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A New Topology Power Generation System with MPPT

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Abstract

We have introduced a microcontroller controlled thermoelectric generator(a turbine free system) which transforms geothermal energy, one of the renewable energy sources, to directly electrical energy and then the system was tested and its performance analysis is explained. In the system, energy transformation is provided by the thermoelectric modules. Since changeable DC voltage depending on temperature difference is obtained by the thermoelectric modules which are used to charge a battery or accumulator. The regulator circuit and inverter circuit are used in order to obtain the values 5V DC, 12V DC and 220V AC in the electrical energy. System control signals are arranged by using the PIC16F877 microcontroller in the system. The system is quite useful to meet electrical energy needs easily, cleanly and cheaply from the geothermal sources.
Keyword- MCGTG, MPPT, Microcontroller

I. INTRODUCTION

The need of electrical energy of the countries around the world is increasing every day. Here a microcontroller controlled geothermal thermoelectric generator (MCGTG), which transforms geothermal energy, one of the renewable energy sources, directly to electrical energy after then the system was tested and its performance analysis was examined. Today in our metro world, there are only eight renewable energy sources as follows.

- Biomass
- Geothermal
- Solar power
- Hydro power
- Wind power
- Tydal power
- Wave power

Our paper deals with the geothermal energy for our today concern. The subtopic follows

- Definition
- Principle
- General Construction
- Basic Thermoelectric Module
- Working
- System control using Microcontroller
- Performance analysis
- Outlook
- Applications
- Advantages
- Disadvantages
- Conclusion

A. Definition

Geothermal power (from the Greek roots geo, meaning earth, and thermos, meaning heat) is energy generated from heat stored in the earth, or the collection of absorbed heat derived from underground.

B. Principle

In 1821, Thomas Seebeck discovered that a continuously flowing current is created when two wires of different materials are joined together and heated at one end. This idea is known as the Seebeck Effect. The Seebeck effect has two main applications including temperature measurement and power generation.

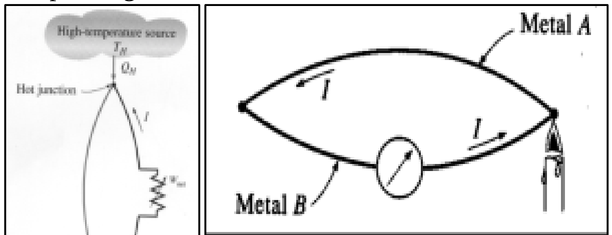


Figure 4: Seebeck effect: Two wires of different metals are connected at both ends to create a closed circuit. If one end is heated a current will flow continuously.

C. General Construction

Thermoelectric modules are formed by P and N type semiconductors which are connected in series electrically and in parallel thermally among two ceramic layers. A TEG is made by heating one face of thermoelectric module, and cooling the other face in the thermoelectric circuit which is made by connecting a load to the end points of the thermoelectric module.

The TEG part of the designed system consists of 3 parts; a heating block, a cooling block and a thermoelectric module arrangement. In the TEG, heat which is produced by the heating block is applied to the thermoelectric module face, and this heat gets sucked by the cooling block from the other side. This ensures the transfer of TEG heat. Aluminium blocks were used for the heating and cooling of the thermoelectric module surfaces. In the system, a thermoelectric module arrangement was made by connecting 12 numbers of thermoelectric modules (Melcor CP1.4-127-06L) in series electrically and in parallel thermally. Thus increasing the output has brought the power of the accumulator charger to its sufficient level.

