PRELIMINARY ANALYSIS OF THE EFFECTS OF SNOWFALL ON PV SYSTEMS

R. Andrews
Department of Mechanical and Materials Engineering,
Queen's University, Kingston, ON

J. M. Pearce
Department of Materials Science & Engineering
Department of Electrical & Computer Engineering
Michigan Technological University , Houghton, MI

Introduction

In a global sense, the implementation of solar photovoltaic (PV) technology for grid-tied power generation applications is increasing at a rapid pace as recognition that this technology can provide an abundant and environmentally friendly source of energy (Pearce, 2002). As the solar industry matures, PV is increasingly being deployed in a distributed pattern in countries with significant snowfall. As such, in 2009 nearly 74% of PV resources were installed in countries which experience some amount of snowfall, namely Germany, Czech Republic, Japan, and recently Canada (Marketbuzz, 2010).

Previous work looking at snow effects on PV systems has been performed on a limited number of panels. For example, a study in Germany showed a loss of 0.3%-2.7% for a highly exposed 28 degree roof mount system (Becker et al., 2007), though other studies have shown up to a 10% loss (Ransome and Wohlgemuth, 2005). Recently a study has shown losses ranging from 6% to 26% for sites located in Truckee, California. Notably, this study has proposed the first steps towards a generalized snow loss model, though the dataset for this study is quite limited (Townsend and Powers, 2011).

The goal of this study is to gain a better understanding of the effects of snowfall on PV performance, using a large array of modules consisting of different PV materials and surface coatings, and to develop a generalized model to predict the effects of snowfall on a PV performance at any location.

Apparatus

A study has been initiated which now spans two years of data related to the effects of snowfall on PV systems. Two main test systems are utilized in this study, the first is the Open Source Outdoors Test Field (OSOTF) developed for this purpose as a collaboration between Queen's University and St. Lawrence College, shown in Figure 1. This test site houses 60 panels divided between amorphous, mono and poly crystalline silicon modules. The panels are then divided into test sections at eight angles ranging from 5 to 70 degrees. This site is also co-located with a meteorological station, which collects information on the intensity of both direct, diffuse solar irradiation and albedo in addition to standard meteorological data. All panels were monitored for short-circuit current and cell temperature at 5-minute intervals since January 7, 2011. A full description of the test site is available online at http://www.appropedia.org/OSOTF

Figure 1: The Open Source Outdoors Test Field

The secondary site (Figure 2) is located a few km east of the OSOTF site and consists of 16 amorphous silicon panels; eight with frames and eight frame-less. These modules are ground mounted racks at 8 angles from 0 to 70 degrees. These panels were similarly monitored for short-circuit current and cell temperature along with co-located meteorological data, with the exception of solar irradiation, at five minute intervals. This site has been running since February, 2010.

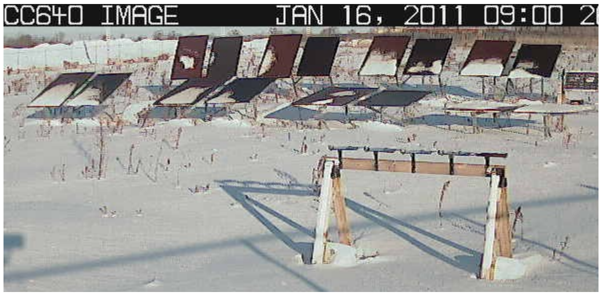

Figure 2: Secondary PV test site

Analysis methodology

In order to determine the effects of snowfall on a PV system, its performance in the absence of snow must be simulated. In order to do this, a method of predicting synthetic days based on past performance of the system was developed. This methodology is based upon the Sandia PV model (King et al., 2004), and uses a least squares parametric optimization of system parameters to fit the model to a set of collected training data, which represents the operation of the system in the absence of snow. Using this parametric model, coupled with collected irradiation measurements from heated pyranometers, the predicted performance of each PV panel was predicted in the absence of snow. The actual output was then compared to the simulated output in order to determine the overall effects of snowfall on the system.

Results

The results of this study demonstrate the broad range of effects that snow can have on a PV system.

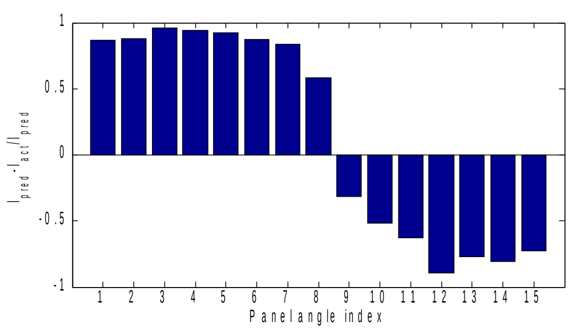

Figure 3: Output of 15 crystalline silicon modules on January 22, 2011 compared to the modelled output. An increasing panel index indicates an increased panel angle.

Figure 3 shows a comparison of daily snow effects expressed as the difference between measured an modelled output, normalized by the modelled output. It can be seen that on the same day, panels which are at a lower angle will loose a significant fraction of predicted energy, and those at a higher angle will gain from increased albedo in the environment, a process which is described more fully elsewhere (Andrews and Pearce, forthcoming).

Work to determine generalized snow losses and an empirical model to correlate these to local meteorological data is ongoing.

Conclusions

Snow can have an appreciable effect on the performance of a PV system. The goal of this research is to quantify this effect, and to attempt to predict it for a given climate, allowing designers and developers of PV systems to more accurately design and finance their PV systems. This study will be carried forward the winter of 2011/2012 and the data will add to efforts to generate a generalized model to predict snowfall losses.

References

Andrews, R. and Pearce, J.M. “The Effect of Spectral Albedo on Amorphous Silicon and Crystalline Silicon Solar Photovoltaic Device Performance” (to be published).

Becker, G., Schiebelsberger B., Weber W., Vodermayer C., Zehner M., Kummerle G., “An Approach To The Impact Of Snow On The Yield Of Grid Connected PV Systems”, Bavarian Association for the Promotion of Solar Energy, Munich, 2007.

King D., Boyson E., and Kratochvil J. A., “Photovoltaic Array Performance Model,” *Sandia National Laboratories*, **87**,185-0752, 2004.

Pearce, J, "Photovoltaics - A Path to Sustainable Futures", Futures **34**(7), 663-674, 2002.

Ransome, S and Wohlgemuth, J, “Findings from Worldwide Studies of PV Module and System Performance” CREST Loughborough PVSAT-2, 2005.

Solarbuzz, “Marketbuzz 2010”, Yearly report published by Solarbuzz., 2010.

Townsend, T, Powers, L, “Photovoltaics and Snow: An Update from Two Winters of Measurements in the Sierra”, Proceedings of the 37th IEEE Photovoltaic Specialists Conference, 908, 2011.