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Performance of artificial light sources for different solar cells

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Abstract

Energy harvester is a new source available for low power devices. Instead of using primary and secondary batteries, use of energy harvester is always preferred. This paper mainly focuses on the use of artificial light for harvesting the energy. Artificial light is easily available in the offices, malls, hospitals, colleges, airports and at many more places. This paper discusses different types of artificial light sources, their wavelengths and selection for the suitable PV panel for harvesting energy from artificial light sources.

Keywords*—energy harvester, low power devices, indoor sunlight, artificial light*

1. I. INTRODUCTION

In recent years, environmental monitoring plays an important role to show the effects of human behavior on the environment. Since low power sensor networks can achieve this task, it gains more and more attention nowadays. Environmental monitoring usually has the following characteristics: outdoor environment, remote area, operating with long periods, so that the lifetime of the sensor nodes has been used extensively as an evaluation parameter in the whole sensor node system [1]. Every node has several other parts: A radio transceiver, a microcontroller, a circuit for interfacing withthe sensors and an energy source usually a set of batteries. The use of batteries severely limits the life of the WSN, as batteries will need to be replaced over time. Hence in the last decades, several efforts have been proposed to prolong the lifetime of sensor networks.

Energy harvesting is a process in which energy is captured from the environment and transformed into usable electricity. In recent years there has been a growing interest of researchers for developing energy harvesting systems at the micro level, from a variety of sources: light, vibration, heat, radio- frequency waves [2].

In recent years, many researchersare working on outdoor energy harvesting where energy is excavated from the sunlight, wind or vibration present in nature. Compared with these, veryfew studies focus on the indoor energy harvesting system. We are spending most of our time in an indoor environment (offices, schools, houses, etc.) so it is necessary to focus on indoor energy harvesting as well.

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In indoor situations, both sunlight and artificial light can be harvested to provide the energy to the load. The dominant energy source for the indoor energy harvesting system would change with time. Therefore the spectral distribution of each kind of light source plays an important role in energy estimation. The light irradiance (W/m2), which is the input of this traditional model, is not a common unit to measure the indoor illumination information. The indoor light irradiance is so low, that we cannot find an efficient method to capture this form of input. Instead, the Lux level of the light sources is a common usage to represent the indoor illumination condition.

There are problems associated with energy harvesting of energy from indoor environment: regardless of the source, natural or artificial, the luminous intensity is very less, usually below 1000 lux. Therefore, the power harvested is much smaller than in direct solar illumination in outdoor conditions.

The traditional solar cell model neglects the impact of spectral distribution, performs badly in the indoor environment as it responds uniformly to different situations.

This paper is divided into four main sections first section gives introduction, second section gives an idea about lighting conditions in indoor environment, third section is about the artificial light sources used and the fourth section explains different PV model used for light harvesting.

II. Lighting conditions in indoor environment

Energy harvesting is a technology that allows to capture otherwise unused ambient energy (such as vibration, strain, temperature gradients, energy of gas and liquid flows) and convert into usable electrical energy which is stored and used for performing sensing or actuation. The general functional blocks of energy harvesting system are shown in fig 1.

The solar panel is a semiconductor device, which can convert the harvested light irradiance to electrical energy. Design consideration for solar panel requires high conversion efficiency in order to provide more power to the load. Since the power energy harvested by the solar cell strongly depends on the discrete light source, an energy storage element is required to store the energy harvested, in order to provide a stable voltage to the load.

The voltage level adapter is equipped with the maximum power point tracking circuit and DC/DC converter is required to provide a constant power to the load which can improve supply efficiency significantly. A typical indoor energy harvesting system integrates, the energy source, the energy harvester, an energy storage element, power management and the load.

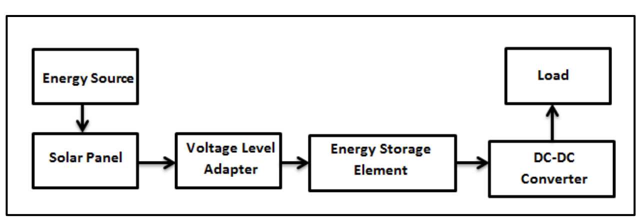

Fig 1 Block diagram of Energy Harvesting System

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Generally, the power extracted from the luminous radiation is extremely variable, depending on day/night alternation, atmospheric conditions, temperature, and geographical location, indoor or outdoor environment – which makes the energy harvest.ed insufficient for use as an exclusive power source to supply sensor nodes. A special case is the indoor environment, in which the solar radiation is strongly reduced, compared to the outside environment, and artificial lighting (typical fluorescent lamps, incandescent or LED lamps) levels are usually below 1000 Lux [3].

