Research Paper
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Design of Microcontroller Based Thermoelectric Energy Harvesting Module for Battery Storage System

Engineering

KEYWORDS : Thermoelectric Energy Harvesting Module (TEHM), Thermoelectric Generator (TEG), Maximum Power Point Tracking (MPPT)

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ABSTRACT

In this paper we propose the conventional method for developing thermoelectric energy harvesting module (TEHM) with battery storage system using low power thermoelectric generator. Thermoelectric generator generates low electric output due to small temperature difference between hot side and cold side. This leads to low productivity and it does not contribute to recharge the battery to store energy. To overcome this, maximum power point tracking is exposed with modified hill climbing fuzzy logic control using PIC microcontroller is taken. This improves voltage and overall efficiency of the system and gives steady state output for battery recharging and storing system. Here we are analyzed TEG with various parameters that shown on MATLAB simulation and also verified this output with TEHM hardware output with maximum efficiency.

1. INTRODUCTION

The most common sources of energy available for harvesting are light (solar), heat (thermal) and vibration. In this thermal energy harvesting using TEM has recently attracted and augmented attention as independent, renewable and clean energy source. Thermoelectric generator (TEG) is a solid state portable device that generates electric power with the temperature variance between hot side and cold side. In most of the cases, a considerable amount of energy is wasted or unused in the form of heat exhaust. TEHM consists of thermoelectric generators generates electric power with the available heat energy (unused exhaust heat). This has been impeded by inconsistent output because of temperature fluctuation. To improve the system efficiency [3]-[4] and steady state, maximum power point tracking (MPPT) control is introduced.

Many of MPPT schemes like perturbation and observation, incremental conductance schemes, adaptive MPPT schemes have been proposed in TEG applications. These perturbation and observation, incremental conductance schemes have been widely used because of its simplicity and easy implementation but these schemes frequently struggle with steady state oscillation and slow dynamic performance [5]. Hence we go for modified MPPT schemes which overcome these difficulties and employ a variable step size. This MPPT scheme is designed with modified fuzzy logic based hill climbing method [8].

Here we implemented the MPPT based control for getting maximum output from TEG through dc to dc boost converter. This energy is taken to recharge the battery system.

2. TEG CHARACTERISTICS AND PARAMETERS

TEG is working with the principle of Seeback effect. It consists of two sides, hot side and cold side. The temperature difference between these two sides causes voltage. The temperature at hot side is taken as T_H and the temperature at the cold side is taken as $T_{C.}$

The characteristic of every TEG may vary depending on manufacturer. The parameters of TEG like Seeback coefficients, gain, operating temperature and coupled ratio are given on the technical guide provided by them [1]. The basic model of TEG is shown in figure 1.

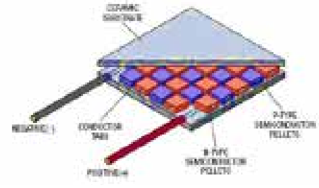


Fig 1: Basic model of TEG.

3. MPPT SCHEME BASED ON MODIFIED FLC METHOD

Modified hill climbing technique operates by Fuzzy Logic Control (FLC) based algorithm [2]. MPPT controller is designed to take advantage of hill climbing simplicity and eliminate all the conventional method drawbacks mentioned below

1) During steady state condition, the output power oscillates that cause power loss in the system.
2) Slow converging to the operating point.
3) During irradiance, the operating point moves away from the maximum power point.

The block diagram of the MPPT scheme based on modified FLC is shown in figure 2.

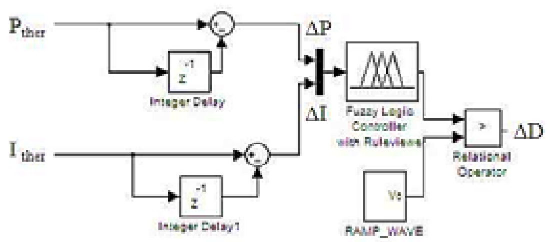


Fig 2: Block diagram of MPPT controller with modified hill climbing FLC method.

