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New Design Methods for Magnetic Flux Loop Arrays in the NCSX Experiment

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Magnetic pickup loops on the vacuum vessel (VV) can provide an abundance of equilibrium information for stellarators. A substantial effort has gone into designing flux loops for NCSX, a 3-field period quasi-axisymmetric stellarator under construction at PPPL. The design philosophy, to measure all of the magnetic field distributions normal to the VV that can be measured, has necessitated the development of Singular Value Decomposition algorithms for identifying efficient loop locations. The fields are expected to be predominantly stellarator symmetric (SS) - the symmetry of the machine design - with toroidal mode numbers per torus, n, equal to a multiple of 3 and possessing reflection symmetry in a period. However, plasma instabilities and coil imperfections will generate non-SS fields which must also be diagnosed. The measured symmetric fields will yield important information on the plasma current and pressure profile as well as on the plasma shape. All fields that obey the design symmetries could be measured by placing flux loops in a single half-period of the VV, but accurate resolution of non-symmetric modes, quantified by the condition number of a matrix, requires re-positioning loops to equivalent locations on the full torus. A sub-array of loops located along the inside wall of the vertically elongated cross-section was designed to detect n=3 m=5 or 6 resonant field perturbations that can cause important islands. Additional sub-arrays included are continuous in the toroidal and poloidal directions. Loops are also placed at symmetry points of the VV to obtain maximal sensitivity to asymmetric perturbations. Combining results from various calculations which have made extensive use of a database of 2500 free-boundary VMEC equilibria, has led to the choice of 227 flux loops for NCSX, of which 151 have distinct shapes.