Concept of Electric Propulsion Realization for High Power Space Tug

(abstract)

L.E. Zakharenkov, A.V. Semenkin and A.E. Solodukhin
SSC Keldysh Research Centre
8 Onezhskaya street, Moscow, 125438, Russia

Electric propulsion as a space technology was born in 60th of twentieth century and it is still successfully applied. Due to high specific impulse values electric propulsion application for spacecraft (SC) stationkeeping, SC orbit insertion, interplanetary and deep space missions and so on provides significant fuel saving in comparison with conventional chemical propulsion.

SC onboard available power level and power of flight electric propulsion keep increasing. For today SC on-board power level is about 20 kW [1] and single thruster power is up to 5 kW. Moreover several projects aimed at high power space tugs based on solar energy (300-600 kW of electric power) [2,3] or nuclear energy with gas-turbine conversion system (1 MW of electric power) [4,5] are in progress. For comparison the highest power level SC for today is International Space Station (ISS) with one hundred kilowatt of on-board power. Development of high power space tugs with electric propulsion system (EPS) will allow providing new challenging near-Earth and deep space missions which are hard realize without such space vehicle. These missions are given below [6]:

- Heavy payload transfer to geostationary orbit;
- Removal of out-of-operation satellites and space debris from near-Earth orbits;
- Earth protection from asteroid and cometary hazard;
- Moon exploration program;
- Mars manned mission;
- Deep space missons;
- …and so on.

Development of transport space vehicle with electric propulsion system (EPS) implies application of several simultaneously operating thrusters or so called cluster [7]. Due to limitation of high power single thruster ground testing possibility and difficulties of large-size thruster manufacturing, such EPS development direction is the only option [8].

Cluster technology potentially allows application of new EPS architecture schemes with power supply and power control functions combined in one unit and with single cathode-neutralizer providing several thrusters operation. In comparison with independent EPS architecture when each single thruster has own power supply and feed system, such common architecture looks more attractive from weight and overall characteristics point of view. In addition common architecture could be optimized by minimal number of back-up elements needed for meeting lifetime and reliability requirements.

However realization of EPS common architecture makes possible negative interference between system elements which have common electrical, gas or other connections. Issues of influence of probable cluster thrusters interaction and electric propulsion system functioning in case of single failure thruster are important for providing the whole system stable operation.

Overview and state-of-art of high power EPS main elements are presented in the paper. Issues of high power EPS elements interoperability as well as EPS control and stable operation are considered. Results of comparison analysis of main technologies and technical solutions proposed for high power EPS realization taking into account requirements to spacecraft power and propulsion systems are given.

References

1 Tom Kessler, «Solar Electric Propulsion. Evolving Capability Supporting Multiple Users & Missions», Boeing Advanced Systems, 8 June 2011.
2 Roger Myers and Christian Carpenter, «High Power Solar Electric Propulsion for Human Space Exploration Architectures», IEPC 2011-261.
3 James E. Polk, et al, «An Overview of NASA's Electric Propulsion Programs, 2010-11», IEPC-2011-330.
4 FP8 Space Research Hearing, «High Efficiency Space Transportation System Based on Nuclear Power and Propulsion», Brussels, December 08, 2010, http://ec.europa.eu/.
5 Workshop: «Implementation of the Safety Framework for Nuclear Power Source Applications in Outer Space: Modern and Planned Applications and Challenges», presentation by the Russian Federation. Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space, Vienna, 6-17 February 2012.
6 Presentation by A.S. Koroteev, Keldysh Research Center Director: «Significant Objectives of Space Exploration in the 21st Century», 1st symposium «Space & Global Security of Humanity», 2009.
7 L.E. Zakharenkov and A.V. Semenkin, «Multi-thruster Electric Propulsion System architecture and ways of simultaneously operating thrusters interaction», 4th European Conference for Aerospace Sciences (EUCASS), 2011.
8 A.V. Semenkin, L.E. Zakharenkov, and A.E. Solodukhin «Feasibility of High Power Multi-Mode EPS Development Based on the Thruster with Anode Layer», IEPC-2011-064, 32nd International Electric Propulsion Conference, Wiesbaden, Germany 2011.