Available online at www.sciencedirect.com

ScienceDirect

Procedia Technology 17 (2014) 343 – 350

Procedia Technology

Conference on Electronics, Telecommunications and Computers – CETC 2013

On the Feasibility of Indoor Light Energy Harvesting for Wireless Sensor Networks

Carlos Carvalho[a,b,*], Nuno Paulino[b,c]

[a] *Instituto Politécnico de Lisboa (IPL), Instituto Superior de Engenharia de Lisboa (ISEL), Área Departamental de Engenharia de Electrónica e Telecomunicações e de Computadores (ADEETC), Rua Conselheiro Emídio Navarro, nº1, 1959-007 Lisboa, Portugal*

[b] *UNINOVA/CTS, Campus FCT/UNL, 2829-516 Caparica, Portugal*

[c] *Universidade Nova de Lisboa (UNL), Faculdade de Ciências e Tecnologia (FCT), Departamento de Engenharia Electrotécnica (DEE), Campus FCT/UNL, 2829-516 Caparica, Portugal*

Abstract

This paper presents the important issues about the design of a low cost, micro power, indoor light energy harvesting system to supply a node of a wireless sensor network (WSN). Possible technology options, available for the photovoltaic (PV) cells, are discussed. Light power and irradiance measurements, in a real indoor environment, are performed and results are presented. From these results, a possible solution for cell sizing is described.

Peer-review under responsibility of ISEL – Instituto Superior de Engenharia de Lisboa, Lisbon, PORTUGAL.

Keywords: Energy harvesting; Irradiance measurements; Light energy; Light power measurements; PV cells; Wireless sensor networks.

1. Introduction

The ability of electronic circuits to obtain their source of power from the surrounding environment is a feature that has gained increased attention [1], either for sensor networks [2], or embedded systems [3]. Sensor networks that only rely on power grid connections are limited to a relatively small range of applications, as network nodes can never be too far from a power outlet. For pervasive operation, relying on the grid is a limiting factor. The use of batteries allows for freedom about sensor distribution, but as their stored charge gets depleted, they need to be

* Corresponding author. Tel.: +351-21-8317239; fax: +351-21-8317236.
E-mail address: cfc@cedet.isel.ipl.pt

Peer-review under responsibility of ISEL – Instituto Superior de Engenharia de Lisboa, Lisbon, PORTUGAL.
doi:10.1016/j.protcy.2014.10.206

replaced. This can be a problem if a large number of sensors are deployed, especially in places that are difficult to reach. Thus, the simple operation of battery replacement can become expensive and burdensome.

To tackle these limitations and achieve indefinite operation, electronic devices must obtain their energy directly from the surrounding environment. This kind of procedure is commonly known as energy harvesting. Besides its pervasive character, energy harvesting is both ecological and thrifty, because sensor systems do not need batteries to power the circuits, and will not contribute to environmental pollution caused by disposing of the depleted batteries, or even their manufacturing, in the first place. In economical terms, this represents cost reduction both in devices and maintenance procedures.

Although there are different possible energy sources that can be harvested to power electronic applications, the context described in this paper uses light energy because, comparing all sources, this is the one that shows the highest energy density by volume unit, for low-power systems [4].

Using indoor light to power an electronic application is an increased challenge, because the levels of available light energy inside buildings are much lower than those that can be obtained outside.

2. Light energy

Light is an electromagnetic wave, comprising an interval of frequencies in which it is visible. In the lower end of this interval, light tends to be red. As the frequency increases, light goes through the known colors, and in the upper end, it gets violet. Thus, light is bounded by infrared and ultraviolet.

The light spectrum outside the atmosphere, also known as the 5800 K blackbody, has the designation of AM0 (Air Mass 0), meaning “zero atmospheres”. This is the standard used to characterize PV cells that are used in space, to power satellites.

The sunlight, after penetrating the atmosphere, at sea level, perpendicularly to the surface of the Earth, has a spectrum which is referred to as AM1 (one atmosphere). AM1 is useful for estimating the performance of solar cells in equatorial and tropical regions. The index “1” is related to the angle of solar incidence, which is minimal in this situation.

In most places, the incidence of the Sun has a different angle than in the Equator, and sunlight must cross a greater amount of atmosphere. As such, this spectrum is referred to as AM1.5 (one and a half atmospheres), on a clear day. This value is the standard test condition (STC) for terrestrial PV panels. For higher latitudes, there are more Air Mass indexes, used for higher incidence angles, above 60º. These indexes can go up to AM38 in the polar zones, where the incident angle is close to 90º. In any of these cases, atmospheric pollution has influence over the irradiated energy, limiting the amount reaching the surface of the Earth.

The light energy is different according to each wavelength. The spectral power density of the solar radiation is shown in Fig. 1, where the top curve is the solar spectrum just outside the atmosphere.

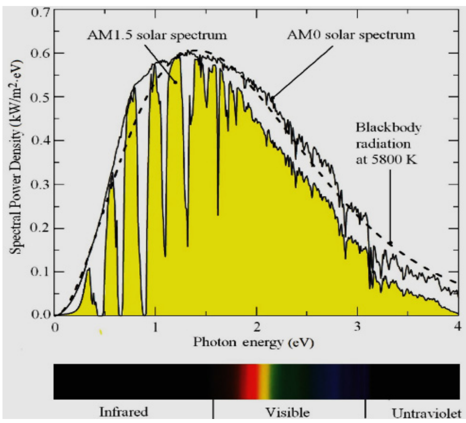

Fig. 1. Spectral power density of solar radiation [5].