A Model of Thermo Electric Energy Harvesting for Wireless Home Sensor

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***Abstract* - Wireless detector networks (WSNs) square measure unreal to own a big impact for several applications like health observance and space police work. Despite several advances in energy aware communication techniques for WSNs, the limitation of energy offer remains an essential issue. one in all the foremost enticing approaches to increase the time period of WSNs is gather energy from the close sources, like star, wind, and vibration. However, the inherent dynamic and randomness of those sources create to several new challenges to modeling and management of harvested energy furthermore because the analysis of energy gather systems.**

***Index Terms* - Thermal, wireless, sensor, energy harvesting, solar energy, Kinetic energy, Pyroelectric.**

I.INTRODUCTION

Smart homes promise nice reductions in energy consumption as well because the ultimate full automation of appliances and residential systems. Progress is walking towards fully machine controlled sensible homes, that have confidence less and fewer human input. For complete automation, sensible homes need extra information provided from hardware sensors distributed round the home. Advances in sensors, wireless transceivers, and low-power microcontrollers have enabled the proliferation of sensors to assist understand this vision of sensible homes. However, powering sensors has remained a serious constraint for embedded applications. Batteries solely have a finite period of time and should get replaced, and infrequently it's dear or impracticable to supply wired power to each node once thousands of them are also gift in an exceedingly building. One answer is energy harvest home, that will not require any energy sources. for instance, a temperature gradient will be wont to power ultra-low power sensing element nodes, creating them self-sustaining and sanctionative a brand-new category of embedded applications. Recently, vacuum insulation panels (VIPs) have shown promise to extend the thermal potency of homes and lower heating and cooling energy prices. VIPs accommodates a vacuum supported by a porous core encircled by associate degree impervious barrier material. VIPs have up to 6x higher thermal resistance compared to standard extruded vinylbenzene (EPS) foam insulation. However, the vacuum within VIPs will leak incidentally or over the building's period of time, leading to a decrease within the thermal resistance [1]. To counter this downside, associate degree absolute pressure sensing element powered by the temperature distinction across the panjandrum may wirelessly transmit the panel's pressure over the building's period of time, triggering a warning that the panel is in want of replacement.

II. ENERGY HARVESTING

Energy harvesting is the new area of the power electronics where user can extract the energy from the environment and using it through control remote sensing elements in wireless applications. Thus, energy harvesting can be stated as a process by which energy is obtained from different external sources, (like kinetic energy, thermal energy, solar energy etc). This type of energy is captured and stored in microelectronic cells or wireless devices which are generally positioned in energy source points.

Usually, Energy Harvesting (EH) also referred as power harvesting or energy scavenging. In this process, energy is derived from other external sources, captured and restored in microelectronic devices or wireless sensor devices. EH provide a little amount of energy for low power electronics which could be utilized for future purpose. However, in this scheme, the system converts the energy (like kinetic energy, thermal energy or solar energy) into electrical energy which is captured form different energy sources. Thus, researchers found the different energy harvesting technologies which is discussing in the following section.

III. THERMOELECTRIC GENERATOR THEORY

Thermoelectric generators (TEGs) harvest electricity from a temperature distinction by utilizing the charge carriers of doped semiconductor materials. once a temperature distinction is gift across either aspect of the lamb, charge carriers in doped semiconductors can migrate from the recent aspect to the cold aspect.

This principle is termed the See beck result, that is that the in-operation principle of thermoelectrical generators.

TEG modules incorporate alternating p-type and n-type bismuthtelluride semiconductor legs connected asynchronous electrically and in parallel thermally. This dissimilar semiconductor joint generates a little voltage across every leg within the module. The series electrical affiliation adds these little voltages to lead to a far higher usable voltage [2].

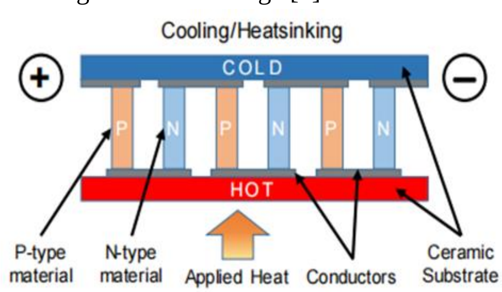

Fig. 1- Components of a thermoelectric generator.

