Maximum power point tracker to enhance output performance of thermal energy harvesting system

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ABSTRACT – The maximum power point tracker (MPPT) method to enhance the output performance of thermal energy harvesting system for suitable electronic device usage is present. The approach is inspired by MPPT concept of simple perturb and observe (P&O) technique for sub mW output produce from thermoelectric module (TEM). The P&O technique is also combined with pulse width modulation (PWM) generator to control the output for dc-dc converter. This technique is chosen due to simplicity and ease circuit design. Results show that the technique proposed has successfully increase current output performance of thermal energy harvesting system from 300 mA into 1.7 A which is 70 % increment from different method previously.

1. INTRODUCTION

In purposes to reduce global dependency on fossil fuel sources, limited lifetime of batteries consumption and provides solution for environmental pollution an application of energy harvesting from ambient environments has been introduce for a past few years. Various perspective of energy harvesting concept has been introduce including kinetic energy (wind, waves, vibration, gravity), electromagnetic energy (photovoltaic m radio frequency), thermal energy, hybrid energy and many more [1,2,3]. Thermal energy harvesting is a process of capturing heat waste, heat energy into electrical energy and convert into electrical energy. As stated by Nguyen and Pochiraju [1], this condition occurs due to thermal difference exist between hot and cold junction of thermo-electric module (TEM). However previous investigation reported by Husna [2], Sharuddin [3] and Hidaka et.al [4], TEM can only provide very low power sources with very small amount of current rating. Therefore, MPPT algorithm technique is propose to enhance the current performance of TEH system. Three MPPT algorithm commonly incorporate with charge controller from various sources under specific condition namely as Perturb and observe (P&O) [5-6], incremental conductance [7] and impedance matching. P&O algorithm, is commonly used because of simplicity and ease design development.

2. METHODOLOGY

The block diagram of TEG system proposed in this paper is illustrated in Figure 1. Basically, temperature differences are detected by the array of hot and cold junction at the TEG sources and supplied to the maximum power point tracker controller as well as to the boost converter. At this point, the minimum input before the boost converter should exceed more than 0.7V. The MPPT controller circuit is implement in between the output of TEG and boost converter, to ensure that the TEG is operated at the peak power in various conditions entry. The P&O technique with direct control of duty cycle is used for MPPT solely system without exhibit power loss oscillation. The Simulink in MATLAB under steady state condition is implemented to validate the output performance.

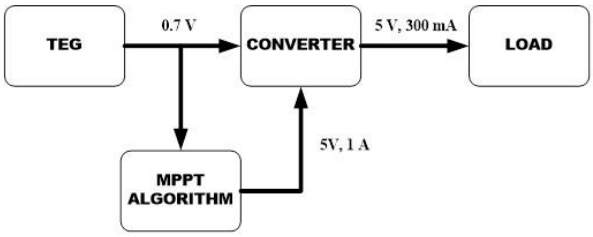

Figure 1 Block diagram for TEG system proposed

Figure 2 depicted the involvement with several subsystems for the whole diagram including TEM, MPPT algorithm, pulse width modulation (PWM) generation block, the boost converter block and output block. The TEG internal resistance, (R_{TEG}) and open circuit voltage, (V_{OC}) are two crucial parameters in DC-DC converter to produce real time temperature varying. In order to get the better output performance for R_{TEG} and V_{OC}, temperature difference also plays an important role. With the MPPT model in the system, the output increment can be obtained. The input parameters for the MPPT model includes the sampling time, duty cycle, the perturbation step, DC voltage and DC current. With all the parameters provided, the input parameter and output current and voltage can be obtained.

