# Px-2.1.7 - Application of the Current Limit Avoidance in condition of low disruption probability and low forces at disruption

Gianmaria De Tommasi[1]

R. Albanese F. Maviglia A. Pironti F. G. Rimini

[1]EURATOM/ENEA/CREATE, Università di Napoli Federico II

detommas@unina.it

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# Outline

# The Current Limit Avoidance System - 1

- The Current Limit Avoidance System (CLA) has been recently designed and implemented **to avoid current saturations in the poloidal field (PF) coils when the eXtreme Shape Controller (XSC) is used to control the plasma shape**
- The XSC allows the SLs to directly specify the target shape, without specifying the PF current waveforms
- The PF current waveforms are *automatically* computed by the model-based control algorithm
- The PF currents may saturate during the experiment

- PF currents saturations may lead to
  - **loss of plasma shape control**
  - **pulse stop**
  - **high probability of disruption**

# The Current Limit Avoidance System - 2

- The CLA uses the redundancy of the PF coils system to automatically obtain almost the same plasma shape with a different combination of currents in the PF coils
- In the presence of disturbances (e.g., variations of the internal inductance $l_i$ and of the poloidal beta $\beta_p$), it tries to avoid the current saturations by "relaxing" the plasma shape constraints
- The CLA implementation project has been successfully closed in Dec 2011 and all the project details can be found on the **CLA Project Wiki Page**

▸ CLA Project wiki page

## The CLA Tools

- The *CLA Tools* are a set of Matlab/Simulink graphic applications developed to ease the design and validation of a *CLA scenario*
- The CLA Tools extend the capabilities of the *XSC Tools* that were developed to assist the development cycle of the XSC at JET
- The CLA scenario is stored as a *configuration file* (text file), and can be used
  - to perform validation via closed-loop simulations
  - to setup the real-time C++ code running on the plant system

- **Main message: in order to use XSC+CLA a scenario must be developed (the configuration should be fixed about one week in advance)**

The main aims of Px-2.1.7 are:

