THE VALUE OF PV IN SUMMER PEAKS

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ABSTRACT: Electricity demand has increased rapidly in Australia over the past decade, accompanied by a significant shift to summer peaks, driven largely by increased air conditioner usage. Recent summer peaks in several States have resulted in supply disruptions and, on some occasions, extremely high spot prices on the National Electricity Market. This is now a major issue for the Australian electricity industry, which is set to spend over AUD 10 billion over the next decade in new generation plant, including significant expenditure on peak load plant, and on new and upgraded network assets. There may be opportunities for PV and other demand side measures to contribute to point of use energy supply, thereby reducing the need for central generating plant and for costly network upgrades. This paper examines the potential matching of PV generation to summer peak loads, using data from PV systems and electricity substations in three States. Preliminary results indicate that PV output on clear days can be a good match to overall system load and to electricity spot prices on peak summer days and for feeders with a high proportion of commercial load. For residential feeders, west facing PV arrays provide a better match to summer load than do north facing arrays.

Keywords: Appliances and Loads, Small Grid-connected PV Systems, Utilities

1 INTRODUCTION

In previous work [1] the authors undertook a preliminary assessment of PV output from a small number of systems during the summer peak load periods in the Australian States of South Australia and New South Wales. This paper reports on more extensive analyses undertaken over the past summer, with data collected from 15 PV systems in 3 States and corresponding load data from 15 substations, as well as State level load and spot price data from the National Electricity Market (NEM). The sites are not identified for reasons of confidentiality.

2 DEFINITION OF PROBLEM

2.1 Load growth and temperature correlation

Electricity demand has grown rapidly in Australia over the past decade and has been accompanied by an exacerbation of the "peakiness" of electricity demand patterns. The latter is highly correlated with temperature extremes [1], [2] as is clearly illustrated in Figures 1 and 2. In the rapidly growing region of Western Sydney, load estimates for new houses have been increased from 3.5 to 4 kVA peak to 6 – 7.5 kVA peak [2].

The summer peak has already, or is about to overtake the winter peak in most States and is compounded by the effective derating of network assets and gas turbine peaking plant when ambient temperatures are high. System load duration curves are becoming "peakier", as shown in Figure 3, with increased air conditioning load considered to be the major cause. In some new residential subdivisions in Adelaide, 50% of local network capacity is now used for only 5% of the time. Similarly in Western Sydney, the peak on hot days is 1000MW higher than the normal summer peak of 2500MW, while 383MW is used for only 25 hours a year [2].

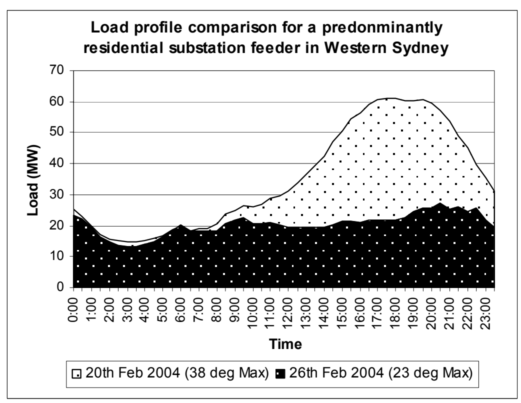

Figure 1: Residential load on a Western Sydney feeder on a typical and a high temperature summer day.

2.2 Electrity industry response

Recent summer peaks in South Australia, Victoria and New South Wales have resulted in supply disruptions and, on some occasions, extremely high spot prices on the National Electricity Market. These events are now driving significant levels of investment in new generating plant, including peaking plant ($5 billion this decade) and in new or upgraded transmission and distribution network capacity ($8 billion this decade) across the country [3].

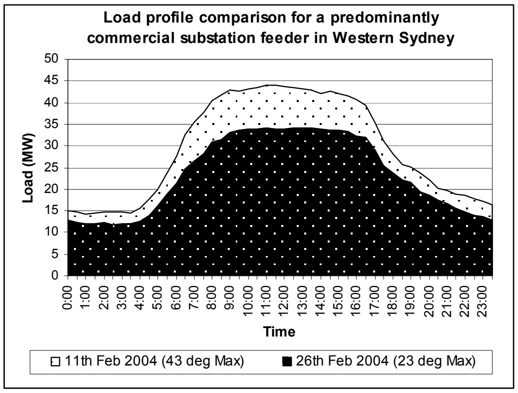

Figure 2: Commercial load on a Western Sydney feeder on a typical and a high temperature summer day.

