Grid parity: A potentially misleading concept?

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ABSTRACT

Grid parity is often cited as the "coming of age moment" for photovoltaic (PV) power. We analyse the complex concept of grid parity and identify shortcomings in some of the most common definitions. The idea that PV systems can and should compete with the retail price of electricity is challenged. The value of PV in reducing network expenditure is unclear as PV systems do not always reduce peak demand. It is shown that as grid energy consumption declines with high PV penetration, tariffs may, indeed, rise to recover fixed network costs unless these costs can also be reduced.

When commercial and residential retail tariffs better represent time and location varying costs, PV systems can be optimally located and oriented to maximise network value and maximise savings through avoided consumption. Enhancements to existing feed-in tariffs are proposed that more closely correspond to the energy value provided by PV systems.

The simple notion of grid parity does not suffice when considering the dynamics of electricity pricing. The clearer the price signal for end users, the more that PV will make economic sense on a case by case basis. The grid parity concept remains a useful benchmark for the PV industry, however as an indicator of market competitiveness, a more complex formulation appears to be needed.

Keywords: grid parity, photovoltaics, time of use, tariffs

Introduction

Grid parity is often cited as the "coming of age moment" for photovoltaics (PV). A common refrain is that once grid parity is achieved, PV will be cost competitive without subsidies and deployment will take off driven by economic fundamentals (Yang 2010). This paper analyses the concept of grid parity and its merit as a policy goal.

We first consider the various standing definitions of grid parity. We then examine some of the shortcomings of the grid parity concept. In particular, current commercial and residential retail tariffs in many jurisdictions poorly represent the underlying costs of electricity provision. Wholesale electricity prices within the National Electricity Market vary by time, location and are subject to uncertainties. Similarly, the network costs of supplying particular customers also vary with time and location (in particular, the correlation between the customer demand and peak network demand). By contrast, most retail customers still pay flat tariffs. The flat retail tariff regulated in the Australian Capital Territory is used to illustrate the cost components of retail electricity. A particularly important issue for PV is the potential impact on network costs. Work to date highlights that residential PV systems do not always reduce peak demand, a key factor for network augmentation. We analyse the implications on tariffs for reducing energy sales through high PV penetration (or demand reduction measures that do not address peak demand) without reducing network expenditure.

Time of use (ToU) tariffs are being used increasingly to reflect the time-varying wholesale price of electricity and encourage demand side management. The tariff structure used in central California offers some insight into how PV systems can be deployed to maximise the economic value of the system. We discuss the implications for future enhancements to feed-in tariffs (FiTs).

We examine some of the issues that will hinder the adoption of PV systems once the levelised energy cost of PV falls to the retail electricity price. Experience with other renewable technology suggests that PV deployment will not grow quickly beyond grid parity, but is likely to be restrained by various social and economic barriers (Yang 2010). Recommendations are made for addressing such barriers well before PV affordability reaches this level.

Defining grid parity

There is no one accepted definition of grid parity. The most common definition, and the one considered in this paper, is the threshold at which a grid-connected PV system supplies electricity to the end user at the same price as grid-supplied electricity. This is the definition used by advocates of distributed generation including small-scale rooftop PV systems. Various alternative definitions exist for centralised

PV systems, however these are not considered in this paper.

Shortcomings of the grid parity concept

The common definition of grid parity compares the levelised cost of PV generated electricity with the prevailing retail tariff simply because this is how the customer would be charged if the electricity was purchased from the grid.

The first shortcoming in this definition is that it uses a flat tariff for grid electricity as the basis for comparison. Wholesale electricity prices vary considerably throughout the day. A flat tariff, regulated in many jurisdictions, obscures the time-dependent cost of electricity. Australian electricity retailers such as Energy Australia are moving to ToU tariffs on new connections, but the changes are contentious. For example, the Victorian Government recently announced a temporary moratorium on the use of ToU tariffs (Victorian Minister for Energy & Resources 2010).

Another flaw in this definition of grid parity is that the definition fails to recognise the cost of a required grid connection. Transmission and distribution networks are required for all grid-connected PV systems to meet additional electricity demand. Transmission and distribution costs are not necessarily avoided when "purchasing" electricity generated from a PV system. The following sections elaborate on the shortcomings of grid parity in the context of PV systems installed at the point of use.

Retail electricity tariff structure

The retail price of electricity encapsulates the various costs of delivering electricity to the end user. Most are fixed costs: capital to build generation plants, transmission networks and distribution networks. Each element is collectively sized to meet expected future demand. A smaller proportion of the cost is variable such as the fossil fuel for conventional power stations. Generators and network operators recover capital by deriving income from the operation of the National Electricity Market.

