

A 40KW ROOF MOUNTED PV THERMAL CONCENTRATOR SYSTEM

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ABSTRACT: The Australian National University, Centre for Sustainable Energy Systems (ANU-CSES) has developed a photovoltaic thermal (PV-T) concentrator system. This system is based on its Combined Heat and Power Solar (CHAPS) collector technology. This paper describes a roof mounted 40 kW PV-T concentrator system which was installed during 2003-4. The system comprises eight 24 metre long single axis tracking reflective solar collectors. Mirrors are used to focus light onto high efficiency monocrystalline silicon solar cells. The mirrors are constructed by laminating mirrored glass onto a metal backing, and provide a geometrical concentration ratio of 37x. Heat is removed from the solar cells using a fluid, which flows through a passage in the cell housings. The fluid is then passed through a heat exchanger to provide heat for domestic hot water and room heating. The collector movement is controlled by a microprocessor using an open loop time based algorithm. The annual output of the system is expected to be 50 MWhr of electricity and 100 MWhr of hot water.

Keywords: Concentrator, PV System, Rooftop, Thermal

1 INTRODUCTION

The Australian National University, Centre for Sustainable Energy Systems (ANU-CSES) has been actively engaged in the development of PV concentrator technology since 1995. The latest development for ANU-CSES is a photovoltaic thermal (PV-T) technology called Combined Heat and Power Solar (CHAPS) Systems. During 2002 the Australian Greenhouse Office made funds available through its Renewable Energy Commercialisation Program (RECP) to assist in demonstrating near market ready renewable energy technologies. In partnership with Rheem/Solahart, ANU-CSES accessed RECP funds to demonstrate its CHAPS concentrator system.

The system comprises eight 24 metre long single axis reflective solar concentrating collectors. Each collector is mounted on a tracking support structure that is controlled by a microprocessor. Mirrors focus light onto high efficiency monocrystalline silicon solar cells. Heat is removed from the solar cells using a fluid, which flows through a passage in the cell housings. The fluid then passes through a heat exchanger that transfers heat to hot water storage equipment.

Currently the thermal component of the system is operational for commissioning to take place. The photovoltaic receivers are expensive and will not be installed until control systems have been fully implemented. Instead, black painted copper tubing has been installed in the focal region of the collector. This step has been taken to ensure proper operation of the infrastructure and to make adjustments to the control systems. Once it has been shown that the system has worked for some time within specification the PV receivers will be installed.

2 BRUCE HALL PACKARD WING

The Packard Wing was built during 2003, and it is a four storey building that accommodates 90 people. The building is provided with hot water storage and hydronic in-slab floor heating.

Equipment associated with the solar collection system was installed during construction of the building.

Thus the installation is fully integrated. The CHAPS collectors were installed on the roof of the building a short time before occupation in 2004.



Figure 1: Bruce Hall Packard Wing – completed 2004

3 SYSTEM

Apart from the CHAPS collectors the building incorporates elements common to both solar thermal and solar electric generating systems. Two Solahart central heat stores are installed in the basement. Heat is transferred from the collector circuit to the heat stores via a heat exchanger. The heat stores are also connected to a circuit that heats the fluid flowing through the hydronic heating. Separate gas fired boosters are fitted to both the potable hot water circuit and the hydronic heating circuit to provide heat when there is no solar contribution. The heat flow from the collectors to the building circuits is controlled by the building management system.

A commercially available inverter has been installed in the building. The electricity supplied to the grid is metered separately and a concession is made against the electricity consumed.

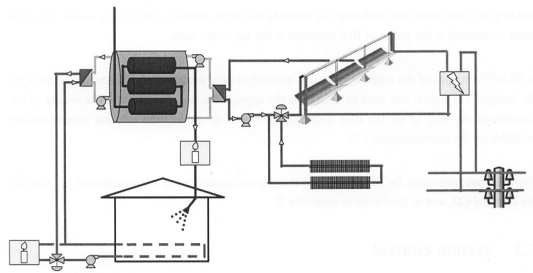


Figure 2: PV Thermal scheme installed in Packard Wing

3 COLLECTOR

Each collector incorporates 17 mirror panels that form a parabolic reflective surface approximately 24 metres long. These are mounted on a tracking support structure attached to a mechanism that is moved by an electric motor. The mirrors focus light onto the receiver, which transports heat by means of a fluid pumped through the circuit.



Figure 3: Mirror panels focus light onto test receiver

3.1 COLLECTOR STRUCTURE

The support structure for each collector is comprised of a main beam that can rotate about pivots connecting it to the three support columns. The main beam carries 17 mirror panels connected by mounting brackets. The mirror brackets also provide mounting points for the receivers. The main beam is connected to a pulley, which is rotated by means of opposing cables connected to the tilt mechanism.