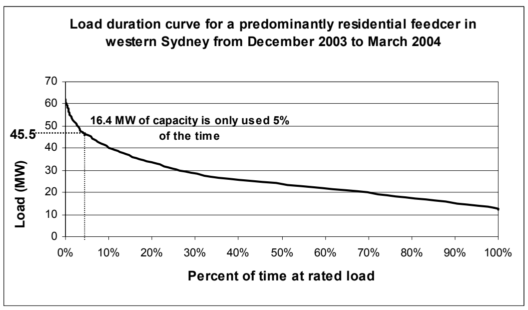

Figure 3: Load duration curve for a residential feeder in Western Sydney – summer 2003-04.

One retailer in South Australia has already introduced a summer peak tariff which is 11% higher than the standard tariff. State governments are beginning to consider means of encouraging demand-side responses which might defer or eliminate the need for some of the planned network expansion [4]. However, the suppy focus of the National Electricity Market and retail electricity regulation makes if difficult to implement effective demand solutions. In addition, the political preference for maintaining uniform tariffs and reluctance on the part of the electricity industry to move towards electronic or time of day metering, eliminates the option of tariff signals in many areas. The analyses undertaken for this paper are aimed at assessing the effectiveness of PV in reducing summer peak loads on the electricity networks in South Australia, Victoria and New South Wales.

3 PV PERFORMANCE

3.1 PV output and electricity load

PV output follows the sun's trajectory and is consistent with ambient conditions. However, electricity load patterns vary by site, by load type as well as by ambient conditions. Hence loads sometimes, but not always, coincide with PV outputs. In addition, as shown in Figures 1 and 2, the load pattern on an individual feeder can change dramatically with temperature. For feeders with predominatly commercial loads, the load increases with temperature, but the load pattern remains relatively consistent. Figures 4 - 6 show PV output and loads for different feeders, while Figure 7 shows PV output and total system load in Victoria.

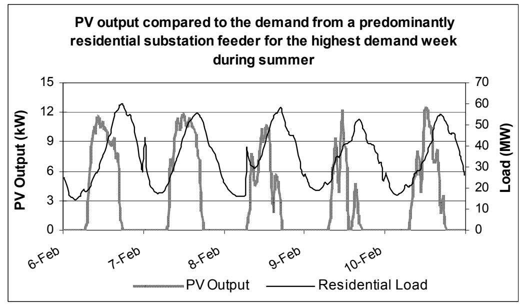

Figure 4: PV and load for a Western Sydney residential feeder over the week of peak demand - summer 2004.

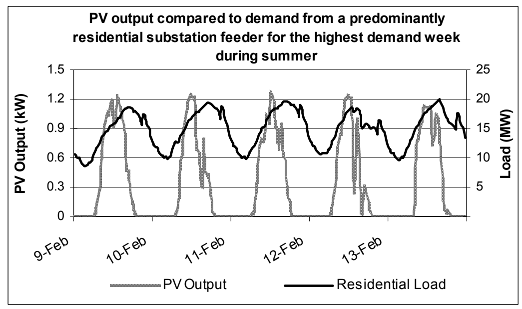

Figure 5: PV output and load for a NSW country town feeder over the week of peak demand - summer 2004.

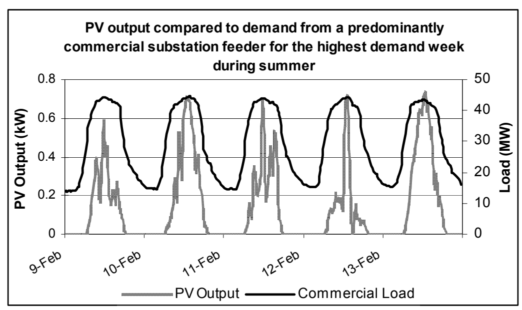

Figure 6: PV output and load for a Western Sydney commercial feeder over the week of peak demand - summer 2004.

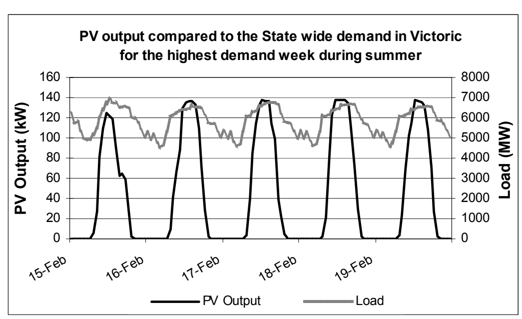

Figure 7: PV output and system load on a peak summer week in Victoria – summer 2004.

3.2 PV output and temperature

The performance of crystalline silicon arrays can decline with high temperatures, especially for rooftop systems where array temperatures can be 30 to 40 degrees higher than ambient. Also, hot days can be characterised by haze or storm clouds. Nevertheless, the results from 15 systems monitored over the past summer indicate that, although impacted by temperature, PV output on summer days remains significant, as illustrated in Figure 8.