The fuzzy logic controller inputs are

$$\Delta P = P(n) - P(n-1)$$

$$\Delta I = I(n) - I(n-1)$$

The output equation of FLC is

$$\Delta D = D(n) - D(n-1)$$

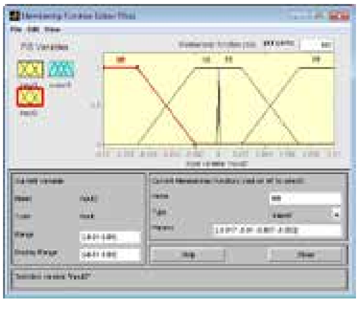
where P_{ther} is thermoelectric generator output power and I_{ther} is output current from the TEG module. Also $\Delta P \Delta P$ is power change in output and $\Delta I \Delta I$ is output current change in TEG [9]. $\Delta P \Delta P$, $\Delta I \Delta I$ and $\Delta D \Delta D$ can obtain by comparing the present value with the past values. $\Delta D \Delta D$ is the change of duty cycle in the boost converter.

In modified hill climbing FLC method one input is compared with all other inputs in order to find all possibilities [2]. Here we have two inputs in FLC $\Delta P \Delta P$ and $\Delta I \Delta I$. Thus we get totally sixteen fuzzification rules. The input and output variable are classified into four subsets negative small (NS), negative big (NB), positive small (PS), positive big (PB). Hence there are sixteen control rules are available on fuzzy rule algorithm based on modified hill climbing algorithm. The fuzzification rules are given below

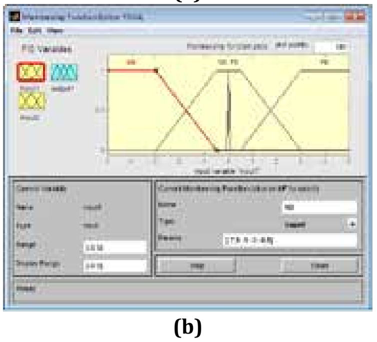
1. If ΔP is NB and ΔI is NB then ΔD is PB
2. If ΔP is NB and ΔI is NS then ΔD is PB
3. If ΔP is NB and ΔI is PB then ΔD is NB
4. If ΔP is NB and ΔI is PS then ΔD is NB
5. If ΔP is NS and ΔI is NB then ΔD is PS
6. If ΔP is NS and ΔI is PB then ΔD is PS
7. If ΔP is NS and ΔI is PS then ΔD is NS
8. If ΔP is NS and ΔI is PS then ΔD is NS
9. If ΔP is PB and ΔI is PB then ΔD is PB
10. If ΔP is PB and ΔI is PS then ΔD is PB
11. If ΔP is PB and ΔI is NB then ΔD is NB
12. If ΔP is PB and ΔI is NS then ΔD is NB
13. If ΔP is PS and ΔI is PS then ΔD is PS
14. If ΔP is PS and ΔI is PB then ΔD is PS
15. If ΔP is PS and ΔI is NB then ΔD is NS
16. If ΔP is PS and ΔI is PS then ΔD is NS

To work with these fuzzy rules, Mamdani's method with max-min is used. The Simulink model gives the fuzzification output as per the modified hill climbing FLC method represented in [2]. The input and output of the fuzzification is show in figure 4.

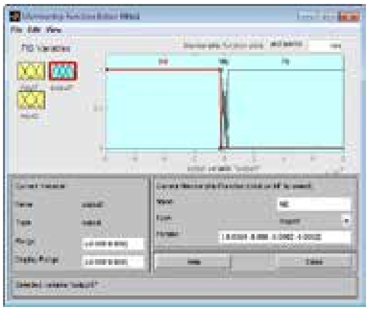
The inputs of fuzzy control are varying with variable step size with respect to TEHM. Also the duty cycle can increment or decrement depending on the variable step sizes computed by the FLC [10]. So that the tracking time is small and the performance of steady state is improved.



(a)



(b)



(c)

Fig 4: Membership functions: (a) input △ P△ P (b) input △ I△ I and (c) output△ D△ D.