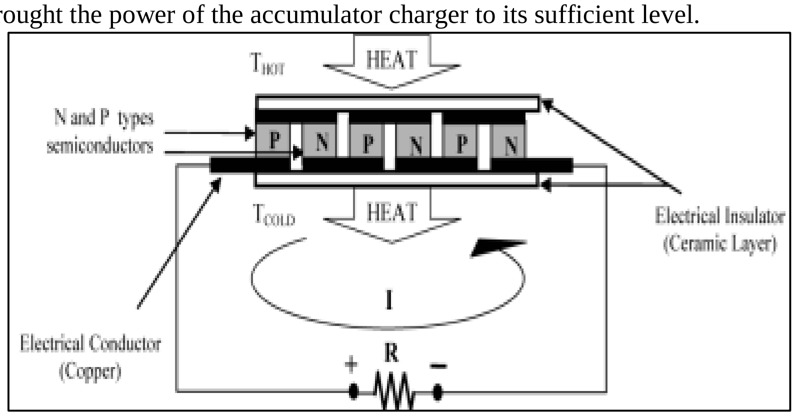
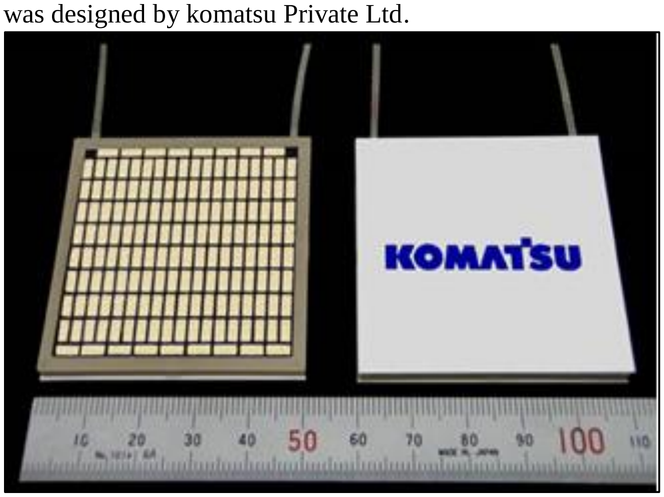


Fig. 1: Thermoelectric module in generator mode

D. Basic thermoelectric module

Here we have shown basic which was designed by komatsu Private Ltd.



E. Working

We have given the flow chart of our overall system of power generation. By means of the temperature sensors in the temperature measurement circuit, heating and cooling block temperatures are measured, and VHOT and VCOLD analog voltages are applied to the microcontroller. In the temperature measurement circuit a linear approach was followed and LM35 temperature sensors, which supply 10mV voltage for each 1°C temperature increase, were used. As 5V is the reference voltage of the PIC16F877 microcontroller and the A/D converter is 10 bits, the sensitivity is calculated approximately 5mV from 5/210. This ensures that for each 5mV increase of the microcontrollers' analog input it is possible to do a measurement with a 0.5°C sensitivity. The accumulator charging (VCHARGE) and accumulator (VACCU) analog voltages get divided with the voltage dividing circuit and reach a level of VA and VC voltage, which is a solubility over 5V for the microcontroller.

