TEG BASED POWER SYSTEM for OPERATION of HEALTH MONITORING SERVER in INDUSTRIES

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***Abstract*— In Hazardous environment industries where the emission of toxic gases and effluents will have an impact on the health of the operators, the recording of health parameters of individual operators is very important. In such situation the health monitoring of operators are being monitored and processed centrally by a server and this can be powered by a system of batteries which can be operated from TEG to ensure reliability and to utilize the exhaust heat energy of industries for better performance. This paper describes the Thermo electric generator with battery that supports medical server. The thermoelectric generator converts heat energy into electrical energy. Mathematical model of thermoelectric generator was developed in MATLAB SIMULINK. This exhibits different voltage and current for various temperature differences. The proposed system uses maximum power point tracking algorithm to obtain the maximum power from the thermoelectric generator. This algorithm is developed in embedded MATLAB controller, which gives the firing angle to the DC-DC Boost converter for various temperature differences. This will increase the efficiency of the system.**

Keywords- Thermoelectric generator, MPPT controller, Boost converter.

I. INTRODUCTION

In India the electric energy demand is increasing day by day because of more industrial related activities and increased comforts of the people etc., In order to meet the demand the government is planning new power projects and also the thought of utilizing renewable energy sources, waste heat recovery and putting non-conventional energy source based power plants. Electrical power in remote areas generated by gasoline motor generators are too noisy require too much maintenance and high fuel costs [5].

Renewable energy sources like solar, wind, and hydro power is preferred, but it has limited use and depends on law of nature, prevailing weather condition and topography. The thermoelectric generators can utilize waste heat from systems and convert it into electrical energy directly. Thermoelectric power generation is maintenance free, silent in operation as it does not involve any moving parts.

In the past years good amount of work was reported on TE Power generation. Killander [2] developed a stove-top generator using two TE power modules, model HZ-20. During the operating time, the model output was about 10W and supplied the battery with a net input from 1 to 5 W. Rahman [3] developed the thermoelectric generator to supply portable electronic equipment or to charge a laptop computer battery. The generator is powered from butane gas; it has a potential power output of 13.5 W. Roth et al [4] developed and tested a photovoltaic/thermoelectric hybrid system as a power supply for a mobile telephone repeater. The system is developed and it supplies enough for 50 W permanent loads. The output parameter was monitored continuously and MPPT control was used in thermoelectric generator system leading to improvement of charging performance. Jensak Eak [1] proposed MPPT techniques used in photovoltaic (PV) systems to maximize the PV array output power by tracking continuously the maximum power point (MPP) which depends on panel's temperature and on irradiance conditions [6].

The proposed system using embedded controller for monitoring of parameters at the input side of boost converter and temperature monitoring over the period of time of TEG will improve the performance and efficiency of the system. This proposed scheme is going to be implemented in a practical scenario involving a battery deployed for health monitoring of operators in industries in which toxic gases in some sections are unnoticed but has an influence on health of operators. The Simulation of the system model was carried out and tested with temperature parameter. This autonomous battery powered by exhaust heat which supplies power to medical server through TEG will improve monitoring activities of plant operators. Likewise the battery charged using this TEG based system can also be used for relaying actions, and act as independent source for operating different loads in critical situations.

II. THERMOELECTRIC GENERATOR

Thermoelectric generator (TEG) is a device works on the principle of 'thermoelectric effect' which directly converts thermal energy into electrical energy. The principle used in TEG is Seeback effect. Seeback effect is responsible for electrical power production i.e., it produces an electromotive force (emf) and accordingly an electric current in a closed loop formed by at least two dissimilar conductors when two junctions are maintained at different temperatures. Thermoelectric generator consists of thermopile sandwiched between two thin ceramic wafers. Thermopile is developed by means of series and parallel combinations of thermocouple which is made up of p-type and n-type semiconductor material. The schematic diagram of TEG is shown in Fig.1. TEG generates electricity when exposed to hot and cold junctions.

The emf (voltage) produced is proportional to the temperature difference present between the two junctions. The proportionality constant (α) is called as the Seeback coefficient, which is the ratio of voltage generated by the seebeck effect and temperature difference between the two junctions, and it is also known as the thermoelectric power or thermo power. Almost any heat source can be used in this TEG to generate electrical power such as solar heat waste heat from the thermal and biomass power plants etc.

