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Author: Mr. Michael Paluszek
Princeton Satellite Systems, United States

Ms. Sarah Fry
Princeton University, United States
Ms. Stephanie Thomas
Princeton Satellite Systems, United States
Dr. Christopher Galea
Princeton Satellite Systems, United States
Ms. Joyce Mo
Princeton Satellite Systems, United States

COMBINED CYCLE POWER PLANT FOR SPACECRAFT

Abstract

Radioisotope power systems (RPS) and solar power systems have powered spacecraft for over sixty years. Solar power is intermittent and affected by environmental factors such as radiation and dust. The most popular RPS for deep space missions, the radioisotope thermoelectric generator (RTG), has low efficiency but no moving parts and is not affected by as many environmental factors. However, radiation from an RTG must be accommodated, and achieving higher power output requires a heavier and more complex power conversion system with Stirling or Brayton heat engines. Spacecraft may need bursts of high power. This requires that the power system be sized for the peak power. Sizing for peak power, or short power pulses, leads to oversized systems.

This paper describes a power system for satellites that uses a combined cycle power plant with a Brayton cycle heat engine as the topping cycle and a Rankine cycle as the bottoming cycle. The miniature power plant drives dual 9-phase permanent magnet generators capable of producing power from any fuel source. On most spacecraft, the generator would use the same fuel as that of the propulsion system. The power system can be started or stopped quickly. The combined cycle permits a smaller recuperator in the Brayton Cycle, leading to higher specific power. The system is scalable from 100's of watts to 100's of kilowatts. The heat exchangers leverage additive manufacturing developed at GE Research. This technology produces very high efficiencies, low-pressure drops, and low masses for the recuperator, the combustor, the heat exchanger, the boiler, and the condenser.

The auxiliary power system is advantageous for spacecraft that must produce closely spaced high-power pulses periodically. It can use combustors but also RTGs as a source. Another application is to increase the power margin of a spacecraft. The system is also suitable for short-duration missions, analogous to Apollo's use of fuel cells for power. It is also applicable to future fission and fusion power systems.

This paper provides the design for the power plant. The optimal heat exchangers are designed. The combustors, power electronics, and turbomachinery are also discussed. The system is compared with radioisotope and solar power systems. Examples of a LEO spacecraft, a fission power plant and a deep space flyby mission are presented.