THE ANU 20kW PV/TROUGH CONCENTRATOR

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ABSTRACT: A 20kW photovoltaic concentrator has been constructed at Rockingham near Perth in Western Australia. The array is a Trough concentrator with a total collection area of 150 m^2. The system comprises foundations, a two axis tracking structure incorporating mirrors & supports and an aluminium passive heat sink receiver with solar cells mounted on the under surface. The primary goal for the construction of the array was to provide a focus for the development of a supplier base for the PV/Trough concentrator system. It also demonstrates the viability of the technology with a view to marketing arrays. With the exception of the tracking controller all PV/trough components have been sourced from Australian companies.
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1. INTRODUCTION

Conventional PV solar powered systems generate electricity at a cost of A$0.40 c/kWh or more. Costs must be reduced in order for the photovoltaic industry to expand further into the diesel fuel replacement, export and water pumping markets. The cost base for conventional PV technology is driven mainly by the cost of silicon wafers. This leads to a need to decouple PV systems from dependence on a large numbers of silicon wafers if costs are to be reduced. It also means that the silicon in use must be used very efficiently.

Concentrator systems have the potential to greatly reduce the cost of photovoltaic power by using a large area optical system to focus sunlight onto a much smaller area of cells. In principle most of the expensive cell area is replaced by a cheap focusing system. A recent paper provides an excellent summary of activity in the area [1].

A PV/Trough system, such as is being developed at ANU, consists of a parabolic reflective trough, concentrating light onto a line of cells. The few remaining solar cells in the system (at the focal line of the trough) are a relatively small part of total system cost. Thus expensive but efficient cells can be used without economic penalty.

The ANU has been actively engaged in the development of PV concentrator technology since 1995. Having gained experience and confidence with these smaller systems the ANU has designed the prototype of a system which promises commercial viability. A system recently constructed in Rockingham, Western Australia (which is 50 kilometres south of Perth) has a power generation capacity of 20kW from a total collection area of 150 m^2. Installation of the array was carried out by Solahart Industries, which is a major solar water heater manufacturer.

2. 20kW PV/TROUGH ARRAY

The 20kW array consists of 80 trough modules. Each trough module consists of a parabolic mirror with an area of 1.92m^2, a receiver heat sink with solar cells and associated supports. A diagram of the system is shown in figure 1. This demonstration array will form the basis for commercialisation of ANU PV/Trough technology, act as a test bed for all system components and provide a means of evaluation for interested parties.

From the start of the project the ANU has maintained an awareness of the functional requirements for the system and have included many features into the design. The 20kW array will be connected directly to the grid thus avoiding the need for an energy storage system. Anticipating a harsh service environment in the Australian outback, the system is designed for a long service life with a minimum of maintenance. Passive heat sinking was chosen for this reason. With the exception of the tracking controller all PV/Trough components have been sourced from Australia companies, which assists with sourcing of spare parts.

2.1 Support structure

The geometry of the support structure of the 20kW system features the widespread use of standard steel sections, which are fully galvanised for long life. It has been optimised with a view to limiting the mass of material used. The distributed mass for the support structure including supports and tracking mechanisms is approximately 29 kg/m^2 of aperture. By comparison the one axis EUCLIDES™ system has a distributed mass in excess of 38kg/m^2 [2]

As the system will have to be transported by road each component is designed so that it may be packed flat. The structure is designed to be assembled on site and assembly of the whole structure may be achieved by a small crew using a truck mounted crane. The foundations consists of 11 cast in-situ piers which are low cost, easy to install and offers flexibility in sizing. This design is very compatible with the methodology used by utilities for the installation of power poles.

2.2 Mirrors

Mirrors for the 20kW array are a laminated hot sagged glass structure of parabolic profile, which encapsulates a silver mirror film. The overall dimensions are about 1600mm long by 1170mm wide. The mirror have a reflectivity of 91% and a focal region intercept of 82%. Physical characteristics of this mirror design are:

