NSTX

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TO: DISTRIBUTION
FROM: J MENARD and S SABBAGH
SUBJECT: PRELIMINARY REQUIREMENTS FOR NSTX RESISTIVE WALL MODE AND ERROR FIELD FEEDBACK COILS AND POWER SUPPLIES

The goal of this memo is to define the preliminary requirements and identify issues relating to the coils and power supplies of an active mid-plane non-axisymmetric radial magnetic field feedback control system. The major hardware components of the feedback system would consist of:

1) 6 window-pane single or multi-turn coils each covering approximately 60° in toroidal extent placed symmetrically around the NSTX device toroidally and centered vertically about the device mid-plane. Each coil would be approximately 0.8 to 1 meter in height.

2) Robicon switching power amplifiers (SPA) or TFTR power supplies for driving the feedback coils.

3) Bus work connecting the coils to the amplifiers. The bus work must generate minimal additional error field.

This memo will focus on 1) and 2) above. An essential element of a preliminary design for this system is the determination of the engineering and physics trade-offs of placing the coils inside the vacuum vessel versus installing them externally. A ***single*** active control system would ideally be capable of the providing the following physics capabilities:

1) Resistive Wall Mode (RWM) control
2) PF coil and passive structure Error Field (EF) correction
3) Low frequency ($f \approx 1kHz$) n=1 rotating tearing/kink mode suppression.
4) Rotation control via n=3 ripple field generation.

Each of these capabilities has specific but not necessarily unique requirements for coil current magnitude and current oscillation frequency. In addition, it is desirable, but may not be possible to provide these four capabilities simultaneously during a shot. Preliminary calculations indicate that goals 1) and 2) and possibly 3) can be achieved simultaneously if the following parameters can be achieved:

1) Zero-frequency major-radial magnetic field at R=1.3m (i.e. near typical q=2 radius inside plasma) from 2 toroidally opposed coils with currents in anti-phase = 50 Gauss. At low frequency, this field should be sufficient to correct all ***known*** static error fields and should be achievable with a single 5kA 3-phase SPA or 3 TFTR power supplies.

2) Fields of 10-15G at the same major radius R=1.3m can be generated at frequencies up to f=1kHz with low ripple/harmonic content. A simple series inductor may not be sufficient to meet this spec, and the influence of wall image currents must be accounted for. This should be sufficient for RWM control, transient error field suppression, and possibly rotating tearing/kink mode control.

Placing the coils inside the vessel has the following physics performance benefits:

1) Because of the reduced relative influence of the image currents in the vessel wall, nearly ideal RWM stabilization up to 94% of the difference between the no-wall and with-wall beta limit can be achieved without toroidal rotation. With external coils, only 72% of this difference can be achieved.

2) Internal coils provide more magnetic field in the plasma per unit supply current, thus either reducing power/cooling requirements or enhancing the resistive wall mode, error-field, and rotating mode suppression capabilities of the system.

3) Internal coils can provide significantly increased n=3 field inside the plasma for enhanced flow-damping and control, since the n=3 amplitude decays much more rapidly with distance away from the coil than n=1. Flow control has important applications for MHD and transport studies. However, there is presently significant uncertainty in predicting the magnitude of non-resonant field needed for significant flow damping both for NSTX and other fusion devices.

The potential draw-backs of the internal coils are primarily due to engineering and cost considerations. A partial list of concerns includes:

1) Initial calculations from C. Neumeyer indicate that external coils could be air cooled between shots, whereas internal coils would require active coiling of a copper inner conductor encased in polyamide or equivalent insulation, both of which would be encased in a stainless tube which may need differential pumping.

2) Internal coils would potentially interfere with in-vessel components such as the HHFW antenna array, neutral beam dump, and possibly other diagnostics and sightlines. Diagnostic interference is also possibly an issue for ex-vessel coils, although the region occupied by the present locked-mode sensor coils would become available if the internal sensors can be used as a substitute.

3) Internal coils must survive thermal cycling associated with bakeout, must be unaffected by disruptions, and must be compatible with CHI operation, especially if the vacuum boundary of the active coil (i.e. the stainless-stell outer shell) is in direct contact with CHI plasma.

The power supplies for driving the active coils must compatible with the desired physics capabilities of the system – some considerations include:

1) If low-frequency feedback control of error fields is all that is desired, TFTR power supplies combined with a large series inductance for coil current ripple suppression would likely be adequate. This would minimize the cost of the supplies, but would require additional bus-work from FCPC to the NSTX test cell.

2) Of particular concern for RWM and rotating mode control is the potential for phase instability due to latency and switching speed. The time lag between requesting and applying a voltage to a coil is as long as 4ms for the present TFTR supplies used on NSTX. This latency combined with the comparatively low switching frequency of the supplies, may make them unusable for RWM control.

3) Robicon switching power amplifiers have a significantly higher switching frequency (7kHz) and much lower latency. These supplies are not cheap ($150k-200k) and have a long procurement time (6 months). Some of the cost would be offset by eliminating the need for buswork from FCPC to NSTX.

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