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Power Conditioner with Variable Switching Control for Thermoelectric Generator Systems

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A thermoelectric (TE) power conditioner maintaining high efficiency over a wide input power range has been developed. Variable switching frequency operation is shown to give an improvement in efficient operating range. The input range showing more than 90% conversion efficiency is expanded to more than 25% by introducing a low-power controller circuit and variable switching frequency control. The TE power conditioner showed excellent response against a change in thermoelectric generator (TEG) output and load, making it suitable for automotive applications.

Key words: Power conditioner, maximum power tracking, variable frequency operation, TEG system, automotive, battery

INTRODUCTION

Thermoelectric generators (TEGs) are all-solid-state devices that convert heat energy to electricity, having advantages such as durability and maintenance-free and noiseless operation. Recent progress in thermoelectric device technology has suggested that TEGs could be competitive with conventional generators in some application fields since they are compact and scalable.[1–8] These properties are especially suitable for use in automotive waste heat recovery systems. The output power of the automotive heat source in the engine exhaust changes greatly with driving conditions. In such TEG systems, use of a maximum power point tracking (MPPT) power conditioner is indispensable to maintain optimum operating conditions, ensuring maximum system performance and flexible system design.[9–12] We have developed a MPPT control method suitable for TEG systems.[11] The TE power conditioner with MPPT inserted between the TE modules and a load controls the V_{out}/V_{in} ratio to match the virtual load impedance with the internal impedance of the TE modules.[11] In addition, parallel operation of the TE power conditioners is possible. Almost all independent systems such as those for use in vehicles and mountain huts require batteries as an energy storage device, and TE power conditioners are useful in such applications.

Generally, the conversion efficiency of power converters drops with decrease of the input power. When TEGs have unstable heat sources, a high-efficiency TE power conditioner with wide input power range is required. We have introduced a low-power-driven controller circuit and variable switching frequency control to improve system performance at low input power conditions.

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EXPERIMENTAL PROCEDURES AND DISCUSSION

Converter Power Loss at Low-Power Conditions

Power loss in direct current (DC)/DC converters in working conditions is mainly caused by energy loss in switching power devices. On the other hand, reduction of conversion efficiency in the low-power region depends on other factors. The power loss in a fully digital controlled power conditioner is expressed as follows:

$$P_{\text{total loss}} = P_{\text{on}} + P_{\text{sw}} + P_{\text{supply}}, \quad (1)$$