TEG modules have 3 main style considerations: Seebeck constant, ohmic resistance, and thermal resistance. The module's Seebeck constant (S) represents the voltagegenerated per degree of temperature distinction and depends on the quantity of semiconductor legs and their electrical configuration.

$$V_{harv.} = S \cdot \Delta T_{harv.} \quad (1)$$

Electrical resistance affects the utmost electric receptacle, wherever the foremost usable power are often extracted from the lamb. The ohmic resistance will increase with the quantity of semiconductor legs (represented by n), electrical resistance of the fabric (ρ), and length of every leg (L), and reduces with space of every leg (A).

$$R_{electrical} = n\rho \cdot \frac{L}{A} \quad (2)$$

The thermal resistance affects the warmth flux across the lamb and also the ability to keep up an outsized temperature distinction. a better thermal resistance interprets to less heat flux and a better temperature distinction. Absolute thermal resistance will increase with thermal resistance (Rλ) and also the length of every leg (L) and reduces with the realm of every leg (A) and also the variety of legs (n)

$$R_{thermal} = R_{\lambda} \cdot \frac{L}{n \cdot A} \quad (3)$$

The actual temperature distinction across the lamb depends on the thermal resistance of the lamb and its heat sinking, that interface the lamb with its surroundings. this can be shown in relative atomic mass. 4.

$$\Delta T_{harv.} = \frac{R_{thermal}}{R_{thermal} + R_{heatsink}} \cdot \Delta T_{actual} \quad (4)$$

For such energy-constrained applications, one should harvest energy at the utmost electric receptacle of the lamb, that happens at 1/2 the harvested voltage, once Rload = Relectrical. the facility extracted from a lamb at the utmost electric receptacle is listed below.

$$P = \frac{(V_{harv.})^2}{4R} = \frac{(S \cdot \Delta T_{harv})^2}{4 \cdot R_{electrical}} \quad (5)$$

Hence, to get the utmost power, we have a tendency to initial elect a thermo electrical generator with a high thermal resistance so as to gift as high ΔT as doable.

We used a landholder OptoTec OT08,32,F0T,0707 thermoelectrical generator. we have a tendency to then elect a matched electrical load to get the utmost power purpose. thermoelectrical generators have potential as energy harvesters, and it's vital to optimize their style for the applying so as to maximise their little power output.

IV. EXPERIMENTAL SETUP

This project measures lamb power generation between within Associate in Nursingd outside temperatures with a check setup mounted within an flat window with a dignitary panel wont to establish a thermal gradient. The check setup consisted of a lamb thermally connected to a sheet of atomic number 13 (0.8mm thick) that lined the dignitary panel for improved heat sinking to the close. The assembly was mounted within a sheet of extruded styrene (EPS) foam insulation for simple installation into the window. The experiment ran for one week, throughout that we have a tendency to collected open circuit voltage, power generated, and temperature. V. A.

Vacuum Insulation Panels

Vacuum insulation panels (VIPs) accommodates a porous core containing a vacuum encircled by Associate in Nursing water-repellent barrier material. benefits embrace way larger energy savings over standard foam insulation. However, the most weaknesses of VIPs area unit value and vacuum run, particularly incidental punctures and gradual leaks. As a result, selfpowered absolute pressure sensing element put in within the vacuum insulation panel may report internal panel pressure and report problems, whereas being maintenance-free over the building's period of time.

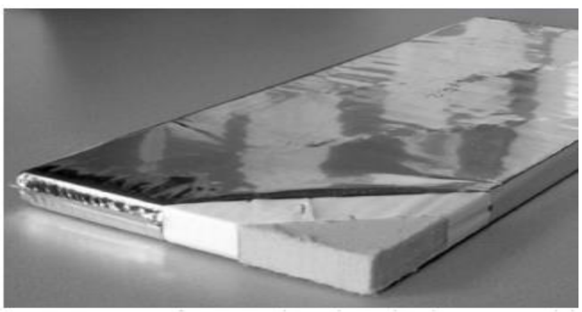

Figure 4.1 A cutaway of a VIP showing the impermeable barrier layers and the porous core material

B. Window Tests

A check setup with a lamb was mounted within Associate in Nursing airconditioned apartment's window over one week to watch power generation. In every check, electrical circuit voltage, within and outdoors temperature, and power generated at the most electric outlet were measured. For temperature measurements, a Raspberry Pi pc connected to a DHT22 temperature sensing element from Aosong physics was used. the space temperature was control constant at 22°C with the apartment's cooling system. All electrical measurements were smitten a Keithley supply Meter.

