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Applying ideal Ohm's law to relaxed MHD equilibrium in Hahm–Kulsrud–Taylor slab geometry

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Multi-region relaxed magnetohydrodynamics (MRxMHD) is a powerful framework for computing smooth MHD equilibria by relaxing the frozen-in constraint, thereby permitting magnetic islands and chaotic field lines. Despite its success, the MRxMHD model has notable limitations. Incorporating plasma flow—particularly cross-field flow—remains a significant challenge. Earlier attempts introduced cross-field flow via an additional angular momentum constraint, a method restricted to axisymmetric configurations [1]. Another limitation is that the existence of MRxMHD solutions is not guaranteed in highly non-axisymmetric systems, such as modern stellarators [2].
The phase-space Lagrangian model proposed by Dewar *et al.* [3] offers a mathematically consistent approach to including cross-field flow in non-axisymmetric systems. It has also been conjectured [4,5] that adding a weak ideal Ohm's law constraint to this model may alleviate the existence problem. In this work, we investigate the solution space of the phase-space Lagrangian model [3] in two-dimensional domains. We derive a necessary condition for the existence of solutions and use it to construct explicit equilibria in slab and cylindrical geometries. We then discuss the effect of imposing the ideal Ohm's law constraint on the existence problem, illustrating the results with an example solution in the Ham–Kulsrud–Taylor (HKT) slab. Finally, we discuss the remaining theoretical challenges associated with enforcing the ideal Ohm's law constraint and their implications for future applications.

References

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Note: Abstract should be in (full) double-columned one page.