Rethinking Business Models for Network Service Providers – Shadow Pricing against Storage

Jenny Riesz, Joel Gilmore
School of Electrical Engineering and Telecommunications and Centre for Energy and Environmental Markets
UNSW Australia
Sydney, Australia
j.riesz@unsw.edu.au

***Abstract*—The potential for a dramatic transformation away from centralized grid electricity supply as a growing proportion of customers choose to disconnect from the network and self-supply raises important questions for the future of network utilities. Indeed, such an outcome likely represents a far more significant challenge to the current supply industry than that of increased renewable and distributed generation since it raises the question of what future role it might have at all. This paper explores potential future business models for network service providers under such circumstances. In particular, it argues in the case where grid disconnection is less expensive than continuing centralized supply under existing regulated network tariffs, Network Service Providers (NSPs) will need to shift towards more competitively-oriented pricing in what could be an increasingly competitive market (in competition with self-supply alternatives). This implies a move away from "cost-recovery" pricing, towards competitive pricing approaches, such as "shadow-pricing" just below the competition (self-supply alternatives). Regulatory frameworks will need to adjust to allow such innovative pricing structures, and eventually might even become unnecessary, with consumers no longer requiring regulation beyond that applied in other competitive industries.**

***Index Terms*—Death Spiral, Network Service Providers, Business Models, Photovoltaics, Distributed Energy Resources, Storage**

I. INTRODUCTION

It now appears likely that future scenarios for power systems around the world will involve significantly higher proportions of renewable technologies. For example, in 2014, renewables represented more than half (approximately 59%) of net additions to global power capacity. By the end of 2014, renewables comprised enough to supply an estimated 22.8% of global electricity [1].

Many renewable technologies (such as hydro, geothermal, concentrating solar thermal and many types of biomass) are similar operationally to conventional fossil fuel generation technologies, and therefore present minimal integration challenges. However, the majority of new investment is in wind (the least cost option for new power generating capacity in an increasing number of locations [1]) and solar photovoltaics. These technologies are more challenging from an integration perspective, since they exhibit variable availability, and are non-synchronous (and therefore do not contribute to system inertia). Displacement of conventional dispatchable synchronous technologies by wind and photovoltaics will therefore require significant changes to the operation of electric power systems. Therefore, this has justifiably become an active and growing area of research around the world [2, 3, 4].

However, in parallel with the shift to higher renewables, the electricity supply industry may be on the cusp of a potentially far more significant industry transformation. The rise of cost competitive distributed energy alternatives (most prominently rooftop solar photovoltaics) and ongoing reductions in the cost of distributed storage creates the potential for customers to reduce reliance upon the grid, and potentially ultimately leave the grid entirely in the imminent future. The implications of this could be far more significant than the shift to renewables. It may mark the onset of a complete transformation of the electricity sector, away from centralized power sources towards a decentralized or perhaps even completely disconnected approach to electricity supply (with individual customers entirely meeting their own needs locally).

Under the present framework, as an increasing number of customers find it a viable alternative to disconnect from the grid, NSPs will need to increase their c/kWh tariffs to recover the fixed costs invested in existing network assets. This increase in network tariffs could in-turn make it rational for more customers to disconnect from the grid, exacerbating the issue. This has been termed the "death spiral" [5, 6], as defined by Severance in 2011 [7].

Despite the potentially dramatic consequences of this transformation, to date it has received little attention in modelling exercises and other planning forums in Australia, although some research has been conducted internationally [8]. The CSIRO Future Grid Forum is one of the few that has considered this issue for the Australian National Electricity Market [9]. This study provided one scenario that considered the potential for customers to disconnect. In this study, the "Leaving the grid" scenario considered a case where disconnection becomes a mainstream option by the late 2030s. The supply chain segment impacts of this scenario were found to be more significant than in the other three scenarios modelled (including a high renewables scenario). However, it could be argued that this scenario still represents a moderate view;

This work is supported in part by funding from the CSIRO Future Grid Forum, and the Australian Renewable Energy Agency (ARENA).

despite significant disconnection, almost 70% of electricity is still supplied from centralized sources in 2050 [9].