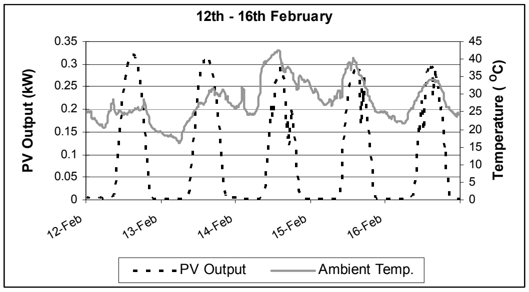

Figure 8: PV output and ambient temperature in Adelaide over a peak temperature week.

4 ANALYSES AND VALUES

4.1 Potential impact on load

For summer peaking feeders, the shape of the load curve determines the potential for PV to defer network upgrades. For feeders with high residential loads, peaking in the late afternoon, PV can reduce load prior to the peak event, thereby potentially reducing transformer heating, however its contribution to the peak load itself is low. Figure 9 shows the load and the load reduced by an appropriately sized PV array for a country town with a predominantly residential load. For feeders with a mixed load, including commercial and industrial, the PV contribution can be more useful. Figure 10 shows the impact PV could have on a commercial feeder load.

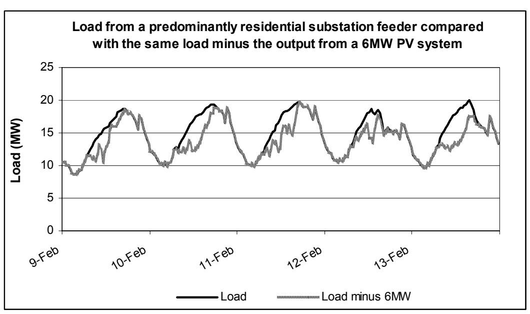

Figure 9: Potential PV contribution to load for a NSW country town on a week of peak demand - Summer 2004.

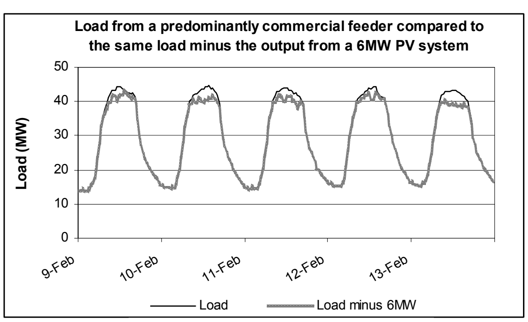

Figure 10: Potential PV contribution to load for a predominantly commercial substation feeder in Western Sydney.

4.2 Assessing Network Value

There are several ways of assessing the network value of PV. One is to compare the long term pattern of PV output with the pattern of electricity demand. In Figure 11 the chronological pattern of a commercial load has been re-ordered as a load duration curve, maintaining the correspondence between PV output and demand. In Figure 12 the load duration curve is shown along with load minus the coresponding PV output. Again, PV output is more concentrated at the higher load points on the commercial feeder, whilst PV output on the residential feeder is spread across a wider range of loads.

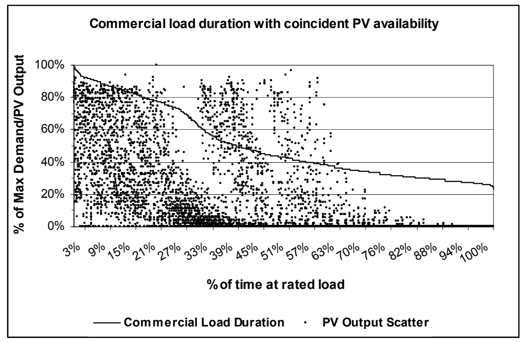

Figure 11: Normalised load duration curve for a commercial feeder in Western Sydney with coincident PV output - Summer 2003-04.

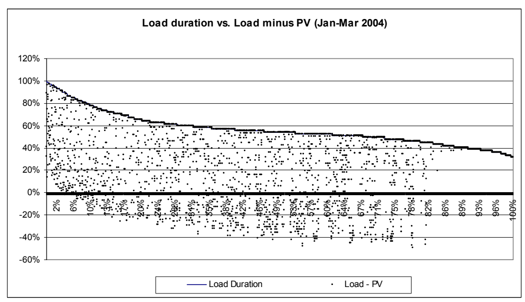

Figure 12: Normalised load duration curve for a NSW country town feeder showing the potential load reduction due to coincident PV output - Summer 2004.

