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XMP 68: First Use of Simultaneous PF-4 & PF-5 With Plasma
XP 1058: Impact of Outer Squareness on High-kappa Discharge Performance

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2010 NSTX XP-XMP Group Review, ASC
Room B-318
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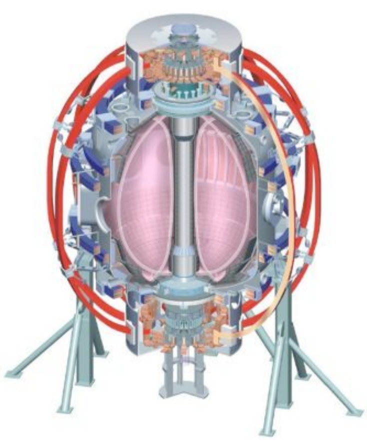

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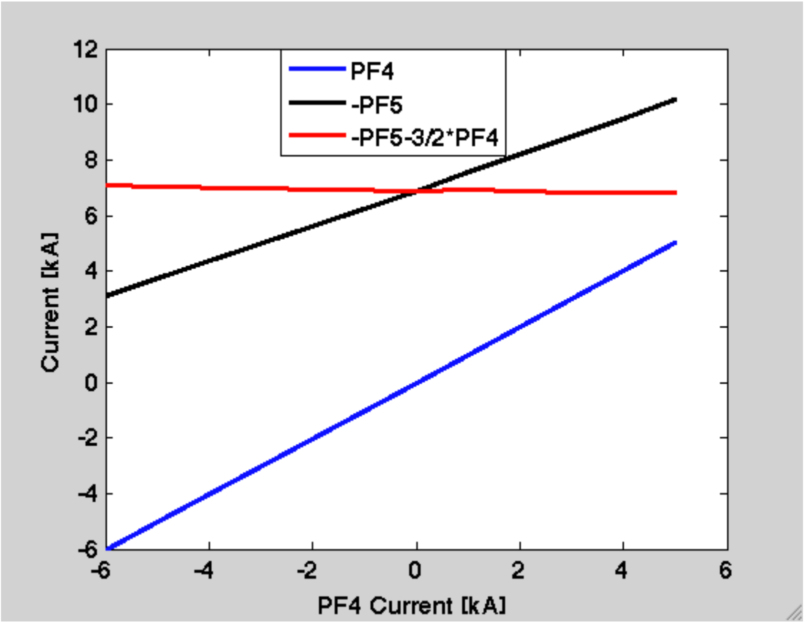
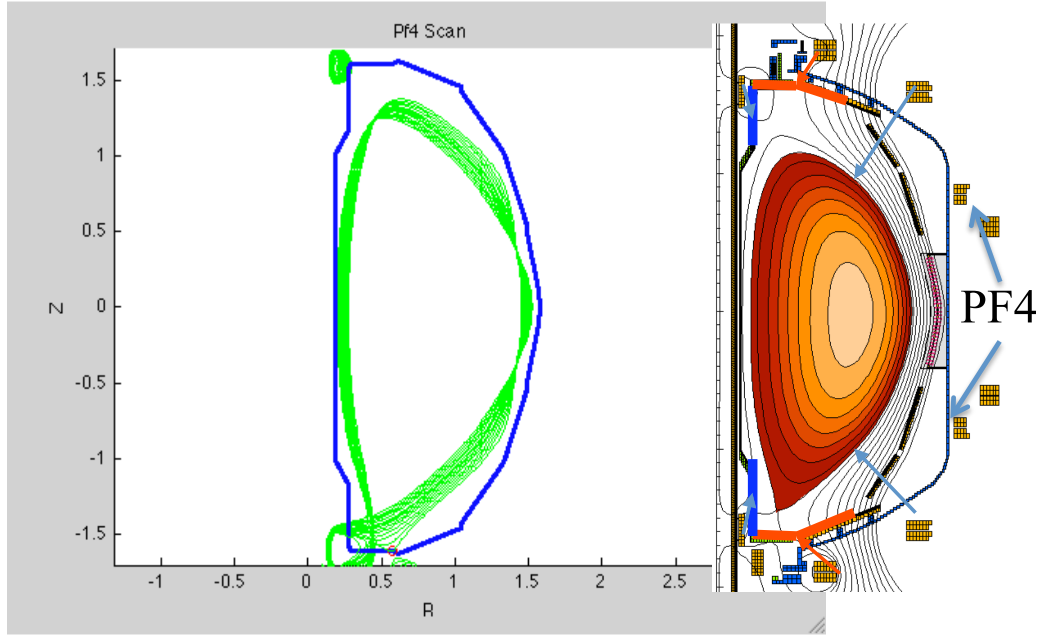
Effect of PF4 without X-Point Control