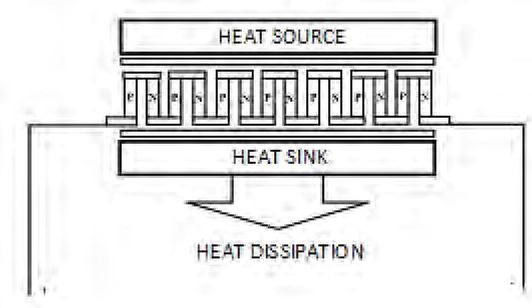

Fig. 1 Thermoelectric generator

III. Open Circuit Voltage and Equivalent circuit model of Thermoelectric Generator

Thermoelectric generator open circuit voltage is given by,

$$Voc=\alpha*N*(T_h-T_c)$$

Where, Voc – Open circuit voltage.

α – Seebeck coefficient.

N – No. of thermo element in the module.

T_h – Temperature at the hot side.

T_c – Temperature at the cold side.

Based on the above equation mathematical model of thermoelectric generator was developed and equivalent circuit model was formed in MATLAB SIMULINK as shown in the Fig. 2.

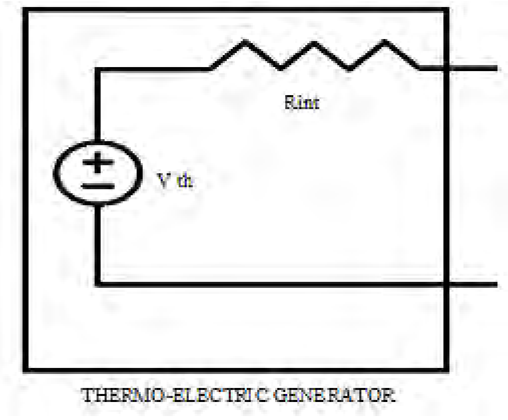

Fig. 2 Equivalent circuit model of Thermoelectric generator

In this thermoelectric generator equivalent circuit voltage source is connected in series with the internal resistance (R_{int}) of thermoelectric generator. The value of the voltage generated from the thermoelectric generator is calculated from the Open circuit voltage equation which is given in the Eq.1.

The block diagram consisting of different sensor nodes deployed for health monitoring of operators which is centrally processed in a server and is powered by a battery which is being charged through rectifier conditioning circuit and thermoelectric generator is shown in the fig.3.

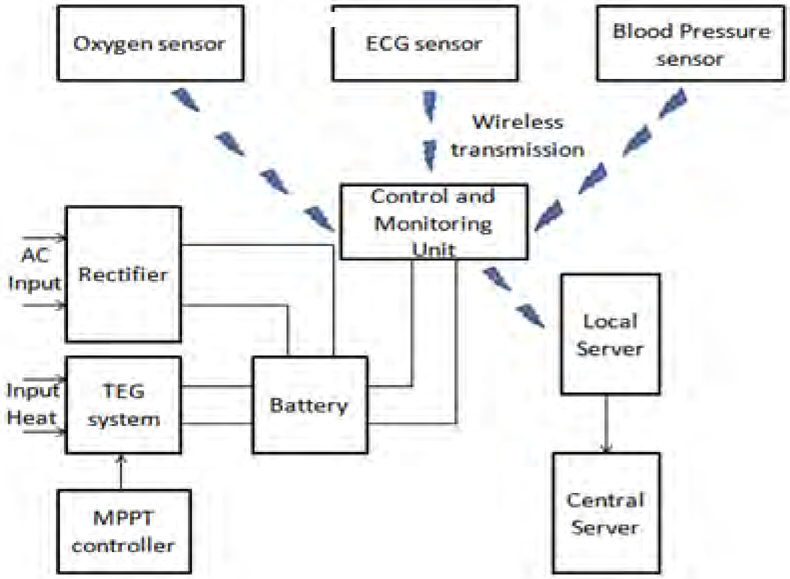

Fig. 3. Block Diagram Battery powered by TEG system

The information from the various sensors such as oxygen sensors, ECG sensor and blood pressure sensor are sent to the control and monitoring unit through wireless transmission. The supply to the control unit is given through battery which is being fed by TEG. The information to the control and monitoring unit is given to the local server from which it is communicated to the central server to analyze and to alert the medical assisting unit in case of emergency situation.

IV. Thermoelectric Generator with MPPT Controller

Similar to all renewable energy sources, thermoelectric generator also exhibits a PV characteristic for every different temperature. The PV characteristics of the thermoelectric generator are shown in the Fig. 4. PV characteristics for every different temperature have one maximum power point.

