Valid coordinate systems for linearized plasma shape response models in tokamaks

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Abstract. In this paper, we examine the issue of definition of coordinates used for plasma shape control simulations and real time implementations and their relation to the validity of linearized plasma shape response models. By doing a careful analysis of these simple concepts, some subtle issues are exposed. Some of the implications are non-obvious and, at first, counter-intuitive.

It is shown that the dynamics and output equations for plasma shape and current evolution, derived using a common method for linearizing around a plasma equilibrium, are each valid in different coordinates and therefore additional work is needed to redefine both in a common coordinate system. In particular, it is demonstrated that the set of poloidal field coil currents that define the equilibrium about which a model is linearized often do not define a valid origin for the linearized model equations. Requirements for a valid coordinate system are determined, and procedures for constructing such a system are described. We extend this analysis to also cover both cases where the transformed coordinate system is defined relative to a constant origin and where the coordinate origin

is a function of time, i.e. to the definition of time dependent feed-forward nominal trajectories.

We also explore the issue of the small signal requirement for maintaining accuracy of the linearized models. It is shown that this requirement does not apply to either coil currents or voltages, but only to certain characteristics of the plasma. In particular, use of a “perturbed” coordinate system is not actually necessary.

The primary motivation for this study is to properly account for relatively large changes in PF coil currents needed to maintain plasma shape and plasma current during long pulse discharges when using “small signal” linearized plasma models. A related objective is to determine conditions under which plasma shape and current controllers must be updated during the discharge to account for the changing plasma response