NSTX-U

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Automatic Rampdowns

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and the NSTX Research Team

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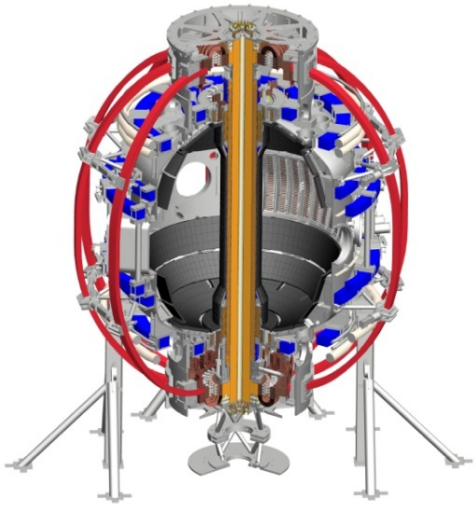

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Motivation for My Proposal

- NSTX Experience:
  - There was no automated rampdown of the plasma current, or any even semi-controlled termination of the discharge.
  - There were a handful of shots with painstakingly hand-tuned rampdowns for the particle retention JRT.
  - Coil protection was essentially limited to overcurrent/overheat/overtime.
- Why is NSTX-U different?
  - We now have a digitial coil protection system, which will compute all sorts of forces & stresses in realtime.
  - The passive plates are approaching their limit of strength for current quenches following a 2MA VDE.
  - If we run NSTX-U the same as we ran NSTX, we will be tripping the DCPS on a large fraction of our shots.
- Goal of this XP:
  - Define a very basic rampdown scenario that can be appended to *ALL* of our shots.
  - My priorities:
    - Limit PF transients from shape, S.P., and vertical position control (#1)
    - Eliminate VDEs (#2)
    - Ramp down the magnetic stored energy (#3)
    - Ramp down the thermal stored energy (#4)
  - I do not care if these rampdowns are not ITER/FNSF relevant.
    - This would complement any XPs dedicated to rampdown physics.