Maximum power point tracking (MPPT) method is based on the source and load impedance matching technique. It works on the principle of the maximum power transfer theorem. i.e. When the source and load impedance are equal then the maximum power is transferred from the source to the load. To track the maximum power point there are plenty of methods available. Some of them are Perturb and Observe, Incremental conductance, voltage based maximum power point tracking, current based maximum power point tracking etc.

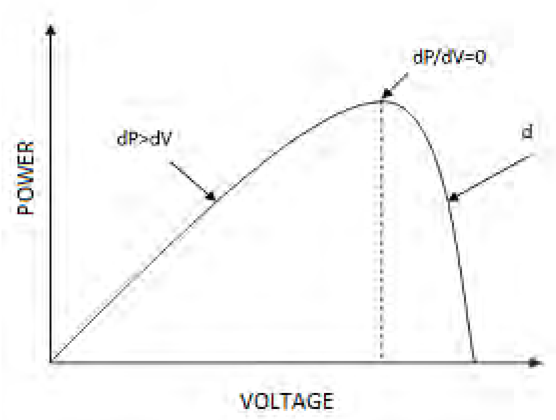

Fig. 4 PV characteristics of thermo-electric generator

In this Perturb and Observe (P&O) based MPPT algorithm is used to track the maximum power that can be extracted from the Thermoelectric generator. Advantage of P&O is that it is very simple and efficient. It uses minimum measurements to track the maximum power. The flow chart of the P&O based MPPT method is as shown in the Fig. 5.

The MPPT algorithm initially measures the instantaneous current and voltage values, from this it calculates the instantaneous power, and then it will calculate the power difference between the present value and the previous value. From the PV curve and the difference in power it will increase or decrease the voltage value to obtain the maximum power. If the change in power (power difference between present and previous value) is positive it will check whether it is occurring because of the increase or decrease in the voltage.[7] If DP/DV is increased with an increase in voltage then it will again increase the voltage otherwise it will decrease the voltage (change in power is positive because of the decrease in voltage). The next condition is to check whether dP/dV is decreased because of the increase or decrease in voltage.

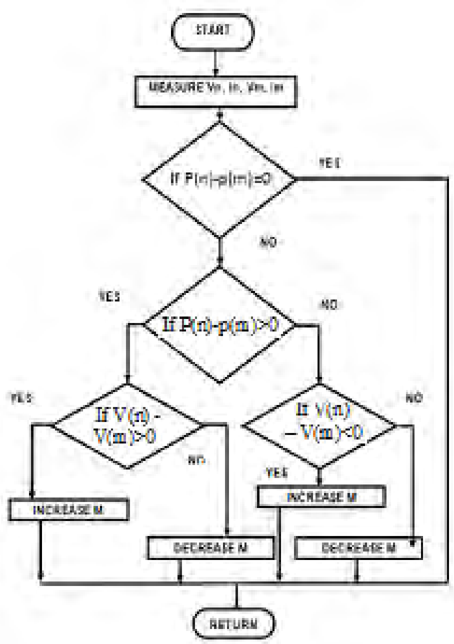

Fig. 5 Flow chart of Perturb and Observe based MPPT method

When the change in power is negative because of the increase in voltage then it will decrease the voltage and if it is because of the decrease in voltage it will increase the voltage. From this flowchart of sequence of active steps the maximum power is obtained. The change in voltage is achieved with the help of variation of duty cycle given to the DC to DC boost converter.

The value of duty cycle to the boost converter can be calculated from this Perturb and Observe based MPPT algorithm and it is developed and executed in the embedded MATLAB controller.

V. MPPT CONTROLLER IMPLEMENTATION

The Matlab Simulink model of thermo-electric generator to embedded MPPT controller is shown in Fig. 6. This is developed in MATLAB/Simulink with the help of DC-DC boost converter and MPPT algorithm.

Thermoelectric generator exhibits different voltage and current for the various temperature difference inputs. In simulation this temperature difference is given to the input using repeating sequence. The instantaneous value of voltage and current of the thermo-electric generator was measured and given to the input of the embedded MATLAB controller. This will generate the pulses based on the P&O algorithm. These gate pulses are given to the DC-DC boost converter. This will track the maximum power from the thermoelectric generator.