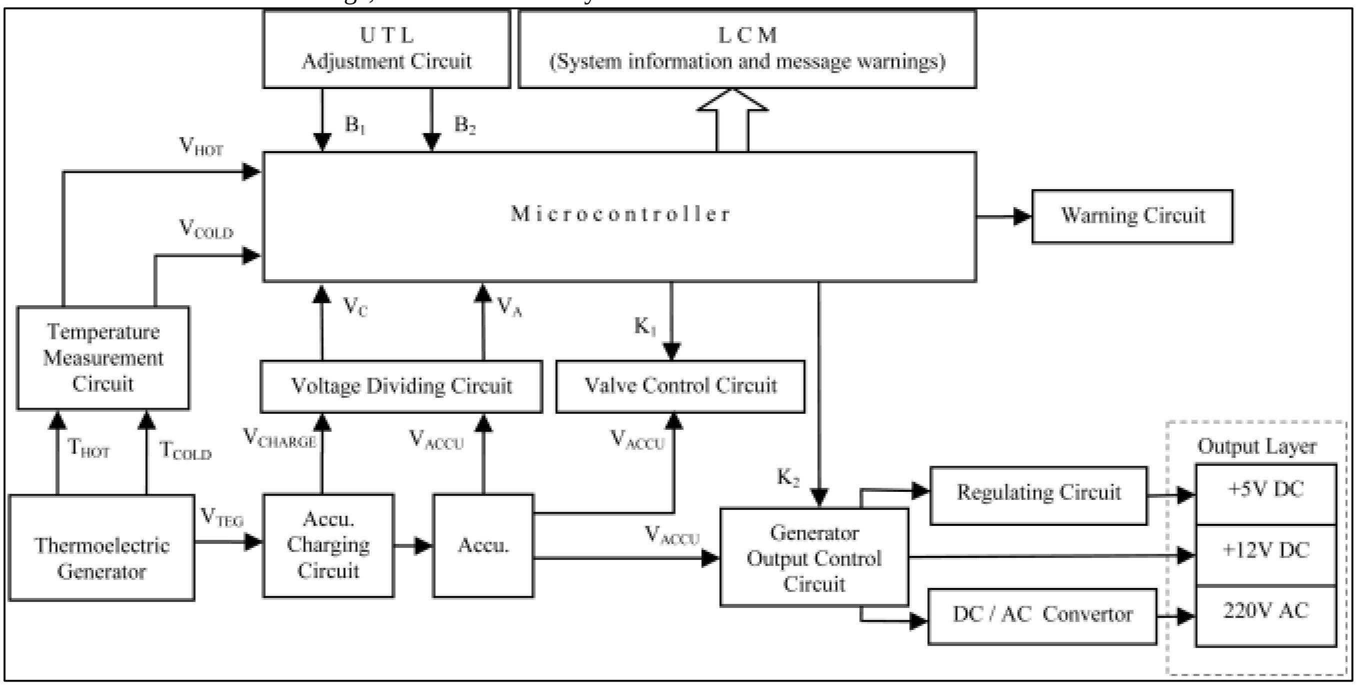


Fig. 3: Block Diagram of microcontroller based thermoelectric generator

In the system, when the heating block temperature reaches the Upper Temperature Limit, the geothermal water input is cut off automatically; similarly, when the accumulator voltage comes below 10V, the generator outputs are closed and a voiced warning is given. An alarm control circuit that gives a voiced warning with a frequency of 4 Hz from the RD1 port was used.

The output voltage Vo generated can be given by the formula,

$$V_o = \frac{\alpha N(T_h - T_c)}{1 + 2rL_c/L}$$

$$I_o = \frac{\alpha A(T_h - T_c)}{2\rho(L+n)(1+2rL_c/L)}$$

$$P_o = \frac{\alpha^2\ NA\ (T_h - T_c)^2}{2\rho(L+n)(1+2rL_c/L)^2}$$

Where $n = 2\ \rho_c/\ \rho$, $r = \lambda/\ \lambda_c$

α is Thermoelectric material Seeback coefficient(V/K),
ρ is electrical resistivity
ρ_c is electrical contact resistivity
N is the number of thermo-element in the module
A is the cross-sectional area of the thermoelectric
L is the length of the thermo element (mm),
L_c is the thickness of the contack layer (mm),
$T_h$is the temperature at the hot side,
T_c is temperature at the cold side
λ is the thermal conductivity of the thermo element
λ_c is the contact of thermal conductivity.

Since the thermoelectric modules used in the design endure up to 130°C, the UTL has been determined and a protection has been taken against the extreme temperature [8, 9]. The value of the UTL is continuously and the arrangement of this value is made with a circuit that shows an increase or decrease of 1°C on each press of the B1 and B2 buttons. The increasing and decreasing signals are given to the RC5 and RC6 ports of microcontroller. A microcontroller controlled solenoid valve that automatically cuts off the geothermally water input when the heating block temperature has reached the UTL and opens it when the temperature is 5°C below the UTL was used. The RD4 port of the microcontroller is used to open and close the solenoid valve.

F. *Microcontroller*

A PIC16F877 microcontroller from the Micro Chip family was used for the necessary controls of the system, the analog/digital converting operations and arranging the operating information. The VA and VC voltages of the voltage dividing circuit and VHOT and VCOLD voltage values of the temperature measurement circuit are applied to the microcontrollers' analog inputs (RA0, RA1, RA2 and RA3). The analog voltages in the microcontroller are converted to the digital signals by its internal A/D converter. In the system, the RD4 port for the control of the solenoid valve, the RC5 and RC6 ports for the adjustment of the UTL, the RC7 port for the opening and closing of 5V DC and 12V DC generator outputs, the RD1 port for voiced warning, and the RB0, RB1, RB2, RB3, RB4, RB5 ports for the LCM were used. The PIC16F877 microcontroller was programmed by using the Parsic program. In the Parsic program, assembly codes were obtained with digital logic principles. The microcontroller program's hexadecimal codes were produced from assembly codes by using MPASM compiler. As it is shown in the flow diagram, the operating of the microcontroller program continues in a circle after giving a 5 second opening message to the LCM. In the microcontroller, VA, VC, THOT and TCOLD values are taken after having controlled the B1 and B2 button inputs. The temperature difference (ΔT)