A dignitary and a lamb were mounted next to every different within a sheet of EPS foam insulation the dimensions of the window. One atomic number 13 sheet is stratified on either facet of the dignitary, covering the panel's entire space, to boost heat sinking qualities and maintain the temperature distinction. On either facet of the setup, the atomic number 13 sink and lamb area unit thermally connected via a slender atomic number 13 wedge and thermally conductive tape. The EPS insulation board was mounted within, flush with the window, with one facet facing within and one facet facing outside. A cutaway diagram and image of the setup area unit hooked up below.

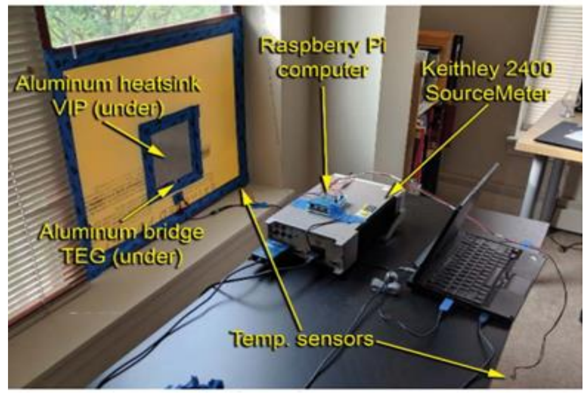

Figure 4.2 Cutaway diagram of window setup, to not scale [6].

V. RESULTS AND DISCUSSIONS

We have performed continuous-time event-driven simulations mistreatment custom written MATLABTM code. The time durations that the system stays within the active states, inactive states and therefore the time length between consecutive events area unit arbitrarily generated.

5.1 WEATHER MODELING

In order to approximate the obtainable power from passive thermo-electric gathering, power generation for town of state capital was characterised over the course of the year and day, with monthly and hourly power generation, severally, mistreatment historical weather information. For monthly information, we have a tendency to averaged daily temperature highs and lows over monthly from 20011-2021. For hourly information, we have a tendency to averaged hourly temperature information for every day, by month, for 2016. All weather information is from the National Center for Environmental info.

For hourly and monthly reports, temperature variations between outside and within were then calculated, employing a constant temperature of 22°C within. Voltage was calculated mistreatment Seebeck's law, assumptive good heat sinking (ΔTharv = ΔTactual) (Eq. 1), and therefore the calculated voltage was wont to calculate harvested power at the utmost power purpose (Eq. 5). electrical phenomenon for our module at 25°C was four.17 Ω.

The monthly information (Fig. 5.1) shows that power gathering capability is that the greatest in January/February and falls to a minimum in could and Sep. This directly follows from the result that the temperature distinction is greatest within the winter months and least throughout the spring/fall months. in addition, the harvested voltage becomes negative throughout summer, once it's hotter outside than inside; but, given bipolar gathering capability, then gathering continues to be attainable and therefore the power is shown to be positive.

Average Monthly Peak Power (uW)
2011-2021

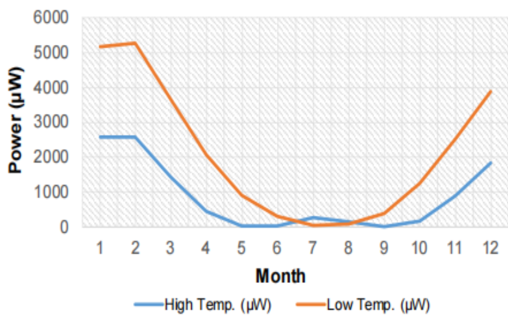

Figure 5.1 Avg. monthly peak power harvesting, with temperature highs and lows

Likewise, within the hourly power generation information (Fig. 5.2), power generation is greatest within the morning and least within the afternoon, once the temperature delta decreases. Most of the ability generation curves area unit identical form, however slightly offset. within the summer months, afternoon is that the peak generation time as a result of the temperature delta reverses, however gathering continues to be attainable.

These simulations show that it's possible to power a sensing element with TEGs, particularly within the winter months. However, this is often a oversimplified model; it doesn't take under consideration the particular temperature distinction across the lamb, that is laid low with heatsinking. For this reason, a lamb setup was inserted into Associate in Nursing flat window to live the particular power generation and validate our model.