As constant temperature is not practically possible in exhaust heat in thermal and biomass power station, thermoelectric generator with varying temperature was also designed. The variation in the inputs such as temperature is applied using repeating sequence stair. Thus the P&O based MPPT algorithm effectively tracks the maximum power with varying temperature and delivers maximum power available.

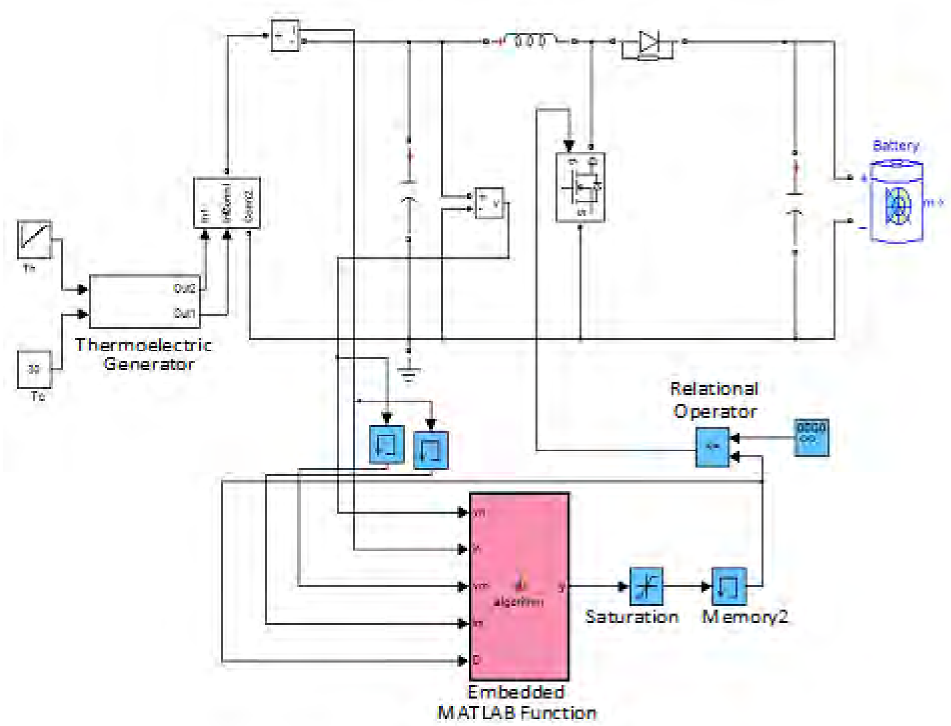

Fig. 6 Thermoelectric generator with MPPT controller

The Maximum power can be tracked at any voltage if the voltage difference between TEG output voltage at maximum power and Battery terminal voltage then huge current will flow from TEG to the battery. It is dangerous because the battery may get severely damaged if the charging current exceeds certain specified value. In order to avoid that, there is a need of charge controller for battery system. If the current value is maximum then this charge controller will divert the current to the other multiple batteries connected in parallel.

VI RESULT AND DISCUSSIONS

If the difference in temperature between the hot and cold junction varies then there will be change in open circuit voltage of thermo electric generator occurs. Let the hot junction temperature varies between 100°c-300°c and the cold junction temperature is maintained constant at 30°c, accordingly thermo electric open circuit voltage will be varying from 5-10V.