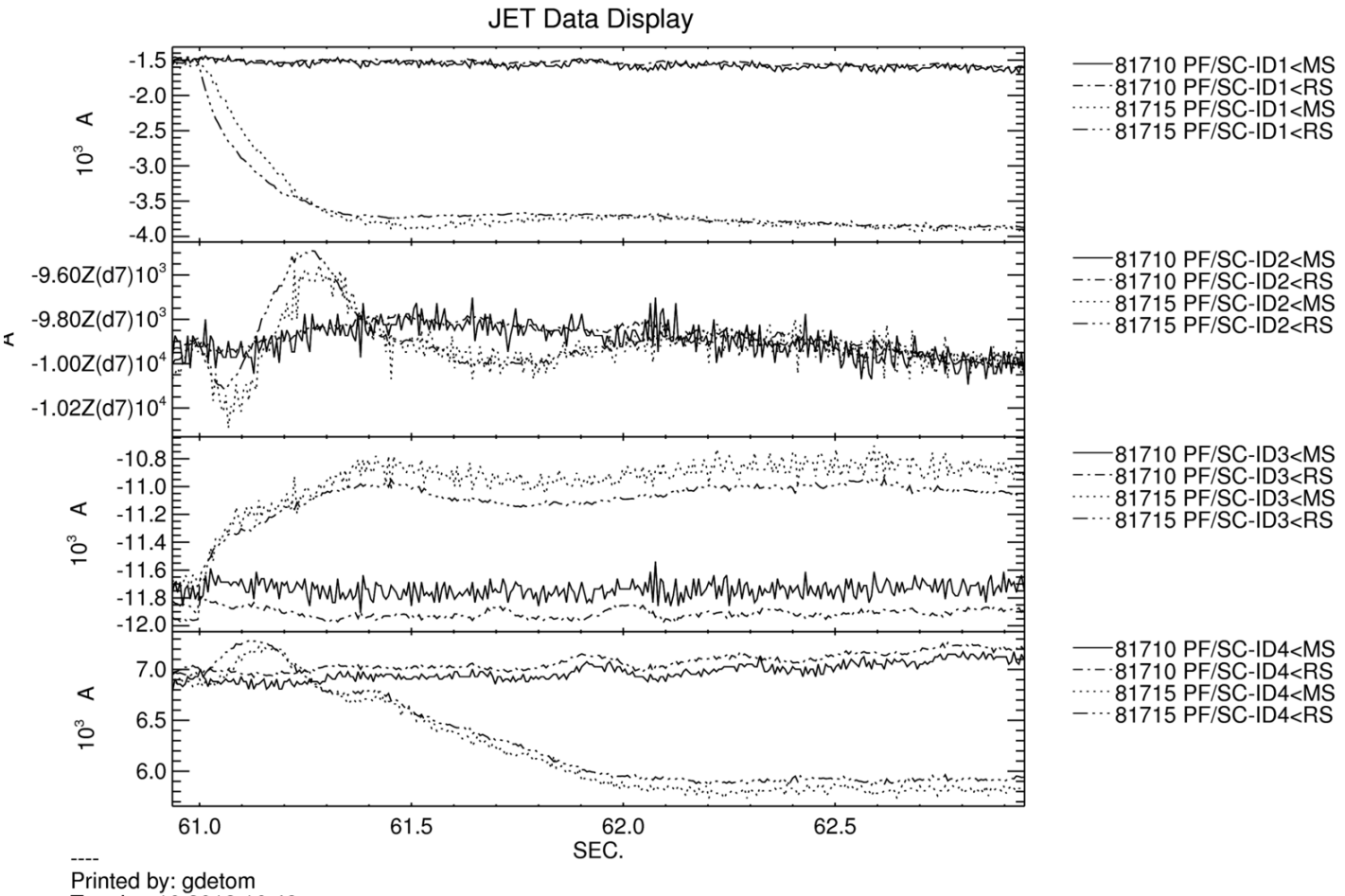
- apply the CLA to realistic plasma scenarios in condition of low disruption probability and low forces at disruption
- show that the CLA can enlarge the operational space of the XSC
  1. when the nominal currents in the PF coils are close to their limits and XSC has no margin for plasma boundary control
  2. when large variations of $\beta_p$ and $l_i$ push the currents requested by the XSC close to their limits

