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Space Power System for Ambitious Missions (4)

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HIGH-TEMPERATURE SUPERCONDUCTOR BASED POWER SYSTEM ARCHITECTURES AS ENABLERS FOR HIGH POWER MISSIONS

Abstract

High-Temperature Superconductors (HTS) have reached a high level of industrial maturity in recent years, and considering their low masses, compact volumes, and high current densities, they offer the potential to act as a disruptive technology in several spaceflight applications such as power processing and management systems, re-entry heat flux mitigation, radiation shielding, and EPS. In the latter case, efforts are already ongoing to develop and commercialise an HTS-enhanced Applied-Field Magnetoplasmadynamic Thruster (AF-MPDT) for high power mission applications. Similarly, the EU-funded MEESST project (Magnetohydrodynamic Enhanced Entry System for Space Transportation) is working to develop superconductor-based re-entry shielding systems. The Tsiolkovsky rocket equation infers that the payload mass fraction should increase indefinitely with increased Specific Impulse (Isp) However, in the case of electric propulsion, the dependence of thrust on the available power complicates this issue when considering missions where the transfer time is a primary driver. Here, the Tsiolkovsky equation becomes inadequate due to the co-dependence between the total thrust, Isp, available system power (and hence power system mass), and transfer time. Rather, a different approach is needed in order to maximise the payload mass fraction for a given mission, which does not necessarily correspond to the maximum Isp. Such an approach is applied here by considering a non-dimensional version of the Tsiolkovsky equation in terms of the mission V and transfer time, the EPS thrust efficiency, and the specific mass of the power system. This paper first discusses the recent advances and status-quo of HTS, and their suitability for spaceflight applications. The development of power system technologies is reviewed, and a conceptual power system architecture incorporating HTS is presented. These technologies are analysed in the scope of the non-dimensional Tsiolkovsky approach and their impacts on the overall payload mass fraction are assessed. For high power missions approaching 100kW and above, the use of HTS is shown to have a highly beneficial impact on the mass of the power system. Correspondingly, this enables higher payload mass fractions achievable at increased specific impulse operation, thus strengthening the case for high-power, high-Isp EPS technologies such as AF-MPDT.