If complete disconnection from the centralized grid becomes the preferred option for the majority of customers, significant industry disruption will result. Retailers (in their current form) will have a significantly reduced customer base. Network Service Providers (NSPs) (both at the transmission and distribution level) will have a significantly reduced customer base, and will own large, expensive stranded assets. Centralized generation (both renewable and fossil fuel) will become large, expensive stranded assets. Given the absence of a large centralized power system, the role of the system operator (in its current form) will become largely obsolete. The role of regulatory authorities will change dramatically, and may also become obsolete, with customers no longer requiring regulatory protection beyond that applied in other (competitive) industries.

Therefore, the consequences of this transformation present an unprecedented scale of risk for all types of participants in the electricity supply industry. This means that understanding and planning for such a potential transformation should be a high priority.

II. Optimal Outcomes for Consumers

In the face of any dramatic industry transformation, the underlying considerations that drive any decision making by policy makers or regulatory authorities should be the welfare of consumers. The best outcomes for consumers in this transformation will depend upon the relative costs of scenarios of grid disconnection, versus the costs of scenarios where the majority of customers remain grid connected. There are two possible circumstances:

- ***Circumstance 1:*** Self-supply alternatives (such as rooftop photovoltaics combined with home storage devices) remain relatively expensive over the long term, such that a centralized supply industry (with the majority of customers continuing to utilize the existing grid) remains the lowest overall cost option.
- ***Circumstance 2:*** Storage technologies and the associate infrastructure for self-supply reduce in cost sufficiently that scenarios of widespread grid disconnection are lower cost in the long-run than continuing centralized supply.

Simplistically, the best outcome for consumers should occur when the lowest overall cost outcome is achieved. This would mean perpetuating the centralized supply industry in Circumstance 1, or facilitating a managed shift to disconnection in Circumstance 2.

The transition process creates an additional layer of complexity. Under Circumstance 2 it is also important to consider the considerable sunk costs in the existing transmission and distribution network assets, and centralized generation assets. These sunk costs suggest that the best outcome for consumers would be a slow transition to disconnection, where existing assets continue to be used to their full capacity, but no further capital investment is made, causing a gradual transition to disconnection as those assets are retired over time when they reach the end of their useful life.

Table I illustrates the two possible Circumstances, and summarizes the potential outcomes that could eventuate in each case. Boxes highlighted in red indicate outcomes that are suboptimal from the perspective of consumers, because the least overall cost option has not been achieved. Boxes in green indicate the preferable outcomes where the least cost option has been achieved.

TABLE I. Possible Scenario Outcomes

	Circumstance 1: **Centralized scenario is lower cost**	***Circumstance 2:*** **Disconnected scenario is lower cost**
Centralized supply continues	NSPs provide pricing that reflect the lower cost of the centralized network alternative.	Likely to be a temporary transition to a disconnected scenario.
Majority of customers disconnect	Could be driven by NSP failure to provide attractive offering to consumers which reflects the lower cost of this solution.	Could occur rapidly and cause stranding of existing network assets, if NSPs do not provide an attractive offering. Transition could be slowed with shadow pricing approach.

III. Managing uncertainty

There remains significant uncertainty as to which of these two Circumstances will eventuate. Storage technologies remain relatively expensive at present; the current costs of disconnecting are estimated at 92-118c/kWh (around four times 2013 retail prices) [9]. However, projections show those costs reducing considerably over the coming decades, potentially to as low as 35-40c/kWh by 2030 to 2040 [9][1]. Local mini-grids and new business models may evolve and provide disconnection alternatives for a wider range of customers, such as renters and apartment dwellers, making widespread disconnection feasible and cost effective.

This uncertainty might appear to make it challenging for decision makers to plan appropriately. Should continuing use of the centralized network be encouraged? Or should the focus be on promoting a managed shift to disconnection?

