SOLAR, WIND AND MARKET POWER IN A HYDRO BASED GRID

Stephen Poletti, University of Auckland, +6499237664, s.poletti@auckland.ac.nz
Mina Gholami, University of Auckland, +6499237664, m.bahramigholami@auckland.ac.nz

Overview

The rise of intermittent generation such as wind in electricity networks has raised concerns about the reliability of supply, and the design of, electricity markets. It is well known that increasing amounts of intermittent generation leads to more price volatility. There is also a need for more peaking capacity to provide electricity when the intermittent supply isn't available. In an Energy Only Market there are also market power concerns. Recent studies have examined increasing wind generation in New Zealand (Browne et. al., 2015) and South Australia (Mountain, 2014) and concluded that periods with low wind generation can allow significant market power to be exercised by the dispatchable generators.

The combination of increased price volatility which sees a large number of zero price hours as well some periods with extremely high prices exacerbated by market power has seen much discussion as to whether increased intermittent generation may mean that electricity markets – particularly Energy Only markets-need redesigning. For example the German government has recently released a green paper (Federal Ministry for Economic Affairs and Energy, 2014) which discusses different possible market design changes to allow the market to work efficiently even with large amounts of intermittent renewable generation.

One possible solution to the issues discussed above would be to have a portfolio of intermittent generators. For example to combine wind and solar in such a way as to reduce the volatility in intermittent dispatch. In the New Zealand context other sources of renewable energy include baseload geothermal plants and significant hydro resources (which account for up to 60% of generation). Whilst on a day to day basis hydro is dispatchable there are dry year constraints which can severely curtail total energy generation over a period of several months.

The New Zealand government has an ambitious target to have over 90% of electricity generation from renewable sources. Current generation from renewables is over 70% - although this varies depending on hydro inflows over the year. By 2050 the aim is to achieve a 50% reduction in Greenhouse gas emissions. Given that agricultural emissions are approximately 50% of total emissions, and are difficult to reduce, it is clear that emissions from the electricity sector and the transport sector need to be close to zero. An electric transport fleet combined with renewable electricity generation is looking like a realistic option with the technological progress being made in electric car design and consequent price reductions.

Relying on significant amounts of intermittent renewable generation has a number of well-known problems. There needs to be enough reserve capacity to cover the periods when intermittent dispatch is low. In New Zealand hydro can, to some extent at least, play the role that thermal peakers play in other markets. However, as noted above, during dry years lake levels run low and hydro generation is expensive. Current plans to retire significant coal generation are meeting resistance, as it is argued they are needed to cover dry year events. A recent study (Gholami et. al., 2016) has confirmed that during dry years there is significantly more sunshine, which suggests the attractive option that, over time period of months, solar generation may complement hydro leading to a more resilient renewable electricity system. This can be the case over a time periods of a day as well with hydro backing off during the day when solar production is at its peak.

The first aim of this study is to see if this is the case and what combinations of solar and wind reduce price and dispatch volatility during normal market condition, which in turn should lead to less market power being able to be exercised. The second aim of the study is to see if significant solar can help to solve the "dry year" problem.

In this paper we examine the interaction between wind and solar penetration, dry year events, and market power by first using a least-cost generation expansion model to simulate capacity investment with increasing amounts of wind generation, then using a computer agent-based model to predict electricity prices in the presence of market power.

Methods

To model electricity prices realistically we use a computer agent based model developed by Young et al. (2014) which uses a modified Roth and Erev algorithm and applies it to a 19-node simplification of the New Zealand electricity market. The computer agents have a portfolio of generator assets and bid into the market. Profits are computed, using a simplified dispatch model of the New Zealand market, which are fed into the learning algorithm.

New bids are constructed and the process is repeated until prices converge. The NZ Electricity Authority's Generation Expansion Model (EA, 2010) is used to generate a number of different scenarios for 2025 with varying amounts of intermittent wind generation. The demand projections from the Statement of Opportunity (EA, 2010) are used as well as expected line upgrades. Simulated wind and solar data was obtained from National Institute of Water and Atmosphere. Different amounts of installed wind and solar capacity scenarios are constructed starting with a given amount of wind generation. The long run generation expansion model is used to determine the capacity mix for each wind penetration scenario. For each given wind penetration scenario we construct solar replacement scenarios which substitute solar energy for wind energy with the constraint that over the course of the year total intermittent wind and solar energy generation is the same. Then strategic behaviour is modelled to simulate wholesale prices for the generated capacity mixes with different amounts of wind and solar using the agent based model.

Results

As expected price volatility increases with market power and with higher intermittent penetration. Our results support Twomey and Neuhoff's (2010) theoretical result that thermal plants are able to exercise market power more than the intermittent generators. With large amounts of wind or large amounts of solar prices are much more volatile with high average prices due to the exercise of market power. However combining solar and wind leads to significantly lower average prices, less market power and lower volatility.

Seasonal price and volatility changes dramatically with different combinations of wind and solar. For example (not surprisingly) large solar penetration leads to very low prices in summer and high prices in winter compared to high wind penetration scenarios. To start with we assume that there water is plentiful and hydro generation is not constrained. Then we run simulations with hydro dispatch modelled dynamically over a year keeping track of inflows and generation outflows and lake levels. We find that large amounts of solar do help with the dry year problem.

Conclusions

The first objective of this paper was to investigate the impact of different mixes of intermittent generation on firms ability to exercise market power. It was seen that there are two effects which counteract each other. The first is the merit order effect – an increasing fraction of the generation mix bids into the market at zero. When the intermittent mix is plentiful the price is pushed down. However when there is little solar or wind generation (for example a cloudy still day) tighter capacity margins allow firms to exercise market power. A mixture of wind and solar gives firms less scope to exercise market power resulting in lower prices and volatility. There is a tradeoff however. To make the system more resilant to dry year events large amounts of solar would be useful compared to the hybrid solar-wind system which results in lower market power. Policy makers therefore need to decide on what is more important – market power during normal market conditions or dry year security of supply.

References

Browne, O., Poletti, S., & Young, D. (2015). How does market power affect the impact of large scale wind investment in'energy only'wholesale electricity markets? Energy Policy, 87(C), 17-27.

Electricity Authority, (2010), Statement of Opportunity, http://www.ea.govt.nz/about-us/ec-archive/about-the-commission/documents-publications/soo/

Federal Ministry for Economic Affairs and Energy, 2014, An Electricity Market for Germany's Energy Transition: Discussion Paper of the Federal Ministry for Economic Affairs and Energy

Gholami, M., S. Poletti, G. Prtichard, and G. Zacheri, Solar PV-generation on a hydro based grid. (submitted to Renewable Energy)

Mountain, B., 2013, Market Power and Generation from Renewables: the Case of Wind in the South Australian Electricity Market. Economics of Energy and Environmental Policy, 2(1), 55-72.

Twomey, Paul and Karsten Neuhoff (2010), "Wind power and market power in competitive markets", Energy Policy 38, 3198-3210

Young, David, Stephen Poletti, Oliver Browne, (2014), Can Agent-Based Models Forecast Spot Prices in Electricity Markets? Evidence from the New Zealand Electricity Market, *Energy Economics* , 45, 415-434