ABSTRACT: Calculation of the irradiance distribution on curved thin film PV from measured sky radiances and the effect of the irradiance (distribution) on the electrical performance of the PV film are becoming more important now that flexible PV is receiving more and more attention, because of its wide variety of applications. However, the development of suitable software for modelling flexible PV is falling behind. The effect of irradiance distribution on the performance of rigid PV modules has only received limited attention, see e.g. [1]. But the effect on the electrical performance of flexible PV is much more apparent: the use of bypass diodes in flexible PV is more complicated than in glass-laminate PV modules and the irradiance distribution on flexible PV is not only determined by properties of the surroundings (e.g. partly obstruction of the sky) but also by intrinsic properties of the flexible PV film, such as the curvature. This paper describes the results of the development of a computer program for calculating the electrical properties of curved thin film on moulded surfaces.

Keywords: Modelling - 1: Thin Film - 2: Software - 3

1. INTRODUCTION

The national R&D project ‘PV façade integration systems’ performed in a joint operation between TNO, Akzo Nobel and Hunter Douglas aims at developing new integration systems for PV façades. One of the aspects in this project is the development of a computer program to calculate the irradiance distribution on curved thin film PV from measured sky radiances and the effect of the irradiance (distribution) on the electrical performance of the PV film. This aspect is becoming more and more important now that flexible PV is receiving more and more attention, because of its wide variety of applications. However, the development of suitable software for modelling flexible PV is falling behind. The effect of irradiance distribution on the performance of rigid PV modules has only received limited attention, see e.g. [1]. But the effect on the electrical performance of flexible PV is much more apparent: the use of bypass diodes in flexible PV is more complicated than in glass-laminate PV modules and the irradiance distribution on flexible PV is not only determined by properties of the surroundings (e.g. partly obstruction of the sky) but also by intrinsic properties of the flexible PV film.

This paper shows the preliminary results of the development of suitable software for the determination of the irradiance distribution on flexible PV and the effects on the electrical performance.

2. MODEL

2.1 General approach

A computer program has been developed based on a set of physical models:

- Sky radiance distribution model
- PV irradiance model
- PV electrical model

The sky radiance distribution model calculates the radiance distribution over the sky (dome) for a given hour of the day from a given input. The PV irradiance model calculates the irradiance distribution over the flexible PV film from the sky radiance distribution and the optical properties of the film itself. The PV electrical model calculates the electrical yield of the PV system from the irradiance distribution on the PV array.

These models have been basically described in [1], although they are a bit different for practical reasons.

3. CALCULATIONS

The software program can be used to perform calculations on various forms of flexible PV. In this paragraph the results are shown for the calculations of the irradiance distribution on a profile as shown in figure 1. This profile is placed horizontally and extends infinitely in the direction perpendicular to the paper. It is also infinitely repeated in the x-direction. The height \( \Delta Y \) of the profile has been varied, see table I.
The calculations have been compared also to a sharp profile is given in the next figure. The ratio $\Delta Y / \Delta X$ was equal to 1.

For all these profiles the hourly irradiance distribution over the profiles has been calculated for a whole year, using climatic data for De Bilt, The Netherlands. Figure 3 shows an example for the irradiance distribution on a typical summer day on profile 1 (sharp). It can be clearly seen that the parts of the profile which face east receive more radiation in the morning (compared to the parts facing west) and vice versa for the afternoon. At no point in time during the day the irradiance distribution over the profile is homogeneous.

An even more simplified way is plotting the average value of the absolute values of figure 3 for each profile. This results in figure 5, showing that the average inhomogeneity (averaged in time and averaged in space) can be as large as 25% for the sharp profile, but still 13% for the round profile.
The irradiance inhomogeneity has a one-on-one relationship with the electrical performance of the flexible PV. This relationship is however very complicated, since it depends on the exact cell positions on the profile and the type of electrical interconnections (series & parallel).

4. COMPUTER INTERFACE

Currently the interface of the software is being programmed, enabling the user to position thin film PV on curved surfaces by defining the surface geometry. This is done by defining planes, which can be folded (in principle infinitely) in one direction, creating various shapes, see figure 6.

The plane is divided in a fine grid which represents part of the PV cells (or complete PV cells). The plane can only be folded along this predefined grid, but the minimum grid distance is fine enough (2 mm) to allow the creation of very complex shapes.

Figure 7 shows part of the user interface of the program for checking the exact position of each cell in the plane.

5. CONCLUSIONS

The software program is still under development; therefore the calculation results that can be shown are very limited. From the first calculations of the irradiance distribution on the shown profiles it becomes clear the irradiance distribution is a very important factor in determining the electrical performance of curved thin film PV. The distribution pattern is determined by the sky radiance distribution, internal shading of radiation from sky elements to parts of the profile by other parts of the profile, reflection between parts of the profile, etc.

6. REFERENCES