For the purpose of illustration, retail pricing for the Australian Capital Territory (ACT) will be used in this section of the paper. Table 1 shows a breakdown of the transitional franchise tariff (TFT) for electricity in the ACT. The TFT is used in the transition to full retail competition for small (under 100MWh/year) customers wishing to retain the incumbent retailer, ActewAGL. The Independent Competition and Regulatory Commission periodically determines a TFT that allows for cost recovery and a 5.4% return on capital (ICRC 2010b).

As can be seen from the table, network costs account for 45% of the total retail price.

Recent steep increases in electricity prices in New South Wales are substantially driven by growing peak demand on the transmission and distribution networks (AER 2009a; AER 2009b). Network costs are recovered by network operators through tariffs that are partly determined by the units of energy transferred. If fewer units of energy are sold, the network service provider must charge more per unit to make the same revenue. This holds true up to a point. Eventually, reductions in energy consumption lead to falling network costs as network augmentation efforts can be deferred or abandoned. In the absence of savings from reduced network expenditure, however, the marginal impact of reduced sales of electricity is higher network charges in the reduced electricity sold.

Policy incentives in Australia such as FiTs do not presently encourage coordinated and orderly development of PV systems in areas with loads correlated with solar output. For example, PV systems provide greater value on commercial feeders in light industrial areas than urban feeders in dormitory suburbs (Passey et al. 2009), yet this is where the majority of PV systems have been installed to date in the ACT (ICRC 2010a). These factors could be incorporated into FiTs, should the schemes be enhanced as PV penetration rises.

Value of PV systems

PV systems supply electricity in a location and time varying manner. Carefully placed around the network, PV systems can reduce the need for network augmentation or reinforcement. Perez (2006) estimates that several hundred megawatts of PV systems situated around the New England region of the United States would have helped to prevent the very large August 2003 blackout.

In many settings, the value of PV systems is less clear. The CSIRO Intelligent Grid

Electricity purchase cost ($/MWh)	58.57
Energy trading desk operation ($/MWh)	0.76
Environmental compliance costs, eg. MRET ($/MWh)	5.15
NEM fees ($/MWh)	0.76
Energy losses (%)	5.92
Total energy purchase cost ($/MWh)	69.01
Retail operating costs ($/MWh)	10.56
Network costs ($/MWh)	71.44
Total retail + energy + network cost ($/MWh)	151.01
Retail margin (% of sales)	5.40
Total retail price ($/MWh)	159.16

Table 1: Composition of transitional franchise tariff retail price for 2010–11 (ICRC 2010b).

Demand reduction %	Network revenue collected ($M/year)	Fixed cost shortfall ($M/year)	Tariff increase ($/MWh)	Tariff increase (%)
0	202	0	0.00	0.00
2	198	4	1.46	0.92
4	194	8	2.98	1.87
6	190	12	4.56	2.86
8	186	16	6.21	3.90
10	182	20	7.94	4.99

Table 2: Tariff adjustments due to reduced sales (baseline 2,831 GWh/year).

Report documented a preliminary study of the impact of small-scale distributed generators on the distribution network (CSIRO 2009). This study modelled the impact of PV on four distribution feeders of various load types: residential, commercial, "greenfield" residential/semi-rural, and rural. The findings were that commercial feeders provided the best opportunity for PV generation to assist in deferring network augmentation due to the coincidence of supply and demand. For the other feeders, the study recommended demand side measures and optimally orienting the PV systems to improve supply and demand coincidence. These findings highlight the location sensitivity of the value of PV systems. Deployed in lower value parts of the network, PV may do little to reduce distribution network costs.

CSIRO also modelled the impacts of PV systems on the transmission network. It was found that carefully sited PV systems can reduce congestion on transmission networks and reduce the average price of electricity. The report gives an example of 20 MW of distributed generation installed in one location on a simulated grid. This led to a reduction in the average price of electricity of 12%. This was achieved through careful placement of a PV generator that comprised a very small percentage of total generation (0.6%).

The value provided by a PV system is potentially much higher than the retail tariff, however the value is time and location dependent. This must be a consideration in any analysis of grid-tied PV economics.