4. DESIGN METHODOLOGY

The thermoelectric generator gets the input temperature from the device which interfaced with it. If the input temperature meets the constant required value of TEG energy conversion takes place. The complete block diagram is shown in figure 5.

Input temperature is given as step input signal to the simulation and is taken into TEHM. Thermoelectric TEHM has the maximum temperature value and minimum temperature value [12]. These values are taken as hot side temperature and cold side temperature. The hot side temperature value can obtain from maximum temperature and input temperature.

$T_H = T_{max} + T_{in}$

$\Delta T = T_H - T_C$

where T_H is hot side temperature and T_{max} is maximum temperature and T_{in} is input temperature. ΔT is temperature difference between hot side and cold side. This difference gives the small amount of unsteady voltage and current.

Fig 5: Block Diagram of Thermoelectric Energy Harvesting Module

This output voltage is taken to dc – dc converter with MPPT controller using modified hill climbing algorithm. The voltage gets maximum boosted by MPP tracking algorithm. Thus the open circuit voltage of thermoelectric TEHM is obtain from the following equation

$V_{OC} = n_{coupled} * 2 * K * \Delta T$

Here V_{OC} is open circuit voltage, $n_{coupled}$ is coupled ratio, K is index constant and ΔT is temperature difference. To calculate modulation index and load resistor following equations are used.

$K_{mod} = ncoupled * 2 * K * G$

$R_{mod} = (n_{coupled} * 2 * P)/G$

here the variables G, K, P are constant parameters available on TEG module. And $R_{load} = 0.5$. To calculate output current

$I = V_{OC} / (R_{mod} = R_{load})$

The steady state output current and boosted voltage can meets the battery specification by means of dc-dc boost converter [11]. So battery gets easily recharged with the help of its own energy also sustain the battery standby time and improves the performance. The result of this module is carried with the help of Simulink in MATLAB. This can be shown in experimental results.

5. EXPERIMENTAL RESULTS

By using the equations and parameters as mentioned above we calculate the output voltage and output current. The MATLAB simulation output is shown in figure 5.

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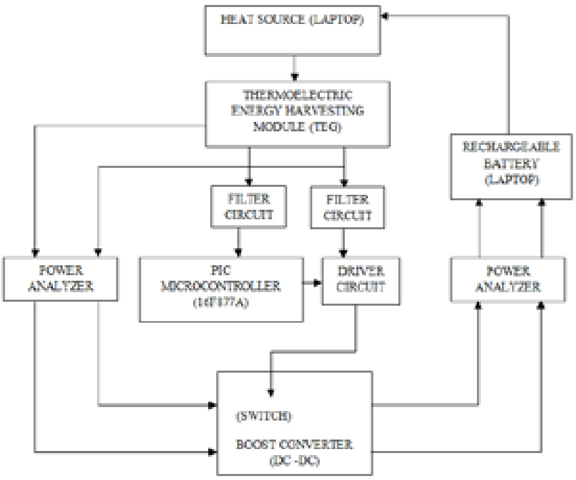
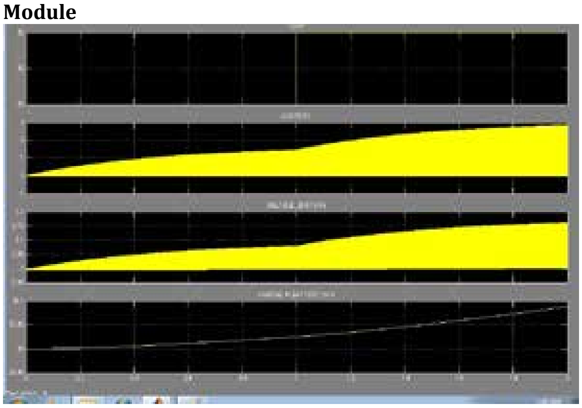


