A Measurement Platform for Photovoltaic Energy Harvesting in Indoor Low Light Environment

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This report presents a platform specially designed for high-accuracy measurement of indoor artificial lighting and environmental information for the evaluation of indoor photovoltaic energy harvesting when used in environments with ultra-low harvesting potentials with less than 1 W/m^2 irradiance.

1 Introduction

Flexibility and modularity of systems have always played a major role in the field of materials handling [1]. Smart objects with ability to understand and react on their environment are a key solution for achieving this flexibility [2]. The autonomous and intelligent load carrier embodied as *Intelligent Bin* (inBin) is developed [1] according to the IoT device requirements to fulfill the current growing demand [2]. It is a container with the ability of storing data about its contents' attributes, showing data on its display, communicating through a wireless network, in addition to interaction with the operator.

Same as any other IoT entity, energy plays a major role on the feasibility and functionality of the inBin. The inBin should have minimum mobility restrictions and all functions should be fulfilled in an energy neutral manner. It has been shown that among light, vibration and thermal energy, the PhotoVoltaic (PV) generated energy is more promising and efficient within this application [2].

Despite maturity of outdoor PV applications, few researches have been undertaken on the PV cells behavior under indoor artificial lighting [3]. Available analysis are mainly

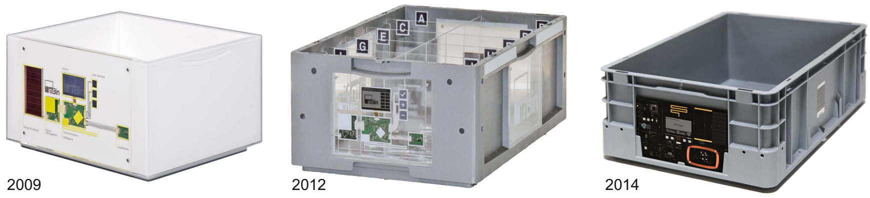

Figure 1: Three generation of the inBin smart object

focused on the applications under Standard Testing Condition (STC) with an arbitrary maximum terrestrial intensity, one sun spectra, 1000 W/m^2 perpendicular to the cell panel in 25 $^{\circ C}$ [4]. In materials handling applications, artificial illumination is mostly the only available lighting. Consequently, an exclusive intensity evaluation and spectrum analysis of this lighting without any outdoor effect is required. A setup to recreate the indoor controlled environment and provide valid PV measurement data is explained here.

2 Measurement Platform

Three types of data are collected within the platform: the lighting and PV cell specification, the environmental condition and set up data of the measurement platform.

Spectrometry is the most reliable way of light measurement. A 2-inch integration sphere from *StellarSphere IC2* with a 180° field of view and wavelength range of 200-1700 *nm* samples the light and transfers it through a fiber optic connection to a BLACK-Comet spectrometer measuring wavelengths in the range of 200-1100 *nm*.

In addition to the integration sphere, three PV cells, temperature sensor, infra red sensor and RGB measurement sensors are mounted on a board which enables measurement of all required parameters within a small area with homogeneous light quality. The homogeneity of the light assures a reliable measurement from all sensors.

An interfacing board connects the control PC to the measurement board. In addition to the conversion and transfer of data, this interface selects the active PV cell on the measuring board according to the command from the operator.

To measure four quadrants VI curve characteristics, the Agilent (Keysight) B2902A as a two channel precision Source/Measure Unit (SMU) with resolution of 100 fA and 100 nV is used. It connects to the active PV cell with a 4-wire connection setup as shown in Fig. 2 to eliminate the voltage error caused by the test leads residual resistance.

Four light sources with different types (LED, halogen and florescent) are used in the measurement platform. All used sources are dimmable and their outcoming light is modified through a dimming board based on the operator's command.

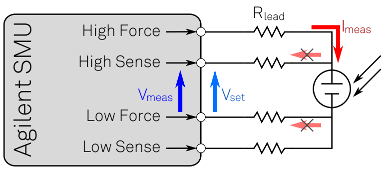

Figure 2: A 4-wire connection setup for measuring IPV cells four quadrants characteristics

The overall signaling structure of the measurement platform, connecting all electrical and electro-optical components is shown in Fig. 3.

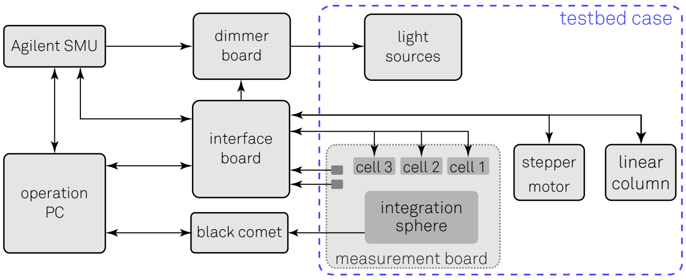

Figure 3: Schematic electrical signaling of all electrical and optical components

All these components and devices are mounted within a black colored hard wooden case with the size of 1700×700×650 *mm*. All interior walls of this case are covered with a rippled black sponge layer to minimize any reflection inside the platform. The overall built platform can be seen in Fig. 4.

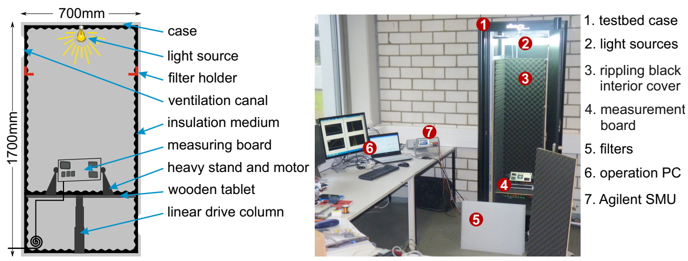

Figure 4: Left: a schematic structure of the platform, Right: the built platform

3 Light Modification

To replicate different indoor light conditions, the measurement platform is able to modify the light intensity with four techniques as below:

Distance alteration: based on the inverse square law, light will lose energy when travels further, leading to a reduced intensity. Therefore, the variation of the physical distance between light source and PV cell represents the most basic modification.

Dimming: manipulation of the input power to the light source changes the illuminance of the light and can be used as a light intensity control parameter.

Filtering: optical filters are able to absorb and reflect some portion of the incident light. Therefore, the energy of the passed light beam would be less.

Incident angle: changing the incident angle between the source and cell reduces the active surface of the IPV cell that leads into a smaller value of the incident light.

4 Conclusion and Future Works

The light quality and characteristics of indoor environments are key factors to consider during the design of smart objects powered by PV cells. The requirements of a measurement platform for evaluation of the indoor light condition is presented here. In addition to the general specification for measurements, a suggestion for components, mechanical structure and required signaling is presented. To replicate possible indoor conditions, four light modification techniques are provided.

Installing an active temperature control system is required as the first future task. Moreover, a better interior cover with less reflection would improve the measurement quality.

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