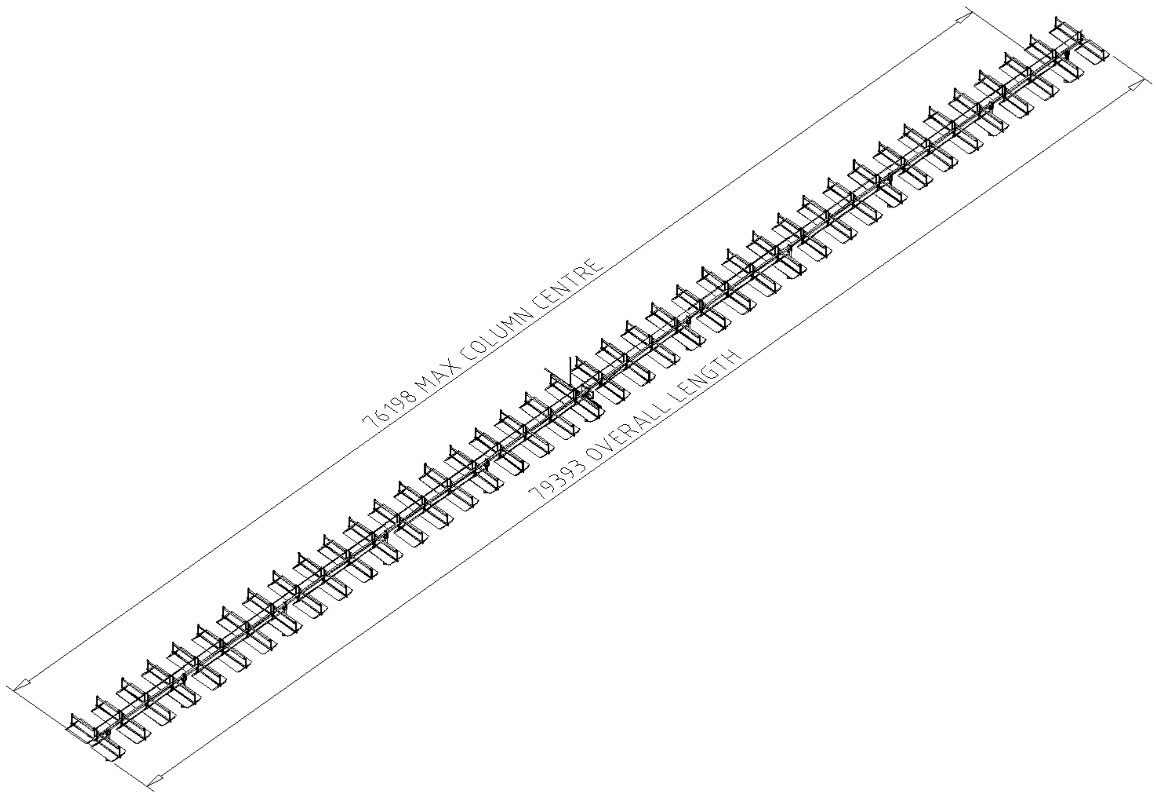

Figure 1: 20kW ANU PV/Trough Array

1. Impact resistance: sufficient to withstand hail damage, handling and transport.
2. Abrasion resistance: sufficient to withstand sand blast in dust storms and cleaning. This is an important requirement in the Australian outback.
3. Rigidity: sufficient to withstand large wind loads.
4. Corrosion resistance: the mirror design is similar to a car windscreen, in which the problem of ingress of water between the two panes has been entirely solved.

2.3 Receiver

Solar cells fabricated at ANU are mounted directly on the receiver which also provides a cooling mechanism via an integrated passive heat sink. The solar cells are assembled into a cell package which incorporates two bypass diodes per cell attached to the copper tabs that later form the cell interconnection. The cell packages are bonded to the receiver and joined in series by interconnecting cell tabs. Once assembled the cell string is encapsulated to exclude moisture and covered with glass for protection.

PV cells work at an optimal level when kept cool. Passive cooling has been developed for this array which exhibits great reliability and low maintenance. The cells are kept at a temperature of 30 to 40^{o}C above ambient, a temperature similar to that experience by cells in a flat plate system. This convective cooling system is constructed by joining aluminium fins directly to an extruded aluminium base (Fig. 2). The profile of the base allows cells to be bonded to it directly. It incorporates a clipping feature to attach glass retainers, which also acts as a heat shield for the cell tabs. The ANU has applied for patent protection for the heat sink design.

Each heat sink is 1.6m long and has a total surface area of 4.54 m^2 and a distributed mass of 4.2 kg/m^2. By comparison the heat sinks developed for the EUCLIDES^{TM} system have a distributed mass of 8.75 kg/m^2 of aperture and the fully extruded ENTECH units are 16.5 kg/m^2 [3].

The heat sink mass can ultimately be reduced to 2.7kg/m^2 through the combination of providing thinner fins and using a wider mirror. The fin material can be reduced from 1.0mm to 0.7mm with minimal loss of performance. This material was unavailable at the time of manufacture. The heat sink is suitable for mirrors up to 1.5m wide.

