SOLAR THERMAL GENERATOR

FAMU-FSU COLLEGE OF ENGINEERING
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ABSTRACT

The Solar Thermal Generator Project is an attempt to harness the solar energy the earth receives every day and convert that into electrical energy with the use of a solid state device. The way this project differs from photovoltaic energy is that the sun provides only heat and no chemical reaction is needed. The TEG chip uses the Seebeck Effect of dissimilar metal junctions and temperature gradients to produce electric current.

SOLAR THERMAL GENERATOR

POSITIVE ASPECTS:

- Portable and quiet
- High reliability due to no moving parts
- Environmentally sound technology
- Modular energy storage
- Intelligent technology provides easy setup and use
- Requires no action or monitoring by the user
- Promotes a “Green” image

TEAM CHALLENGES:

- Maintaining the mirror surface
- Precise motion control
- Low power consumption control circuit
- Heat rejection/transfer
- Increasing system efficiency
- Creating a user friendly design

APPLICABLE MARKETS:

Civilian/Consumer Market:

Modern awareness of the global condition has driven demand for green energy technology. Consumers are willing to pay a premium for products that do not use fossil fuels. These consumers see green energy devices as their way of contributing to preservation of the environment. Low noise and small footprint make it ideal for use in parks and public areas.

Possible Applications:

- Camping/Hiking in remote areas.
- Tailgating/Cookouts.
- Emergency power for mobile devices during natural disasters and power outages.

Military/Defense Market:

While on deployment in remote areas lacking infrastructure, a solar thermal generator has practical applications for military personnel. Though necessary for powering larger equipment, modern gas generators are impractical for small applications in remote areas due to their bulky design and limited mobility. The inherently portable design and quite operation of a solar thermal generator make it ideal for applications requiring limited power and low profile equipment.

Possible Applications:

- Emergency power generation for signal sending and communications.
- Cooking and small equipment charging when deployed in the field.
- Design can be implemented using a collapsible Mylar dish maximizing portability and functionality.

PROJECT SCOPE:

- **SOLAR COLLECTION:**

  The method chosen for collecting and focusing the solar radiation is a parabolic reflector. The nature of the parabolic shape provides a fine point for the total energy collected per square inch of dish. This beam will focus on a “hot plate” designed to evenly distribute the heat to the TEG modules. The dish size should collect one-third of the power spread over a square meter. This should be about 350 Watts.

- **SOLAR TRACKING:**

  For the greatest efficiency the dish must focus its main axis directly at the sun. To accomplish this a microcontroller cached with geo data with adjust the azimuth and elevation of the dish at a defined time interval. There is no need to constantly change position as the power used by the mechanism makes this power intensive.

- **MOTION MOUNT:**

  The dish will be mounted on a 2 axis gimbal-type mount with a base that rotates 360 degrees and an elevation range from 0 to 90 degrees. This motion will be implemented using standard servos and a custom controller to be designed by the team. This will allow the dish to cover the full hemisphere of sky possible.

- **FIXED MOUNT:**

  At first the generator block will be mounted above the dish and at the focal point of the parabola. Here there will be a hot side and cold side. The hot side will face the dish and cold side will dissipate heat to the air. Various methods of cooling will be explored. As another approach the focal point would contain a convex mirror and redirect the solar beam through the bottom of the dish and heat would be dissipated to the ground.

- **TEG COOLING AND HEAT DISSIPATION:**

  The production of power from the TEG or combination of TEG's is dependent on the temperature gradient of chip. Thus, cooling and heat dissipation is necessary in order to maximize efficiency. Initial prototypes will use fin style aluminum CPU heat-sink for proof of concept. Final design will utilize a combination of fin style heat sinks and convection cooling utilizing a radiator style water cooling system or magnetic Ferro-fluid convection cooling.

- **ENERGY STORAGE AND POWER OUTPUT:**

  Power generated by the TEG will be regulated and stored in a power bank or power bank array. Possible methods of energy storage include the implementation of an array of Nickel Metal Hydride batteries or a safe cell $LiCoO_2$. The design will feature a 5V USB charging port and 12V vehicle style power outlet for device charging.

- **SCALABILITY:**

  Although the size of dish is the ultimate limiting factor for solar collection the technology and size of the dish can be theoretically scaled to any size.

- **PROGRAMMING MODEL**

  A particular tool for determining the current position of the sun relative to the geo location of the device would be the solar position algorithm provided by the National Renewable Energy Lab. Coupled with a GPS module operated with a microprocessor, the relative date and time as well as the geo location can be used as received parameters for the solar algorithm.