# The first proposed experiment - January 2012

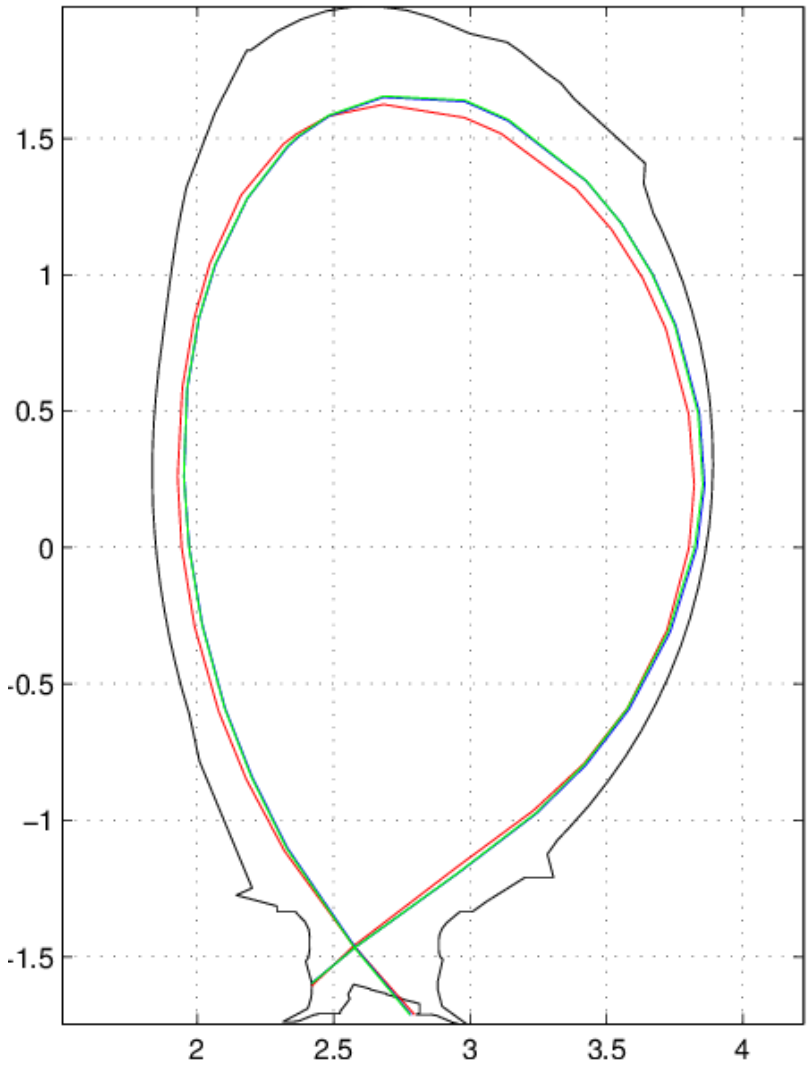
- The *Experiment #1* of Px-2.1.7 was carried parasitically to Restart 4 on January the 9th 2012
- During commissioning pulse #81078 the **four divertor currents were limited** and **a soft stop was triggered due to the error on plasma shape**
- The XSC and CLA behavior were reproduced in simulation and it was shown that the problem was due to non-optimal weights of the CLA cost function
- A new CLA scenario was designed to solve this problem, by tuning the parameters of the cost function
- **The limitation of the four divertor coils represents a severe constraint for plasma shape control**
- Experiment #1 was aimed to repeat pulse #81078

# The currents in the divertor coils

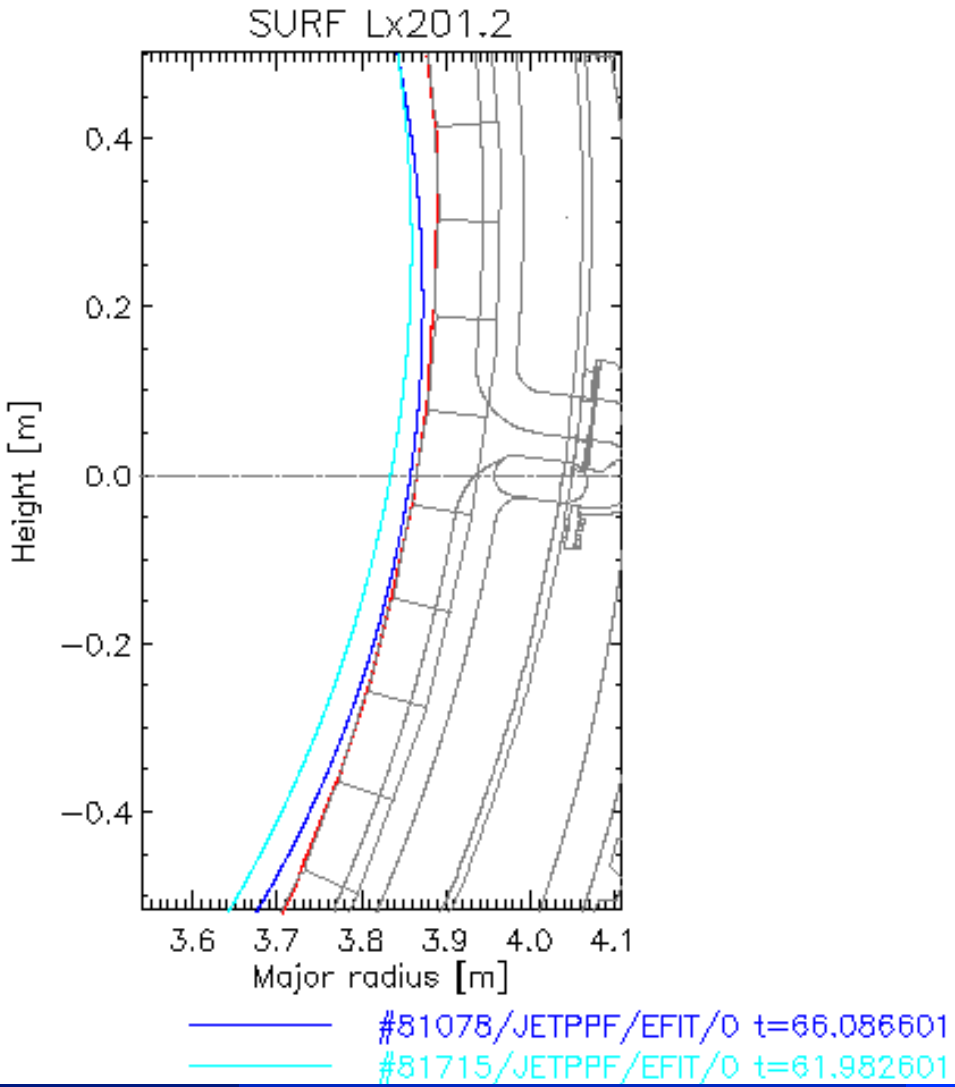
- $I_{D1}$ in $[-16.5, -4]kA$
- $I_{D2}$ in $[-31.45, -10]kA$
- $I_{D3}$ in $[-11, -2]kA$
- $I_{D4}$ in $[0, 6]kA$