Software Spec. has been Drafted

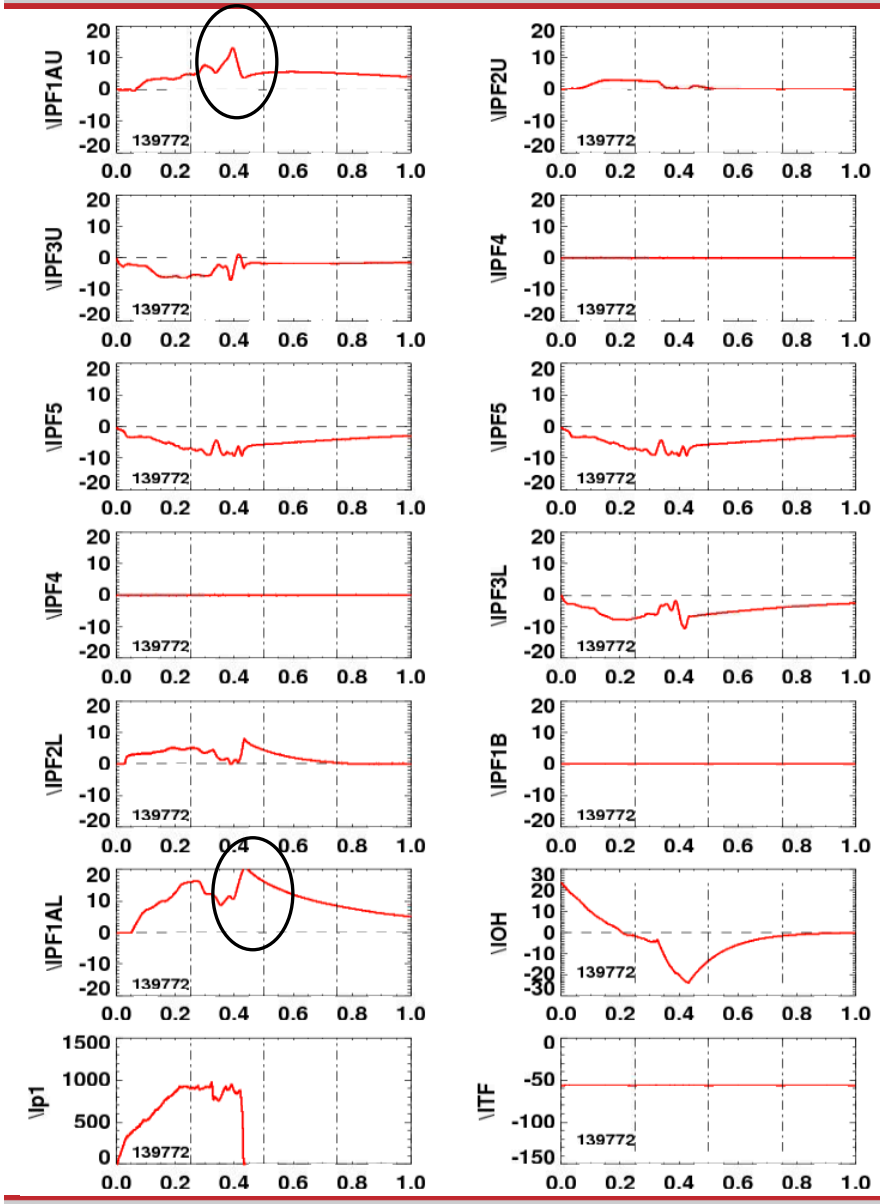
- Bring a subset of highly reliable realtime signals into the system category, and use these to assess if a shutdown should be initiated.
  - I_P error, $B_{P,n=1}$ amplitude, vertical motion detector, operator trigger,…
  - This is all perfectly well defined at this point…read the spec.
- When it is initiated, make specific changes in a number of other categories (this part is less well specified at present):
  - I_P-OH: ramp down the plasma current over a predefined duration.
  - System: transition to shape category control of the PF voltage requests
  - Shape: Limit on the inner wall.
  - NBI: turn the beams off (probably just immediately off at first).
  - RWMEF: Turn the SPAs off
  - GIS: less sure…
- Note: this is NOT a general exception handling mechanism.
  - We should look into that, but I don't want to bog this down.

General Plan Towards an XP

- Need to finalize the software requirements, especially for the phase transitions.
  - I could use some practical help in assessing how the system and shape category phase transitions should be handled from a PCS specific perspective.
- Finish code.
- Run in the background: check it is alive
- Run the XMP: just to check that the most basic functions work.
- Optimization within this XP:
  - Pick an H-mode scenario of interest (probably the fiducial, whatever that ends up being).
  - Using the operator trigger, spend ~10 shots optimizing the rampdown for the allowed parameters (I_P ramp-rate, shape change timing,…).
  - Deliberately trigger disruptions (n=1 fields, turning off vertical control), and see system respond (5 shots).
  - Then append rampdown scenario to a second scenario of interest (5 shots).

Backup

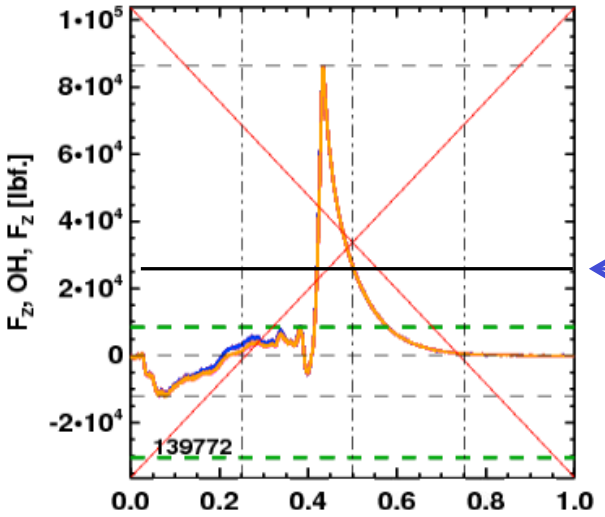
Semi Random Example #1: F_Z on OH Coil



Shot with strike-point control on.