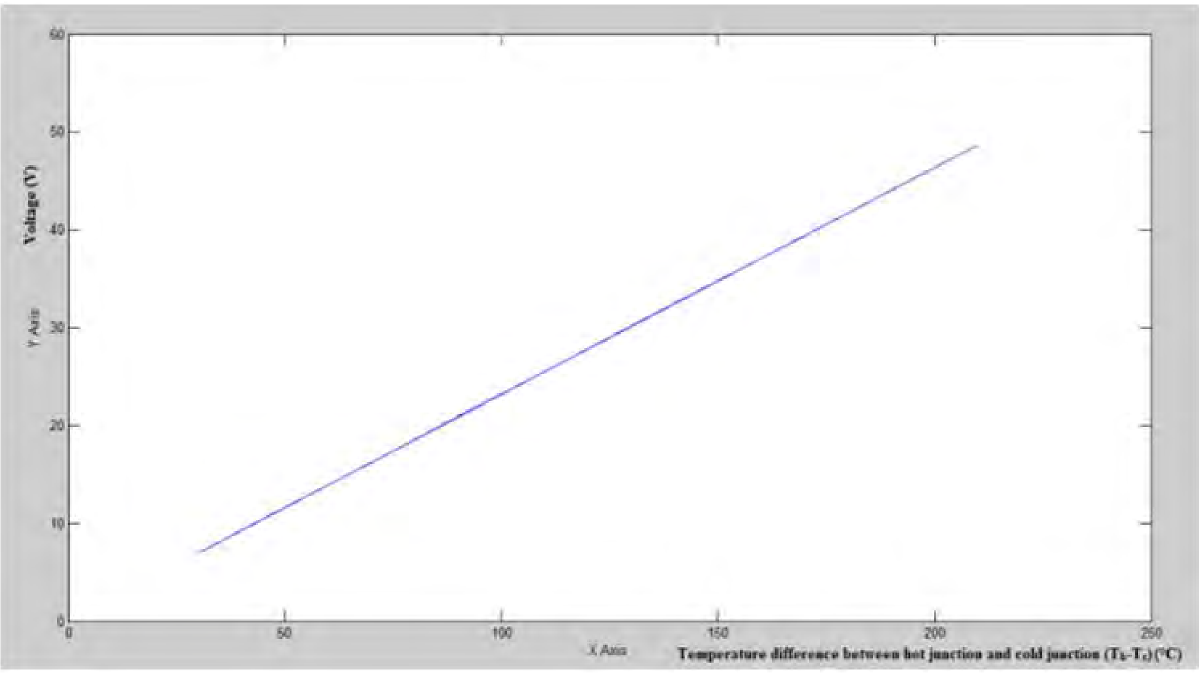

Fig. 7 Temperature difference versus open circuit voltage of Thermoelectric generator

The temperature difference versus open circuit voltage of thermoelectric generator is shown in Fig. 7. In this open circuit voltage is linearly varies with the temperature difference between the hot junction and cold junction.

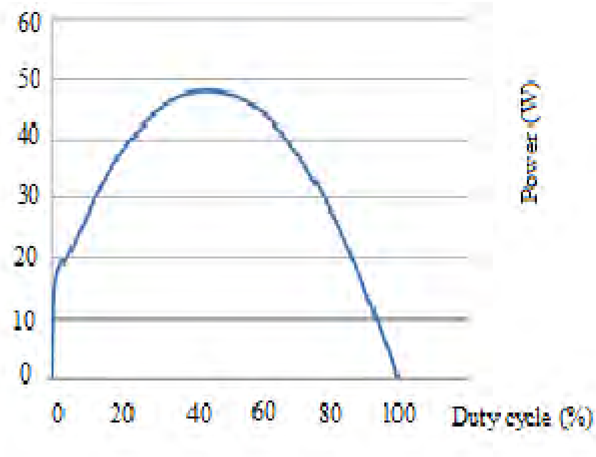

Fig.8 Duty cycle versus power

The Thermoelectric generator with boost converter gives the various power outputs for the change in duty cycle from 0 to 100 % which is shown in the Fig. 8. While increasing the duty cycle from zero, power is increased from zero up to some value which is the maximum power that can be extracted from the TEG, after that value of power starts to decrease even though the duty cycle is increased.

