

RECENT EXPERIENCES IN BUILDING INTEGRATED PHOTOVOLTAICS

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Abstract -. The 629 x 1kWp grid connected, roof integrated photovoltaic (PV) systems at the Athletes Village housing development demonstrates that, with correct design and management, integration of PV products into roofs is accepted and achieved by builders utilising trades and skills common to that industry. This was achieved by taking a holistic approach to material selection, packaging, training, sound design and project management.

1. INTRODUCTION

This paper provides an overview of the activities and issues involved in the turnkey provision of 629 x 1kWp grid connected, roof integrated, PV systems. The application is for the housing development by Mirvac Lend Lease Village Consortium at the new suburb of Newington in New South Wales, Australia.

The overall project is the result of the successful bid by the Mirvac Lend Lease Village Consortium (MLLVC) to build a residential development adjacent to the Olympic venues in Sydney. Pacific Power, on behalf of MLLVC had the responsibility of tendering, selecting and managing the turnkey supplier of the PV systems. The initial use of most of the development is to house athletes competing in the Sydney 2000 Olympic and Paralympic Games, after which the houses will be used as residential dwellings.

The major challenges facing the project team were;

- The integrity of the integration method as a weatherproof membrane.
- Meeting the visual requirements of the architects and hence purchasers.
- The requirement of each system to deliver 1,600kWh per annum.
- Health and safety during installation and after commissioning and hand over.
- Compliance with Australian Standards, guidelines and development and verification of best practice where standards did not exist.
- Developing components and installation techniques familiar to or easily employed by the residential building industry.
- Rapid deployment to fit in with other trades and activities during the building of each dwelling.

As the supplier, our aim was to meet all the above requirements as economically as possible. From day one we took a holistic approach, rather than seeking least cost components. In many instances we opted for more expensive components knowing that their use would be more than compensated for by lower installation time and hence cost.

2. DESIGN

2.1 *Stage 1*

The first cut design brief for the PV was "simple" - weatherproof, flush with the roof, uniform in colour and generating 1,600kWh per annum per system. At the time of contract award MLLVC had not finalised their roofs. All that was known was the pitch and that there would be a mix of tiled and metal roofs plus a flat roof. We had done a review of overseas designs, but most were based upon structural glazing techniques. Our opinion was that this was too specialised, expensive and difficult to repair in the event of damage. A number of other options had been submitted with the bid and the most promising utilised a metal sub tray, which was eventually chosen as the basic concept to refine.

2.2 *Prototyping*

Stage 2 involved building a roof within our premises to test the design concepts. Here we spent hundreds of hours trialling and refining methods, plus regular reviews with builders, fabricators architects and engineers from a variety of disciplines.

The tray concept was developed in conjunction with BP Solar custom designed mounting clips to fasten the solar from the front. Frameless modules (laminates) were chosen instead of framed solar modules to reduce cost and embodied energy. Each laminate is held in places by six diamond-shaped clips.

In designing the tray material minimising material wastage was a target. The design was such that offcuts from the sheeting are used to provide the weatherproof joint between trays.

The final application involved a number of configurations, all of which employ the same tray system, with the exception of a small number of raised frames for flat roofs.

2.3 *Visual*

Visual impact was a major concern for the architects. A standard laminate has a white backing layer which shows through between the dark solar cells. This was perceived to be visually unpleasant in the environment and an alternative colour was sought. To eliminate this visually distracting pattern, a dark grey backing layer was used to produce the more uniform colouring that was called for in the design specification.

2.4 *Weatherproofing*

The concept of the tray, utilising standard building techniques allowed the trays to be the principal barrier. The result is that even if there was no PV installed or if it was damaged, then the integrity of the roof would be unaffected.

