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Evaluation of High Step-Up Power Electronics Stages in Thermoelectric Generator Systems

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To develop practical thermoelectric generator (TEG) systems, especially radioisotope thermoelectric power supplies for deep-space exploration, a power conditioning stage with high step-up gain is indispensable. This stage is used to step up the low output voltage of thermoelectric generators to the required high level. Furthermore, maximum power point tracking control for TEG modules needs to be implemented into the power electronics stages. In this paper, the temperature-dependent electrical characteristics of a thermoelectric generator are analyzed in depth. Three typical high step-up power converters suitable for TEG applications are discussed: an interleaved boost converter, a boost converter with a coupled inductor, and an interleaved boost converter with an auxiliary transformer. A general comparison of the three high step-up converters is conducted to study the step-up gain, conversion efficiency, and input current ripples. The interleaved boost converter with an auxiliary transformer is found to be the most suitable topology for TEG applications, which is verified by experiments.

Key words: Thermoelectric generator, power electronics stage, DC–DC converters

INTRODUCTION

Thermoelectric generation is increasingly being used in remote locations in the absence of solar power or where long lifetime and high reliability are of primary concern, such as deep-space missions, offshore engineering, and oil pipelines.[1,2] However, it is always difficult to use a single series-connection design of all thermocouples to match the exact internal resistance with the load or to meet the high output voltage requirement. A power electronics stage, such as a DC–DC converter, is indispensable to connect the thermoelectric generator (TEG) modules with the power load, especially in high step-up applications.[3] Figure 1 shows the diagram of the overall system.

Many DC–DC converter topologies have been applied in some specific thermoelectric generator applications. A boost converter, which employs three interleaved phases to permit a large current with low ripples, is applied to step up the output voltage for battery charging in Ref. 4. Some DC–DC converters, which can realize either step-up or step-down power conversion applied in waste heat energy recovery systems, are introduced in Refs. 5–7. The DC–DC Cuk converter has the feature that both its input and output current are nonpulsating, which can significantly minimize the disturbance of TEG operation and enhance the maximum power point tracking (MPPT) control precision. However, the output and input voltage terminals are of opposite polarity. The input current of a single-ended primary inductor converter is nonpulsating, but the output current is discontinuous. Both of these step-up/down converters suffer from high component stresses, and thus are inappropriate for high-power applications. The boost–buck cascaded converter has low input/output current ripples and

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