ENERGY STORAGE COMPARISON

Typical Application Features	NiMH vs. Lithium Primary
Rated Voltage	1.25V vs. 1.5V
Discharge Capacity	NiMH will not last as long as primary lithium (single cycle)
Recharge Capability	Several hundred cycles for NiMH, N/A for lithium primary
Discharge Voltage Profile	Both relatively flat discharge
Self Discharge Rate	NiMH retains 50-80% @ 6 months Lithium retains 80% @ 15 years
Low Temperature Performance	Lithium better than NiMH
Battery Weight	Lithium is lighter
Environmental Issues	Recycling options available for NiMH and lithium

Nickel Metal Hydride Battery:

Pros	Cons
Cheap ($34 for 12 count pack)	Heavy
Can be recharged and reused 150-500+ times	Lose power when sitting idle (1% per day) Need to be recharged and used every 1-2 months
Steady and lasting discharge	Begin to hold charges for shorter periods late in their life cycle
Delivers energy capacity at a more constant rate (flatter discharge rate)	Should not be stored in warm areas (affects longevity)
Much safer than Lithium. Environmentally friendly.	Must be charged before first use
Recyclable	Suffer from memory effect.
Low internal impedance	Low operating voltage (1.2 V)
Can tolerate overcharge and over discharge	
Rapid Charge possible in 1 hour	

Lithium Ion Battery:

Pros	Cons
Low discharge rate (retain charges longer than any other battery)	Loses energy capacity with time (even if not used)
High energy density (stores more energy in a smaller and lighter battery)	Expensive ($4-$20 per battery)
500-1000+ number of recharging cycles	Dangerous
Impossible to overcharge	High voltage capacity can make the battery too powerful for some devices and can damage circuitry
High cell voltage (3.6 V– 3.7 V)	Require battery management system

http://www.mpoweruk.com/nimh.htm

VOLTAGE REGULATION

In order to make this project a useable device, it is necessary that outputs are regulated and protected in order to keep the device, users, and any devices that may be connected safe. In order to generate a stable voltage, it is necessary to create a voltage regulator. Because this project is limited to how much power it can use, this must be a very efficient voltage regulator.

While a linear voltage regulator would be easiest to implement, it will waste a lot of energy. Linear regulators monitor the output voltage and in order to keep the voltage steady, they dissipate energy as heat. This is not acceptable for our application.

Instead, a switching power supply would be much more efficient. A switching power supply uses the properties of inductors to store energy to either step up or down DC voltages. A boost converter (steps up DC voltage) charges an inductor by switching it between charging a capacitor and shorting to ground. When the inductor is shorted to ground, the voltage rises and is then switched back to the capacitor where it dumps the energy at a high voltage. Depending on the switching speed, size of capacitor, and size of inductor, a very high voltage with very little ripple can be implemented. If necessary, in order to perfectly smooth the output, a Zener diode may be used in parallel with the capacitor.