IV. Moving Beyond Cost-Reflective Pricing

There is a general trend towards implementation of cost-reflective pricing of network services, although the precise meaning of cost reflective pricing remains an area of debate [10]. Cost reflective pricing is sometimes used to describe the practice of reflecting past costs incurred (ie. Achieving cost recovery). However, it can also refer to the practice of attempting to provide accurate price signals to customers about present and/or future costs, to incentivize economically optimal behaviors. In a period of rapid industry change, these may not

[1] All prices are quoted in Australian real dollars.

be the same (or even similar, in the case where there are substantial stranded assets).

Despite the significant uncertainty over which circumstance might occur (centralized or disconnected becoming the lowest cost solution), the general thinking often appears to be that decision makers need only implement cost-reflective pricing. Then, customers will make choices that reflect the changing technology cost relativities over time, and the lowest cost outcome will be achieved. This removes the need for any decision maker to pre-empt cost relativities. While highly non-trivial to implement in practice, the concept of cost-reflective network pricing has therefore gained traction.

Cost-reflective pricing could be an effective approach in Circumstance 1 (where centralized grid connection remains the lowest cost solution). In this case, if cost-reflective pricing is implemented, and if customers behave rationally[2], the lowest cost outcome will be achieved (customers continue to use centralized supply).

However, in Circumstance 2 (where a disconnected scenario is ultimately lower cost) cost reflective pricing could be a poor approach, both for customers and for NSPs. In this case, cost-reflective pricing could promote a sudden transition to widespread disconnection, unnecessarily stranding network assets. In this case, cost-reflective pricing could cause a rapid industry disruption, and leave large centralized assets stranded. If those assets are government owned, customers will still need to pay for them (through an effective government subsidy) but will not be accessing any value from those assets.

As discussed above, in Circumstance 2, a better outcome would be to continue to utilize the existing network assets to their full capacity, until they gradually retire at the end of their useful life. The transition to the (lower cost) disconnected scenario would still occur eventually, but would be slowed as existing assets continue to be used (but no new capital investment occurs).

These arguments suggest that if Circumstance 2 could eventuate, it's necessary to think beyond cost-reflective pricing.

V. SHADOW PRICING

Under Circumstance 2, with growing availability of distributed energy resources and storage options, customers will have an increasingly realistic alternative to network services. This disturbs the 'natural monopoly' long held by NSPs. Thus, the way in which networks are priced and regulated may need to change dramatically. NSPs will become part of a competitive industry. This has been termed disruptive competition [11]. No longer being an essential part of the electricity delivery process, network providers will need to *compete* with storage options. Therefore, like businesses in other competitive industries, NSPs will need to price *competitively*, rather than cost-reflectively.

In this case, the primary competitor is decentralized generation alternatives (such as rooftop photovoltaics) combined with home battery storage. Under these circumstances, a rational market participant would *shadow price* against their main competitor, implying that NSPs should price network services at just below the comparable storage alternative.

This suggests that NSPs will need to commence careful tracking of the storage alternative prices being offered to consumers (such as the recently released Tesla Powerwall [12]), and implement flexible tariff-setting approaches that can adapt rapidly to those price offerings, as required. This is a significant departure from the present highly regulated approach to tariff setting based around the concept of cost-recovery, as discussed further in Section IX.

The shadow pricing approach could allow NSPs to maintain a wide customer base, ensuring utilization of the existing grid, and allowing NSPs to recover as much revenue as possible, even if storage alternatives become cheaper than centralized grid connection.

VI. WRITE-DOWN OF ASSET VALUE

In Circumstance 2, the shadow pricing approach acknowledges that full cost recovery of the sunk costs in the existing network may no longer be possible, but seeks to utilize the existing infrastructure to the maximum benefit of consumers, and recover as much of the sunk cost as possible. For government owned assets, this would represent a significant reduction to government revenues, while for private NSPs or for equity investors, it would require a major write-down of asset value. For networks owned by governments a reduction in government revenue, while continuing to supply network services at a price below cost reflectivity, represents a government subsidy. Governments could subsidize tariffs for all consumers or, alternatively, just the most marginal customers. Although funded from government revenues, the total cost to consumers - taxes plus electricity - would still be lower than a disconnection scenario and each consumer should, at least monetarily, "prefer" these subsidies.

