13-961024-CLN-01

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SUBJECT: AXIAL LOAD COMPUTATIONS

References:

[1] 13-961016-CLN-01, "Assumptions for Load Computations"

This memo presents the results of calculations of worst case net axial loads on the NSTX PF coil bundles following the general assumptions outlined in [1].

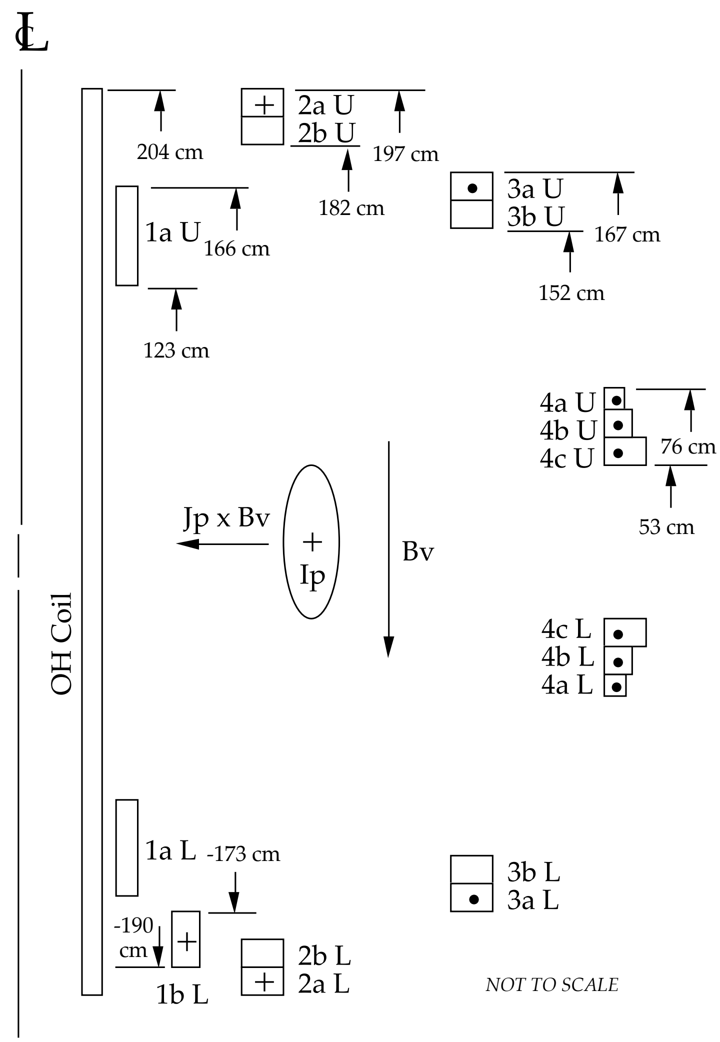
Coil circuits and limits on maximum current per turn were assumed as follows.

Circuit	u=upper/ l=lower	#turns above/below mid plane	max |kA/ turn|	max |kA-turn|
OH	u+l	476	24.0	11424.0
PF1a	u	48	10.0	480.0
PF1a	l	48	10.0	480.0
PF1b	l	36	15.0	540.0
PF2a	u+l	14	20.0	280.0
PF2b	u	14	20.0	280.0
PF2b	l	14	20.0	280.0
PF3a	u+l	15	20.0	300.0
PF3b	u	15	20.0	300.0
PF3b	l	15	20.0	300.0
PF4(a+b+c)	u+l	22	20.0	440.0

It was assumed that the relative polarity of a subset of the circuits is fixed as required for plasma operation for a given plasma current polarity. The polarity of these circuits is given in the following figure for the case of a positive plasma current polarity (counterclockwise viewed from above). A (+) symbol indicates current into the page (CCW viewed from above) and a (•) symbol current out of the page.

The polarity of the PF4 circuit is fixed since it is required to produce a downward vertical field and inward radial force on the plasma. The polarities of the PF2a and PF3a circuits are fixed since they contribute to the vertical field as they perform their shaping functions (this is confirmed by a review of the equilibria thus far calculated for double null and natural divertor plasma configurations). The polarity of the PF1b circuit is fixed due to its role in shaping the field near the single null X-point as required for CHI.

The polarity of OH cannot be fixed since it is bipolar and a plasma may exist with either OH polarity. The polarity of the PF1a upper and lower circuits may vary depending on the plasma shaping requirement. The polarity of the PF2b and PF3b circuits will vary depending on whether the plasma has an X-point configuration and on the manner in which the radial field, vertical position control is accomplished.



Based on guidance from physics the plasma was modeled using two current filaments at r=91.5 cm and z=+/- 21.7 cm, with the current set to 1.0MA in which ever filament produces the worst case force, and to zero in the other.

A code was developed to find the worst case net positive and negative axial forces on each bundle. The following procedure was used.

1) coil input data (r, z, #turns, circuit#, bundle#, nominal polarity (if fixed) and circuit input data (|Imax|) are read from a file

2) a coil-to-coil influence matrix is constructed which contains in each element of the matrix the axial force on one coil due to the field produced by another. The row entries are the "source coils" which produce the field and the column entries are the "target coils" which experience the force. Maximum current is assumed in the source coil, and maximum current is assumed in the target coil. Polarity is set to nominal unless it is not fixed, in which case positive is assumed). Since the net force on each bundle is the quantity of interest, the matrix elements corresponding to coils within the same bundle are set to zero.

3) a coil-to-bundle influence matrix is formed by summing the columns of the coil-to-coil matrix for those coils in the same bundle.

4) a circuit-to-bundle influence matrix is formed by summing the rows of the coil-to-bundle matrix for those coils in the same circuit.

5) a scan of the circuit-to-bundle matrix finds the maximum positive force on each bundle. For each circuit, if the direction of force is positive, it is added. If the direction of force is negative and the circuit polarity is fixed, then the current in that circuit is assumed zero so as not to reduce the positive force. If the direction of force is negative but the circuit polarity is not fixed then it is assumed that the current polarity is negative and the force is added.

6) in the same manner as 5), a scan is made to find worst case negative forces.

7) for those bundles whose current polarity is not fixed, if the result of the scans in 5) and 6) resulted in one case higher than the other, then both the maximum positive and negative cases are set to the maximum, since the bundle current could be in either direction.

In order to obtain accurate results it was necessary to divide (along the z-axis) the OH, PF1a, and PF1b coils into sub coils as follows:

OH	52 sub coils
PF1a	6 sub coils
PF1b	6 sub coils

Results are summarized in the attached table. For the OH interaction the results were compared to those obtained by H. M. Fan using the ANSYS model and were found to be in agreement within 20%. The accuracy was worst for PF1 (within 20%), and much better (within 10%) for the larger radius coils.

As can be surmised from the results the OH launching load depends mostly on PF1b, but PF2b has a strong effect as well (PF2a has no effect because equal currents are assumed in the upper and lower coils), and PF1a has a somewhat lesser effect. It may be possible to rule out the coincidence of all of these coils acting on the OH with the worst case polarity. However, this cannot be done until the single null equilibria requirements are established. The hope would be that the nominal coil polarity and usage (which would be constrained via administrative procedures controlling allowable bus link combinations) could rule out the case where PF1a lower, PF1b lower, and PF2b lower would all be of the same polarity.

cc:

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NSTX File