The effectiveness of a system of harvesting energy, for indoor environment, primarily depends on the performance of the transducer, typically a photovoltaic device. Therefore, the determination of the conditions of lighting is important to the proper characterization of a source of energy, and is useful for choosing the type of photovoltaic device.

III. Artificial Light

Compare with the sunlight, the indoor artificial lights radiant electromagnetic wave of a limited wavelength and intensity. It exists in all kinds of buildings, offices and in malls [8]. People can easily control its state (turn on or turn off), and the light intensity is almost constant. Therefore, the artificial light is promised to be another contributor to provide the energy to the load under the indoor environmental condition [4].

In Artificial light sources, every type of lights have different spectral power distribution, providing the diverse quantity of energy, it is necessary to have a thorough understanding about these lights [5]. Nowadays incandescent lamp, fluorescent lamp and LED are three of the most common selections.

TABLE 1.TYPICAL LIGHT SOURCES USED

Type of Source	Brand	Temperature	Power [W]	Wavelength [nm]
Warm LED	Philips	2800	55	320-950
Cold LED	Philips	2800	38	480-570
Fluorescent	Deltaco	2800	3.5	420-720

IV. Photovoltaic Devices

A photovoltaic module (PV) is a device consisting of several solar cells connected in series or in parallel, which has the ability to transform light energy directly into electricity because result of the photoelectric effect. The solar cells are classified according to the material employed: amorphous silicon, crystal silicon, and compound semiconductor solar cells. The crystalline silicon can be further divided into monocrystalline and polycrystalline. Other classifications can be made depending on the substrate (glass, stainless steel, film) or environment of use (indoors, outdoors) [7].

TABLE 2. OVERVIEW OF CHARACTERISTICS OF PV MODELS

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Type	Wavelength Response (nm)	Application	Cell efficiency
Mono-Crystalline	300-1100	Suitable for indoor and outdoor applications	Higher conversion efficiency but costly
Poly-Crystalline	500-1100	Suitable for outdoor applications	
Amorphous thin-film (A-Si)	300-600	Suitable for indoor applications	Lower conversion efficiency
dye-sensitized solar cells (DSSC)	300-600	Suitable for indoor applications	Higher conversion efficiency but limited customization is possible

Amorphous- Silicon (a-Si) and dye-sensitized solar cells (DSSC) have been tested extensively as indoor light harvesters due to their wide band gaps that are optimum for absorption of the spectra from compact fluorescent lamp (CFL) and light-emitting diode (LED) bulbs. DSSC give very high performance in indoor conditions but customization for artificial light environments is limited. Dye solar cells are based on a nanostructured high band gap TiO2 layer which is sensitized with a dye that absorbs light in the visible range [6].

The spectral sensitivity of the classical indoor solar cell (also called a-Si, amorphous, thin film solar cell) overlaps totally the human eye. Its spectral sensitivity range is from 350 nm to 750 nm having a maximum peak around 555 nm [7].

The lux is one$\mathrm{lm/m^2}$, and the corresponding radiometric unit, which measures irradiance, is the W/m2. There is no single conversion factor between lux and $\mathrm{W/m^2}$. Every wavelength has a different conversion factor, and it is not possible to make a conversion unless the spectral composition of the light is known. The peak of the eye–sensitivity curve is at 555nm (green).

For 1lx of light at this wavelength, the correspondent value is 1.464$\mathrm{mW/m^2}$, in the same way, 1$\mathrm{W/m^2}$ equal to 683$\mathrm{lm/m^2}$

From this consideration a primitive conversion rule can be extracted:

$$Ev_{(555nm)} = 683 * \mathrm{Ee}_{(555\mathrm{nm})} \quad (1)$$

Vice versa for a source emitting light only at 555nm with an illuminance of Ev, the irradiation is:

$$\mathrm{Ee}_{(555\mathrm{nm})}\left[\frac{\mathrm{W}}{\mathrm{m}^2}\right] = 1.464 * 10^{-3} * \mathrm{Ev}_{(555\mathrm{nm})} \quad (2)$$

Conversion of the radiation in the infrared spectrum is not possible, because illuminance consider only the visible spectrum.

