HIGH EFFICIENCY MAXIMUM POWER POINT TRACKING POWER CONDITIONER FOR TEG SYSTEMS

Hiroshi. Nagayoshi[1], Kenta Tokumitsu[1], Hiroshi Maiwa[2], and Takenobu Kajikawa[2]

1- Tokyo National College of Technology, 1220-2, Kunugida-machi, Hachioji, Tokyo, Japan
2- Shonan Institute of Technology, 1-1-25, Nishikaigan, Tsujido, Kanagawa, Japan Contact author: nagayosi@r2.dion.ne.jp

Recent progress on thermoelectric device technology reveals a possibility of spreading large thermoelectric generator systems in near future as well as various applications such as cars, micro electronics, etc. On the other hand, most heat sources are unstable and have temperature distribution, causing mismatch power loss since output voltage of TE module largely changes with temperature difference. To derive maximum power from TE modules in the large TEG systems, a power conditioner with maximum power point tracking control is needed. We have been investigated the mismatch power loss caused by the temperature distribution on a heat source of large TEG systems[1,2]. TE modules are connected in series to obtain required output voltage, composing string. The strings are connected in parallel to obtain required output power. The mismatch power loss is affected a lot by an electrical connection topology on heat source and such mismatch power loss could be reduced by an insertion of MPPT power conditioners. We have estimated the mismatch power loss by calculation and developed the Maximum Power Point Tracker (MPPT) control method suitable for TEG systems. The prototype circuit was composed of basic buck-boost circuit with conversion efficiency of up to 80%. This time, we have developed the practical MPPT power conditioner unit with high conversion efficiency. In the large TEG systems, many TE modules are connected in series. The break down of TE module in the string causes a failure of all other TE module output in the string. To avoid such power loss, we have introduced the bypass diode to each TE modules. The paper describes the string power conditioner system with bypass diode.

Variation of TEG systems with power conditioner

Figure 1 shows schematic model of power conditioner systems. The power conditioner is composed of step up/down converter with MPPT control. The step up/down mode of converter depends on the combination of TEG and a load. When the load voltage at optimum operating point is higher than the TEG's optimum output voltage, step up converter is needed. The boost converter circuit can be used as step up converter. Usually, conversion efficiency of Boost converter degrades with increase of conversion ratio. The Boost converter circuit is simple however, maximum conversion ratio is limited. Higher conversion ratio can be obtained using transformer type converter circuits. At the opposite condition, Buck converter circuit can be used as step down converter. Buck/Boost converter circuit shows wide matching ability. The variation of MPPT power conditioner system can be classified to three systems: single converter system, string converter system and module converter system. When all TE modules have same temperature distribution, the single converter system effectively reduces the mismatch power loss between load and TE modules. However, the mismatch power loss caused by temperature distribution cannot be minimized by this system. When a TE module breaks down, all other TE

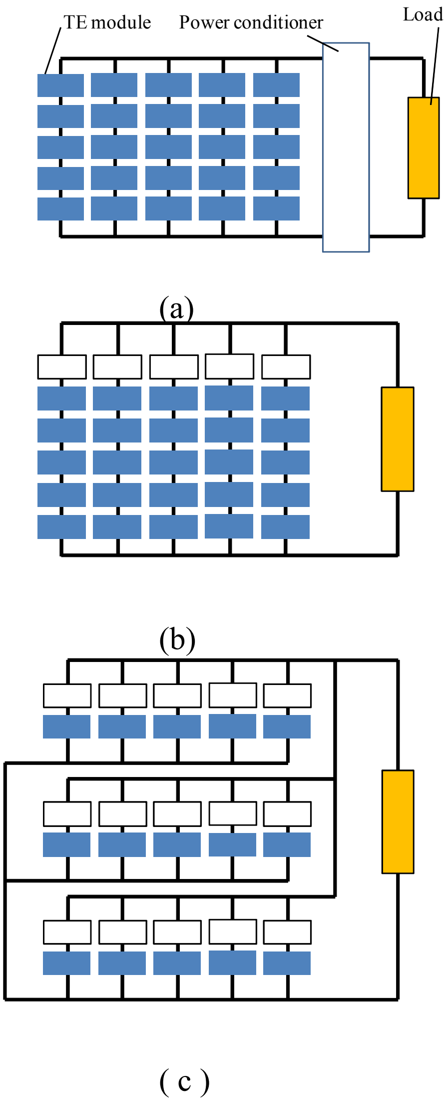

Fig.1 Variation of TEG systems with MPPT power conditioner: (a) single converter system (b) String converter system (c) module converter system.

modules in the string also become fail to contribute power generation since they are connected in series. We must design power conditioners to match the required power of each system. In the module converter system, each TE module has small MPPT power conditioner, being minimized mismatch power loss at any conditions. The power scale of conditioner does not depend on the scale of TEG systems. Such systems need many power conditioners, but we can expect cost reduction by mass production. The power conditioner might be required high step up conversion ratio since present TE modules show low output voltage. The output power of present practical TE module is some ten Watts, so we are thinking module converter system is not cost effective now. In the string converter system, each string has one power conditioner, connected in parallel. The output voltage depends on the number of TE modules connected in series. The mismatch power loss caused by temperature distribution depends on connection topology of TE modules. When the string is placed along to the isothermal line, mismatch power loss can be minimized. The mismatch power loss caused by temperature distribution in the string cannot be reduced by MPPT power conditioner since each TE module has different optimum current. The power scale of power conditioner does not depend on the total output power of TEG system, but depends on power scale of string. We are thinking this system is most practical in the present technology.