Analysis of higher PV deployment

Using the breakdown of ACT retail electricity prices above, a scenario was investigated where energy demand is reduced but peak power demands are not altered. This reduction in energy consumption from the grid may come from rooftop PV systems, but equally could be any demand reduction measure, such as electrically boosted solar hot water, that does not substantially reduce demand for peak power.

Table 2 gives illustrative figures for the total network revenue collected on the sale of 2,831 GWh of energy delivered across the ActewAGL distribution network in 2007–08 (ICRC 2009). For each 2% reduction in energy demand, the calculated fixed cost shortfall is given. The required tariff increase on the remainder of energy sales to recover this shortfall is shown in both dollar and percentage terms.

The table shows that as demand for grid electricity is reduced, the full cost of electricity is not avoided. Instead, the fixed network costs are diverted into the tariff paid on electricity that is not met by PV and must be purchased by the consumer. The table also shows that tariffs continue to increase as energy sales are reduced through greater deployment of PV or other demand reduction measures. At higher penetration levels, an unsustainable situation emerges where PV systems become economically attractive, but do not contribute to network costs. This in turn causes costs to rise, making PV more attractive.

Time of use tariffs

ToU tariffs adjust the retail price of electricity during the day so that it more closely corresponds to the varying wholesale price. A complex tariff structure used by Pacific Gas & Electric Co. (PG&E) in central and northern California gives consumers an incentive to deploy PV in a way that improves the economic value of the PV system. This tariff structure will be explored in this section. In the absence of similar tariff structures in Australia, enhancements can be made to existing FiTs to achieve a similar effect.

With ToU tariffs, PV electricity becomes much more competitive with the retail price at certain times of the day and less competitive at others. PG&E customers have a tariff structure that places customers into climate zones which determines an acceptable baseline level of consumption. This is combined with an inclining block (tiered) component and a ToU component.

Electricity pricing in California provides a clear time and location specific indication of demand. At the time of writing, the tariffs for a typical customer plan are given in Table 3. The timing of different ToU periods is shown in Table 4. As can be seen from the tables, the summer peak demand period occurs on weekdays between 1pm and 7pm and is charged at between US 30c/kWh for tier 1 (baseline) and US 58c/kWh for tier 5 (300% over baseline and above).

A PV system can be cost competitive if it supplies sufficient electricity to the end user during peak periods. In California, the peak period of 1–7pm is well suited to solar generation. Hence, PG&E customers in California have been known to orient PV systems with a westerly bias to avoid buying grid electricity during this tariff period (Webster 2009). Moreover, high consumption end users will find PV a better investment than low consumption end users if it helps to keep consumption out of the higher pricing tiers. This is a desirable outcome from the perspective of the utility.

In Australia, the primary policy instrument for encouraging the installation of PV systems is FiTs. To date, FiTs in Australian jurisdictions are structured to reward maximum energy yield and pay generators independently of value to the network. A PV system owner typically points a system towards solar north and at the latitude tilt angle to maximise energy generation.

To get a similar effect to consumer using PV to avoid high tariffs in California, it is necessary to compensate PV system owners for generating at times of highest demand, given that they will produce smaller daily yields. This idea has been suggested by Weinholz (2010). A recent update on FiTs worldwide by Jacobs (2010) suggests that creative enhancements to FiTs are being considered elsewhere to achieve particular policy objectives.

One possibility would be to re-structure FiTs to vary the tariff with time of generation. A high tariff could be paid during peak periods, a lower tariff for the shoulder periods and a small (or zero) tariff during the off-peak period. The three tariffs could be balanced such that a PV system oriented to meet peak demand would achieve a rate of return similar to current FiTs. PV systems installed in the traditional northerly direction would achieve lower than present returns. This would also address the possibility that net feed-in tariffs encourage end-users to shift mid-day loads to the evenings to maximise their return, and increase peak demand.

This tariff structure is not PV-specific. It follows the demand profile and any renewable generator could be compensated similarly. The more closely that feed-in tariffs represent the value of electricity, the less that the feed-in tariff amounts to a subsidy.

PV deployment beyond grid parity

How energy users will respond to falling PV costs in the absence of FiTs is an open question. It is not clear that PV systems will be rapidly installed once the levelised energy cost of PV falls below the retail price of electricity. The levelised energy cost will vary among PV owners, as it depends on the discount rate. The CSIRO Intelligent Grid report identified a consumer tendency for high hurdle rates ("the minimum acceptable rate of return") when investing in energy efficiency measures

Season	Time-of-Use	Tariff (US c/kWh)				
	Period	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Summer	Peak	30.631	30.631	46.218	57.158	57.158
	Off-peak	9.003	9.003	24.590	35.530	35.530
Winter	Peak	11.936	11.936	27.523	38.463	38.463
	Off-peak	9.318	9.318	24.905	35.845	35.845

Table 3: PG&E tariffs for schedule E-7 (PG&E 2010).