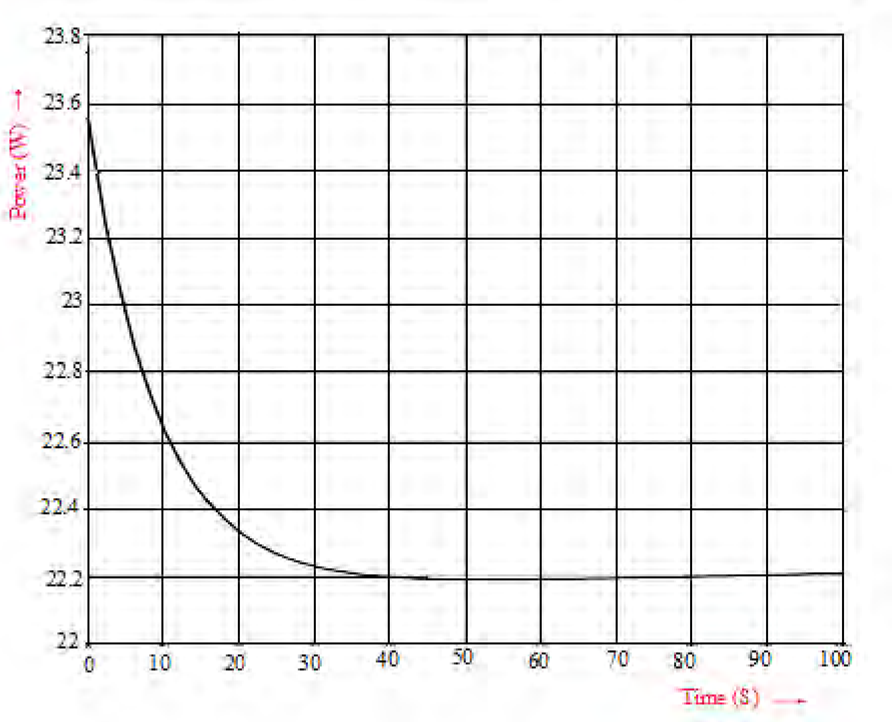

Fig.9. Output power without MPPT technique

The output power without and with MPPT controller is shown in Fig. 9 & Fig.10 respectively. This is constructed against the hot side temperature of 100°C and cold side temperature of 30°C.

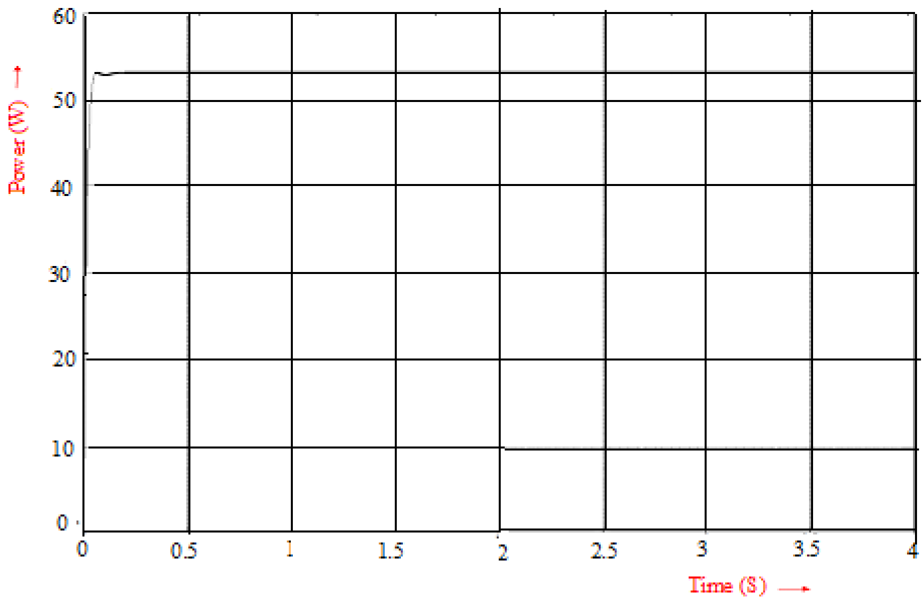

Fig. 10 Output power with MPPT controller

The variation of power extracted from the TEG is shown in Fig. 11. This is because temperature given to the hot side input of the TEG is varying between 60-100°C and cold side temperature is maintained at 30°C.