2.5 *Electrical*

The 1,600 kWh per annum was a challenge, when the design brief had limited area available, thermal effects of the dark materials and the need for a solar array flush with the roof. To meet the specifications the systems all utilise BP Solar's high efficiency Saturn. The effect of the dark coloured backing material reduces performance at Standard Test Conditions by 2%. The dark backing material not only collects more heat, but less of the light incident on it is reflected internally into the

cells. As increasing temperature reduces the power output of crystalline cells maximising cooling within the design constrains was also a challenge. Utilising the trays with an inverted "U" joint allowed an air gap between the laminates and the trays thus aiding natural convection cooling. Utilising laminates also minimise obstructions to this airflow and hence turbulence. Mesh was installed in the inlet and outlet to allow the convective cooling and to stop leaves and vermin getting behind the panels. The temperature rise is only 10°C above the temperature experienced in free standing solar arrays.

3. OUTDOOR CONSTRUCTION

3.1 Construction

In conjunction with Pacific Power, two prototype roofs were constructed using a variety of tile profiles and corrugated iron.

The aims were to carry out weatherproof testing and a design review with all parties to ensure that all were satisfied with progress. These prototypes then became the test bed for visual inspection and waterproofing.

3.2 Visual inspection

With the high level prototypes, consultative meetings were held to discuss visual appearance and other issues such as flashing. Given that the installation of the trays was to be done by others, it was decided that, whilst we could work to tight tolerances on array location, it would be simpler to allow a 50mm gap each side of the array. The result is that misalignment or off centre placement of the array would not be noticeable.

3.3 Testing

With the solar arrays now on "real" roofs the major milestone to achieve was the waterproof test. High pressure, high volume water was aimed at the array in every applicable direction with a positive result. Within weeks of the witnessed tests a high wind, high rainstorm hit the site and once again the integration method passed. Thermal tests were also carried out which verified the predicted temperature rise being within the design limits.

4 STANDARDS

Quite a few standards apply to the implementation of integrated and grid connected PV.

Independent structural consultants were used to verify compliance of the tray and mounted PV with Australian Standards.

Safely handling high voltage DC from a photovoltaic array was another issue that had to be addressed. Since there were no existing standards to guide us, Pacific Power engaged the University of New South Wales to review international guidelines and standards. The aim was to ensure that we met or exceeded prevailing world's best practice. The review led to some modifications of connector systems and verification that double insulated cable and Class II connectors (double insulated) were fit for their purpose.

The inverter was the most challenging item to gain approval. Whilst there is currently no Australian Standard for grid connect inverters, industry and electricity authorities had already developed guidelines under the auspices of the ESAA. These guidelines were used and met for the inverter employed. Being the first installation of its kind in Australia and probably the largest conglomeration of grid connected inverters in the world, the local electricity distributor, energyAustralia, was obviously mindful of the pioneering implications! Testing requirements included compliance testing of 1 inverter, testing of 5 inverters at once, Compliance with C Tick and a Certificate of Suitability. All requirements were met after extensive testing with the ultimate test to come - reality.

5 IMPLEMENTATION

Roof tray installation was carried out by the roofing crews whilst installing the whole of the roof. Once the roof was completed there was a very short time available for our crew to install the array before the builder removed the scaffolding. This made programming extremely hectic at times! The record was 9 arrays installed in one day. Each solar array is installed and wired to junction boxes mounted in the roof cavity at the same time, but it can be several months before power is brought down to the DC isolation switch in the meter box and the inverter installed.

Commissioning takes place when the electricity meters are installed and mains power is connected to the dwelling.

Pacific Power's on site representative co-ordinated the activities of the various contractors on site and our installation crew. This role involved managing variable resources to best meet the ever changing demands that are common on building sites, particularly in this case with over 600 dwellings.

To minimise waste and cost, a packaging system was developed with re-usable wooden containers for 12 laminates. Laminates were packed in the factory and sent to a marshalling area ready for installation. After installation the empty containers were returned to the factory for repacking ready to start the cycle again.

6 CONCLUSIONS

Through training and selection of appropriate integration materials the project demonstrates that there is acceptance by builders for the installation and use of PV in the built environment.

Building integrated PV is here and now as a mainstream building product, not confined to the domain of technicians, specialists and demonstrations.

REFERENCES

ESAA - Electricity Supply Association of Australia. (1999) *Guidelines for the Connection of Energy Systems via Inverters*, web site <http://www.esaa.com.au/>