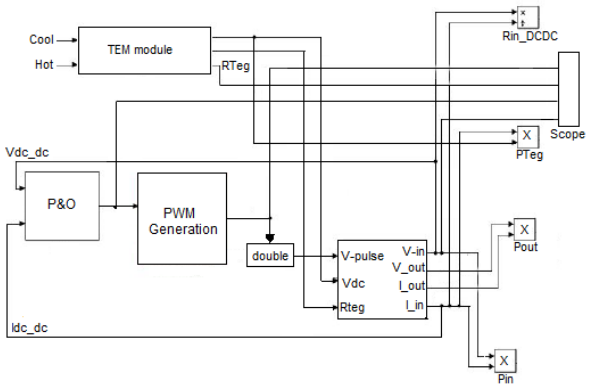

Figure 2 Summary of TEH simulation system

3. RESULTS AND DISSCUSSION

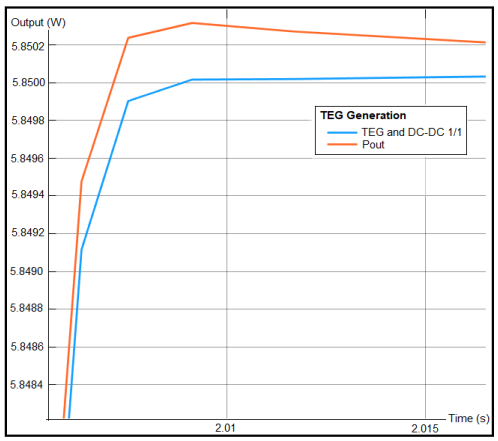

Figure 3 Input TEG versus voltage output

Several parameters are observe during the simulation such as duty cycle, power delivered to boost converter, the output power system as well as input and output voltage to dc converter. Figure 3, shows magnification graph of the TEG input and output voltage simulation for the TEH system. Due to very small amount of output, perform in the graph, the magnification of the image for each output is highly ambiguous. It shows that output voltage (red line) is increment of 2% higher than the input voltage (blue line).

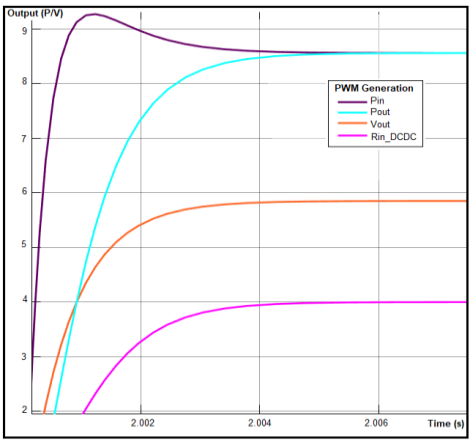

Figure 4 Input TEG versus voltage output

Figure 4 illustrated the input and output power of the system. The graph obviously shows that the input power at the peak value before reach at the steady-state condition. In contrast with theory, output power should be higher than the input power. At this point, input power is higher than the output power before both achieved their steady-state condition. This spark probably happens due to higher temperature difference detected at the TEG array source,

Finally, P&O technique proposed has successfully increase current output performance of thermal energy harvesting system from 300 mA into 1.7 A which is 70 % increment from different method previously.

4. CONCLUSIONS

The MPPT algorithm to enhance the output performance of thermal energy harvesting system has attained by simulation using Simulink in MATLAB. No doubt, the P&O technique proposed has significantly enhanced the output performance of thermal energy harvesting system. Therefore, this technique is recommend to be utilise with TEG module to improve the output performance of thermal energy harvesting for electronic device usage in future.

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REFERENCES

[1] Nguyen, N. Q., Pochiraju, K. V. (2013). Behaviour of thermoelectric generator exposed to transient heat sources. *Appl. Therm. Eng. 51,* 1-9.

[2] Husna, N. M. (2016), Thermal energy harvesting for small device application, Final Year Project, *Universiti Teknikal Malaysia Melaka*.

[3] Sharuddin. M.S. (2016), Thermal energy harvesting for electronic devices application, Final Year Project, *Universiti Teknikal Malaysia Melaka.*

[4] Hidaka, A., Tsuji, A., Matsumoto, T., S. A thermoelectric power generation system with ultra low input voltage boost converter with maximum power point, 2012, *Int. Con. on Renewable Energy Research and Applications (ICRERA),* 1-5.

[5] Mamarelis, E., Petrone, G., Spagnuolol, G., (2014) A two steps algorithm improving P&O steady state MPPT efficiency. *Int. J. Elect. Power Sys. 59,* 141-154.

[6] Yusop. A. M., Mohamed, R., Ayob, A., Mohamed, A. (2017), Shapeable maximum power point tracking algorith, to imporve the stability of hermoelectric-solar output behavior of thermoelectric solar hybrid energy harvesting system. *J Assoc. Arab Univ. for Basic Applied Science, 22,* 1-8.

[7] Kumar, K. K., Bhaskar, R., Koti, H. (2014). Implementation of MPPT algortihm for solar photovoltavci cell by comparing the short circuit method and incremental conductance method, *Procedia, Technol. 12,* 705-715.