Plasma shape control with XSC during the ramp-up and ramp-down phases

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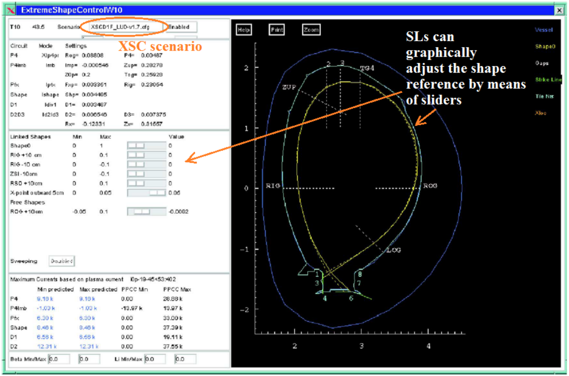
Outline

1. Px-2.1.7 – Backgrounds
2. Shape control during I_p ramp-up
3. Shape control during I_p ramp-down

XSC and CLA



- 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
- The Current Limit Avoidance System (CLA) has been recently designed and implemented **to avoid current saturations in the PF coils when the XSC is used to control the plasma shape**

Aims of Px-2.1.7

The main aims of Px-2.1.7 are:

- to apply the CLA to realistic plasma scenarios in condition of low disruption probability and low forces at disruption
- to 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 β_p and l_i push the currents requested by the XSC close to their limits (**variations of I_p, l_i and β_p are seen as disturbances by the plasma shape control**)

Px-2.1.7 - Experiment #2 - 18 May 2012

- The early session on Friday 18th May was aimed to study the behavior of XSC+CLA during plasma current ramp-up and ramp-down
- This session was aimed to perform a preliminary assessment of the CLA performance during a variation of l_i
- **As important "by-product", the first pulse ever in full XSC control has been run** ▸ Jotter pulse 83014
- More details (pulse list, comments, etc.) can be found on the ▸ wiki page

Comparison between SC and XSC

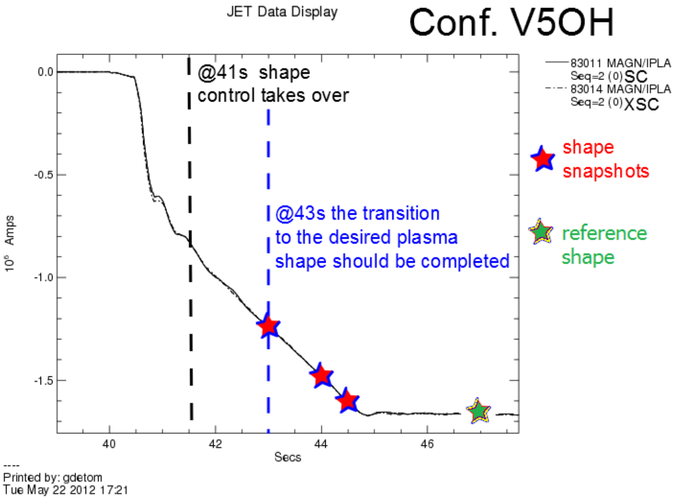
The following pulses are considered in order to compare the behavior of the two plasma shape controllers during the I_p ramp-up

- #83011 – with SC
- #83014 – with XSC

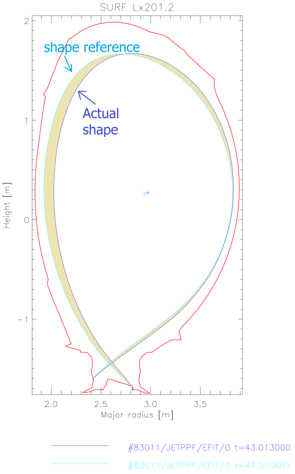
while the comparison during the I_p ramp-down is done considering the pulses

- #72203 – with SC
- #83014 – with XSC

Pulses #83011 and #83014 - I_p ramp-up



#83011 - Shape tracking during the ramp-up with SC



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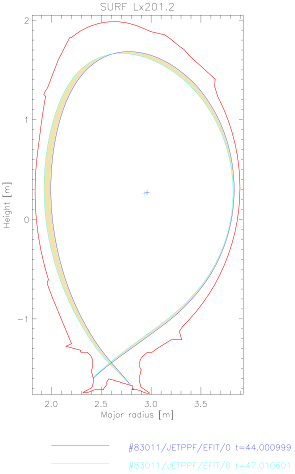

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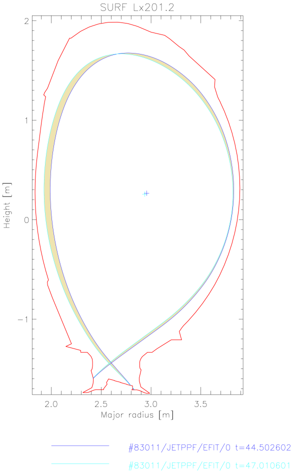
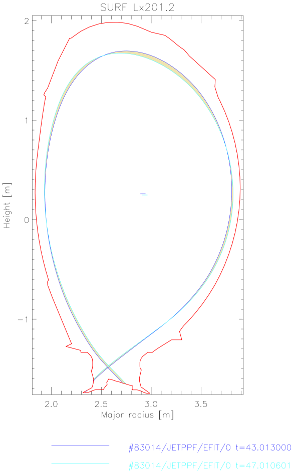


