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Thermoelectric Generator and PV Panel Integrated Hybrid Energy Harvesting System

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ABSTRACT

Our proposed paper takes into account the decrease of energy bill, the reduction of power consumption during peak hours using hybrid energy harvesting system. The effective scheduling of charging and discharging cycles of battery and ensuring of user's comfort is done using Global System for Mobile Communications(GSM).A hybrid Energy Harvesting(EH) system consisting of solar panel with thermoelectric generator(TEG) placed on the lower side of solar panel has been proposed. The solar panel gets warmed up due to the radiations .This heat is transmitted to the TEG's hot side, which is installed at the back of the solar panel and is able to generate voltage if temperature gradient is applied across TEG. The proposed system employs the solar panel capable of generating of +20V with the average power of 10 watts per hour. The TEG installed at the rear side of solar panel is capable of generating the voltage of 12 V and the current of 300-500mA.The harvested energy by means of solar panel and TEG is sufficient enough to store it in a +12 V lead acid rechargeable battery. The generated energy is applied to the boost convertor to maximize the output power. The output voltage from the boost convertor is supplied to the inverter. Then it is stepped up to 230V AC using step-up transformer. The switching ON and OFF of the specific loads can be controlled by using GSM. The proposed hybrid energy harvesting system is nearly 80% efficient in comparison to existing solar energy harvesting system.

KEYWORDS – *Thermoelectric generator; PV panel; Energy harvest; GSM; DC-DC converter*

I. INTRODUCTION

The reduction of the use of the fossil-based fuel leads to the reduction of green house gas emissions, and consequently leads to the reduction of the severity of this phenomenon. The electric grid [1], one of the big consumers of the fuel is now searching for new alternatives to compensate it. Smart grid [3] provides consumers with greater information and choice of supply and allows them to play a part in optimizing the use of energy. One of the challenges that smart grid should face is to reduce the dependence on non-domestic energy sources rely mostly on renewable energy sources [8]. Renewable sources cannot be predictable and the balancing task becomes less evident to apply. The role of the Demand Side Management (DSM) [8] is to reduce the electrical energy consumption minimize the energy cost and reduce the environmental degradation.

The energy demand in the world is steadily increasing and new types of energy sources must be found in order to cover the future demands, since the conventional sources are about to be emptied .One type of renewable energy source is the photovoltaic (PV) cell [7], which converts sunlight into electrical current. PV cells are usually connected together to make PV modules, consisting of 72 PV cells, which generates a DC voltage between 23 Volt to 45 Volt and a typical maximum power of 160 Watt, depending on temperature and solar irradiation. The electrical infrastructure around the world is based on AC voltage, with a few exceptions, with a voltage of 120 Volt or 230 Volt in the distribution grid. PV modules can therefore not be connected directly to the grid, but must be connected through an inverter [6]. The two main tasks for the inverter are to load the PV module optimal, in order to harvest the most energy, and to inject a sinusoidal current into the grid. The electric output characteristics of the solar devices depend upon the luminous intensity of sun as well as on the area exposed to the light rays.

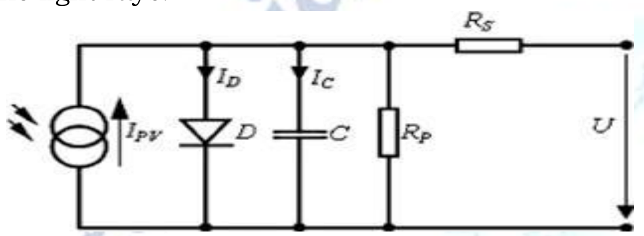


Fig 1. Electrical model of a PV cell

Thermo electric power generation [6] has emerged as a promising alternative green technology for the power generation from waste-heat. Thermo electric devices generate voltage and output electrical power from waste heat to electronic load by means of the temperature difference across the devices serving as an energy source.A thermoelectric generator (TEG) is a solid state device that converts heat (temperature differences) directly into electrical energy through a phenomenon called the Seebeck effect (a form of thermoelectric effect) which is also called as seebeck generator

