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The Effect of Shadow Lines on a Low Concentrating Photovoltaic System

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Introduction

During measurements on an low concentrating Photovoltaic system (LCPV) based on reflective mirrors it was found that shadow lines appear caused by the glass rods of the construction of the mirror. This mirror was part of the in the building construction, a greenhouse (*Figure 1*). These shadow lines on the CPV module will result in a considerable drop in the energy yield of the system.

Figure 1 the occurrence of shadow lines

The power measurements on the system show a very low fill factor less of 0.1. In another LCPV system based on a Fresnel lens system the effect of the shadow lines was diminished by parallel bypass diodes on each cell, as result a fill factor of about 0.22. The effects of shadows on the array of PV cells are: 1. A voltage drop with about 0.6 V per cell in shadow. 2. An extra voltage drop of again 0.6 V due to the bypass diode losses. Therefore the energy loss at a current of 20A will be 24W per shadow line. In this investigation different options are studied to diminish these energy losses.

Approach

Three solutions are compared to reduce the energy losses caused by shadow lines:

1. Applying better (Schottky) bypass diodes (*Figure 2*).
2. Applying "ideal" bypass diodes based on MOS-FET switches forming an active bypass (*Figure 3*).
3. Special parallel-series connection of a number of cells between repeating shadow lines (*Figure 4*).

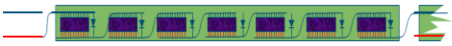

Figure 2 Schottky bypass diodes for each CPV-cell

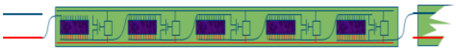

Figure 3 An active bypass for each CPV-cell "Ideal Diodes".

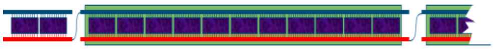

Figure 4 Special parallel-series connection:

The first method reduces the losses of the bypass diode to about 300mV when oversized Schottky diodes are used. With the second method it is possible to reduce the voltage losses further to about 60mV for FET's with a resistance of 3 milli Ohm. Disadvantage is that extra electronic components are required to control the FET's. With the third method each "unit length" of the distance between glass rods is parallel connected, so only one shadow line per module. Series connection of these parallel modules will result in zero energy losses because no bypass diodes are needed at all. Disadvantage is the very high output current of up to 200A. A simulation is used to study the effect of shadow lines on such an array of 10 PV cells.

Result of simulations

In the simulation the shadow line moves only over PV cell 1 and 2, the other 8 cells are unshaded. At simulation time t=5 (*Figure 5a*) both cells half shaded. The shade changes linear in time as a result the generated current will decreases from 20A to 0A and back again. During shading the bypass takes over and the current, voltage and power of the load will decrease (*Figure 5b,c,d*), also the voltage over the PV cell gets negative (*Figure 5e,f*). The load is kept constant. This simulation shows that the Ideal Diode Module IDM (blue graphs) performs much better than the Schottky diode (green graphs). In case of a MPP tracker the main current will be kept close to 20A, the power loss in the Schottky diode will be U*I=6W and the loss in the IDM I^2*R=1.2W. If the shadow line crosses two cells both cells are bypassed and the losses double to 12W and 2.4W, simulated at t=4 to t=6 S. This is most of the time the situation in a greenhouse. Without shade the fill factor will be 6.5 and at t=5 it will be 5.5.

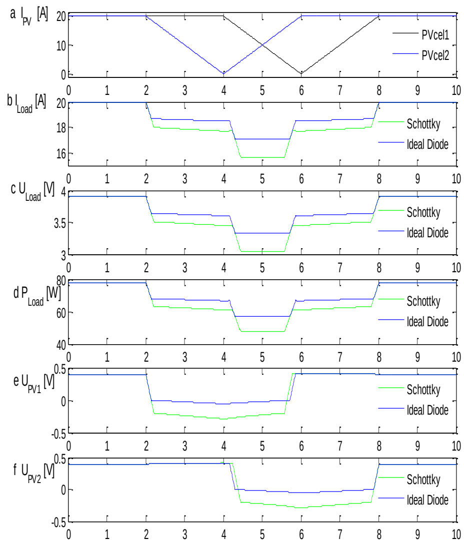

Figure 5 Simulation of a moving shadow lines.

Conclusions

The application of the special parallel-series connection has the highest efficiency needs no extra components but is due to extreme high currents hardly practical. The application of Schottky bypass diodes is practical and economical. The application with "ideal" bypass diodes gives an improved efficiency (fill factor) but requires more components.

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