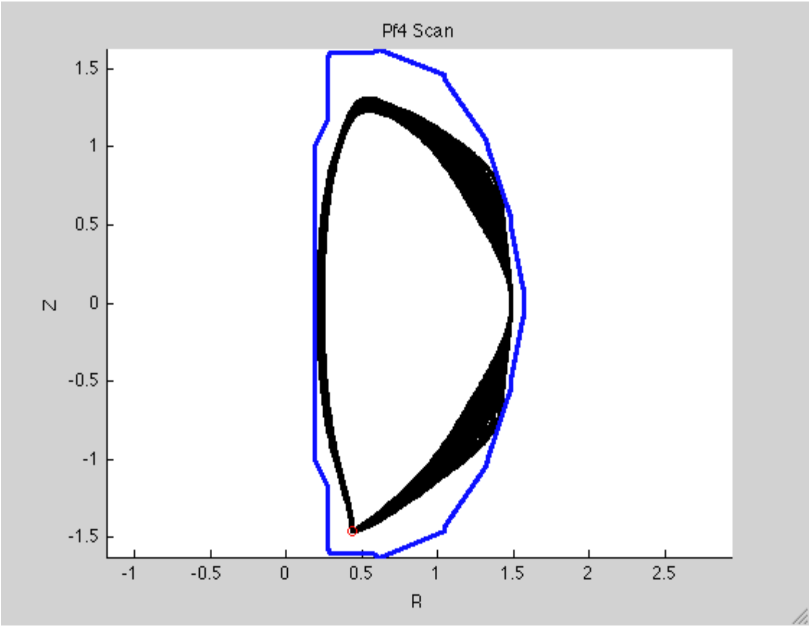


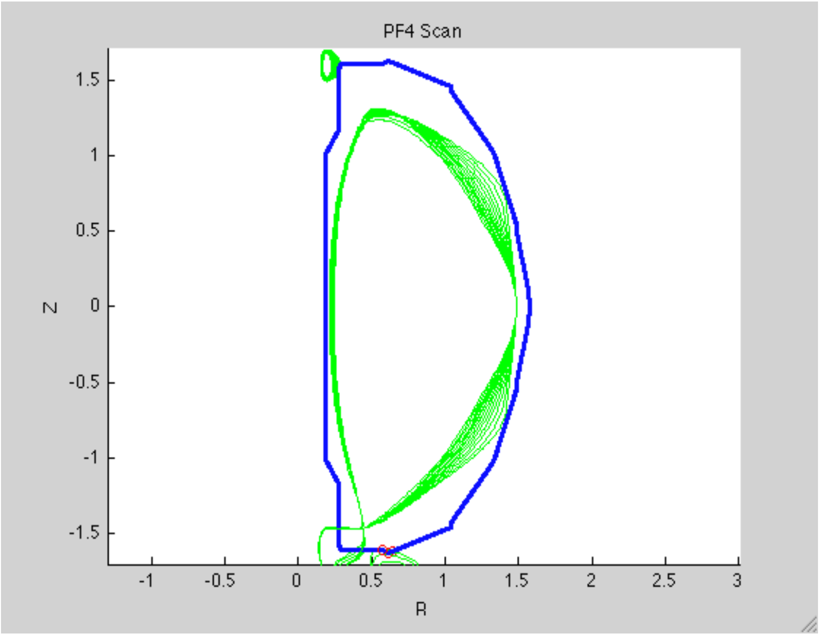


PF4 Scan from -6 kA to +7 kA

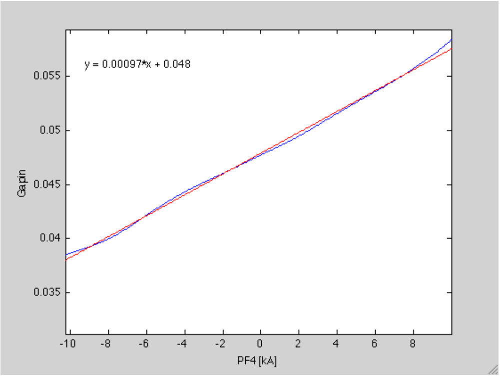
- Keep all the coil currents same other than PF5
- Change PF4 only
- PF5 compensates for PF4 by increasing 3/2*PF4 to keep the plasma in the vessel.
  - ΔPF5 = -1.5*ΔPF4

