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Synthesized Vacuum Calculation in Toroidal Geometry*

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The boundary value problem for the perturbed magnetic field in the vacuum region of a plasma with external conductors is usually solved by directly incorporating the boundary conditions in the solution method. Alternatively, the calculations involved can be broken down, or synthesized, to extricate the contributions of the fields due to the separate components of the system. This is useful for feedback studies against external MHD modes, in which one can artificially enhance the induced currents in individual components, and the interactions between the separate contributions lend insight into the determination of the self and mutual inductances of the components of the feedback system.

The vacuum code [1], in it's original form, incorporates the Neumann boundary conditions directly by solving the the inhomogeneous Fredholm integral equation of the second kind which is generated from the use of Green's second identity with the free space Green's function and the magnetic scalar potential as the requisite functions. To include the additional flexibility mentioned above the vacuum code has undergone an extensive modification. This was outlined previously [2]. Briefly, one considers the contribution of the fields from the plasma and the conductors separately assuming first that the originating driving source is due to a plasma surface perturbation in the absence of any conductors. One then solves the reciprocal problem of the shell in the absence of the plasma, but using as the Neumann source the perturbation at the conductor's position due to the plasma which was calculated in the first step. The Neumann source is chosen so that the total normal component of the perturbed magnetic field arising from the plasma and the induced current in the virtual shell vanishes. Then the boundary conditions at the plasma surface must be normalized such that the total perturbed field is continuous across the plasma vacuum interface.

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Both methods of calculations will be outlined. The salient physics are best elucidated using the long straight cylindrical or confocal elliptical models, both of which result in diagonal vacuum matrices, although those involved in the intermediate steps of the latter need not be diagonal. The results of the calculations are identical in both methods. In the 2-D case the numerical results are in agreement to within four or five digits.

Because of the synthesized calculation we are now able to:

1. Calculate the scalar potential at each of the separate components (plasma or conductors) due to itself or the other components.

2. Calculate the induced current at the surface of each component due to the others.

3. Calculate the normal magnetic perturbation at each component's virtual position due to the induced current in the other.

4. Calculate the energies arising from the induced fields on the conductors and plasma.

One can now artificially modify the effects of the conductors to simulate an active feedback system. For example, since the eddy currents on an enclosing shell is induced by Lentz's law to suppress an unstable plasma perturbation one can enhance this current in the calculation to attempt to completely stabilize the mode. Care must be taken to ensure that the integrity of the methods – self-adjointedness, homogeneity, etc. are not compromised. In the two dimensional case the feedback coils must be designed carefully so that otherwise stable modes of the plasma are not driven overstable by the coils.

These calculations are also helpful in calculating the self and mutual inductances of the coils which are needed for the engineering calculations of the feedback circuits.

References

[1] M. S. Chance, Vacuum Calculations in Azimuthally Symmetric Geometry, Phys. Plasmas 4 (1997) 2161.

[2] M. S. Chance, S. C. Jardin, J. Bialek, et al., Coupling the pest and spark Codes for δW Stability Analyses with Three Dimensional Wall Configurations, 15th

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– Prefer poster