Fast Model Predictive Control for Magnetic Plasma Control

Kick-off Meeting (24-26 March 2015)

Minutes of the Meeting

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March 24th – Afternoon session (14:30-17:30)

- At beginning of the session **GDT** welcomed the participants and briefly introduced the agenda of the overall meeting

- At the beginning of his presentation on the project organization, **SG** introduced the IJS team, which includes **SG** and **BP,** who are researchers at IJS, and **AD** who is a PhD student working at IJS, currently finishing his PhD

- In his first presentation (slides), SG presented a summary of the proposal, which includes:
    - the **main aim of the proposal**, which is to investigate on the feasibility of MPC for plasma axisymmetric magnetic control and possible extension to the control of resistive-wall modes
    - the background activities, partially carried out in collaboration with **GDT**
        - During the discussion:
            - **AP** pointed out that, in order to specify the scenario, it would be better if the architecture of the control system includes feed-forwards references for the PF currents. **SG** said that PF current feed-forwards can be accommodated in the MPC approach
            - **AP** and **MA** suggested to look also at the total power when assessing the performance of a plasma magnetic control system
            - **AP** commented that the maximum error on the gap control should be constrained/checked, since with linear simulations it may happen that the plasma

enters the wall during the transients, which is not feasible
    - the **objectives of the project** (which correspond to the **main deliverables**)
    - the **available resources** (in terms of manpower and mission costs that can be claimed)
    - the **tentative project schedule** (the project duration is 3 years)
    - a more **detailed plan for the 2015 activities**, which will be mainly devoted to
        - the definition of a reference scenario (including a set of plasma linearized models and reference disturbances) to be used as benchmark
        - the definition of a model for the disturbances to be used in the design of the observer for MPC
        - a conceptual design of the MPC controller
        - the assessment of the performance of the MPC controller by means of simulation against the plasma magnetic control system recently proposed by the CREATE team, and, possibly, by means of nonlinear simulation of a scenario

- In his second presentation (sides), **SG** gave an overview of the state-of-the-art on MPC control, and on possible alternatives for the real-time implementation:
    - The main aim of this ER project is to make a proof of concept that MPC is feasible for real-time control of plasma current, shape and position
    - Since standard MPC is not suitable for the implementation of control systems with sampling time smaller than 0.1s, alternatives that rely on fast solvers must be investigated. The sampling time envisaged for ITER is about 1 ms; the controller sampling times that do not cause obvious performance deterioration are about 0.1 s for plasma shape & current control and about 5 ms for vertical stabilisation. Controller worst-case computation time of less than a tenth of the controller sampling time are desired; in practice, controllers may also be implemented assuming one whole sample for computation, but the performance is impaired compared to that with no computational delay.
    - Iterative solution (given the desired precision) should also be investigated

March 25th – Morning session (10:00-13:00)

- **GDT** gave an overview on the CREATE software tools for modeling of 2D axisymmetric plasma behavior, and for the design of plasma magnetic control systems (slides).
    - During the presentation, the participants agreed that the work will be focussed on control of the flat-top phase (including the final stage of the ramp-up phase) of ITER Scenario 1, where control should be implementable with a single MPC controller or by switching between a small number of local MPC controllers of the same structure based on different local models, and that nonlinear simulations of a set of time windows during an ITER pulse containing the set of disturbances anticipated in the Scenario will be useful to assess the performance of the MPC control system

- In his presentation **AP** presented the recent results achieved by the CREATE team for the axisymmetric plasma magnetic control of the ITER tokamak (slides). All the recent studies were performed on a specific reference scenario, and a control strategy from the plasma formation up to the end of the ramp-down was proposed. CREATE proposed to consider this reference scenario as benchmark for the project activities.

- **MA** presented the proposal recently made by the CREATE team of an integrated solution for the control of the plasma vertical instability and of the resistive wall modes in ITER (slides)

March 26th – Morning session (10:30-13:00)

- The participants agreed to use the scenario recently considered by the CREATE team as reference - **ACTION→ CREATE will send the scenario data to IJS. This data includes, the linearized models, the feed-forwards waveforms for the PF current, the reference disturbances**. This action has been closed on March 30th by **AP**

- **AP** discussed some modeling details related to neglecting the plasma resistance. Indeed the resistance of the plasma acts as a disturbance on the plasma, affecting the current in the PF coils. As a consequence of having a plasma resistance not equal to zero, the currents in the PF coils ramp to generate the so-called transformer field.

    - **SG** asked if it is possible to include the effect of the plasma resistance in the linear simulation, and **AP** showed how to do that, that is by adding an additional contribution to the input

voltage equal to $I_{Pnominal}*\delta R_p$, where $I_{Pnominal}$ is the nominal value of the plasma current, and δR_p is the variation of the plasma resistance (whose nominal value is supposed to be equal to 0)

March 26th – Afternoon session (15:30-16:30)

- As conclusion of the KoM, the participants have revised the actions to be carried out in the next future. The following list of actions were agreed:

    a. **CREATE** Send scenario data to IJS (CREATE) → by 1/4/2015 CLOSED

    b. **SG** (as project leader) ask for credentials for the project wiki for all the members of the project team, which at the moment includes MA, AD, GD, SG, BP, and AP → ASAP

    c. **GDT** will prepare a first draft of the KoM minutes → ASAP

    d. **GDT** will update the wiki → ASAP