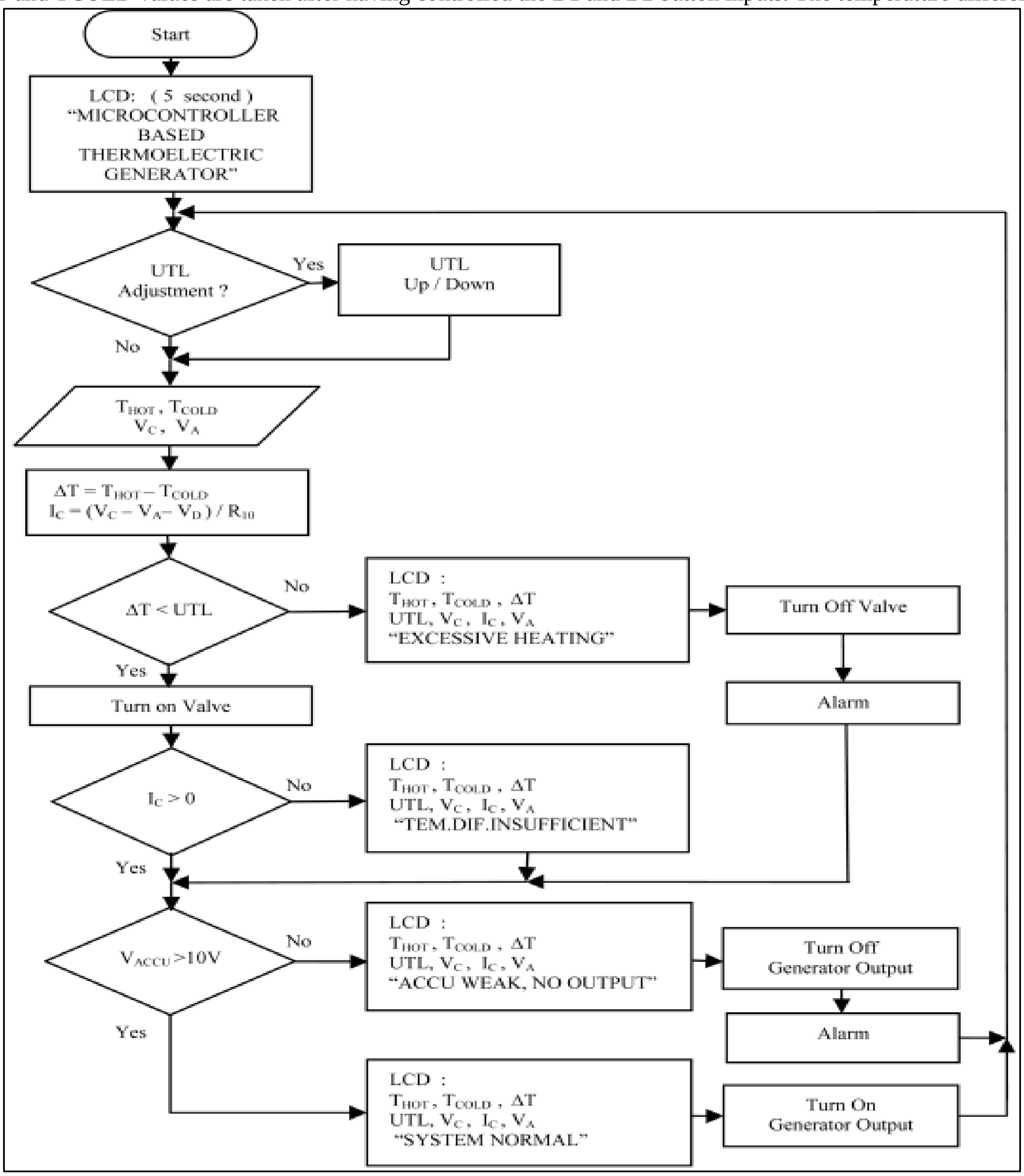


Fig. 5: Flow diagram of microcontroller program

and the accumulator charging current (IC) are calculated. THOT, TCOLD, VC and VA values which are taken from analog inputs, and IC and ΔT which are obtained after calculation are shown in the LCM.

