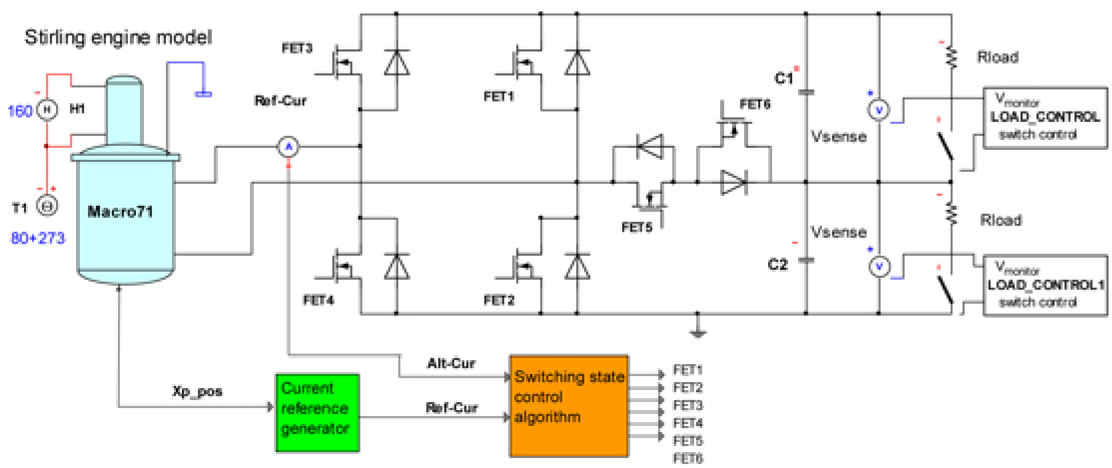
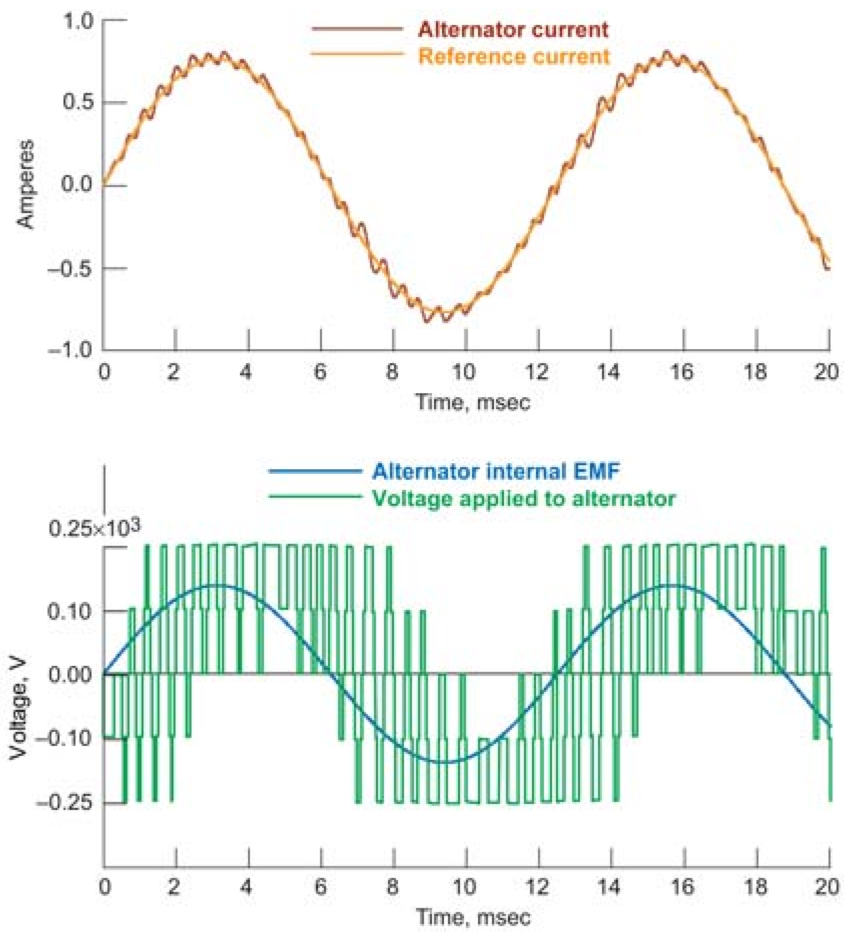
Advanced Controller Developed for the Free-Piston Stirling Convertor

