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REPLY

Reply to Comment on 'Optimal design of a multi-couple thermoelectric generator'

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Abstract
The model used in the paper by Chen *et al* (2000 *Semicond. Sci. Technol.* **15** 184–8) is general and useful and has been used by several authors to optimize the performance of thermoelectric generators. The content of the comment by Chen and Liao (2004 *Semicond. Sci. Technol.* **19** 558) is incorrect.

Chen and Liao have not fully understood the optimization method widely used in the performance analysis of a thermoelectric generator, so they mistakenly believe that the model used in [1] is an incomplete model.

It is easy to see from the four heat balance equations (7)–(10) in [1] that, for given semiconductor materials and parameters L_H, L_C, T_H and T_C (the symbols used here have the same meanings as in [1]), there are five variables, i.e., Q_H, Q_C, T_{Hj}, T_{Cj} and I when the optimal problem of the internal structure of a thermoelectric generator is not considered, i.e., K is also a given parameter. In the model, there are only four equations for the five variables Q_H, Q_C, T_{Hj}, T_{Cj} and I. Using the expression of the power output or efficiency derived from the four heat balance equations in [1], we can determine the optimal value of the electric current I at the maximum power output or efficiency through extremal calculation. In fact, the optimization method has been adopted by several authors [2–6] and some significant results have been derived from the four heat balance equations (7)–(10) in [1].

When the optimal problem of the internal structure of a thermoelectric generator [1] (or cooler [7, 8]) is considered, K is also a variable. In such a case, there are six rather than five variables for the four heat balance equations (7)–(10) in [1]. From these equations, we can derive the expression of the efficiency [1]

$$\eta = \eta(I, K) = \eta[j(Q_H/T_H, K), K]. \tag{1}$$

Equation (1) may be used to optimize the internal structure of a thermoelectric generator and consequently we can determine K_{opt}, $j(\eta_{\max})$ and other optimal performances [1] of a thermoelectric generator for a given Q_H/T_H. When Q_H/T_H is not given, the efficiency η is a function of I and K. From equation (1), we can also derive other new optimum results.

The above discussion shows that the model used in [1] is not only complete but also general and useful.

When the load matching problem of a thermoelectric generator is further considered, the power output may be expressed as [5]

$$P = I^2 R_I, \tag{2}$$

where R_I is the load resistance of an external circuit. From equations (8) and (9) in [1], we can easily derive another expression of the power output as

$$P = Q_H - Q_C = AI(T_{Hj} - T_{Cj}) - I^2 R. \tag{3}$$

From equations (2) and (3), we obtain

$$R_I = \frac{A(T_{Hj} - T_{Cj}) - IR}{I}. \tag{4}$$

It is seen from equation (4) that the parameter n should not be included in the expression given by Chen and Liao. Equation (4) provides the matching condition of the load resistance for a thermoelectric generator. Using the electric current determined by the optimization method mentioned above, we can find the optimal value of load resistance [5].

If the load resistance R_I is taken as a given constant and the optimal problem of the internal structure of a thermoelectric generator is not considered, equation (4) and the four heat balance equations (7)–(10) in [1] may be directly used to determine five variables Q_H, Q_C, T_{Hj}, T_{Cj} and I, so that there is no optimal analysis problem of the electric current and the thermoelectric generator cannot be, in general, operated in the optimal state. It is thus clear that in the optimal design of a thermoelectric generator, the load resistance R_l should be taken as a parameter to be determined rather than a given constant.

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