Princeton Plasma Physics Laboratory

NSTX Machine Proposal

Title: **Software Test for Upgraded n=0 Control**		
OP-XMP-77	Revision**: 0**	Effective Date: Expiration Date: *(2 yrs. unless otherwise stipulated)*

Procedure Approvals

Responsible author: **Stefan Gerhardt**	Date
ATI (NSTX Physics Ops): **D. Mueller**	Date
RLM (NSTX Expt. Research Ops): **M. Bell**	Date

Responsible Division: **Experimental Research Operations**

Procedure Requirements

designated by RLM

	NSTX Work Permit		T-MOD (OP-AD-03)
	Independent Review		ES&H Review

RESTRICTIONS AND MINOR MODIFICATIONS

Approved by RLM

REVIEWERS (designated by RLM)		
Organization/Position	Name	Signature
ATI	D. Mueller	
Test Director		
Independent Reviewer		
NB system		
RF systems		
FCPC systems		
Diagnostics		

TRAINING (designated by RLM)

Training required: No ■ Yes ☐ Instructor ____________________

Personnel (group, job title or individual name)	Read Only	Instruction	Hands-On

RLM ______________________________

NSTX MACHINE PROPOSAL

TITLE: **Software test for upgraded n=0 control** No. **OP-XMP-77**
AUTHORS: **S.P. Gerhardt** DATE: **7/11/2011**

1. Overview:

The goal of this XP is to test the code upgrade to the vertical position controller.

The vertical position controller in use for the past number of years is written as:

$$V_{PF-3U/L} = V_{PF-3U/L,ISOFLUX} \pm D \cdot \left(\dot{\psi}_{PPPU2} - \dot{\psi}_{PPPL2} \right)$$

The first term is the (slow) ISOFLUX shape control, while the second term is the (fast) vertical position control. The term in parenthesis is the difference in the voltages between two flux loops, specifically those labeled "PPP2", mounted equal distance above and below the midplane. D is the derivative gain, and is typically set to 80. There is also a proportional term, but it is generally turned off and not included here.

The upgraded controller will have this equation written as:

$$V_{PF-3U/L} = V_{PF-3U/L,ISOFLUX} \pm D \cdot \frac{d\left(I_P Z_P\right)}{dt}$$

$$\frac{d\left(I_P Z_P\right)}{dt} = \sum_{loop} \alpha_{loop} \left(\dot{\psi}_{loop,upper} - \dot{\psi}_{loop,lower} \right)$$

Here, "loop" is an index over the various loops which exist as up-down symmetric pairs. There are now 9 total loop pairs brought into PCS, with the difference in the voltage taken in hardware before digitization. The units of $d(I_P Z_P)/dt$ in PCS are MA·m/s

The "PPP2" loops used in the previous controller remain one of the pairs that are available, so the upgraded controller includes the original one in the limit that $\alpha_{PPP2} = 2.2$, all other coefficients are zero and D=80/2.2=36.

It is the purpose of this XMP to use the new formulation, but recover the effect of the old controller. This will allow a quick test of the new software implementation.

Optimizing the values of the parameters α will be done in a subsequent XP.

We also have added the provision to add a term to the SPA request of the form $D \cdot LPF(d(I_P Z_P)/dt;\tau)$. Here, $LPF(f(t);\tau)$ is a causal lowpass filter. This same quantity is added to each SPA request, so that the resulting field is dominantly radial n=0. We will test that the implementing code is working correctly.

The optimization of n=0 control with RWM coils will be done in a subsequent XP.

2. Justification:

Improving the NSTX vertical control system is likely important for robust operation in NSTX upgrade, and is part of the R11-2 milestone. This motivates the changes above.

Given those changes, it is desired to test the software, to ensure that there are not coding errors or unexpected bugs. The successful completion of this XMP will allow XP-1106 to begin with confidence in the underlying PCS code.

3. Plan:

3.1. Load and run the reference discharge, likely a 2011 morning fiducial. Should maybe delay the early heating to have l_i be a bit higher. This step should have the system category "Old/New Switch" waveform set to zero, so that it uses the original n=0 controller. Set the quantity α_{PPP2}=2.2 (all other quantities α should be zero)

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Shot number(s)

The realtime calculation is $d(I_P Z_P)/dt$, archived in the MDS+ tree as "\PCS.SY:SYS_DZIPDT", should be compared to the values of $d(I_P Z_P)/dt$ computed off-line. Note that this will be a poor approximation to the actual value of $d(I_P Z_P)/dt$, as only a single loop pair is being used.

3.2. Repeat, with the "Old/New Switch" set to 1 (this activates the new controller). Set the derivative gain equal to 80/2.2=36. If vertical motion is unstable, it is likely that there is a sign error on the n=0 control. Change the sign of the parameter α_{PPP2} and repeat.

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Shot number(s)

3.3. In the PCS setup, at 0.4 seconds, turn off n=0 control with the PF-3 coils, by ramping down the system category derivative gain from 80 to zero over ~30 msec. Over the same period, ramp up the n=0 derivative gain in the RWM category, from zero to a given value. Set the filter time constant to zero.