Comparison of Solar PV Models

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As per previous discussion, different types of PV cell models are available for energy harvesting. Following graphs give performance of solar cell models at different light intensity levels.

TABLE 3: SOLAR CELL MODEL

Model No	Material	Application	Dimensions (mm)	Open Circuit Voltage (V)	Short Circuit Current (mA)
E-19	Monocrystalline Silicon	Indoor and Outdoor	80X60X2.7	6.0	130
15870	Polycrystalline Silicon	Indoor and Outdoor	112X84X3.0	6.0	200
E-28	Amorphous Silicon	Indoor	27X27X1.1	4.0	9.1

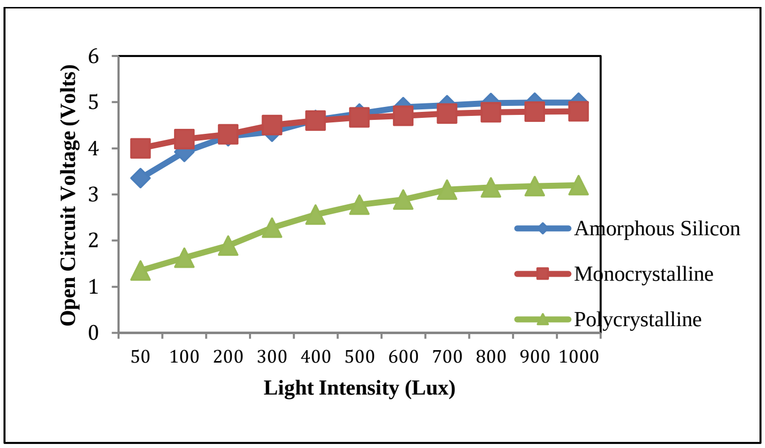
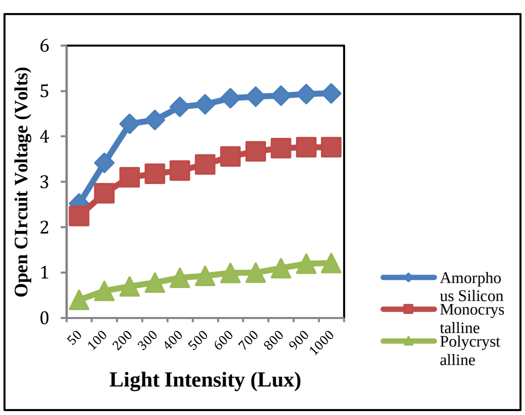


Fig 2 Performance of Incandescent Light



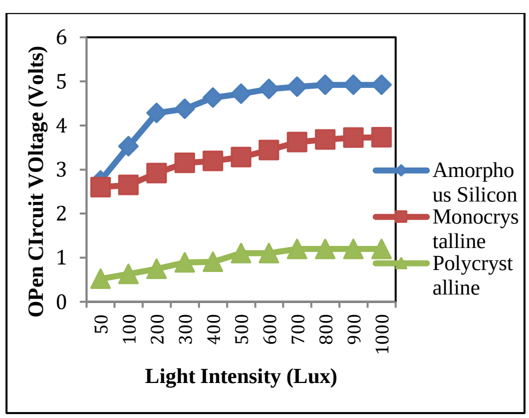


Fig 3. Performance of Fluorescent Lamp Fig 4
Performance of LED

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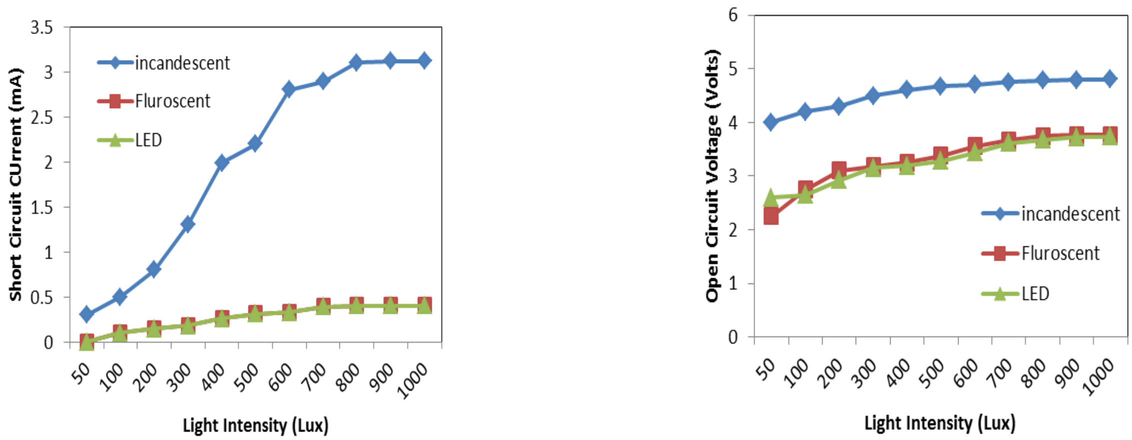