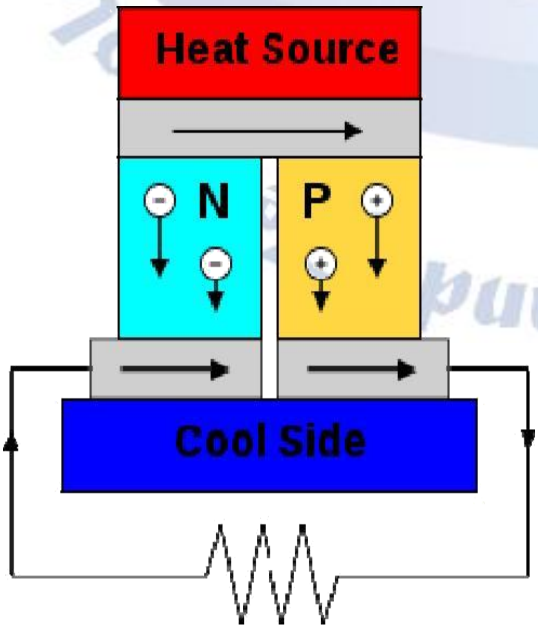
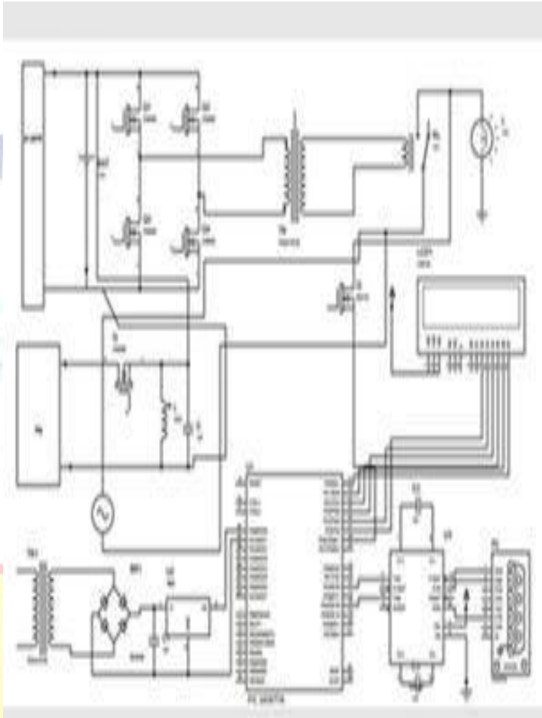


Fig.2 Simplified illustration of TEG

II. Proposed System

In the proposed system, the solar panel and thermoelectric generator is connected in series to generate energy. The waste heat from the solar panel is efficiently utilized by using thermoelectric generator.



In this circuit diagram, the generated renewable energy from both the PV panel and TEG is given as an input to the boost converter. The boosted voltage from the boost converter is stored in a lead acid rechargeable battery. The DC voltage from the boost converter is converted into AC voltage using inverter circuit. The 230V AC is achieved using a step up transformer.

A relay is used to change the mode of source from utility to renewable energy. Microcontroller PIC16F877A is used to control the relay switches and control the driver circuit of converter and the inverter. The V_{DC} supply for the microcontroller is given from the power supply unit which consists of a step down transformer, bridge rectifier, voltage regulator.

The GSM technique is used to control the source and the loads. The command given by the user using mobile to the GSM circuit is sent to the microcontroller via MAX232. It is used to transfer the information without signal interference.

III. DC-DC Converter

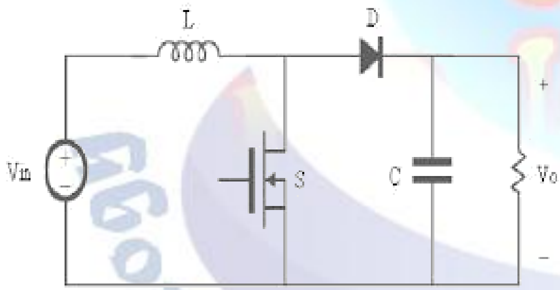
A DC-to-DC converter [2] is an electronic circuit which converts a source of direct current (DC) from one voltage level to another. The battery voltage declines as its stored energy is drained. Switched

DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing.

Most DC to DC converters also regulate the output voltage. Some exceptions include high-efficiency LED power sources, which are a kind of DC to DC converter that regulates the current through the LEDs and simple charge pumps which double or triple the output voltage. DC to DC converters are used to maximize the energy harvest from PV panel and thermoelectric generator.

A. Boost converter

A boost converter is a DC-to-DC power converter steps up voltage (while stepping down current)from its input to its output. It is class of a switched–mode power supply (SMPS) containing at least two semiconductors and at least one energy storage element, capacitor, inductor or two in combination. To reduce ripple, filters made of capacitors are added to such a converter's output(load-side filter) and input(supply-side filter).Power for the boost converter can come from any suitable DC sources such as batteries, solar panel, rectifiers and DC generators.



IV. MICRO-CONTROLLER 16F877A

Peripheral Interface Controllers (PIC) is a family of microcontrollers introduced by Microchip Technology. PIC microcontrollers (16C/FXXX series) have attractive features and they are suitable for a wide range of applications. PIC microcontrollers are RISC processors and uses Harvard architecture. It is a newer concept and it came out of the requirement to speed up the processor. Harvard architecture makes use of a separate program and data memory. PIC 16F8XX is a family of CMOS 8-bit flash controllers. Apart from the flash program memory there is a data EEPROM.

Microcontrollers with internal ADC can directly accept analog signals for processing. The switching pulses required for inverter operation are generated using PIC16F877A Microcontroller, thus reducing the overall system cost and complexity. It generates a PWM pulse at particular frequency and switching pulses for the MOSFET switches. The crystal oscillator is used to generate the required clock for microcontroller. The microcontroller and its support circuits often built into or embedded in the devices they control.

V. GSM

. GSM (Global System for Mobile Communications) is a set of standards for cell phone networks established by the European Telecommunications Standards Institute and first used in 1991. Their procedure refers to the steps a GSM [1] network takes to communicate with cell phones and other mobile devices on the network. IMSI attach refers to the procedure used when a mobile device or mobile station joins a GSM network when it turns on and IMSI detach refers to the procedure used to leave or disconnect from a network when the device is turned off.

