Advanced Solar Shading

THE UNIVERSITY OF WARWICK

ES410 Group Project developing integrated building renewables

The Project

Over the past decade the significance of a buildings energy performance has been highlighted by rising energy costs. As a result, solar shading systems have becoming increasingly prevalent on new commercial buildings. Occasionally dismissed as simply an architectural feature, few understand the benefits such systems provide.

The purpose of this project is to design, manufacture and test a system that combines the function of solar shading ,with electrical power generation through the use of photovoltaic panels.

Our system will reduce solar gain, negating the need for air conditioning whilst maximizing natural light.

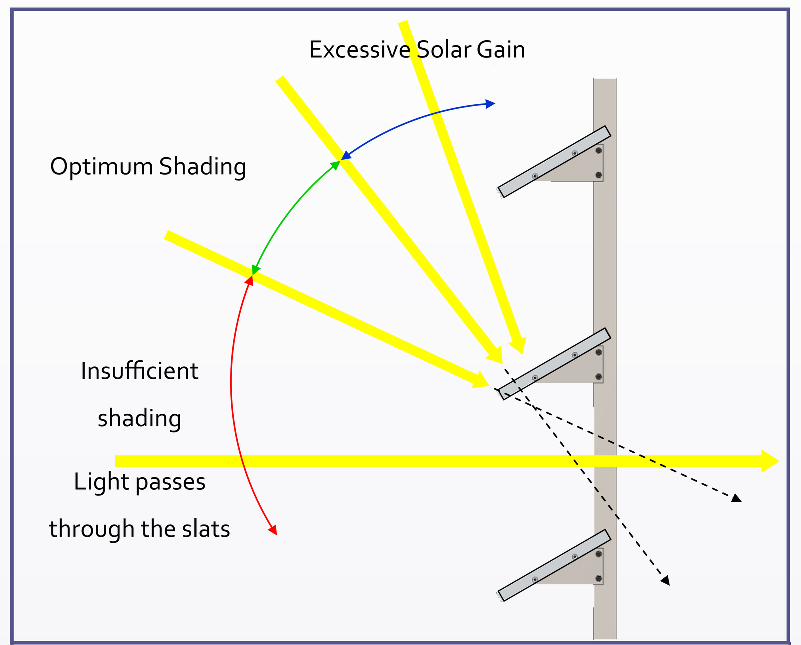
The system has been designed to be retrofitted onto the windows of the Institute of Education. This is a south facing building on campus, that suffers from excessive solar gain during the summer months.

Warwick University's Library features solar shading

Key Objectives:

- Design and produce brise soleil with integrated PV panels to combine the function of both solar shading and electricity generation.
- Install the system onto one of the ground floor windows of the Institute of Education.

Theory



Calculating the optimum orientation of the slats

Solar Geometry:

The sun rises in the east and sets in the west, travelling in the shape of an arch. Shading design should be considered as an integral part of the building design process, with an emphasis placed on balancing day-lighting requirements with the need for reduced solar gains.

The system has been designed so that the individual slats do not shade one another, allowing for maximum electricity generation and optimum shading to be achieved. The benefits are as follows:

- Reduced air conditioning load.
- Reduced operating costs of the building.
- Increased comfort for the occupants of the building
- Enhanced use of natural daylight.

Photovoltaic Cells - A Brief Introduction

PV cells are made from layers of semi-conducting materials such as silicon.

This consists of weakly bonded electrons occupying a band of energy .

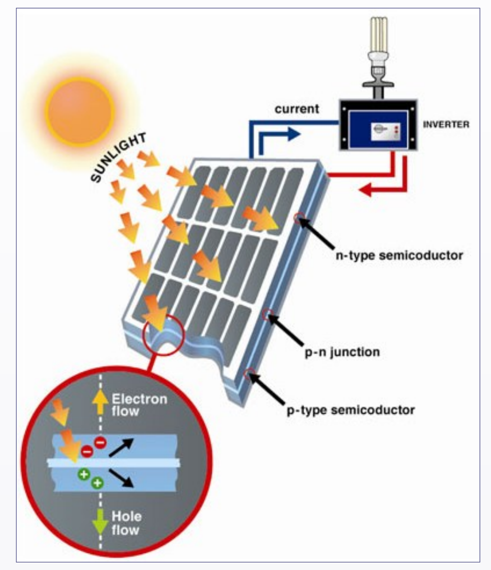
Sunlight contains photons, which can impart energy to electrons, allowing them to escape from the silicon lattice.

The electron leaves behind a 'vacancy/hole.' . The two are referred to as an electron-hole pair.

When electron hole pairs are created near the force field at the p-n junction, electrons are pushed to the n-side.

The N-side of the cell is connected to the P-side of the next cell with metal conductors . The force at the junction causes the electrons to flow as current.

An inverter is used to convert the DC to AC for grid connection.



