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SUBJECT: INITIAL REQUIREMENTS FOR SCOPING PCS HEAT FLUX CONTROL FOR R18-1/1-G4

<u>Background</u>

Control of heat flux to PFCs is expected to be an important component of commissioning and operating NSTX-U to run sustained pulses at high powers. Other activities in the Working Group are focusing on understanding the engineering limits of the PFCs and looking at means of monitoring, either using real-time observations or validating, shot-to-shot, models which can be used in real-time to predict heat flux.

The expectation is that some measure of PCS-based control of heat flux will be used, perhaps optional over a range of operating space and required for discharges approaching the $\Delta t \sim 5$ second, $P_{NBI} = 10$ MW design limits. NSTX-U presently lacks the equivalent of specific operations guidance for this issue, e.g the JET Operating Instructions Section 2: Limits on Energy Levels for In-Vessel Components.

<u>Description of Control Needs</u>

To scope possible new methods needed in PCS the following should be assumed to be known in addition to existing proven PCS capabilities

1) Real-time knowledge of the outboard midplane heat flux width, λ_q, determined by a model, e.g $\lambda_q = C_1 I_p^{C_2}$ with C_1 and C_2 known constants.
2) The use of all inner PF coils is allowed

The first stage will be to develop a way to control all of the parameters relevant for divertor heat flux with limited consideration for the impact on the background discharge.

A. Control the time history of all four strike point positions (Upper Inner=UI, Upper Outer=UO, Lower Inner = LI, Lower Outer = LO)
    a. for each outer strike point prescribe R_O @ $Z_o = f(R)$ versus time (e.g. $R_{LO}(t)$and $R_{UO}(t)$)
    b. for each inner strike point prescribe Z_I @ $R_I = g(Z)$ versus time
B. Control the time history of the normalized magnetic balance, dr_{sep}/λ_q
C. Control the time history of the average angle of incidence in the common flux regions
    a. for each outer strike point define an averaging window, e.g. $dR_{LO}(t)$
    b. for each outer strike point control the average of $|\hat{n} \cdot \hat{b}|$ over the range $R_O + dR_o$

c. for each inner strike point define an averaging window, e.g $dZ_{LI}(t)$
d. for each inner strike point control the average of $|\hat{n} \cdot \hat{b}|$ over the range $Z_I + dZ_I$

It is of interest to know which of the following, or other typically controlled plasma equilibrium values, are still controllable or weakly impacted from achieving (a)-(c): inner gap, outer gap, kappa, upper triangularity and lower triangularity?

To begin to develop the control assume the following fixed values:

1. Assume λ_q = 3 mm
2. Assume the PFC contour shape from NSTX-U prior to Recovery to get $Z_o = f(R)$ and $R_I = g(Z)$
3. Assume $dR_O = 2$ cm
4. Assume $dZ_I = 2$ cm
5. Assume $|\hat{n} \cdot \hat{b}|$ is fixed at the equilibrium value
6. Vary R_O from its equilibrium value, $R_{O,e}$

t [sec]	R_o [cm]
0.00	$R_{o,e}$
0.25	$R_{o,e}$-4.0
0.50	$R_{o,e}$
0.75	$R_{o,e}$+4.0
1.00	$R_{o,e}$

7. Vary Z_O from its equilibrium value, $Z_{O,e}$

t [sec]	Z_o [cm]
0.00	$Z_{o,e}$
0.25	$Z_{o,e}$-2.0
0.50	$Z_{o,e}$
0.75	$Z_{o,e}$+2.0
1.00	$Z_{o,e}$

It is expected that in practice the algorithm will be used to derive a linearized control matrix for a demonstrated equilibrium allowing long-pulse control of short-pulse experiment. In this case the primary input will be an EFIT shot and time point. In addition, to scope control for shapes that have not yet been developed the ability to load TRANSP data should be possible. For the purposes of scoping, use for examples

- EFIT
  - shot=204112
  - tree=EFIT01
  - time=0.700
- TRANSP
  - shot=142301
  - id='Y65'

- runid=1423012565
- time=3.0

The ranges of interest for the control parameters will be updated in a future version of this MEMO.

The eventual output for this activity will be the time-evolving set of equilibria consistent with the controller. This will take the form of a set of g-files. Details of addition I/O and formatting will be the subject of a future memo. The immediate output should be a feasibility demonstration within the PCS/TOKSYS framework that shows the linearized control is possible and documents the impact on other equilibrium parameters.

Record of Changes

Rev.	Date	Description of Changes
0	3/20/18	Initial release for review