

## **A Multivariable Analysis of the Plasma Vertical Instability in Tokamaks**

M.L. Walker and D.A. Humphreys

For more than a decade the vertical position instability intrinsic to vertically elongated tokamak plasmas has been relatively well understood. Controllers that stabilize this instability have been in routine use at experimental devices since the 1980's. In this paper, we exploit a full multivariable model of the vertical instability using a matrix pencil analysis to provide for the first time a rigorous demonstration of some well known results in the general case, and to clarify issues which have heretofore not been clearly resolved.

We examine two models of the tokamak-and-plasma system, one assuming the plasma has mass, the other assuming zero mass. Although the plasma with mass model is more correct, the massless model is most often used in control analyses. We find that answers to questions regarding vertical stability, with or without feedback, depend on whether the plasma is assumed to have mass or not. We provide examples where analyses conducted using a massless plasma model can reach erroneous conclusions.