Effect of PF4 with X-point/Outer Gap Controller On



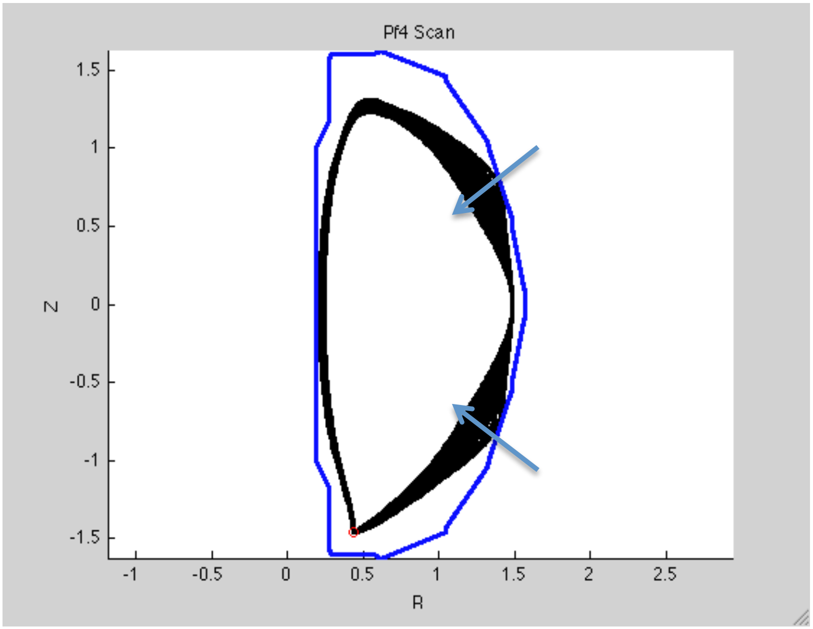


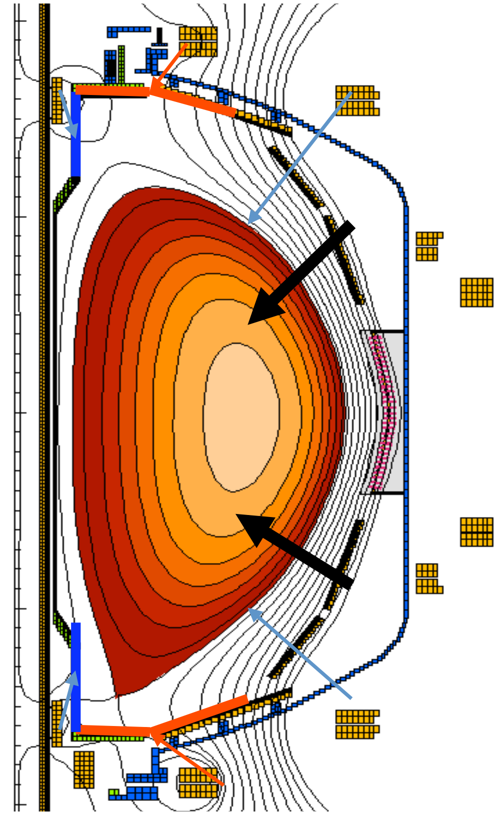
PF4 Scan from -10 kA to +10 kA



- PF1 and PF2 stays roughly constant.
- PF5 shows the same -1.5*ΔPF4 behavior.
- Minimal compensation in PF3: ΔPF3 = 0.15*ΔPF4
- We can change squareness while keeping the other parameters cons
- Inner gap moves minimally (~1 mm) for 1kA change in PF4.

How to Proceed?





Choose Segment Along the Highest Change Direction.

- Add a new segment to control squareness with PF4.
- Keep everything else the same for first XP.
- We can move the segment for PF3 inwards to give more leeway to PF4 if needed.
- Once the control works, do a squareness scan.

XMP: Test PF4 working with PF5 in the loop

- The successful completion of this procedure will have:

1) Demonstrated use of the PF4 coil during a plasma discharge using the “gap-control” algorithm. In this case, PF5 will be used to control the outer gap, while the PF4 is pre-programmed.

2) Demonstrated that rtEFIT correctly calculates the plasma equilibrium when PF4 is energized.

