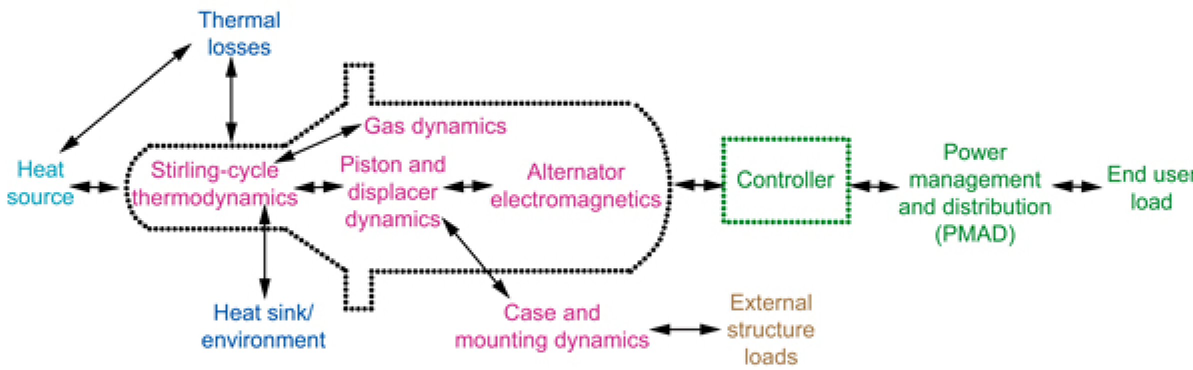
Stirling Convertor System Dynamic Model Developed



Scope of the Stirling convertor SDM within the domain of the entire spacecraft power system.

Long description of figure. Diagram showing heat source, thermal losses, Stirling-cycle thermodynamics, heat sink/environment, gas dynamics, piston and displacer dynamics, alternator electromagnetics, case and mounting dynamics, external structure loads, controller, power management and distribution, and end user load.

Free-piston Stirling convertors are being developed for potential use on NASA exploration missions. In support of this effort, the NASA Glenn Research Center has developed the Stirling convertor System Dynamic Model (SDM). The SDM models the Stirling cycle thermodynamics; heat flow; gas, mechanical, and mounting dynamics; the linear alternator; and the controller. The SDM's scope extends from the thermal energy input to thermal, mechanical, and electrical energy output, allowing one to study complex system interactions among subsystems. Thermal, mechanical, fluid, magnetic, and electrical subsystems can be studied in one model. The SDM is a nonlinear time-domain model containing subcycle dynamics, which simulates transient and dynamic phenomena that other models cannot. The entire range of convertor operation is modeled, from startup to full-power conditions.

The SDM has been developed as a "bottom-up" model based on first principles. Components are modeled separately, then combined into subsystems. The SDM can be set up to include multiple convertors in various mechanical and electrical configurations, including dual-opposed, parallel-electrical, and series-electrical configurations. It is being used to model free-piston convertors from less than 100 W to over 10 kW.

In modeling the Stirling cycle thermodynamics, the SDM assumes the isothermal Stirling cycle of the Schmidt model. It considers pumping losses through the heat exchangers and internal gas flows through the clearance seals. It includes the piston and displacer masses, along with case masses. The SDM models the piston offset due to the so-called seal pumping effect, and it connects the case mass to a ground through a compliant damped linkage. The temperature-dependent alternator model includes the output current, voltage, and electromagnetic force. A library of various controller models has been created.

The 55-We Technology Demonstration Convertor hardware and data available at Glenn are being used to validate the SDM empirically. The available data include test results documenting steady-state normal operation as well as test results that explore the robustness of the system. These include three different tests in which the power factor of the load circuit was varied by varying the value of a capacitor in series with the load. The tests covered different system configurations and different power levels. SDM simulations were performed that duplicated the test conditions for each of these tests. The results were compiled and used in the SDM validation. The model is also useful in the design of controllers and in the study of various systems issues.

The Glenn SDM uses the Ansoft Simplorer 7.0 platform. It is now being linked with Sage (Stirling cycle simulation software) to provide enhanced thermodynamic capability. The Sage thermodynamics option will be used in simulations where the isothermal Stirling cycle is not sufficiently accurate.

Bibliography

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Find out more about this research at http://www.grc.nasa.gov/WWW/tmsb/

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