A free-piston Stirling power convertor is being considered as an advanced power-conversion technology for future NASA deep-space missions requiring long-life radioisotope power systems. The NASA Glenn Research Center has identified key areas where advanced technologies can enhance the capability of Stirling energy-conversion systems. One of these is power electronic controls. Current power-conversion technology for Glenn-tested Stirling systems consists of an engine-driven linear alternator generating an alternating-current voltage controlled by a tuning-capacitor-based alternating-current peak voltage load controller. The tuning capacitor keeps the internal alternator electromotive force (EMF) in phase with its respective current (i.e., passive power factor correction). The alternator EMF is related to the piston velocity, which must be kept in phase with the alternator current in order to achieve stable operation. This tuning capacitor, which adds volume and mass to the overall Stirling convertor, can be eliminated if the controller can actively drive the magnitude and phase of the alternator current.



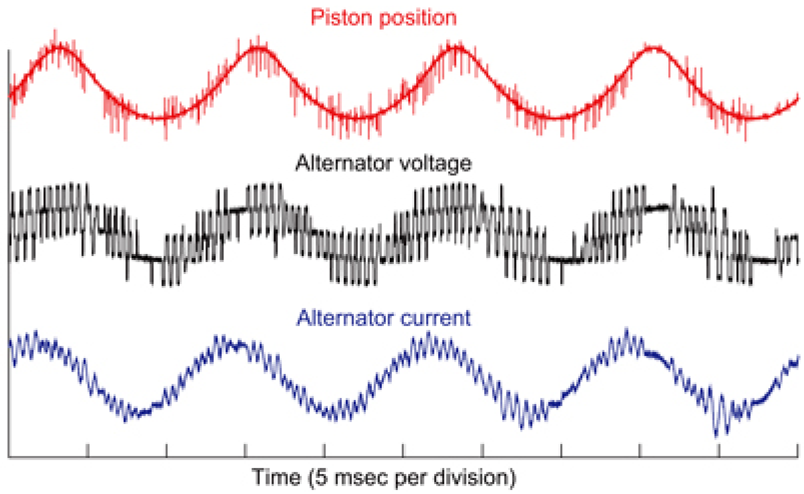
Active Power Factor Controller (APFC) and the Technology Demonstration Convertor's system dynamic model (ref. 1). Alt-Cur, alternator current; C1 and C2, capacitors 1 and 2; FET1 to FET6, MOSFET (metal oxide semiconductor field effect transistor) control signals 1 to 6; H1, hot-end temperature; Ref-Cur, reference current signal; Rload, load resistor; T1, cold-end temperature; Vsense, load voltage; Xp_pos, piston position.

To support the state-of-the-art development activity, the Active Power Factor Controller (APFC) has been developed. This controller utilizes active power factor correction electronics and microcontroller-based controls. The selected power-stage topology for the APFC is based on a three-level full-bridge circuit (ref. 2). This circuit, which was modeled in Simplorer (Ansoft Corporation, Pittsburgh, PA), as shown in the preceding diagram, is similar to a standard full-bridge circuit, except that it can provide five voltage levels for positive current control and five voltage levels for negative current control. The full-bridge topology can provide only two voltage levels for each current polarity. The next two graphs show Simplorer simulations of the alternator current, the reference current, the alternator internal EMF, and the voltage applied to the alternator by the power stage.



Simplorer simulations of the APFC.

A breadboard version of the controller has been designed, fabricated, and tested successfully with dual-opposed Stirling convertors at light loads as shown in the final graph. Future plans are to continue the development process and to test at the full rated convertor power.



APFC operation with dual-opposed Stirling Technology Demonstration Convertors.

References

1. Regan, Timothy F.; Gerber, Scott S.; and Roth, Mary Ellen: Development of a Dynamic, End-to-End Free Piston Stirling Convertor Model. NASA/TM--2004-212941, 2004. http://gltrs.grc.nasa.gov/cgi-bin/GLTRS/browse.pl?2003/TM-2004-212941.html
2. Bor-Ren Lin; and Zong-Liang Hung: A Single-Phase Bidirectional Rectifier With Power Factor Correction. Proceedings of IEEE Region 10 International Conference on Electrical and Electronic Technology, IEEE Catalogue No. 01CH37239, vol. 2, 2001, pp. 601-605.

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

ZIN Technologies, Inc., contacts: Scott S. Gerber, 216-433-5226, scott.gerber@zin-tech.com; and Mike Jamison, 216-433-2588, mike.jamison@zin-tech.com
Glenn contact: Mary Ellen Roth, 216-433-6288, MaryEllen.Roth-1@nasa.gov
Author: Scott S. Gerber
Headquarters program office: Science
Programs/Projects: Project Prometheus