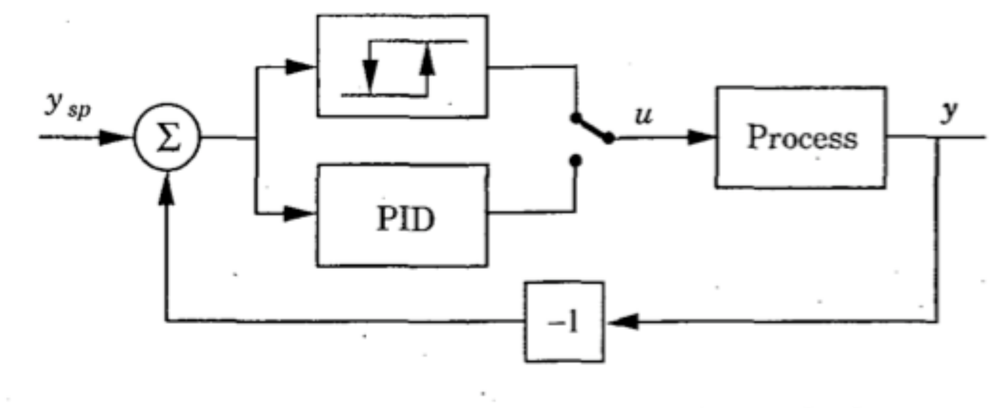
3) Demonstrated use of PF4 in isoflux control. This will verify that the line segments and process by which voltage requests are generated are working correctly.

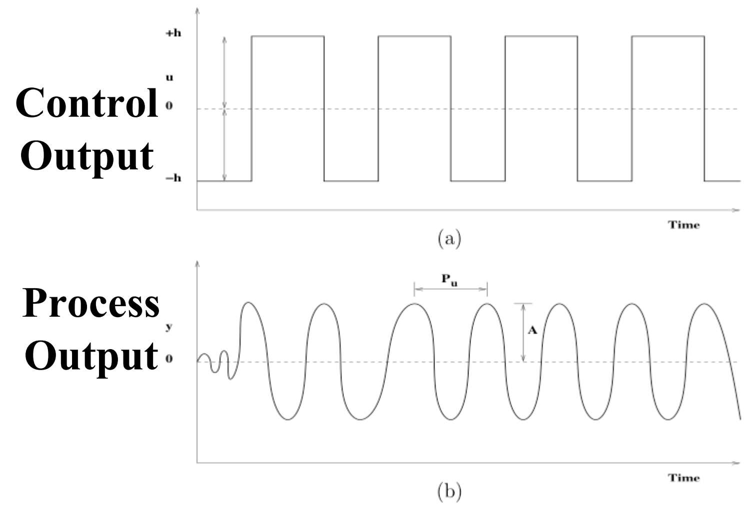
XMP: Test PF4 working with PF5 in the loop

- Time request: ½ day (10-12 shots)
- PF-4 should be configured to be in the "pulling" direction, i.e. in opposite direction to the vertical field from PF-5 (and anti-parallel to I_P). This is the standard direction for PF-4, which is usually configured to run parallel to I_p during MSE calibration.
- ***1: Gap control test.***
- 1.1: Load Helium gap control shot 129414 (or 132855). Verify that shot runs through. Check that rtEFIT is running and properly calculating the equilibria.
- 1.2: At start of flat-top (t=0.15 sec.), add a ramp of the PF-4 coil from 0 kA to 0.5 kA over 250 msec. This should have minimal impact on the plasma, and is a test of the ability to power the coil from within the pcc algorithm.
- 1.3: At start of flat-top, add a ramp of the PF-4 coil from 0 kA to 3 kA over 250msec. This should be a major change to the equilibrium, Test that rtEFIT is indeed calculating the equilibrium correctly. Overlay the boundaries from EFITRT, EFIT01 & 02.
- ***2: Isoflux test.***
- 2.1. Reload and run a standard 4MW high-delta, high-kappa morning fiducial discharge. Reduce Ip to 700 kA.
- 2.2: Add a new segment, starting on the plate at Z=80, R=140 to control the plasma boundary with PF4 coil. Turn on the PF4 control with low Proportional only (~100) gain. Test that the Isolfux algorithm can control the PF4 coil. Ramp up/down the squareness request by 0.05 during the shot to see that isoflux can follow changes in the request. Then increase by 0.1 for the final test.