Another way of assessing network value is to correlate PV output with load. Figure 13 shows this correlation for a PV system in Adelaide with the household's own load over the time period 14:30-15:30, which shows high correlation, while Figure 14 shows lower correlation over a longer time period.

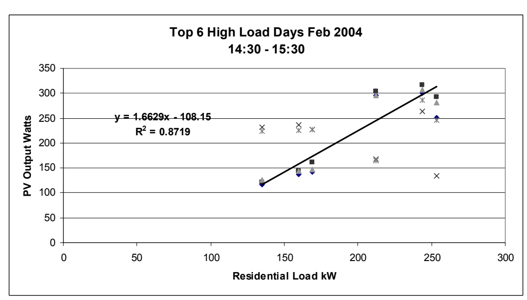

Figure 13: PV correlation with household load in Adelaide (no air conditioning) (R^2 = 0.87) - Feb 2004.

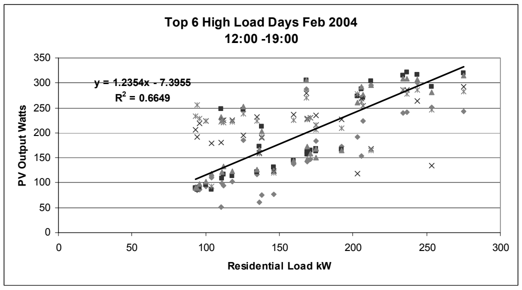

Figure 14: PV correlation with household load. Adelaide (no air conditioning) (R^2 = 0.66) - Feb 2004.

4.3 Assessing Retail Value

Peak summer days can see spot prices on the National Electricity Market (NEM) rise substantially. If PV can contribute to load during these surges, it will be of increased value to retailers. Figure 15 shows PV output and NEM price during a peak summer temperature week in New South Wales.

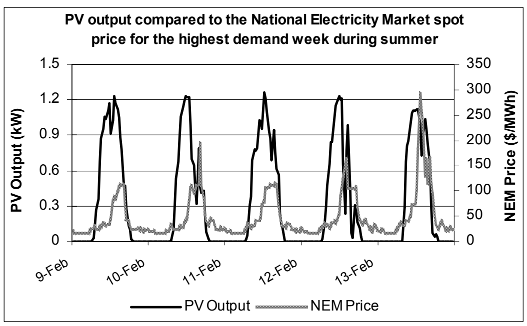

Figure 14: PV output and NEM price for a peak temperature summer week in NSW – Summer 2004..

4 DISCUSSION

PV can make a useful contribution to summer electricity loads, although the value to electricity networks and electricity retailers is dependent on actual feeder load patterns and on bulk electricity prices. PV output over the peak load weeks of last summer corresponded well to system load at regional nodes for Victoria, South Australia and New South Wales, although load lags PV output slightly on some days. Similarly, PV output corresponds well with NEM price over peak load weeks for all three States. However, further analyses are needed to asssess the PV value over summer. At an individual feeder level, PV output correlates well with commercial loads, indictating a strong case for PV use in commercial buildings in Australia. PV systems on schools also correlate well with their daytime load profiles, although schools in Australia are closed for 6 to 8 weeks over summer, so that PV output would contribute to wider load reduction.

For residential loads, the peak is typically in mid to late afternoon. In areas with high air conditioner penetration the peak load is significantly higher on hot days and can remain high up to 6 or 7pm. For PV to contribute usefully to the peak, the PV output curve must be displaced or storage added. This may be in the form of electrical or thermal storage. Earlier studies [1, 5] have shown that west facing arrays, with higher tilt angles would allow the PV load curve to be shifted towards the afternoon, with the PV output peak moving from noon to 3pm in Sydney for a west facing 45 degree tilt array. Summer PV energy production is not greatly affected by this change in orientation, compared to a north facing array at 35 degree tilt, however, winter energy production is reduced, as is overall annual output. Hence, if the electricity industry wishes to encourage summer output, PV system owners would need to be compensated for lost winter revenue by higher summer revenue.

A key requirement also is the need for improved residential building energy performance, so that overall cooling needs can be reduced. This should include greater use of insulation, as well as appropriate building orientation and shading on north and west facades over summer. One BIPV option may be PV window shades or pergolas for west facing walls.

PV installations provide a year round source of day-time electricity. Their value for peak load reduction is dependent on the load pattern of the individual feeders to which they are connected. Appropriately placed PV installations, along with moves to reduce electricity use and to better manage peak demand, may provide lower risk investments than network augmentation. The use of distributed generation can also improve the resilience and security of the electricity system. Finally, in Australia PV use displaces fossil fuels and so has an important role to play in reducing greenhouse gas emissions.

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