If the ΔT value that is obtained from temperature measurements is greater than the UTL value, the geothermal water input valve is cut off and a written and voiced warning that there is an extreme heating in the heating block is given by the microcontroller. In the system, as long as VC < (VA + VD), the electrical energy obtained from the TEG will not be sufficient for the charging of the accumulator. For this reason a written and voiced warning which indicates that the temperature difference is not sufficient is given from microcontroller. The VD voltage value is the threshold voltage of the D1 diode which is used in the accumulator charging circuit and was measured as 0,81V. When there is no electrical energy production in the generator and the accumulator measurement voltage decreases to less than 10V, the 5V DC, 12V DC outputs are closed to prevent the accumulator from getting absolutely empty and a written and voiced warning is given. The generator outputs are open when the accumulator voltage reaches over 10V after sufficient charging. By using the RC7 port of the microcontroller, the inputs are turned on and off.

G. Thermoelectric battery charger system

In the battery charger system, the appropriate type of dc-dc converter for the termoelectric battery charger system is SEPIC. The SEPIC converter is non-inverting and can generate voltages either above or below the input. The input current is non-pulsating but the output current is pulsating. The SEPIC is an acronym for Single Ended Primary Inductace Converter. A typical circuit is shown. AThis circuit has three dynamic energy storage elements, L_1, L_2 and C_1.The ratio of the output voltage to the input voltage and the duty cycle are defined as

$$M = V_o/V_t$$
$$D = t_{ON}/T$$

Relation between D and M is given by $D = M/(M + 1)$
The output voltage is expressed as $Vo = DVi/(1 – D)$
Where M is the conversion ratio,
D is the duty cycle,
Vi is the input voltage,
Vo is the output voltage,
T is the switching period,
t_{ON} is the on time

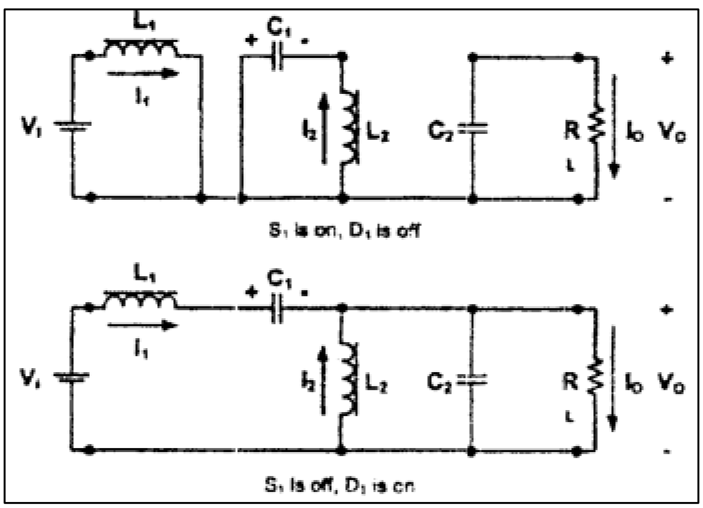


Fig. 6: Topology sequence of the SEPIC DC- DC Converter

H. Maximum Power Tracking System

The maximum power transfer to the battery occurred when input impedance of dc-dc converter equal to output impedance of TE power generator. The input impedance of dc-dc onverter can be controlled directly by changed the duty cycle of gate driving signal; then we can find the maximum power point of power transferred to a battery.

For battery charging application, where the dc-dc converter output voltage can be assumed almost constant, and a feed-forward MPPT controller may be applied. The value of the battery charging current is used to directly control the duty cycle of the PWM control signal applied to the dc-dc converter. An output power increase results in both higher output current and higher PWM control signal duty cycle, until the maximum power is transferred to the load. The system control uni consists of the ATMEL microcontroller unit T89C51AC2 features an 8-bit, 5-I/O port, 8-bit PWM on chip, 10-bit resolution A/D converter with 8 multiplexed inputs, used by the control program measure the signals required for the power flow control. This type of microcontroller was chosen because it has the necessary features for the proposed system, such as an on-chip A/D converter, PWM output, high clock rate, low power consumption and low cost.