Hourly Power Generation by month (uW)
2016

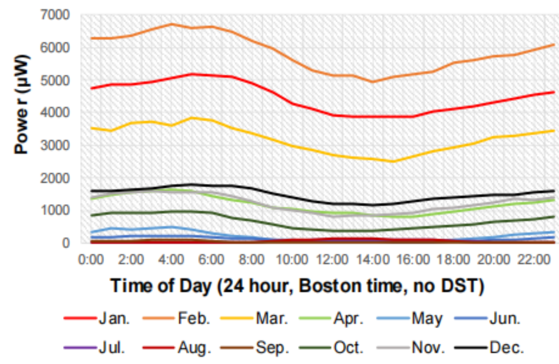

Figure 5.2 Hourly power generation by month

A. Window Tests

Data was gathered over the course of 1 week, and therefore the results area unit shown below. the skin temperature, shown in red, fluctuates over the course of the day, whereas the within temperature stays fairly constant. the ability generation may be a sq. perform of the temperature delta. Power generation probably peaks at around 5:00 PM thanks to the sun hanging the building wall, inflicting a localized temperature spike. This information (Fig. 5.3) shows a mean output of twenty eight.7 µW of power over the course of a summer day, enough to charge a electrical device and power a sensing element node that duty-cycles measurements and transmissions. the typical power generation is predicted to be way larger within the winter months dueto a larger temperature distinction. Powering a sensing element node mistreatment this harvested power is possible, and this may be shown as a proof-of-concept within the next section.

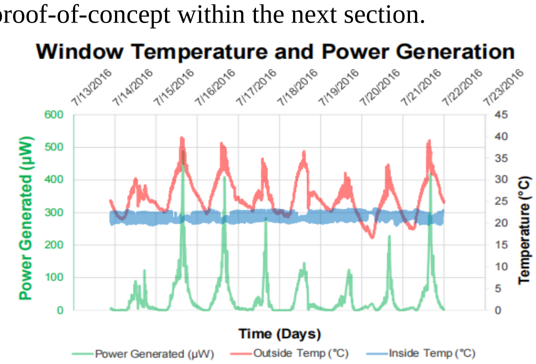

Figure 5.3 Data from the window experiment. The green curve is peak power generated. The red and blue curves are outside and inside temp., respectively.

B. Powering the sensing element Node

To show conceptually that the ability will be wont to power a sensing element node, we have a tendency to created a controlled setup within the research lab to experiment with temperature distinction versus power generation capability for an advertisement harvester this is often a proof-of-concept showing the practicability of low-ΔT TEGpowered sensing element nodes.

The lamb module was thermally connected to a hot plate at 35°C and a sink, cooled by a follower. it's electrically connected to a LTC3108 radical low voltage boost convertor and power manager from Linear Technology, that accumulates the energy during a two MF ceramic storage electrical device and powers the sensing element node. The sensing element node uses the LTC3108's three.3V output and PGOOD pin, that signals once the output voltage is among an appropriate vary.

The sensing element node contains a PIC12LF1840 micro-controller (MCU) with Associate in Nursing integrated temperature sensing element and wireless transmitter from semiconductor. The MCU's power pin is connected to the LTC3108's three.3V pin and is interrupted bya switch connected to the LTC3108's PGOOD pin.

When the voltage drops below three.0 V, the PGOOD pin is brought low, the switch turns off, and therefore the MCU is shut off, permitting the storage electrical device to charge. Once the PGOOD pin is brought high and voltage is bigger than three.2 V, then the MCU takes a temperature reading and wirelessly transmits the information. the information measuring and transmission cause a call the output’s and storage capacitor's voltages, however thePGOOD pin remains force high. With the PGOOD pin force high, the microcontroller samples the VDD voltage each two seconds and performs a measuring if it's more than three.2 V.

In simulated conditions employing a hot plate with a ΔT of 15°C, the frequency of knowledge transmission was each two seconds,which for this sensing element node, represents an influence delivered of 109 µW. whereas the MCU's aboard temperature sensing element was employed in this check, any low-power sensing element beneath one hundred µW couldbe used, sanctionative a replacement category of embedded, self-sufficing sensing element nodes.

VI. CONCLUSION

Conclusions area unit drawn supported the results obtained from experimental and characteristic analysis of projected system.

This paper investigates a unique application for thermo-electric generators in Associate in Nursing embedded application. mistreatment the temperature distinction across Associate in Nursing insulation panel, one will harvest ~100 µW of power to run Associate in Nursing radical low power sensing element node. we've got incontestible the practicability of this approach, which might change a replacement category of self-powered sensible home sensors, and within the future we'd wish to integrate the boost convertor with the sensing element to get long run measurements.

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