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An extended magnetospheric energy principle including neutral atmosphere

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By constructing an extended magnetospheric energy principle including the neutral atmosphere, it is shown that the existence of perturbed magnetic energy in the neutral atomosphere does not influence the existence of ionosphere-driven magnetospheric interchange instability. The instability is destabilized owing to finite horizontal plasma displacement on the spherical ionospheric surface and its discovery is based on magnetospheric energy principle. The magnetospheric energy principle neglects the existence of the neutral atmosphere below the ionosphere. Since the neutral atmosphere is not completely shielded from the influence of magnetic perturbation in the magnetosphere and may make a stabilizing positive contribution to the potential energy, the neglect of the neutral atmosphere in the magnetospheric energy principle must be properly justified in the analysis of ionosphere-driven magnetospheric interchange instability. In the well-known extended energy principle used in fusion plasmas, which incorporates the perturbation of magnetic energy in a vacuum region surrounding confined plasma, the vacuum region is known to make a stabilizing positive contribution to the potential energy. That is, energy must be fed into the vacuum region surrounding the confined plasma to perturb the magnetic field in that region. Therefore ideal MHD stability of the confined plasma must be studied by taking account of the vacuum positive stabilizing contribution to the potential energy. Assuming that the neutral atmosphere is represented by a massless neutral gas with finite pressure and that the solid earth is a perfectly conducting wall, an extended magnetospheric energy principle is constructed to investigate the possible influence of the existence of the neutral atmosphere on the magnetospheric instability. Three boundary conditions, i.e., the pressure balance and the continuity of the tangential component of the electric field at the unperturbed ionospheric surface, and a condition for the vector potential at the solid earth surface, are used in the extended magnetospheric energy principle. The extended principle is based on a single assumption that the unperturbed magnetic field is incident vertically on the unperturbed ionospheric surface. First, it is shown that for ionospheric perturbation having no displacement vertical to the unperturbed ionospheric surface and satisfying the continuity of the perturbed horizontal magnetic field component, the self-adjointness of ideal MHD force operator is satisfied and thus energy conservation in the magnetosphere is validated. Next, a destabilizing negative ionospheric potential energy term, which was found in the magnetospheric energy principle, is also found to appear in the extended magnetospheric energy principle. Thus, a destabilizing influence of the horizontal plasma displacement on the spherical ionospheric surface is confirmed. No stabilizing positive contribution due to the existence of the neutral atmosphere appears in the potential energy. Thus, the existence of the ionosphere-driven interchange instability is not affected even if the existence of the neutral atmosphere is taken into account in the magnetospheric energy principle. Therefore, the use of the magnetospheric energy principle neglecting the neutral atmosphere is justified in the analysis of magnetospheric interchange instability. Although the energy principle is based on a set of ideal MHD equations without any dissipation terms, the energy dissipation due to ionospheric Pedersen conductivity can be neglected in comparison with the negative ionospheric destabilizing contribution in the potential energy for an instability with a growth time slower than 2 minutes, when the Alfven conductance is nearly equal to the Pedersen conductivity.

Keywords: magnetosphere, energy principle, ionosphere-driven, interchange instability,
MHD instability, neutral atmosphere