A central column incorporates the tilt mechanism, essentially a trolley in track arrangement. As the tilt trolley translates it induces rotation of the beams through the cables and pulley. The collector is thus able to tilt through 180° to follow the sun. The trolley is moved by a linear actuator, which is propelled by a DC motor.

Considerable effort has been made to minimise shadow bands induced by the margins around each mirror in order to improve flux uniformity on the solar cells. As a result the mirrors are mounted above the main beam, which in turn is offset from its pivot. This compromise in the geometry has introduced imbalance in the structure about the beam pivot. Finite element analysis has

provided a choice of beam section with sufficient stiffness to limit torsional flex to less than 0.5°

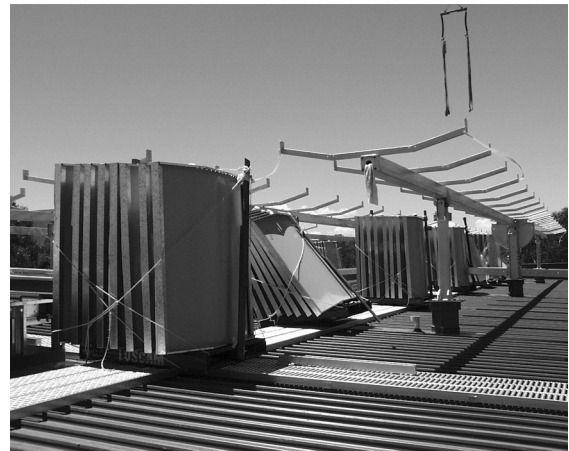


Figure 4: Collector support structure during installation.

3.1 MOUNTING

Each collector is mounted on three pedestals that protrude through the roof cladding and are sealed against the weather. The pedestals are attached to the building structure and comply with relevant building codes

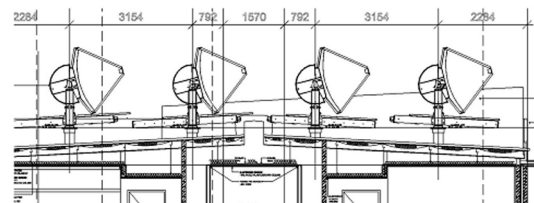


Figure 5: Structural section through building roof.

4. MIRRORS

Mirrors for the collector are manufactured by laminating mirrored glass to a galvanised steel sheet. Stamped tab ribs fitted to each end of the sheet impart the correct parabolic profile. Both the mirrored glass and the steel backing are approximately one millimetre thick. This construction provides a mirror that is both lightweight and durable.

Extensive laboratory and field testing has proven that the mirrors maintain the required physical characteristics. Impact resistance is sufficient to withstand hail damage, handling and transport. The glass top surface is abrasion resist and withstands repeated cleaning. Rigidity is inherent in the geometry of the mirror structure and is sufficient to withstand large wind loads. The use of commercially coated steel ensures a long service life through good corrosion protection.

5. PHOTOVOLTAIC THERMAL RECEIVER

The receiver body is an aluminium extrusion that incorporates several functional features. A fluted passage is integrated with a profiled solar cell mounting tray. Additional features provide a mounting surface for hardware and wiring. Before assembly both ends of each

receiver are drilled and tapped to accept treaded couplings.

ANU solar cells 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. Typical operating parameters for the solar cell at 30 suns and 25 C are an open circuit voltage of 750 mV, a fill factor of 0.78 and a short circuit current of 22 amps.



Figure 6: ANU Photovoltaic Thermal receiver

The receivers are fitted with wiring, mounting brackets, packed with dense glass fibre insulation and finally a galvanised steel cover is installed. When mounted on the collector the receiver ends are coupled together to provide a continuous passage for the circulation of heat transfer fluid.

6. HOT WATER PRODUCTION

The heat transfer fluid (HTF) is heated by solar radiation in the PV-T receivers. There are two pumps that operate independently to transport heat to the hot water store (HWS). Proper control of the two pumps provides delta T control between the collectors and the HWS. At times of sufficient insolation Solar Pump No. 1 circulates the HTF through the roof mounted receivers and through a heat exchanger located in the basement. If the heat stores require heating Solar Pump No. 2 is also switched on to transfer heat from the heat exchanger to the HWS.

The heat transfer fluid is water based and contains additives to prevent freezing and corrosion but is not toxic. The HWS is made up of two banks each incorporating ten potable water tanks, giving a total hot storage capacity of 6000 litres. In addition to the solar collectors two gas boosters are install to heat water when required.



Figure 7: One bank of the HWS supplied by Solahart



Figure 8: Packard Wing Plant room Equipment

9. OVERTEMPERATURE CONTROL

A concentrator system can cause cells to run extremely hot as a great amount of sunlight is directed to the cell. The PV cells work at an optimal level when kept cool but the thermal system has a competing requirement. There is potential to overheat the photovoltaic package installed in the PV-Thermal receiver if the thermal supply is not balanced by demand.