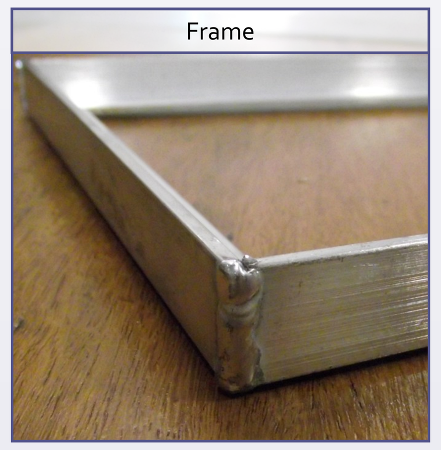
Design

Final Concept Drawing

- The design was constructed using SolidWorks CAD software and is comprised of twelve slats mounted onto a supporting frame
- Each slat is inclined at an optimum angle of 30° from the horizontal. Providing shading from the high summer sun, reducing solar gain at hottest time of year and producing maximum power output.
- Five photovoltaic cells are integrated into each slat. The monocrstaline silicone cells are of size 6" squared and offer increased performance over more commonly used polycrystalline cells. However they are more expensive and fragile

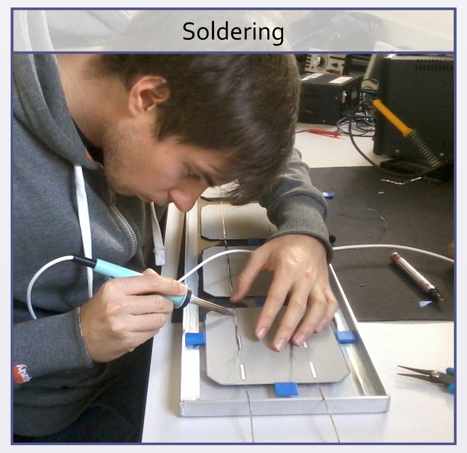
Fabrication

Frame



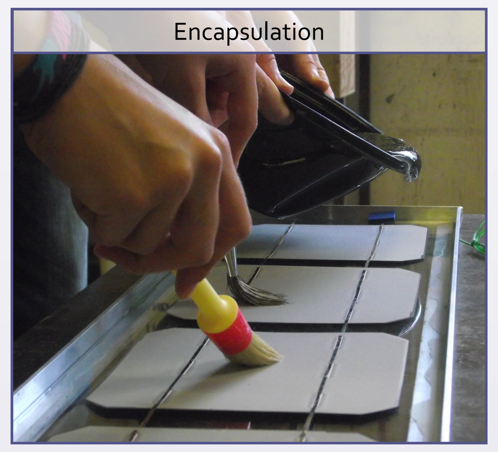
- The frame was made from 25 mm aluminium anglebecause of its excellent durability, low density and high strength.
- The aluminium angle was cut at 45° and then welded to form the frame.
- A single pane of 4 mm of toughened, low iron glass was then placed inside the frame and secured with silicone sealant.

Soldering



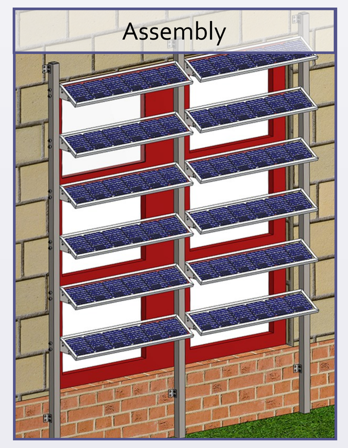
- The PV cells were laid out on the back of the glass and soldered together in series
- The negative bottom side of each cell was connected to the positive top of the adjacent cell.
- Diodes wired into system to prevent build up negative voltage across slats

Encapsulation



- To secure the cells onto the back of the glass, a two part epoxy resin, silicone encapsulate system was applied
- In order to avoid air bubbles from forming between the cells and glass, the slats were placed on a vibrating table whilst curing

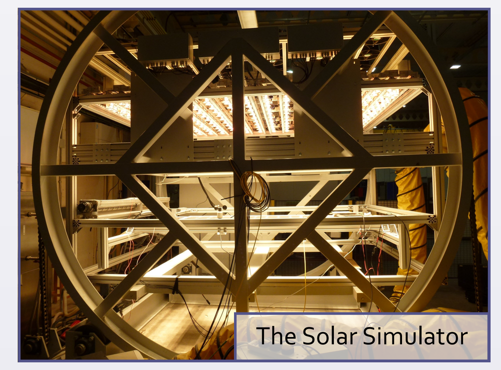
Assembly



- The twelve slats were mounted to a steel frame
- The steel frame was treated to give protection from the atmosphere
- The slats are wired together in a combination of series and parallel, to achieve a system voltage of 12 volts

Testing

After fabrication, an initial test slat was evaluated under the solar simulator to produce power curves of the slat and subsequently, the system. The tests were carried out at different solar irradiances to produce a range of realistic power outputs for the local climate.



The Solar Simulator

Test Slat placed under the simulator

Tests were also carried out to analyse the effects of shading on the output of the photovoltaic cells. Using these results, realistic estimations of the predicted electrical output can be calculated.

The Team

Each member played a crucial, bespoke and changing role in the project. The diversity in technical skills was crucial for the success of this project, which involved electrical, structural, mechanical and sustainability issues.