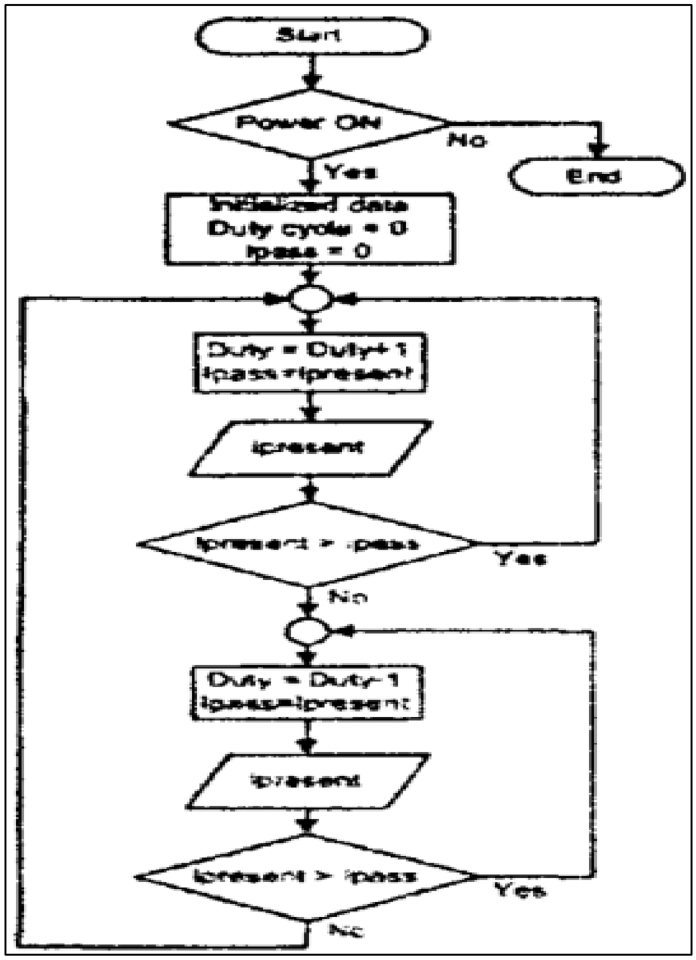


Fig. 8: MPPT Control Program Flowchart

I. Performance

By doing a performance analysis of the thermoelectric generator, the operating characteristics to obtain the maximum power from the system have been determined. The system's output power was calculated by measuring the voltage and current values related to the difference of the temperature of the thermoelectric generator. Load – Power relation graphics of the system have been drawn according to the measurements. For experimental measurements in the system, hot water which was produced with a water heater were given into the MCGTG's geothermal water input, and thus measurements (between 20°C and 70°C temperatures) were made. By connecting a voltmeter at the end points of the TEG thermoelectric module arrangement, 28.12V DC voltage value was measured at the 43°C temperature difference. The system's output power was calculated according to the measured current and voltage values which were provided by the R loads of 10Ω, 30Ω and 50Ω getting connected onto the end points of thermoelectric module arrangement. The system load-power relation was obtained according to current, voltage and power values based on load resistance at fixed temperature differences.

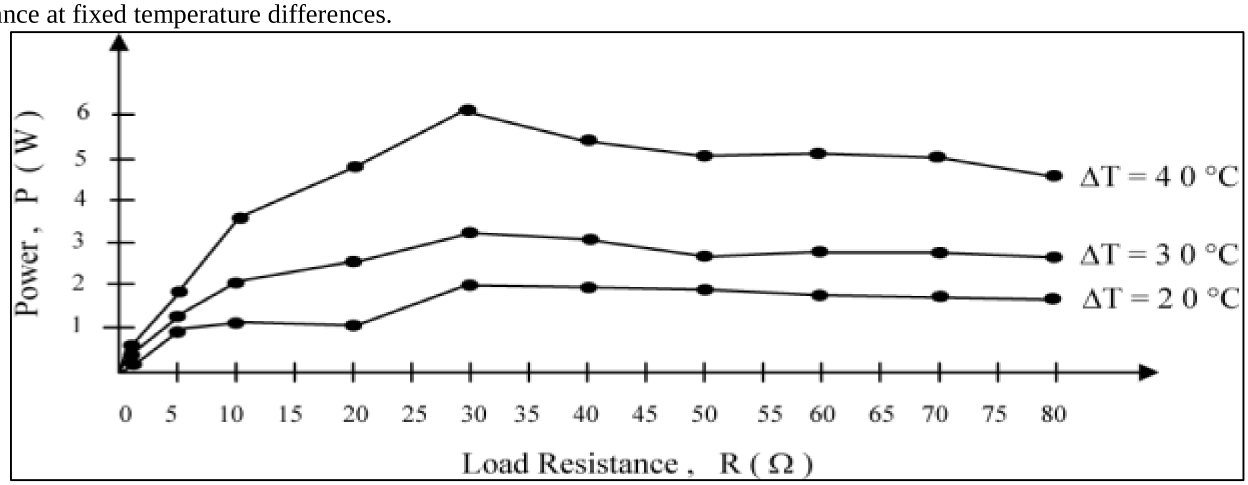


Fig. 6: The Systems Load – power relation

J. Outlook

The overview of explained is shown as such. A Xiamen GDM2004D series 4x20 characters LCM was used for the screening of the microcontroller based results and condition messages belonging to the system operating environment