A simple way to control temperature in a thermal only concentrator system is to roll the collector off focus once the heat store is up to temperature. This method is not desirable for a PV/Thermal concentrator as electricity production ceases as a result. During the summer months thermal output for the CHAPS system exceeds building demand so an alternative method is employed to control temperature.

In the event that the receiver temperature rises above a critical level, heat is shed through radiators. The radiators are convective units mounted on the roof adjacent to the collector. Heat Transfer Fluid is diverted through these units once the receiver reaches 80°C.

7. SYSTEM CONTROL

6.1 Tracking Control

The tracking control for CHAPS has been developed by ANU. Each collector rotates about its longitudinal axis to track the sun. The actuator position for all collectors is controlled by a single time based open loop microprocessor controller. Each of the eight motors is switched via a separate motor driver interface every 30 seconds to ensure that all collectors are properly align with the sun.

6.2 Systems Control

The Packard Wing is fitted with a building management system (BMS). The Satchwell BAS 2800+ provides control of automated building services. It controls heating, ventilation, lighting and metering within the building. The BMS is being used to control the balance of the CHAPS system. Its functions include

- switching Solar Pumps 1 & 2 in response to temperature conditions in collectors and the heat store.
- HTF bypass to the radiators to avoid overheating of collectors.

- Fault condition monitoring and control.
- Coordinating control of the solar system with building services.
- Data collection for temperature, flow and electrical out.
- Remote access for systems control.

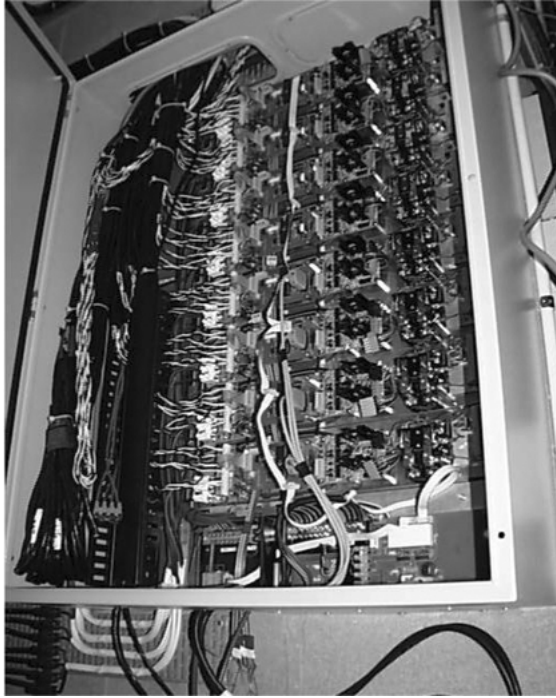


Figure 9: ANU tracking controller

The actuator motors and tracking control are powered from a 24-volt backup battery pack. This system is provided so that the collectors can be parked off sun in the event that power is lost and fluid circulation fails.

10. INVERTER

The 40kVA Power Solutions Australia inverter is connected directly to the grid. Receivers mounted on the array are connected in a combination of series and parallel to meet the power requirement of the inverter. Nominal input to the inverter is 525 VDC at 76 Amps and output is 240V 50Hz AC.

| Characteristic | Specification |
|-------------------------------------|---------------------|
| Mirror aperture | 2.18 m ² |
| Number of Mirrors | 136 |
| Total aperture Area | 297 m ² |
| Total Solar Cell Area | 6.8 m ² |
| CHAPS Collector Rotation | ± 90° |
| Tracker accuracy | 0.1° |
| Geometric Concentration | 38 x |
| Mirror Efficiency | 83% |
| Cell Efficiency | 21% _{nom} |
| Receiver Efficiency | 94% |
| Hot Water Storage | 6000 litres |
| Nominal DC _{peak} Output | 32 kW |
| Nominal Heat Output _{peak} | 160 kW |

Table I: Specified system performance
(SOC: DB:900W/m² Amb:20°C Wind:1m/s)

The combined thermal and electrical efficiency of demonstration CHAPS systems exceeds 60%.

11. CONCLUSION

Costs still remain high for conventional PV solar generation. Costs may be reduced by utilising highly efficient solar cells in concentrating technology, but the need for cooling is seen as a disadvantage. The CHAPS has been developed with a view to offsetting this. The waste heat can be harnessed because its receivers are a compact heat source.

The thermal component of the Combined Heat and Power Solar (CHAPS) system is operational for commissioning to take place. It is expected that the solar thermal component will be fully operation in August 2005. The system provides heating for hot water and 25% of the space heating for the building occupied by 90 residents.

It is anticipated that the installation of PV/Thermal receivers will be complete by the end of 2005. Once installed the CHAPS system will also generate about 30% of the electricity used in the building.

11. REFERENCES

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