@44.5s

#83011 - Comments

- Bad shape control in the inner side.
- This is mainly due to the fact that P4 is used to control ROG, while RIG is not controlled

#83014 - Shape tracking during the ramp-up with XSC



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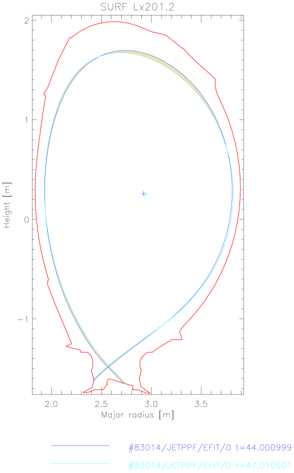

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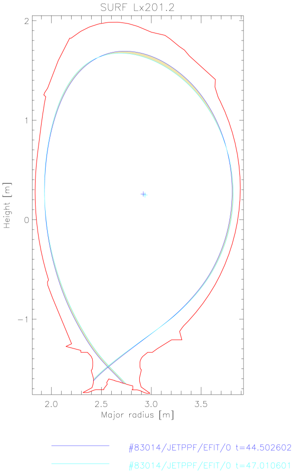
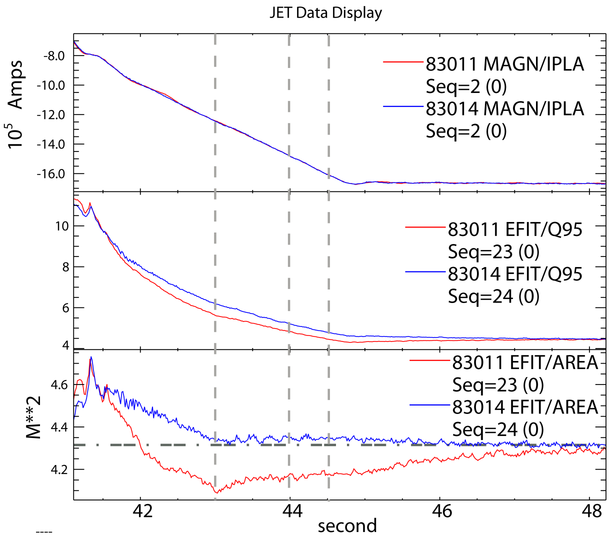


@44.5s

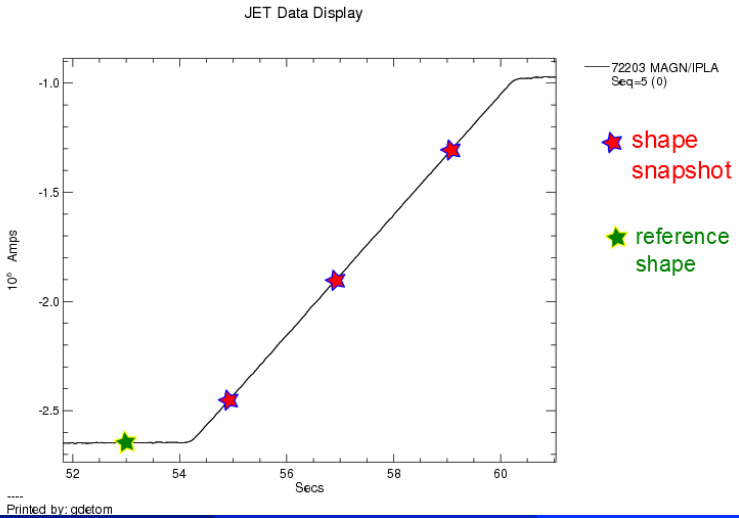
#83014 - Comments

- The biggest error in shape control is in the top outer region (remember the XSC minimizes the shape error in least mean square sense!)
- This error could be reduced by increasing the error in a different region (i.e. in the divertor region)
- Good shape tracking in both RIG and ROG regions, and good tracking of strike points and x-point position
- **By using the XSC the transition time can be further reduced, i.e. the desired plasma shape can be achieved about 1s earlier during the ramp-up (at 42s)**

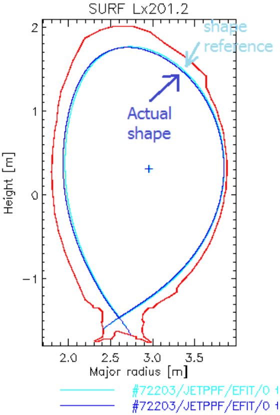
Plasma surface and q95



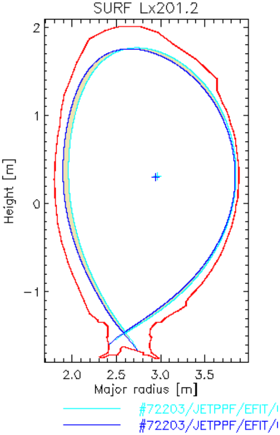
Pulse #72203 - I_p ramp-down with SC



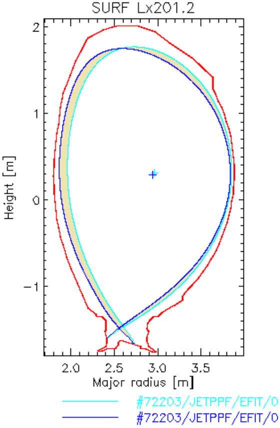
#72203 - Shape tracking during the ramp-down with SC



