momentum of the different shared ongoing activities.

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