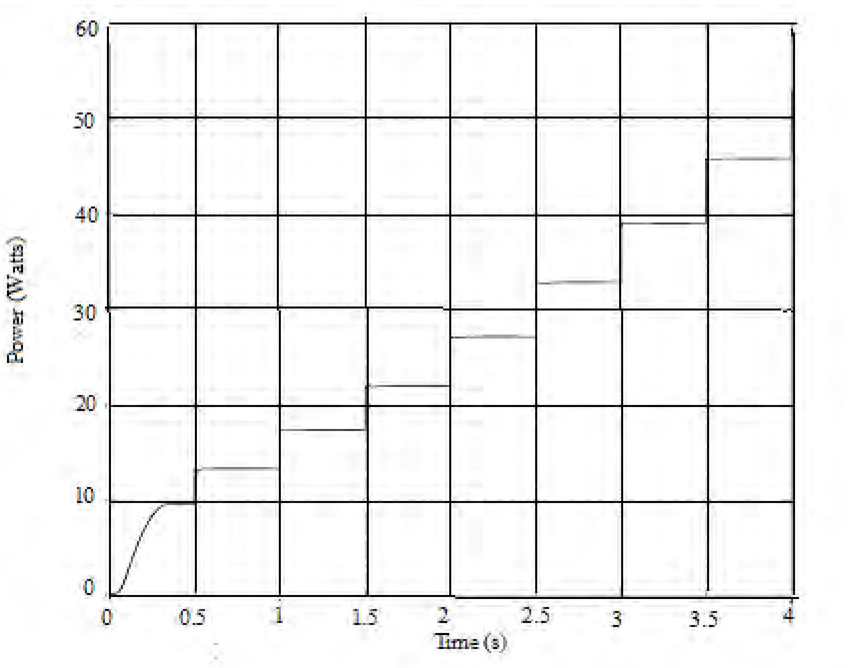

Fig.11 Variation of output power for various input temperature differences

This proposed technique uses fewer parameters to track the maximum power and hence it is very convenient to use. Using this, battery and group of batteries can be charged in an efficient way that are used for operating different loads such as health monitoring server and critical loads during emergency.

VI. HARDWARE IMPLEMENTATION

A. *MPPT Controller*

MPPT algorithm is implemented using PIC 16F877A which is shown below. A Constant 5V supply is given to the PIC (pin number 1,11,30) to operate and pin number 12 and 31 are grounded. The voltage and current measurement are given as a analogous input to the second and third pin respectively and this will produce variable pulses at pin 35 to track the maximum power from the TEG. These pulses are given to the gate terminal of the Boost Converter.

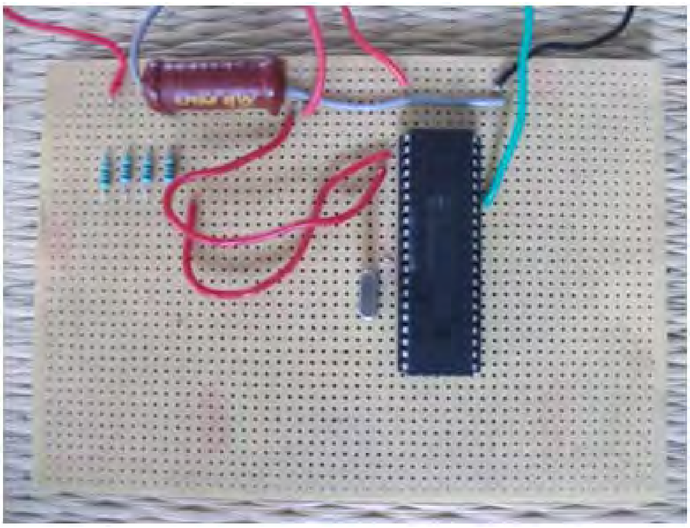

Fig.12. PIC 16F877A for MPPT

B. *Implementation of the model*

The Different temperature differences are given as a input to the two different sides (Hot side, Cold side) of TEG temperature is measured with temperature measurement transducer which is shown in figure 13 and figure 14 respectively. The TEG which is used in implementation is shown in figure 15.

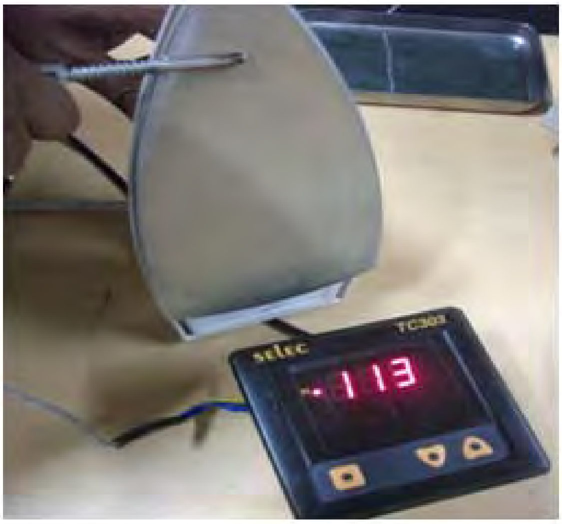

Fig.13. Display of Hot Junction Temperature

Fig.14. Display of Cold Junction Temperature

When temperature difference exist between two sides of the TEG 12710 it starts to produce electrical power instantly i.e., it directly converts heat energy into electrical energy. It produces emf and accordingly current in closed path which is shown in figure 16. The table showing the variation of temperature , TEG output and boost converter is shown below. The table provides information about the change in voltage and current with respect to the variation of temperature at hot side of TEG.