@55s

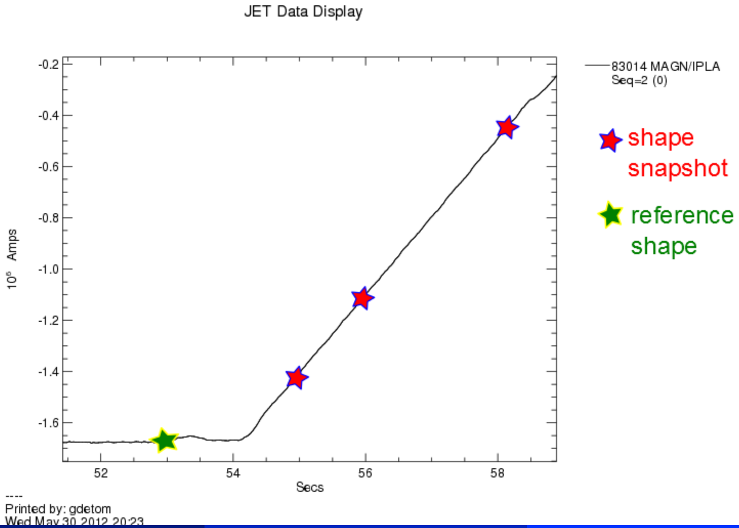


@57s

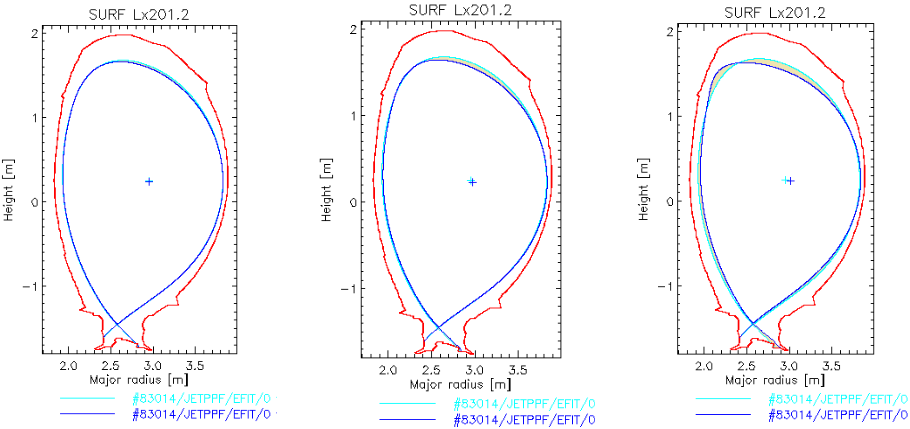


@59s

Pulse #83014 - I_p ramp-down with XSC



#83014 - Shape tracking during the ramp-down with SSC



@55s @56s @58s

Comments

- Also during I_p ramp-down, XSC has demonstrated to better controls the shape
- As for the use of the CLA during the ramp-down (when PF currents approach 0), the following preliminary considerations **need to be further investigated**:
  - the use of CLA with 0 low limits seems to delay the soft stop, hence to enlarge the XSC operational space
  - this improvement seems increase when the derivative of I_p is increased

Conclusions

- By using XSC a better control of plasma shape can be achieved during both I_p ramp-up and ramp-down
- Thanks to the CLA safe operations are guaranteed
- **Although only ohmic ramp-up/ramp-down have been run with XSC, simulations have been performed also for high confinement scenarios with β_p variations**
- **The use of XSC+CLA is recommended during I_p ramp-up and ramp-down, where large variations of I_p, l_i and β_p are expected**

Reference

eXtreme Shape Controller (XSC)

M. Ariola and A. Pironti
Plasma shape control for the JET tokamak
IEEE Control Systems Magazine vol. 25, no. 5, pp. 65–75, Oct. 2005

G. De Tommasi et al.
XSC Tools: a software suite for tokamak plasma shape control design and validation
IEEE Transactions on Plasma Science, vol. 35, no. 3, pp. 709–723, Jun. 2007

Current Limit Avoidance (CLA)

G. De Tommasi et al.
Nonlinear dynamic allocator for optimal input/output performance trade-off: Application to the JET tokamak shape controller
Automatica, vol. 47, no. 5, pp. 981–987, May 2011.

G. Varano et al.
Performance assessment of a dynamic current allocator for the JET eXtreme Shape Controller
Fusion Engineering and Design, vol. 86, no. 6-8, pp. 1057–1060, Oct. 2011.

G. De Tommasi et al.
A Software Tool for the Design of the Current Limit Avoidance System at the JET tokamak
accepted for publication on *IEEE Transactions on Plasma Science*, May 2012.