# #81715 - plasma shape @63s



# Comparison between #81078 and #81715



## Experiment #2

- We propose to exploits the CLA to perform the plasma current ramp-down with the XSC
- This experiment is aimed to perform a preliminary assessment of the CLA performance during a variation of $l_i$
- Before the experiment the following preliminary work is needed
  - The XSC/CLA scenario to be used during the current ramp-down should be designed and tested in simulation
  - The new XSC/CLA should be commissioned (POG procedure, one 1s time window is needed to do that before the current ramp-down)
- **IF THE XSCD1F_V5_4M5_LT_V2-v1.3.cfg SCENARIO CAN BE USED DURING THE CURRENT RAMP-DOWN, THE DESIGN AND COMMISSIONING OF A NEW SCENARIO IS NOT NEEDED!**

# Experiment #2 (cont'd)

In order to perform the experiment

- **2 time windows** with the XSC/CLA enabled are needed:
  - the first time window should last 1s and should be placed 1s before the ramp-down, in order to reach the desired configuration
  - the second should be placed during the current ramp-down
  - At least a 1 MA variation of the plasma current is required during the second time window (e.g. from 2 MA to 1 MA). The slope of the variation must be chosen by the Session Leader.

- Other details are listed on the Px-2.1.7 Wiki Page

  ▸ Px-2.1.7 Wiki Page

## Experiment #3

- The **JET pulse #78668 at** $t = 53.4\ s$ is used as **reference** to develop a dedicated scenario (at lower plasma current)
- The aim is to **demonstrate that the CLA permits to improve the performance of the XSC in most of the critical cases when the PF currents are close to their limits**
- In the reference scenario the equilibrium values currents in PFX and in the SHP circuits are very close to their limits
- The CLA can be used to limit the currents in both the PFX and the SHP circuits

## Experiment #4

- The **JET pulse #74177 at** $t = 48.8\ s$ is used as **reference** to develop a dedicated scenario (at lower plasma current)
- The aim is to **demonstrate that the CLA permits to enlarge the operational space of the XSC**
- In the reference scenario the plasma current is limited by the current in the D2 circuit, which is close to its saturation limit
- The CLA can be used to to increase the plasma current without, keeping the current $D2$ within the limits

# Proposal for advanced/hybrid scenarios

- Advanced/hybrid scenarios developed with standard SC, can be developed also with XSC/CLA
- Experiments could be dedicated to validation these XSC/CLA scenarios in case of large excursion in $\beta_p$ and/or $l_i$.