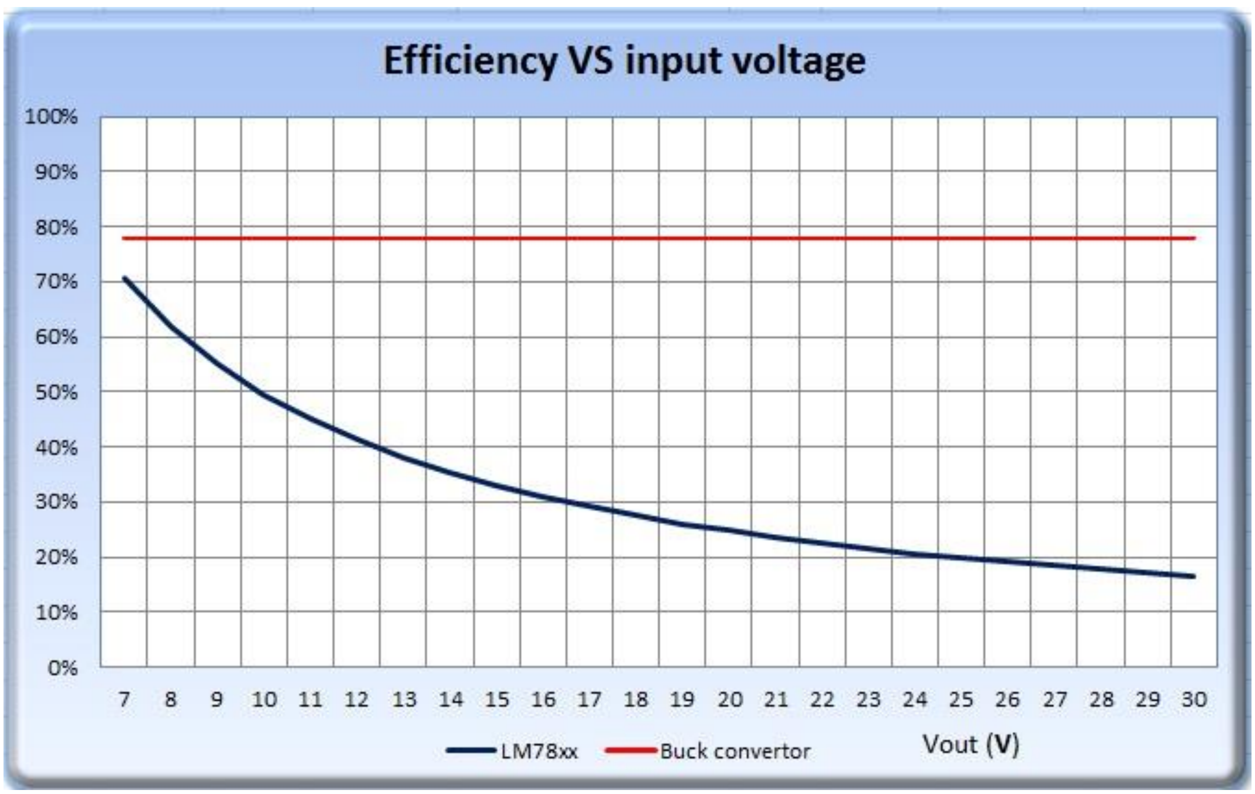
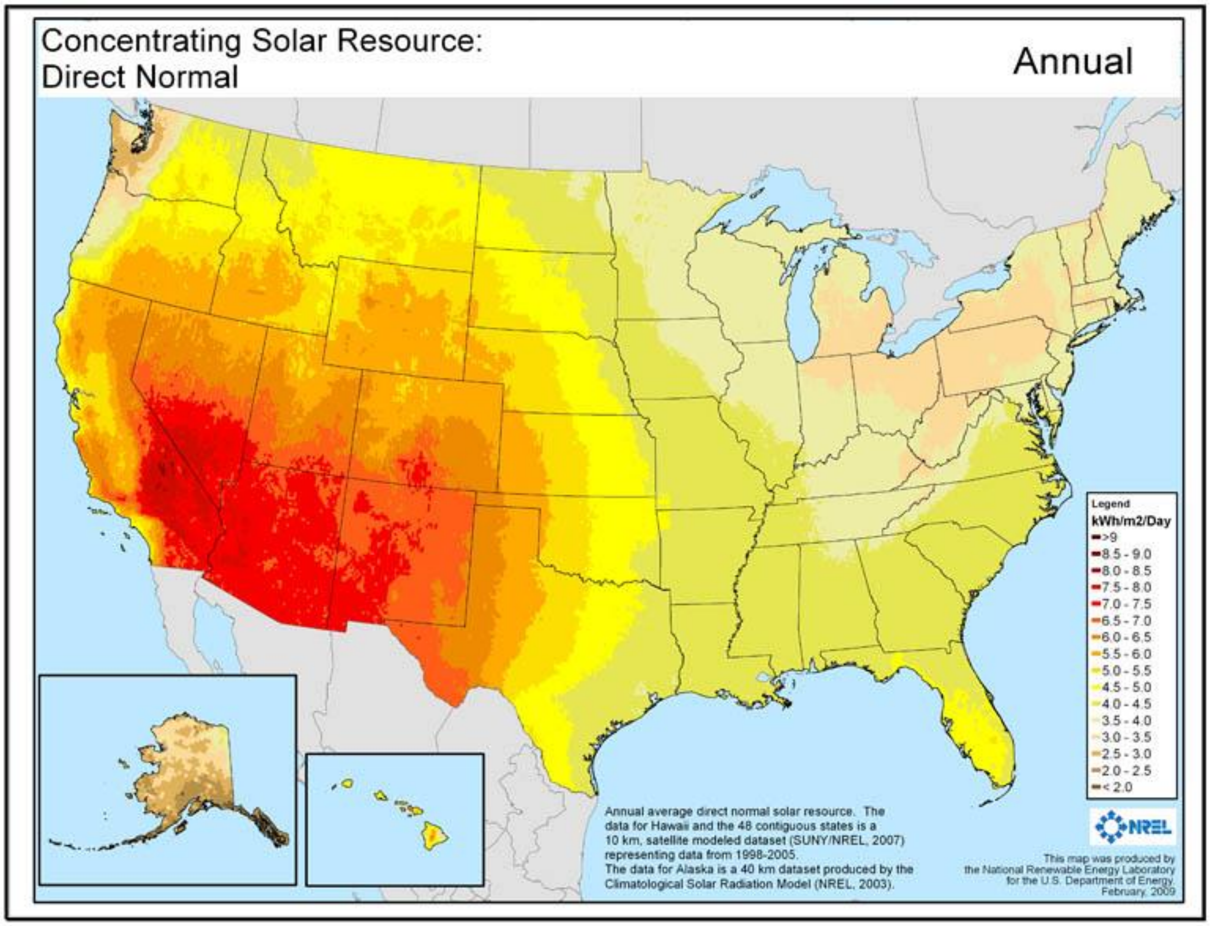


Figure 1

Figure 1 shows the efficiency of a Buck/Boost switching supply opposed to a Linear LM7805 voltage regulator. (Credit Joris Achten http://www.joris8en.be)



SOLAR COLLECTION ENERGY LEVELS OF THE CONTINENTAL U.S.