CHAPTER 1

INTRODUCTION

1.1 RATIONALE BEHIND THIS STUDY

Photovoltaic (PV) conversion of solar energy into electrical energy is one of the many sources of energy promising to compliment conventional sources. In order to make photovoltaics a major energy contributor, many factors that play a pivotal role in its performance have to be understood. The three primary factors singled out are the cost, efficiency and life-time. These factors are of great concern with regards to sustainability and viability of renewable energy. In order to reduce cost of PV devices in the global economic market, low-cost materials are being used to fabricate these devices, unfortunately compromising efficiency and sometimes lifetime.

In order to address these issues mentioned above, research in photovoltaic industry should be carried out in all spheres. Issues which at first glance may appear trivial, should now be given special attention through more indepth analysis of research. The effect of varying outdoor spectrum has not been fully researched although some researchers acknowledge the effect it has on device performance [Kenny, et al., 2006; Gueymard, 2005; Tang, et al., 2004]. This may have attributed to difficulties encountered in obtaining outdoor data and in some instances where data is available, lack of knowledge in interpreting such data poses a huge challenge. This thesis is devoted to unearth the ‘mysteries’ associated with varying outdoor spectrum during the course of the day, during cloudy/clear days and finally during seasons. An assessment procedure is also introduced.

1.2 OBJECTIVES OF THIS STUDY

The primary objective of this study is to develop a methodology of quantifying the outdoor spectral effects on PV devices of different technologies. This is realized by designing and building an automated current-voltage tester that uses a programmable external power supply unit as a variable load. This tester is used to measure all the electrical parameters of the PV devices while the spectroradiometer is continuously measuring the instantaneous outdoor spectrum. The secondary objective is to analyze the possible causes of hot-spots associated with crystalline silicon cells. An assessment procedure is developed to assess the causes and effects of hot-spots formation.

1.3 METHODOLOGY

In chapter 2, the physics governing the operation of PV modules is discussed with special emphasis on the electrical parameters and the factors that affect its performance. Equations describing the processes in solar cell p-n junctions are elaborated on to provide an essential foundation for understanding the consequential processes. The theory of spectral distribution and some indoor results is also presented. The concept of Air Mass (AM) is used to evaluate the performance of five PV modules of different technologies on site; the results are presented to augment the theoretical foundation.

Chapter 3 discusses different methodologies adopted for evaluating the effect of outdoor spectrum. Some shortfalls of each method are also highlighted from which the concept of Weighted Useful Fraction is developed. An analysis and a full description of the Weighted Useful Fraction are clearly elaborated. It is established that the mean WUF represent the preferred spectrum to which the device responds best during the entire period of outdoor exposure. A figure clearly illustrating the physical meaning of the statistical terms associated with the Gaussian distribution and how the terms are used to interpret the WUF data is discussed. It is demonstrated that the concept of WUF is indeed useful in interpreting outdoor spectral data, which so far does not have a standard methodology.

Chapter 4 presents a full description of the I-V tester used in this study including its main components and operational modes. The sequence guideline of the I-V tester together with a clearly elaborate circuit diagram is also presented. A good fit between the I-V curve obtained using the solar cell model and the one obtained using the I-V tester is also presented. The use of Infrared thermography in PV applications as a diagnostic tool is also discussed. Spectroradiometry as a methodology for measuring such spectral shifts during the course of the day and its basic operation is presented.

Chapter 5 presents results for crystalline-Si modules. The results showed that for summer season, mc-Si "prefers" to operate optimally at WUF = 0.8099, which is an indication of a full spectrum. For winter season the mc-Si module responds optimally at WUF = 0.8099 which corresponds to AM 2.19. Results for mono – Si module showed that the device performs best at WUF = 0.6457 which corresponds to AM 1.83 during summer season, while it operates optimally under a winter spectrum indicated by WUF of 0.5691 (AM 2.58). The seasonal changes resulted in the shift in day time corresponding to the "preferred" spectrum. For poly-Si, it was also observed that the WUF values are lower than the other two crystalline-Si counterparts. The pc-Si module was observed to prefer a low AM spectrum indicated by WUF = 0.5813 during winter season while for summer it prefers a spectrum characterized by WUF = 0.5541 at AM 3.36.

Chapters 6 presents comparative results of hydrogenated amorphous-Si (a-Si:H) and Heterojunction with Intrinsic Thin Layer (HIT) modules. The a-Si:H module degraded just after 16 kWh/m^2 of outdoor exposure with a 67% reduction in Fill Factor (FF) while HIT module did not. The Staebler-Wronski phenomenon was found not be prevalent in HIT devices which had its efficiency and fill factor stable during the entire period although it has amorphous silicon material in its structural composition. The degradation of a-Si:H device revealed that the device spectral response was also affected by a 7.7% after degradation.

Chapter 7 illustrates outdoor spectral effects on Copper Indium diselenide (CIS) device. A 17% decrease in the short - circuit (I_{sc}) current is observed after a change in season. The change in season from summer to winter results in a variation of the outdoor spectrum and consequently a decrease of 1.5% in WUF, which could contribute to the decrease in the device I_{sc}. Furthermore, this chapter reveals a close correlation between WUF and temperature. Temperature coefficients for spectral induced effect (WUF) were found to be -0.001/^{o}C for winter period and -4×10^{-5}/^{o}C for summer seasons.

Chapter 8 presents hot-spot analysis of mc-Si cells. Results obtained reveal a direct correlation between areas of high impurity contaminants and hot-spot heating in different samples of mc-Si. This chapter is therefore, is devoted to analyzing the elemental composition of a hot-spot region in a solar cell.

In chapter 9, conclusions are drawn from all results obtained in this study. Finally, appendix A lists the research outputs associated with this study and appendix B presents some of the equations used in this work.

1.4 REFERENCE

Gueymard, C.A, (2005), “Interdisciplinary applications of a versatile spectral solar irradiance model: A review,” Energy, 30; 1551 – 1576.

Kenny, P.R, et al., (2006) “Performance of thin film modules”. Thin solid flims, 511-512; 663 – 672.