XP: Experimental Closed Loop System ID

- This year: **Auto-tuning with Relay Feedback Method**





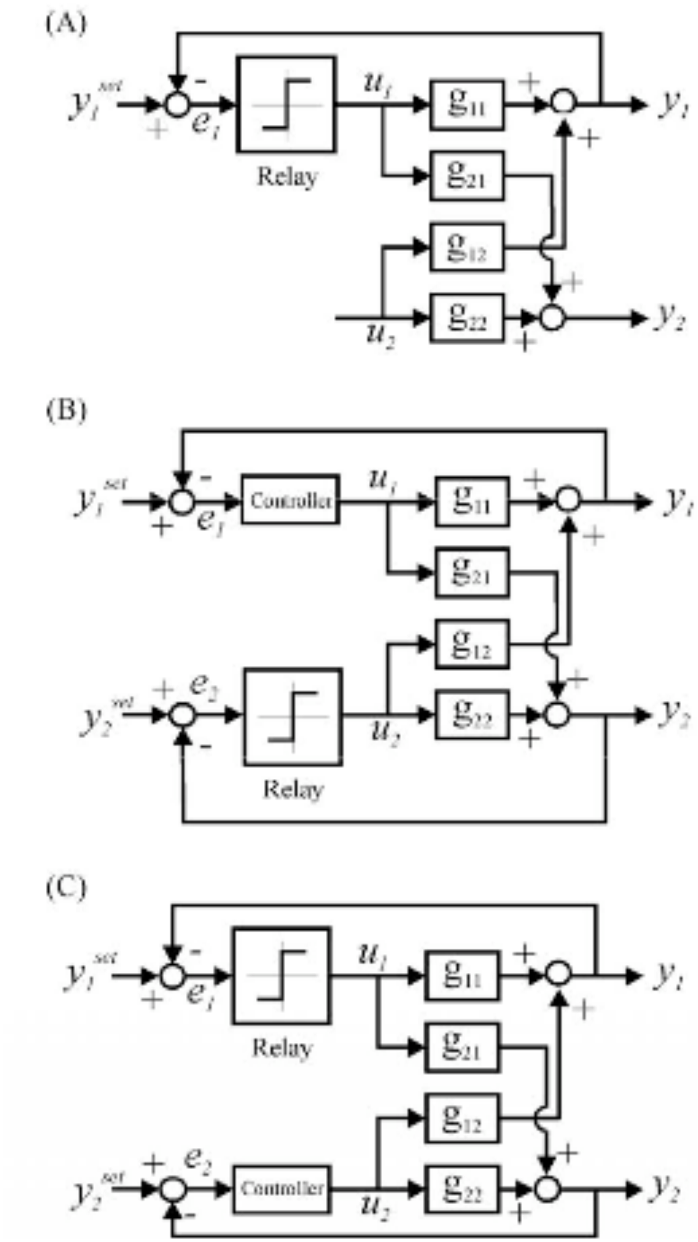
- When we reach this closed-loop plant response pattern the oscillation period (P_u) and the amplitude (A) of the plant response can be measured and used for PID controller tuning.

	K_c	τ_I	τ_D
P	$0.5K_{cu}$		
PI	$0.45K_{cu}$	$P_u/1.2$	
PID	$0.6K_{cu}$	$P_u/2$	$P_u/8$

where $$K_{cu} = \frac{4h}{\pi A}$$

- Only a single experiment is needed.
- Closed loop: More stable
  - Relay Feedback is almost implemented on PCS.

Sequential SISO



1. Perform relay-feedback for y1-u1 while loop 2 is on manual (Figure A)
2. Design the PI/D for u1 for based on on K_{cu} and P_u.
3. Perform relay-feedback for y2-u2 while loop 1 is on automatic (Figure B)
4. Design PI/D for u2.
5. Perform relay-feedback for y1-u1 while loop 2 is on automatic (Figure C)
6. Redesign PI/D for u1.

Experimental Plan for Squareness Controller

- Time request: 1day
- Load the X-point controlled shot and see if the shot is still the same and X-point and SP controllers are working (2 shot)
- Relay Feedback Test (1-2 shots)
  - **This will be tested in X-point control XP beforehand.**
  - Start with a h value of ~200 Volts. If this is not appropriate scan h.
  - Set the hysteresis value to 2*RMS measurement ~0.3/4 mWebers/rad. Test.
  - Run relay-feedback on OSP with PF2L. Compare the results with already running control for OSP with PF2L (sanity check).
  - Start with a small P only control for PF4 (based on the found K_{cu} and P_u). Test the controller is behaving as expected (correct sign and relative magnitude).

Experimental Plan for X-point Height/SP controller

- Sequential PID Tuning (8 shots)
  - Set PID based on K_{cu} and P_u. Manually tune for stability and performance.
  - Relay-feedback on PF4 while PF5 control is on.
  - Set PID for PF4. Manually tune for stability and performance.
  - Relay-feedback for PF5 to OSP while PF4 control is on.
  - If needed repeat this process for PF4 again.

- Decision Point (3-4 shots):
  - Depending on the effect of PF3, detune this controller ~20%.
  - Move PF3 segments 10 cm inwards (leave more room for PF4 to control the squareness).

- Scan Squareness in the range from 0.15 to 0.5 (8-10 shots).
  - Binary search: [0.5, 0.15, 0.325, 0.41, 0.25, 0.37]