Princeton Plasma Physics Laboratory
NSTX Machine Proposal

Title: **Software Test for n=1 RWM and Error Field Control with 6 SPAs**

OP-XMP-72	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 n=1 Proportional Control** No. **OP-XMP-78**
AUTHORS: **S.P. Gerhardt** DATE: **7/11/2011**

1. Overview:

The goal of this XP is to test the PCS code related to RWM control with 6 SPA subunits

These code modifications were made within the mode-ID category (which identifies the amplitude and phase of the n=1 perturbation), and within the RWM category (which generates the actual power supply current requests).

These code modifications will be tested off-line, both on old data and on the 2nd PCS machine during initial plasma operations. It will then be necessary to test the code changes using real plasma discharges.

In particular, the XMP will test:

- The application of pre-programmed currents during plasma operations.
- Feedback n=1 control with the B_P and B_R sensors.
- Feedforward n=1 OH x TF correction.

It is hoped that the outcome of this XMP will be a qualified n=1 DEFC/RWMF + n=3 EFC configuration that can be loaded into any subsequent discharge.

2. Justification:

PPPL/NSTX installed an additional SPA during the outage in the center of the FY-11 run. The use of the three additional subunits, and reconfiguration of the coil/subunit mapping, has required that the PCS code for n=1 control be rewritten. Given the importance of this particular control capability, it is desirable to test it with a short dedicated XMP.

3. Plan:

3.1: Pre-programmed current control (1-2 shots).

Load and run the reference discharge, likely a 2011 morning fiducial. Add n=3 correction waveforms as in the following table. Ramp the currents on from 0.25 to 0.3 seconds

SPA #	SPA Request Level
1	+250
2	-250
3	+250
4	-250
5	+250
6	-250

This should produce positive currents (in the physics sense) in RWM coils 2, 4, and 6, and negative currents in coils 1, 3, and 5; these should be the polarities in the “IRWM_X” signals (X=1,2,3,4,5,6). The RWMX_I signals should have the polarity consistent with the above table.

Note that this step may be completed during the startup XMP.

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Shot number(s)

3.2: n=1 RWM control with B_P sensors

3.2.1: (4 shots) Development with n=1 feedback with B_P sensors.

Repeat target shot with n=1 RWM control turned on. Timing of waveforms is as per shot 133964.

B_P Feedback: Turned on at t=0.3.

B_P Feedback Gain: Ramping from 0 to a final value from t=0.35 to t=0.4.

B_P Feedback Phase of 250, followed by 70 (historical good and bad phases).

B_P Low-Pass Filter Time Constant: Ramping to 0.001 sec from t=0.36 to t=0.41.

B_P sensor re-zero during time window 0.33 < t <0.34.

B_p Gain	B_p Phase	Shot Number(s)
0.5	250	
1.0	250	
1.0	70	

3.2.2: (4 shots) Add with n=1 feedback with B_R sensors.

Using best B_P feedback configuration, add B_R feedback with the same timing, and the following parameters. The historical result is that this difference in feedback phase should result in a stark difference in plasma performance

B_R Gain	B_R Phase	Shot Number(s)
0.75	180	
1.5	180	
1.5	0	

3.3: Feedforward OHxTF Correction (2 shots).

Repeat the target plasmas discharge, but turn off all pre-programmed and n=1 feedback currents. Then use the OHxTF correction waveforms from shot 138101.

The form of the SPA current request for the i[th] coil is:

$$I_{SPA,i} = D_i\left[G_{S,i}LPF(I_{OH} \cdot I_{TF};\tau) + G_{A,i}LPF(I_{OH} \cdot I_{TF};\tau)\right]$$

The governing parameters of the OHxTF algorithm are three numbers per subunit: D_i, $G_{S,i}$, $G_{A,i}$. There were thus 9 numbers previously, and 18 numbers when the 2[nd] SPA is included.

Due to a remapping of the SPA->RWM coil connections when going from 3 to 6 subunits, the reload of the parameters will need to be done as follows:

Copy this from old shot/algorithm…	…into the new shot/algorithm
D_2	D_1
D_3	D_2
D_1	D_3
$-1 \cdot D_2$	D_4
$-1 \cdot D_3$	D_5
$-1 \cdot D_1$	D_6
$G_{S,2}$ (=8.8e-7)	$G_{S,1}$
$G_{S,3}$ (=5.9e-7)	$G_{S,2}$
$G_{S,1}$ (=1.48e-6)	$G_{S,3}$
$G_{S,2}$ (=8.8e-7)	$G_{S,4}$
$G_{S,3}$ (=5.9e-7)	$G_{S,5}$
$G_{S,1}$ (=1.48e-6)	$G_{S,6}$
$G_{A,2}$ (=-4e-8)	$G_{A,1}$
$G_{A,3}$ (=2.8e-7)	$G_{A,2}$
$G_{A,1}$ (=3.2e-7)	$G_{A,3}$
$G_{A,2}$ (=-4e-8)	$G_{A,4}$
$G_{A,3}$ (=2.8e-7)	$G_{A,5}$
$G_{A,1}$ (=3.2e-7)	$G_{A,6}$

The RWM current waveforms should be compared to those from 138101. There will be some difference, as the OH current evolution may be somewhat different. However, the polarities, time-evolution, and approximate magnitudes (especially neat t=0) should be comparable.

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Shot number(s)

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 4 MW of neutral beam power. The achievable β_N should be ~4 or greater.

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Shot number of reference shot

The “tmf” and “miu” algorithms should have been thoroughly tested using the background computer before this XMP is completed. In particular, the proper calculation of the “AC” and “OH×TF” compensations should have been verified against off-line codes. The resulting mode amplitudes and phases must compare favorably to those from off-line analysis. The basic functions of the TMF algorithm must also have been correctly benchmarked by comparing realtime calculations on the backup computer to those from off-line calculations.

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

TITLE: **Software Test for n=1 Proportional Control** No. **OP-XMP-78**

AUTHORS: **S.P. Gerhardt** DATE: **7/11/2011**

(use additional sheets and attach waveform diagrams if necessary)

Brief description of the most important operational plasma conditions required:

We need the standard 900 kA morning fiducial shot to be running out to ~0.8 seconds. It should be achieving β_N~4

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: Parts of 133964 & 138101 can be used.

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: Pre-programmed and Feedback (on n=1)

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

DIAGNOSTIC CHECKLIST

TITLE: **Software Test for n=1 Proportional Control** No. **OP-XMP-78**

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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**