RWM category n=0 derivative gain ____________ ______________________

Shot number(s)

3.4. Repeat, but with the RWM category n=0 filter time constant equal to 3 msec.

RWM category n=0 derivative gain ____________ ______________________

Shot number(s)

For both 3.3 and 3.4, check that the observed RWM coil currents are consistent with calculations from off-line codes. Also note that n=0 instabilities in this case are not unexpected, as the gains have not been optimized.

If the above has been successfully completed, the new software is ready for parameter optimization in subsequent XPs.

4. Required machine, beam, ICRF and diagnostic capabilities:

Capability to run the target shot, which is likely a 2011 morning fiducial discharge, with at least 2 MW of neutral beam power.

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Shot number of reference shot

Need the "active" version of PCS to have the "tmf" algorithm operating.

SPAs must be configured for 6 subunit operation.

Magnetic calibration shots have been taken and it has been checked that the difference voltages are working correctly, and that there are no sign errors.

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Shot number or range of calibration shots

5. Sign off at run time:

5.1 Permission to Proceed: ___________________________

Physics Operations Head

5.2 Successful completion of tests

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Cognizant Physicist/Test Director

5.3 Documentation of results:

Documentation of the results completed, attached to proposal and sent to Ops. Center with copies to Cognizant Physicist and Head of Physics Operations.

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Cognizant Physicist/Test Director

PHYSICS OPERATIONS REQUEST

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(use additional sheets and attach waveform diagrams if necessary)

Brief description of the most important operational plasma conditions required:

We simply need the standard 900 kA morning fiducial shot to be running out to 0.8-1.0 seconds. Some MHD activity is OK, as long as it is not too disruptive.

We also need 6 subunit operation of the SPAs to be operational, and the TMF algorithm to be installed in the running PCS implementation.

Previous shot(s) which can be repeated: Any morning fiducial

Previous shot(s) which can be modified:

Machine conditions *(specify ranges as appropriate, strike out inapplicable cases)*

I_{TF} (kA): **0.45 T** Flattop start/stop (s): **0/1.3**

I_P (MA): **0.9** Flattop start/stop (s): **0.2/1.2**

Configuration: **LSN**

rtEFIT controls: **Isoflux**

Outer gap (m): **0.1** Inner gap (m): **0.05** Z position (m): -0.02 – 0.0

Elongation: **2.3** Triangularity (U/L): 0.7/0.7 OSP radius (m): **~0.35**

Gas Species: **D** Injector(s): **LFS & HFS**

NBI Species: **D** Voltage (kV) **A: 90** **B: 90** **C: 70** Duration (s): 1.0

ICRF Power (MW): **0** Inter-strap phase (°): **NA** Duration (s): **NA**

CHI: **Off** Bank capacitance (mF): NA

LITERs: On Total deposition rate (mg/min): 5-10

LLD: Temperature (°C): **whatever**

EFC/RWM coils: Feedback (on n=0)

Configuration: **6 subunit operation of the SPAs**

DIAGNOSTIC CHECKLIST

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Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
Beam Emission Spectroscopy		X
Bolometer – divertor		
Bolometer – midplane array		X
CHERS – poloidal		X
CHERS – toroidal		X
Divertor L-alpha array		X
Divertor visible camera		X
Dust detector		
Edge deposition monitors		
Edge neutral density diag.		X
Edge pressure gauges		X
Edge rotation diagnostic		X
Fast cameras – divertor/LLD		X
Fast ion D_alpha - poloidal		X
Fast ion D_alpha - toroidal		X
Fast lost ion probes - IFLIP		X
Fast lost ion probes - SFLIP		X
Filterscopes		X
FIReTIP		X
Gas puff imaging – divertor		X
Gas puff imaging – midplane		X
Hα camera - 1D		X
High-k scattering		X
Infrared camera – standard		X
Infrared camera – 2-color		X
Infrared camera – wide-angle		X
Interferometer - 1 mm		X
Langmuir probes – divertor		X
Langmuir probes – LLD		X
Langmuir probes – bias tile		X
Langmuir probes – RF ant.		X
Magnetics – B coils	√	
Magnetics – Diamagnetism		X
Magnetics – Flux loops	√	
Magnetics – Locked modes		X
Magnetics – Rogowski coils	√	
Magnetics – Halo currents		X
Magnetics – RWM sensors	√	

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
MAPP		
Mirnov coils – high f.		X
Mirnov coils – poloidal array		
Mirnov coils – toroidal array		X
Mirnov coils – 3-axis proto.		
MSE-CIF		X
MSE-LIF		X
NPA – E‖B scanning		
NPA – solid state		
Neutron detectors		X
Plasma TV	√	
Reflectometer – 65GHz		
Reflectometer – correlation		
Reflectometer – FM/CW		
Reflectometer – fixed f		
Reflectometer – SOL		
RF edge probes		
Spectrometer – divertor		X
Spectrometer – SPRED		X
Spectrometer – VIPS		X
Spectrometer – LOWEUS		X
Spectrometer – XEUS		X
SWIFT – 2D flow		
TAE Antenna		
Thomson scattering		X
USXR – pol. arrays		X
USXR – multi-energy		X
USXR – TG spectr.		X
Visible bremsstrahlung det.		X
X-ray crystal spectrom. - H		X
X-ray crystal spectrom. - V		X
X-ray tang. pinhole camera		X