Temperature		TEG Output		Boost Converter Output	
Hot Side (°C)	**Cold Side (°C)**	**Voltage (V)**	**Current (A)**	**Voltage (V)**	**Current (A)**
88	28	2.25	0.43	5.48	0.15
92	28	2.37	0.43	5.78	0.164
105	28	3.09	0.51	7.75	0.189
113	28	3.48	0.57	8.58	0.213

TABLE 1 Output of TEG and Boost Converter

Fig.15. Thermoelectric Generator (TEG)

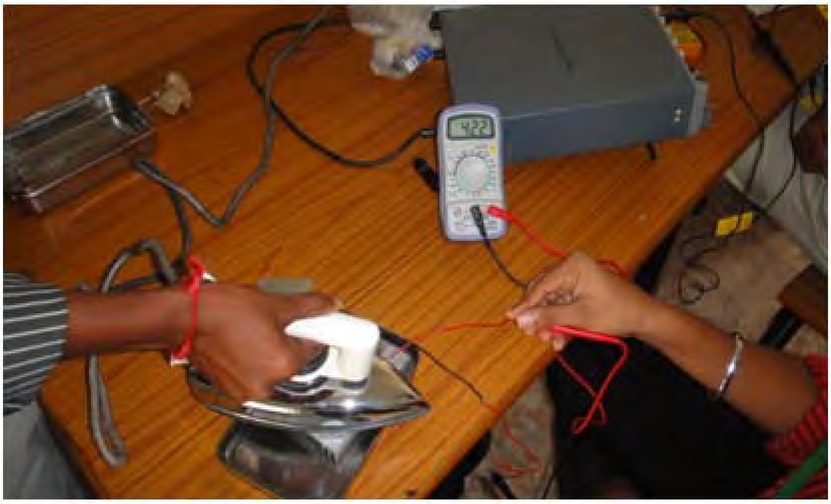

Fig.16. Testing of Thermoelectric Generator (TEG)

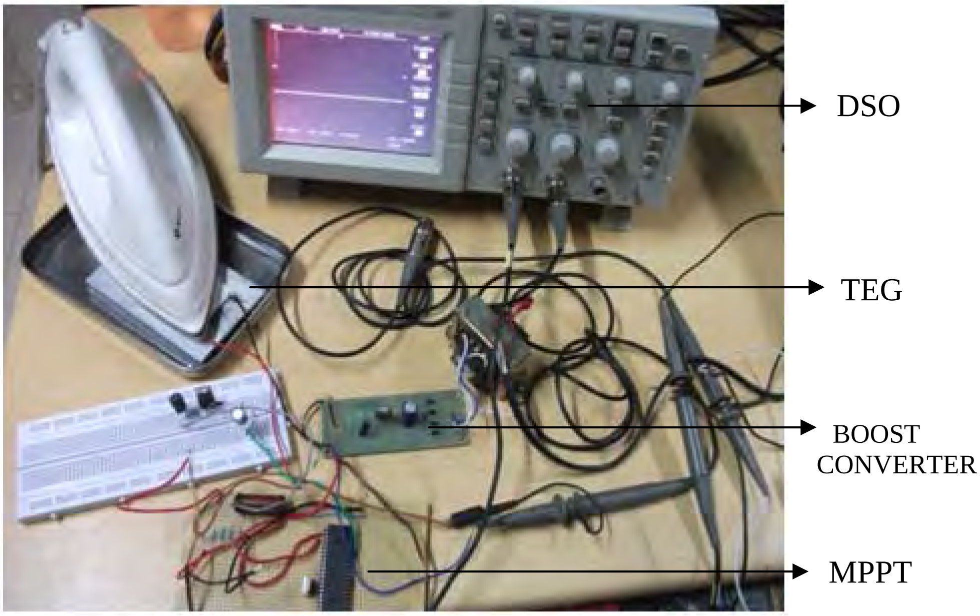

Fig.17. Complete Circuit Setup

VII. CONCLUSION

The experimental model produces the power of about 1.2 watts, but by increasing the number of modules and providing maximum temperature differences, the total power can be improved. This work can be further extended to increase the power with the use of exhaust heat in power plants like thermal power plants and biomass power plants to operate essential loads in case of emergency. Hence considerable amount of power can be produced from the exhaust heat and will increase the system efficiency and performance. By combining several TEG modules and group of batteries which are charged using this TEG system and by employing fuzzy logic techniques an advanced TEG based storage and utilisation system can be developed and implemented for critical loads.

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