Power conditioner

Figure2 shows the schematic diagram of the power conditioner circuit. We have introduced the Buck/Boost converter to obtain wide matching ability. To improve its conversion efficiency and reduce the size of components, high frequency synchronized switching controller circuit has introduced. The power conditioner is mainly composed of high frequency synchronized switching converter circuit and microcontroller. Maximum input power is 60W.

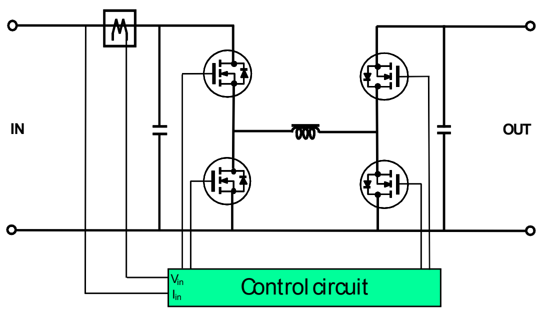

Fig.2 Schematic of the circuit.

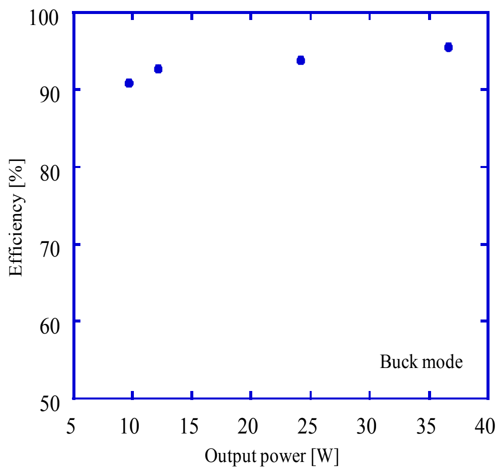

Fig.3Output power vs conversion efficiency

The circuit showed high conversion efficiency up to 95% as shown in Fig 3. We have been developed the MPPT control algorithm suitable for TEG systems. The circuit periodically measures an internal conductance of a string and controls the virtual load conductance to match the internal conductance of the string.

Effect of bypass diode

Reliability against thermal stress is an important issue on TE modules. There is a possibility of TE module break down in large TEG systems. To avoid power down of a string by TE module failure, we've introduced bypass diode system as shown in Fig.4. At the normal operating condition, each bypass diode is reverse biased. When the TE module in the string breaks down, string current can flow through the diode. Calculated result of bypass diode effect is shown in Fig.5. The TEG is composed of 25 modules and each string has five TE modules.

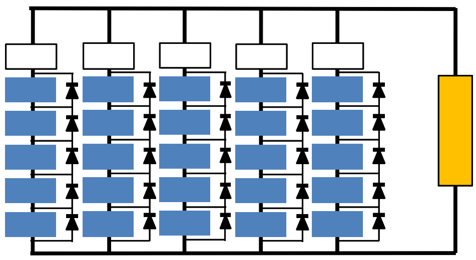

Fig.4 Schematic of electric connection of bypass diode.

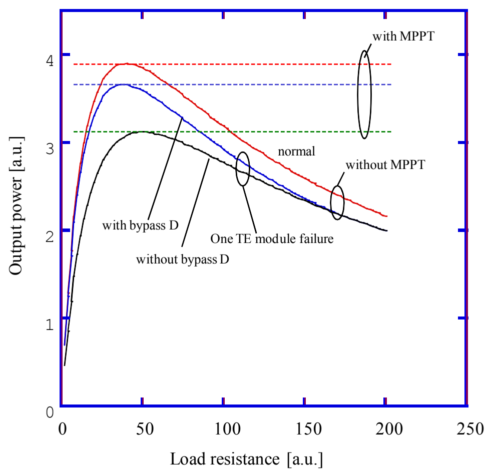

Fig.5 Effect of bypass diode on output power vs load resistance.

As shown in the Figure, power reduction by TE module failure effectively minimized by bypass diode. The internal conductance changes by the TE module failure. There is a possibility that the change of internal conductance leads the mismatch power loss. The affect of the conductance change depends on the number of TE modules connected in series. The result shown in Fig.5 does not show large difference. A detection of TE module failure in the large TEG system is practically important. It is possible to detect TE module failure by measuring the change of internal conductance of string.

Summary

The variation of MPPT power conditioner systems was discussed. The string converter system is most practical in the large systems in terms of cost and power scale flexibility. High efficiency MPPT power conditioner has been developed. We proposed the bypass diode system to minimize the .power down by the TE module failure in the large TEG systems.

References

[1] H. Nagayoshi and T. Kajikawa Proceedings of 25th International Conference on Thermoelectronics, 2006□210

[2] H. Nagayoshi, K. Tokumitsu and T. Kajikawa:, Proceedings of the 5th European Conference on Thermoelectronics, 2007, 80