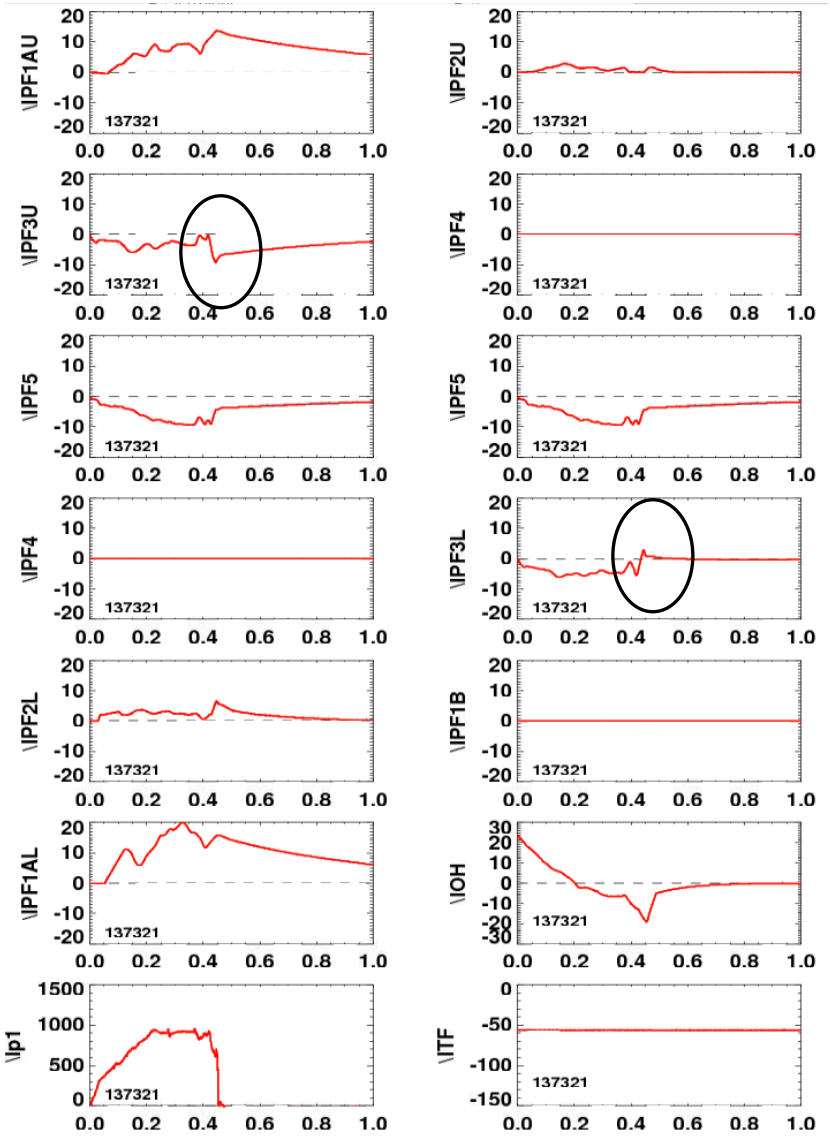
Large asymmetry in the PF-1a currents.

Easily leads to excessive vertical force on the solenoid.