(a) (b)

Fig 5 Comparison of open circuit voltage (b) and short circuit current (a) at different light intensities for model E-19 (Monocrystalline Silicon)

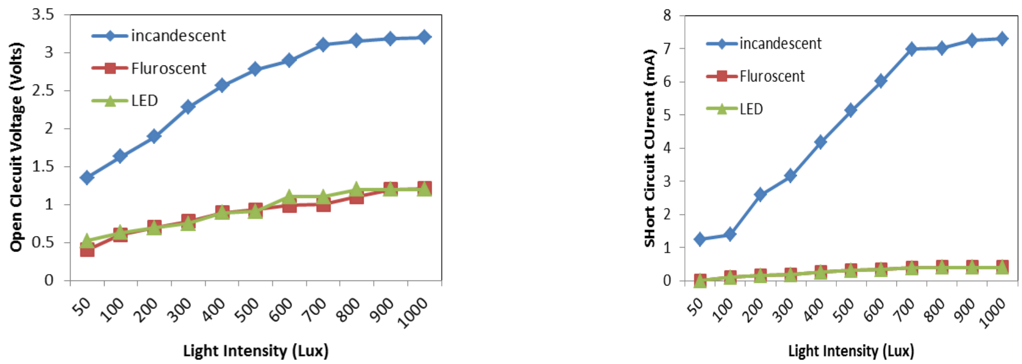

Fig 6 Comparison of open circuit voltage and short circuit current at different light intensities for model 15870 (Polycrystalline Silicon)

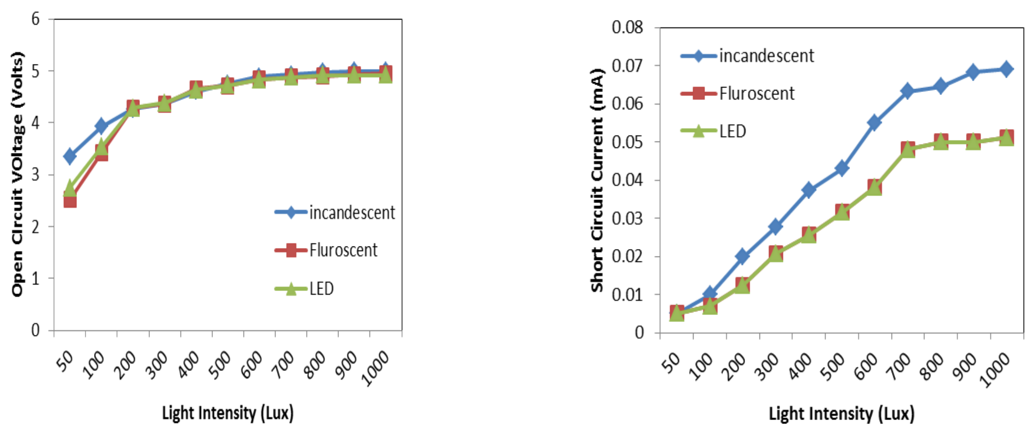

Fig 7Comparison of open circuit voltage and short circuit current at different light intensities for model E-28 (Amorphous Silicon)

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CONCLUSION

Energy harvester is a need of today's era as it can be used at remote spaces to energize low power devices. The artificial light is promised to be another contributor to provide the energy to the load under the indoor environment. The indoor artificial lights radiant electromagnetic wave of a limited wavelength and intensity as compared to the outdoor sunlight,. Different lights may generate different energy, it is essential to choose a suitable PV cell model for each kind of light. After the comparison of three PV models i.e. Monocrystalline Silicon, Polycrystalline Silicon and Amorphous Silicon, it is observed that the performance of Amorphous Silicon model is better for all types of artificial light sources. The performance of Amorphous Silicon can be further enhanced by improving algorithm.

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