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A viable megawatt-class space power installation under the Rankine cycle

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Abstract. The aim of the article concerns to the description of the main achieved research results regarding the viability of a megawatt class space power plant based on the Rankine cycle. The main objectives are to find the key issues to improve the Rankine cycle efficiency. With the proposed modifications, the ideal thermal efficiency achieved using the proposed strategies increases significantly with respect to conventional power plants. This benefit associated to the reduction of the required payload capacity, reduction of the condenser radiation surface and reduction of the power plant or installation weigh; represent the main advantages of the proposed technique.

Key words

Energy conversion, Efficiency criteria, Rankine cycle efficiency; Concentrated solar power, Solar Dynamic Power System.

1. Introduction

In the near future, space missions such as synchronous geostationary and synchronous Low Earth Orbit (LEO) space stations will require magawat type power systems characterised by increased versatility and capabilities to deliver powers of thousands of kWe, being its power levels several times the order of magnitude greater than provided on previous and existing spacecrafts [1]. For a number of reasons, including cost, growth flexibility, and operational factors, the initial space station power generating system is shared between photo-voltaic (PV) solar cell array and solar dynamic component [2]. While the advantages of the Solar Dynamic Power System (SDPS) from its high efficiency and small size, it is also important that the technology today has been well developed for terrestrial applications. It is worth great effort to extend and perfect the SDPS technology for space applications encouraging the implementation of High-Temperature Solar Thermal (HTST) as SDPS.

SDPS can be classified according to the thermodynamic cycle as: (1) Closed Brayton Cycle(CBC), (2) Rankine Cycle(RC):alkaline metal cycle, and (3) Stirling Cycle(SC), for example, free piston Stirling engine. Detailed studies were conducted on these systems for space missions over last 50 years by NASA and other research departments [3-5].

The selected and applied technology so far, has been relayed on the CBC which has been the chosen system due to its good performance such as efficiency, which is better than RC, and due to its well-proven technology compared to free piston Stirling engine system. The CBC system operates under the efficiency of about 30%, and rejects about 70% of the absorbed heat from sun radiation as waste heat to space. Based on the possibility of recovering a fraction of CBC waste heat, the conceptual design of cogeneration cycles combines Organic RC (ORC) or the two-phase power cycle, with CBC. A scheme of mentioned characteristics contributes increasing the global power plant efficiency, while decrease the concentrator and radiator areas, and reduce the overall power plant weight.

A. The Solar Dynamic Power System (SDPS) concept

A typically conceived SDPS includes the following major subsystems and/or components [6]:
1 High temperature solar concentrator.
2 Solar receiver with thermal energy storage devices.
3 Power conversion system, based on an advanced thermodynamic cycle.
4 Radiator to dissipate the rejected heat towards the outer space.
5 Appropriate controls and power conditioning and.
6 All the necessary auxiliary accessories required to make up the complete system.

SDPS concentrates sun-radiated heat into a receiver where the thermal energy is transferred to a heat engine for conversion into electrical power.
A power conversion system converts the heat engine's electrical output according the required applications of the spacecraft. The waste or rejected heat is removed through a heat exchanger and dissipated by radiator panels to space.

The concentrator is responsible for captures the incident solar energy and focuses it into the receiver aperture. The rigid deployed concentrator design includes a multi-panel deployable reflector with rigid reflector panels, a segmented deployment boom, and pointing and tracking mechanisms [7]. The deployment booms are inflated and then rigidized to position the reflector with respect to the focal plane [8].