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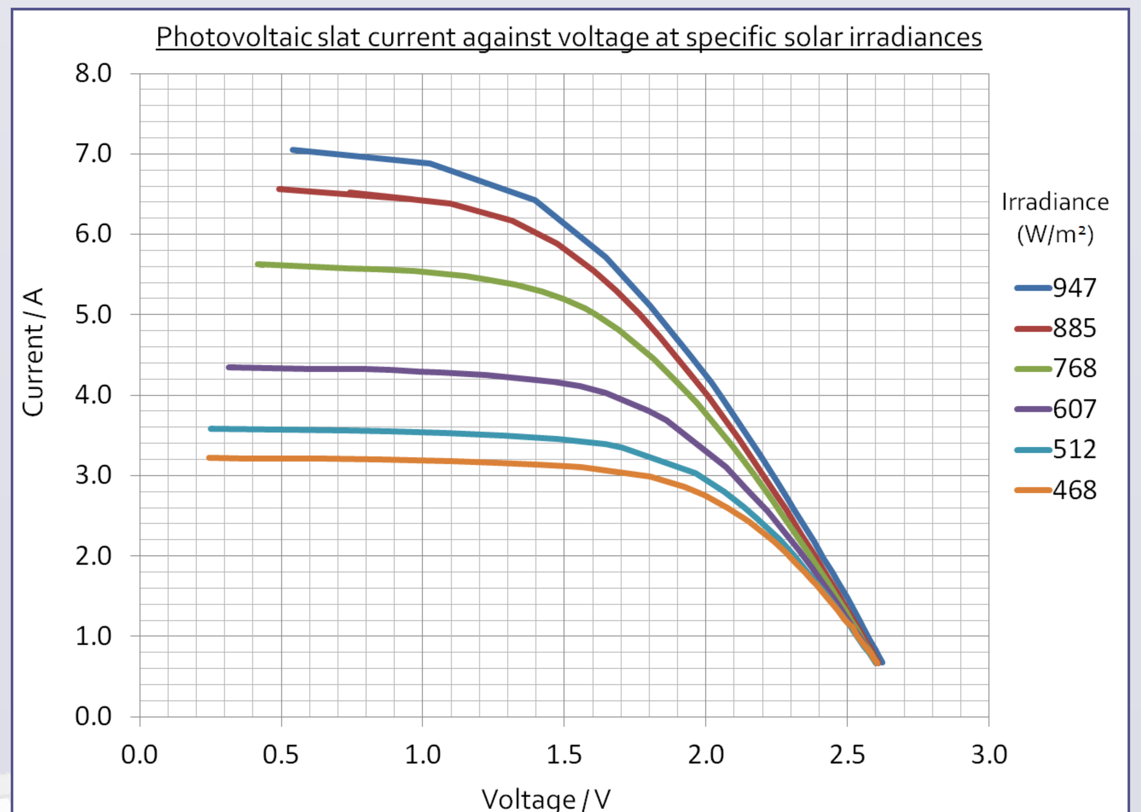
Results

The results from the slat testing are shown on the graph adjacent. A higher solar irradiance produces a higher output from the photovoltaic cells. The peak power output from the slat at standard testing conditions of 1000 W/m^2 was 9.4W . The short circuit current was found to be 7 A, which needs to be taken into consideration when designing the solar circuitry .

The peak electrical output of the system is estimated at 113W under standard testing conditions, with an efficiency of 8.56%. This equates to an estimated annual output of 132kWh in the Coventry area.

During the months between May and September the total monthly heat flow into the room (from direct sunlight, conduction and electrical equipment) is 174 kWh. In order to reverse this effect and maintain a room temperature of 20.6°C over these months an air conditioning system would do 58 kWh of work per month, costing £8.12 per month. By installing the system, the heat flow would be reduced by 53%, giving a monthly saving of £4.30.

Photovoltaic slat current against voltage at specific solar irradiances



Graph showing power output curves of single test slat placed under the solar simulator

Conclusions

The solar shading system has no running costs or emissions and in fact saves £2.85 a month if the electricity produced was used to power a device previously powered from the grid. If the system was grid connected the system would be eligible for the Feed in Tariff and so could provide a monthly income of £8.80 if all the electricity was exported to the grid. Or if all the electricity was used in the building, it would produce an income of £8.23 and a saving of £2.85 a month from not needing to import the equivalent electricity.

An air conditioning system consumes approximately 345KWh of electricity each month at a monthly cost of £31 and emissions of 129 $kgCO_2$.

The solar shading system has an estimated embodied energy of 4704MJ and an initial cost of £655,whereas a system of blinds and an air conditioning unit has an estimated embodied energy of 5323MJ and an initial cost of around £691.

REFERENCES

- Hammond, Geoff, and Craig Jones. *Invention Of Carbon & Energy (ICE) Version 1.6a.* University of Bath: Carbon Trust, 2008
- ARC Taunton Ltd. "How the PV cell works." *Photovoltaic Cell Systems and Solar Energy.* Taunton, 2010.
- The German Energy Society. *Planning & Installing Photovolatic Systems.* London: Earthscan, 2008