Fig 5: Block Diagram of Thermoelectric Energy Harvesting Module



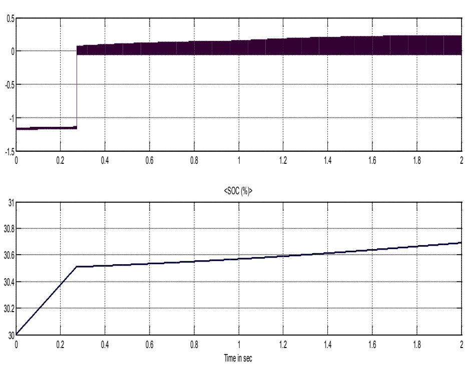


Fig 5: MATLAB Simulation Output

The simulation output shows the proposed system performance and it is compared with the corresponding TEHM hardware output. The hardware of TEHM contains microcontroller unit and TEG unit. The output of MATLAB simulation is compared with TEHM hardware output. The hardware consists of PIC16F88 microcontroller and boost converter modules with TEHM. It has the overall control system to produce steady state output with fuzzy control method. This proves the proposed system is stable and also exhibits maximum performance of TEHM for battery storage system for portable applications.

6. CONCLUSION

This paper shows the design and output performance of TEHM with maximum power point tracking algorithm. The MPPT is designed with modified hill climbing method with FLC controller. This provides steady state output and improves overall performance and efficiency. This also improves battery duration and keeps long working. Also it can easy to design and implement in any of portable applications which runs on battery.

REFERENCE

[1] Rae – Young Kim, "Analysis and design of maximum power point scheme for thermoelectric battery energy storage system," IEEE Trans. Industrial Electron., vol.56, no.9, pp. 3709 – 3716, Sep.2009. | [2] Alajmi,B.N. "Fuzzy-logic-control approach of a modified hill climbing method for maximum power point in micro grid standalone photovoltaic system," IEEE Trans. Power Electro., vol.26, no.4 , pp. 1022 – 1030, Apr.2011. | [3] T. Kyono, R. O. Suzuki, and K. Ono, "Conversion of unused heat energy to electricity by means of thermoelectric generation in condenser," IEEE Trans. Energy Convers., vol. 18, no. 2, pp. 330–334, Jun. 2003. | [4] R.-Y. Kim and J.-S. Lai, "A seamless mode transfer maximum power point tracking controller for thermoelectric generator applications," IEEE Trans. Power Electron., vol. 23, no. 5, pp. 2310–2318, Sep. 2008. | [5] A. Meehan, H. Gao, and Z. Lewandowski, "Energy harvesting with microbial fuel cell and power management system," IEEE Trans. Power Electron., vol. 26, no. 1, pp. 176-181, Jan. 2011. | [6] Y. K. Ramadass, "Energy processing circuits for low-power applications," Ph.D. Dissertation, Massachusetts Institute of Technology, Cambridge, MA, Jun. 2009. | [7] J.-P. Im, S.-W. Wang, K.-H. Lee, Y.-J. Woo, Y.-S. Yuk, T.-H. Kong, S.-W. Hong, S.-T. Ryu, G.-H. Cho, "A 40mV transformer-reuse self-startup boost converter with MPPT control for thermoelectric energy harvesting," in IEEE Int. Solid-State Circuits Conf. Dig. Tech. Papers, Feb. 2012, pp. 104–105. | [8] T. L. Kottas, Y. S. Boutalis, and A. D. Karlis, "New maximum power point tracker for PV arrays using fuzzy controller in close cooperation with fuzzy cognitive networks," Energy Convers., IEEE Trans., vol. 21,no. 3, pp. 793–803, Sep. 2006. | [9] L. Fangrui, K. Yong, Z. Yu, and D. Shanxu, "Comparison of P&O and hill climbing MPPT methods for grid-connected PV converter," in Proc. 3rd IEEE Ind. Electron. Appl. Conf., 2008, pp. 804–807. | [10] C. Larbes, S. M. Ait Cheikh, T. Obeidi, and A. Zerguerras, "Genetic algorithms optimized fuzzy logic control for the maximum power point tracking in photovoltaic system," Renewable Energy, vol. 34, no. 10, pp. 2093–2100, Oct. 2009. |