VII. TARIFF STRUCTURES

The specific structure of the tariffs is likely to be extremely important, and non-trivial to optimize. Differing combinations of c/kWh tariffs, capacity charges, time of use charges and other innovative pricing methodologies may be appropriate for different customer groups, depending upon the local alternatives for distributed energy resources and storage, the local costs of network augmentation, and the amount of 'headroom' available in the existing network capacity. This could be highly locationally specific, perhaps extending as deeply into the network as the individual feeder level. This creates new challenges for regions that have previously smoothed prices over large areas, ensuring that remote customers are not disadvantaged. For example, in the Australian state of Queensland, the Australian Community Service Obligation subsidizes rural networks out of government revenue [13]. Equity between customers and protection of vulnerable consumers are likely to be key issues for consideration.

[2] There are no guarantees that customers will behave rationally; this is discussed in Section X.

The shadow pricing methodology will also require distinction between existing network assets with sunk costs, and investment in new network assets. For example, regulators and policy makers should be careful to avoid implementing network subsidies that encourage new infrastructure to be installed where allowing a decentralized approach to evolve would be more cost effective in the long term.

VIII. Varying reliability requirements

Customers will face decisions as to the size of the home generation and storage system they want to install, with larger systems offering a higher level of reliability. Some customers may be prepared to accept lower levels of reliability than that offered by the grid at present, in exchange for lower costs. Others may prefer significantly higher levels of reliability, and will be prepared to install large storage and home generation systems to achieve that.

Analysis in Australia suggests that while the average value of customer reliability may be around $95,000/MWh, residential customers may value reliability at a much lower level of around $20,000/MWh, with small businesses valuing reliability at a much higher level [14]. Therefore, rather than the market operator making a judgment on the customer value of reliability in aggregate, customers would be able to tailor their energy services to meet their individual needs.

This means that NSPs may need to consider offering a variety of network service alternatives to customers with a range of levels of reliability, in order to provide an attractive and competitive offering to consumers. Advanced Metering Infrastructure (AMI) could facilitate this, and it could be managed in conjunction with other initiatives designed to promote greater demand side participation. Customers willing to receive lower levels of reliability could accept constraints such as maximum capacity levels, or reduced supply on extreme peaking days, for example, reducing NSP costs in areas where the network is constrained. A potential complication may be the localized nature of distribution network constraints, and the potential need to offer similar products to customers in different areas of the grid on the basis of perceived “fairness”.

IX. Reduced regulation

The present regulatory regime does not allow for innovative pricing structures, and thus prohibits a shift to a shadow pricing approach (or similar). To allow this to occur, significant changes to the regulatory framework will be required, enabling NSPs to implement more innovative pricing structures that reflect their new status as a participant in a competitive industry.

Eventually, if Circumstance 2 eventuates, and NSPs are genuinely operating in a competitive market, extensive regulation of the network industry may no longer be required. With NSPs operating in direct competition with storage alternatives, customers will no longer require such extensive regulatory protection. NSP investment decisions may increasingly be made on the basis of maximizing competitiveness.

At present storage alternatives remain significantly more expensive than centralized grid connection, so highly regulated cost reflective pricing of the centralized network remains appropriate. However, as storage prices approach the point where parity is achieved between disconnection and centralized grid connection, a shift to reduced regulation may be required. At a minimum, adjustment of the regulatory framework to allow greater innovation by NSPs will be necessary. Care would be required, however, to ensure that true competition was available to all classes of households and businesses (e.g., renters, low-income households, etc.).