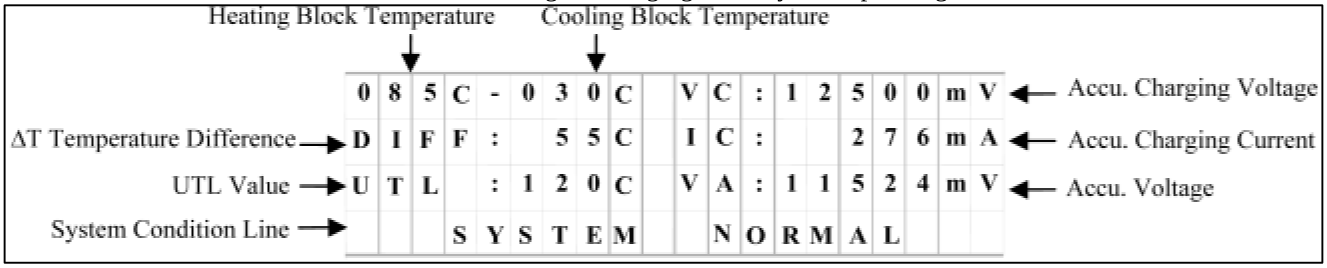


Fig. 4: LCM Screen

Here we have given the overview of Liquid Crystal Module.

Fig. 2: microcontroller controlled geothermal thermoelectric generator

Dimension	48 cm x 44.5 cm x 92 cm
Weight	25 Kg
Maximum geothermal water temperature value	130 °C
Generator Power (for $\Delta T = 40°C$)	Maximum 6.15W
Duration of generator charging (for $\Delta T = 40°C$)	Minimum 24 Hours
Output Voltage (DC and AC)	5V DC, 12V DC, 220V AC

K. Applications

This system can be used anywhere, where there is a change in temperature. By using this change in temperature we can generate power for our domestic usage. Thus it is having enormous applications some of them follows.

- Overall power generation for a country using geothermal power plant using our technique.
- Heat generated over the gas stove and other boilers can be used.
- Power can be generated from the heat generated by firing waste materials etc.

L. Advantages

- No need of turbines or other frequency synchronization techniques for the generation of power
- (NO MOVABLE PARTS ARE USED).
- Usage of Lubricants and is avoided.
- Geothermal power requires no fuel, and is therefore virtually emissions free and insusceptible to fluctuations in fuel cost.
- Geothermal power station doesn't rely on transient sources of energy, unlike, for example, wind turbines or solar panels, its capacity factor can be quite large, up to 90% in practice.
- Our Thermoelectric Geothermal power generation has minimal land use requirements; existing geothermal plants use 1-8 acres per megawatt (MW) versus 5-10 acres per MW for nuclear operations and 19 acres per MW for coal power plants.
- It also offers a degree of scalability: a large geothermal plant can power entire cities while smaller power plants can supply more remote sites such as rural villages.
- Geothermal energy does not produce greenhouse gases
- The energy source is free and will not run out

M. Disadvantages

- There are not many places where we can build geothermal power stations Harmful gases and minerals may occasionally come up from the ground below. These can be difficult to control.
- Brine can salinate soil if the water is not injected back into the reserve after the heat is extracted.
- Well costs scale exponentially with depth

N. Conclusion

As far we have discussed we can generate a remarkable amount of electrical energy by using this thermoelectric power generation. In foreign countries this technique is going to be launched since there is a requirement of other energy sources of our future world. This system is the most feasible use in rural community or remote area. The advantage of the TE battery charger system can charge a battery by using the heat energy directly, and not have the moving parts, then it can be applied to the heating devices such as a cook-stove, a boiler or the other heat source for waste heat recovery. The photovoltaic system provides electrical power during sunshine while the battery charger system provides power as long as the heating device is in use.

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