Fig.5 GSM

VI. PULSE-WIDTH MODULATION

Pulse-width modulation (PWM) is a technique used to encode a message into a pulsing signal. Although this modulation technique can beused to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. In addition, PWM is one of the two principle algorithms used in photovoltaic solar battery chargers, the other being MPPT. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load.

The PWM switching frequency has to be much higher than what would affect the load (the device that uses the power), which is to say that the resultant waveform perceived by the load must be as smooth as possible. Typically switching has to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on. The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

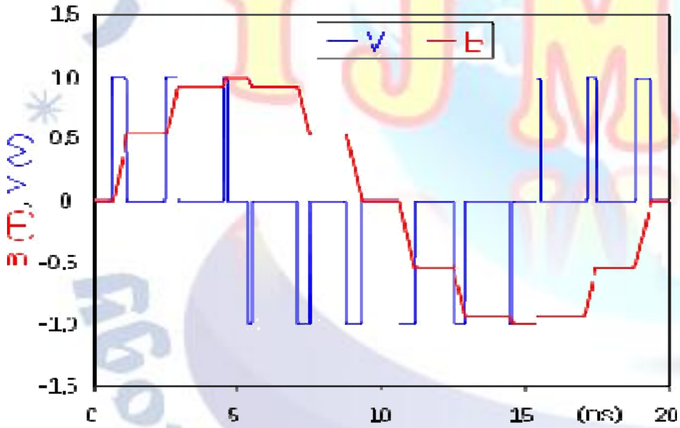


Fig.6 PWM waveform

VII. PRINCIPLE AND EQUATIONS

A. photo voltaic effect

When the solar cell (p-n junction) is illuminated, electron-holes pairs are generated and acted upon by internal electric fields, resulting in a photo current (I_L). The generated photocurrent flows in a direction opposite to the forward dark current. This current depends linearly on the light intensity, because absorption of more light results in additional electrons to flow in the electric field force.

The overall cell current I is determined by subtracting the light induced current I_L from the diode dark current I_D.

$$I = I_D - I_L \quad (1)$$

Therefore, $I = I_0 \, [\exp(eV/kT) - 1) - I_L$

This phenomenon is called photovoltaic effect.

B. Seebeck principle

The term thermo power, or more often, Seebeck coefficient of a material, is a measure of the magnitude of an induced thermoelectric voltage in response to a temperature difference across that material. The Seebeck coefficient has units of V/K, though it is more practical to use mV/K. The Seebeck coefficient of a material is represented by S (or sometimes σ), and is non-linear as a function of temperature, and dependent on the conductors absolute temperature, material and molecular structure.

VIII. SIMULATION

The Simulation for this proposed circuit is done using Proteus Software.

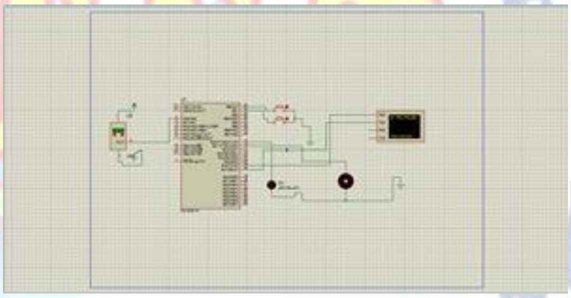


Fig.7 simulation circuit

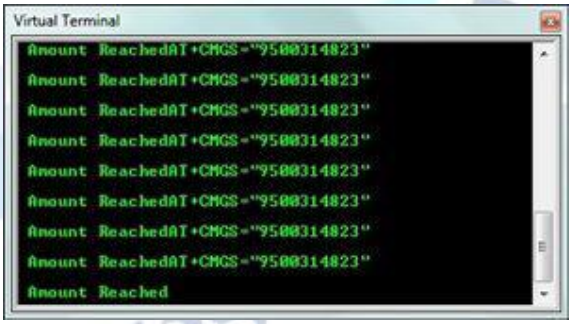


Fig.8 GSM window

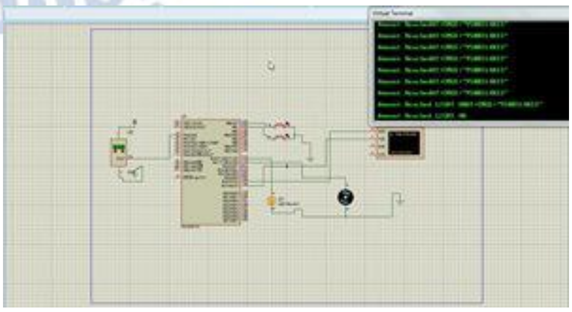


Fig.9 Load ON using renewable energy

IX. CONCLUSION

In this paper, a hybrid energy generation using PV panel and TEG is implemented. The proposed paper takes into account the elaboration of an effective scheduling of charging and discharging of batteries depends on user comfort. The effectiveness of the suggested model is demonstrated through simplified simulation using Proteus software. The purpose of the proposed system is to decrease the total cost of the energy bill and reduce the energy consumption during peak loads.

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