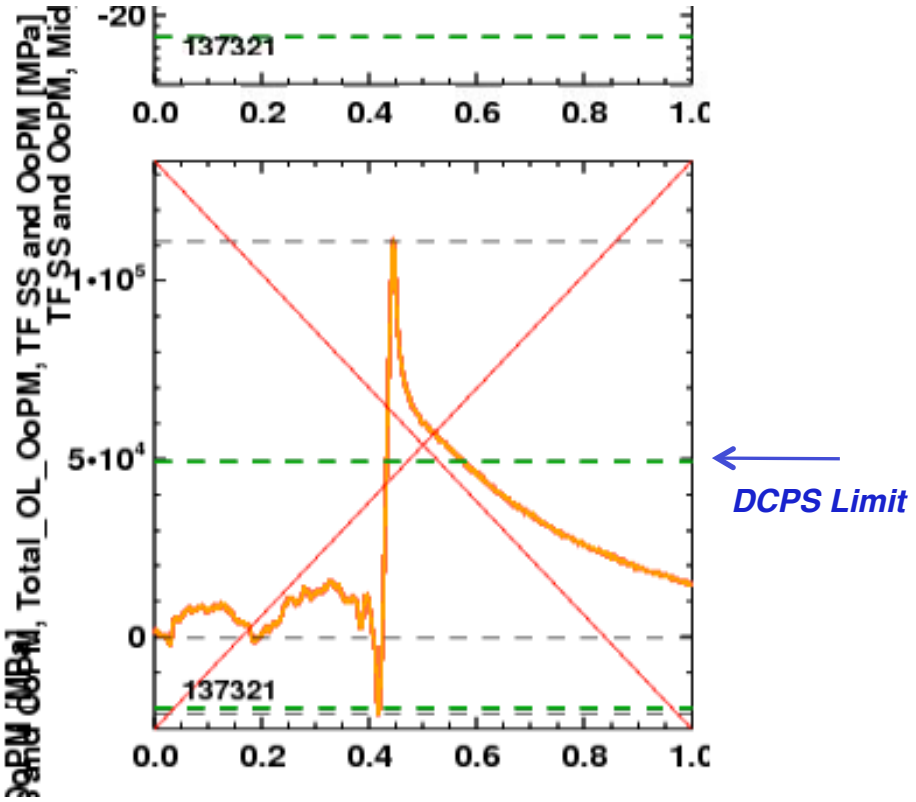


Design Limit is 20k-30k lbs.

Semi Random Example #2: Total Outer Leg (OL) Out of Plane Moment (OoPM)



SPG Comments
Again, large force set by transient response (PF-3U/L)



You Must Carefully Identify Your Goals for a Rampdown XP

- With pre-programmed rampdowns:
  - You can:
    - Study transport and MHD physics in great detail.
      - Like Steve is proposing.
    - Make nice "trophy" examples
      - And this does have value moving forward.
    - Support specific XPs.
      - Like Charle's particle retention XP in the past
  - You can't:
    - Reduce the number of disruptions
      - Because you will be deciding ahead of time when to program the rampdown.
    - Transfer the capability from shot to shot
      - Or at least, it will take a lot of work.
    - Limit forces on the machine
- With automated rampdowns:
  - You can:
    - Limit forces
    - Reduce disruption rate
      - ***assuming*** that you are willing to count rampdown disruptions separately from those where no action is taken.
  - You can't:
    - Guarantee that the rampdowns will be clean
    - Ensure that they will be scientifically interesting.

Motivation for My Proposal

- NSTX Experience:
  - There was no automated rampdown of the plasma current, or any even semi-controlled termination of the discharge.
    - If the solenoid reached the current limit, then it brutally took the OH current back to zero
      - Steve Jardin is looking at one of these cases I believe.
    - Beams only turned off when I_P dropped beneath 200(?) kA.
  - There were a handful of shots with painstakingly hand-tuned rampdowns for the particle retention JRT.
  - Coil protection was essentially limited to overcurrent/overheat/overtime.
- Why is NSTX-U different?
  - We now have a digitial coil protection system, which will compute all sorts of forces & stresses in realtime.
    - And if any limit values are exceeded, it results in an immediate shutdown of the coil systems.
  - The passive plates are approaching their limit of strength for current quenches following a 2MA VDE.
    - So we should learn how not to have VDEs.
  - If we run NSTX-U the same as we ran NSTX, we will be tripping the DCPS on a large fraction of our shots.
    - And then have to beg for resets after each one…
- Goal of this XP:
  - Define a very basic rampdown scenario that can be appended to *ALL* of our shots.
    - Includes both the disruption detection and the rampdown response
  - My priorities:
    - Limit PF transients from shape, S.P., and vertical position control (#1)
    - Eliminate VDEs (#2)
    - Ramp down the magnetic stored energy (#3)
    - Ramp down the thermal stored energy (#4)
  - I do not care if these rampdowns are not ITER/FNSF relevant.
    - This would complement any XPs dedicated to rampdown physics.