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A Novel Optimization Method for the Electric Topology of Thermoelectric Modules Used in an Automobile Exhaust Thermoelectric Generator

RUI QUAN,[1,3] XINFENG TANG,[1] SHUHAI QUAN,[2] and LIANG HUANG[2]

1.—State Key Laboratory of Advanced Technology for Material Synthesis and Processing, Wuhan University of Technology, Wuhan, China. 2.—School of Automation, Wuhan University of Technology, Wuhan, China. 3.—e-mail: quan_rui@126.com

Based on Bi_2Te_3 thermoelectric modules, a kind of automobile exhaust thermoelectric generator (AETEG) with a single-column cold-source structure was designed. To enhance its net power and efficiency, the output performance of all the thermoelectric modules was tested with a temperature monitoring unit and voltage monitoring unit, and modeled using a back-propagation (BP) neural network based on various hot-source temperatures, cold-source temperatures, load currents, and contact pressures according to the temperature distribution of the designed heat exchanger and cooling system. Then, their electric topology (series or parallel hybrid) was optimized using a genetic algorithm to achieve the maximum peak power of the AETEG. From the experimental results, compared with when all the thermoelectric modules were connected only in series or parallel at random, it is concluded that the AETEG performance is evidently affected by the electric topology of all the single thermoelectric modules. The optimized AETEG output power is greatly superior to the other two investigated designs, validating the proposed optimized electric topology as both feasible and practical.

Key words: Thermoelectric modules, automobile exhaust thermoelectric generator, electric topology, genetic algorithm

INTRODUCTION

The efficiency of traditional internal combustion engines is about 30%, while nearly 40% of the fossil energy is wasted directly through the exhaust or coolant.[1] Thus, recovery of exhaust heat energy via thermoelectric technology for use in the vehicle system is important and can significantly enhance both fuel economy and system performance. To achieve this goal, use of thermoelectric generators (TEGs) based on single, low- and intermediate-temperature thermoelectric modules has been a novel research focus. Some prototype serial TEGs with optimal net power $W_e = 1$ kW for trucks and $W_e = 0.2$ kW to 0.5 kW for cars are under development.[2–4]

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The single thermoelectric module is a kind of advanced generator based on the Seebeck effect.[5] Its output performance is proportional to the temperature difference between its hot side and cold side. An AETEG usually includes many thermoelectric modules with different characteristics and temperature distributions according to their location between the heat exchanger and cooling system, and their electric topology (series or parallel) directly affects the overall output performance. Thus, it is essential to optimize the electric topology according to the characteristics of each thermoelectric module and the temperature distributions of the heat exchanger and cooling system.

DESIGN OF THE AETEG

A schematic of the designed AETEG is shown in Fig. 1. In our experimental setup there is an