<table>
<tr><th>Summer</th><th>Sun.</th><th>Mon.</th><th>Tue.</th><th>Wed.</th><th>Thu.</th><th>Fri.</th><th>Sat.</th></tr>
<tr><td>12am–6am</td><td colspan="7">Off-peak</td></tr>
<tr><td>6am–10am</td><td colspan="7">Off-peak</td></tr>
<tr><td>10am–1pm</td><td>Off-peak</td><td colspan="5">Part-peak</td><td>Off-peak</td></tr>
<tr><td>1pm–7pm</td><td>Part-peak</td><td colspan="5">Peak</td><td>Part-peak</td></tr>
<tr><td>7pm–9pm</td><td>Part-peak</td><td colspan="5">Part-peak</td><td>Part-peak</td></tr>
<tr><td>9pm–12am</td><td colspan="7">Off-peak</td></tr>
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Table 4: PG&E residential ToU summer tariff periods (PG&E 2010).

(CSIRO 2009).

Deployment may not necessarily flourish beyond this point, as experience with other renewable technology suggests. Yang (2010) reports moderate adoption of solar water heaters in Hawaii and recommends policies to encourage uptake rather than relying on "economically rational" consumers. The current retail price of electricity in Hawaii is US 27.8c/kWh (US Energy Information Administration 2010). For some time, it has been cheaper to heat water using solar energy than electricity in Hawaii, yet solar water heaters are installed in only one third of homes (Hawaiian Electric Company 2009). Electricity in Hawaii is largely generated from oil-fired plants making electricity prices volatile. In 2008, the retail electricity price peaked at 37c/kWh (US Energy Information Administration 2010). Volatile price movements highlight one difficulty in making an investment in solar hot water. Instead of predicting the future price of electricity, a consumer may prefer to buy a lower cost electric water heater and bank the savings for a lower, but more certain return.

Other barriers will continue to inhibit the take up of various renewable technologies such as solar water heaters and PV: high upfront costs, high hurdle rates, investment risk, lack of access to finance, insufficient consumer information, uncertain solar access laws and local regulations governing building aesthetics. These factors undermine an economically rational decision to install PV once prices provide a good rate of return.

Conclusion

Grid parity is a complicated and potentially misleading concept as currently conceived. At the margin, an individual PV system owner can avoid the retail price for electricity they generate in the absence of feed-in tariffs or other incentives. However, if high PV penetration were to occur, the fixed infrastructure costs that are recovered through the retail tariff may need need to be recouped through a higher tariff applied to electricity purchased from the grid.

It is difficult for PV to be competitive with a flat retail tariff due to the varying time and location value of electricity. PV systems can supply power during periods of high demand and high costs, where it is easier to be cost competitive. In central California, very high peak pricing applies during the summer afternoon, allowing PV systems to be oriented in an optimal direction (ie. more towards the west) to avoid high prices. Furthermore, inclining block tariffs provide a strong financial incentive for high consumption customers to use PV to keep consumption below the high pricing tiers.

In a future absent of PV subsidies, a clear price signal that captures all of the relevant costs (and externalities) is essential to enable renewable generation to be invested in the most efficient manner. The Californian situation shows that a price signal closely tied to demand encourages generators to supply at the times of highest demand. For as long as subsidies are required, policies are needed which direct PV deployment in a similar manner. Current versions of FiTs in Australia are structured to reward maximum energy yield and pay generators independent of the value of the PV system to the network. Some possible enhancements that vary FiTs with time and location have been proposed in this paper.

A simple notion of grid parity does not suffice when considering the dynamics of electricity pricing. The clearer the price signal for end users, the more PV systems will make economic sense on a case by case basis. The grid parity concept remains a useful benchmark for PV system manufacturers to drive towards, however as an indicator of market competitiveness, more complex definitions are needed. Further, the PV industry should address the barriers to adoption that will still exist even when PV systems are economically viable without subsidy.

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Biography of presenter

Ben Elliston is a PhD candidate in the School of Electrical Engineering and Telecommunications at UNSW. After 10 years of developing optimising compilers and other programming tools, he commenced a PhD in 2010 to pursue his interest in renewable energy. His research investigates integrating solar electricity into the grid at high penetration.

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