X. The Importance of Customer Relations

It is becoming widely accepted that customers do not always behave in an economically rational manner. Even if NSPs provide economically preferable pricing options, customers may still prefer to disconnect from the grid. This could lead to sub-optimal outcomes, even if appropriate pricing tariffs are introduced.

Given the significant recent price increases observed in many jurisdictions (such as the Australian National Electricity Market [15]), customers can be particularly distrustful of electricity utilities at present, and may see self-supply of electricity as a lower risk alternative (protecting against future price increases). Understanding these “irrational” customer decision making influences will become of high importance if NSPs are attempting to provide attractive offerings to customers.

Furthermore, NSPs will need to invest heavily in developing strong customer relationships, building trust, and constructing a respected and favored brand. This is another significant departure from the present role of NSPs, who at present are largely unknown by the customers they serve.

XI. Partnership with Retailers

Electricity retailers may be better placed than NSPs to undertake the role of building customer relations, since retailers already have close contact with customers, and therefore have a recognized brand and the facilities for customer engagement. Also, to manage the risk of widespread disconnection, retailers may diversify by moving towards a new business model of providing “electricity services”. This may include offering to install and maintain home distributed energy and storage systems. Retailers may even consider offerings where the customer is indifferent to whether electricity services are provided via local generation and storage, or centralized generation and network, as long as the desired level of reliability is delivered. These factors may suggest that in a future market, NSPs could partner with (or even merge with) electricity retailers to provide competitive electricity supply offerings (with the retailer determining whether to provide the service from centralized network or local generation and storage, on a case by case basis). It will be important for regulators to consider what degree of vertical integration is desirable, and to what degree this should be permitted.

XII. Further Thoughts for Policy Makers

Policy makers will have significant influence over which of the situations illustrated in Table I eventuates. Policies that promote uptake of home storage and home distributed energy systems (through subsidies, feed-in tariffs or other approaches) could promote a shift towards disconnection, even if this is not the least cost option in the long-run. Policies that cause distributed energy to be priced more favorably than centralized energy are likely to be particularly problematic, where that difference in pricing is not driven by underlying cost differences. The influence of any policies of this nature on these outcomes needs to be carefully considered before they are implemented.

It is important to recognize that centralized generation investors are also highly exposed to the risk of disconnection. If the majority of customers elect to disconnect from the grid, this reduces the size of the centralized electricity market, reducing the customer base for centralized generators. This will act to reduce investment incentives, and may be seen as a significant risk by institutions providing capital. If this eventuates, the cost of capital for new centralized generation investment could rise. Since renewable generators are highly capital intensive, this could disproportionately disadvantage renewable investments, and inhibit a transition to low carbon electricity. Since this risk is driven by the perceptions of likelihood of a transition to a disconnected future, it is difficult for policy makers to address directly. An appropriate response may be to reduce capital risk in other areas (such as providing greater regulatory certainty around mechanisms such as the Renewable Energy Target).

XIII. Conclusions

There is great uncertainty around the future cost of self-supply alternatives (such as rooftop photovoltaics and home storage systems) which may make it cost competitive for customers to choose to disconnect from the grid in the near future. This creates the potential for a dramatic transformation of the electricity supply industry, and is likely to be far more significant for the industry than the shift to high renewables (which, to date, has received far more research attention). A complete re-think of the nature of the electricity supply industry will be required, and this will probably involve recognizing that NSPs and centralized power in general will be operating in a competitive market, rather than as a highly regulated industry. Thinking needs to move beyond cost-reflective pricing, towards innovative pricing structures (such as shadow pricing against competing alternatives) which have the potential to optimize outcomes for consumers in the long-run. Importantly, NSPs and other participants in the electricity supply industry are not helpless bystanders to an inevitable "Death Spiral". These organizations retain significant influence over outcomes, if innovation can be supported.

Acknowledgment

The authors gratefully acknowledge the contributions of Magnus Hindsberger and Chris Reidy for discussions to develop this thinking, which was first partially presented in [16].

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