2.4 Solar Cells

An elegant fabrication technique for high performance concentrator silicon solar cells has been devised. A total of 2,500 cells of area 20 cm^2 are being fabricated at ANU on 100mm wafers for the 20 kW project. The minimum acceptable efficiency is 20%, but the average cell efficiency is close to 22% at 20-30 suns. The cells are of a conventional design with an electroplated silver metal grid on the front surface.
A novel flash tester has been constructed for cell measurement. A reliable measurement can be made of a cell's complete current voltage characteristics at five to ten different light intensities over a decade range in a

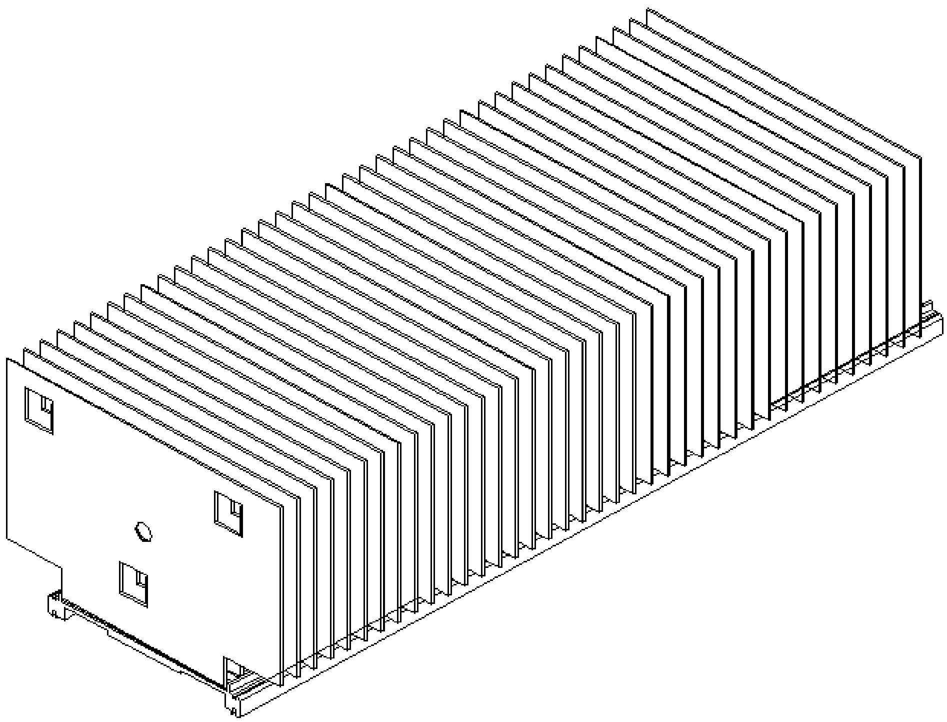

Figure 2: Section of an ANU Heat sink which incorporates fins attached to an extruded base.

few seconds. The complete measurement, including mounting and dismounting of the cell, takes about 30 seconds. The system automatically computes and displays all of the important cell parameters.

An important aspect of cell fabrication is environmental testing to ensure cell performance stability. Accelerated life testing of the cells is being carried out for humidity and UV resistance, air-ageing at elevated temperatures, temperature cycling and salt spray resistance. Similar tests are being performed on finished receivers.

Mirror Aperture	1170mmx1600mm
Number of Mirrors	80
Total Reflector Area	150 m^2
Concentration Factor (Geometric) (Actual)	 30:1 23:1
Cell Efficiency	22% under concentration
Power Output per Module	250 Watts(peak) (SOC)
Power Output of System	20kW
Tracking Mechanism	2 Axis (accurate to 0.5^o)
Total System Efficiency	14.8%

Table 1: System performance for 20kW array(SOC: DB:900W/m^2 Amb:20^oC Wind:1m/s)

2.5. Array Tracking

The 20kW system features two axis continuous tracking. All trough modules are mechanically linked so that one motor actuates the tilt and another actuates the roll. Both motors are controlled by a time based open loop central processing controller via a motor driver interface and position feedback system. The range of motion for the array is 180^o about the tilt axis and 130^o about the roll axis. It has been calculated that the array will have an average intercept of 87% of the direct beam at a latitude of 35^o.

3. CONCLUSION

The ANU PV/Trough technology has been developed with a view to creating a commercially viable system for outback Australia. A 20kW demonstration array has been constructed, and the project has reached the commercialisation phase. Economic analysis shows that the PV/Trough project can produce electricity for US$0.20 kWh if appropriate manufacturing economies of scale are achieved. There is an awareness that demand already exists in Australia for this type of technology. The next step will be to take the technology to full commercialisation.

4. ACKNOWLEDGMENTS

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