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Understanding the Evolving NEM

Bill Nixey, Lead Consultant

This article describes how the IES electricity market forecasting tool, known as PROPHET, is used to model the National Electricity Market (NEM). PROPHET generates long term projections of wholesale electricity prices and dispatched generator outputs. Dispatch modelling can be used to investigate many uncertainties facing the NEM of the future, such as:

- How will additional coal generator retirements impact wholesale prices?
- To what extent will energy and pumped water storage participate in the evolving NEM?
- How will the energy produced from photovoltaic (PV) sources impact the wholesale price in the middle of the day?
- Will new transmission interconnectors lower wholesale prices?

1 An Evolving Market

The NEM generation supply mix is undergoing substantial change. Since 2012 a total of 4,800 MW[i] of thermal generation has exited the market. This represents 10% of the total generation capacity in the NEM. The largest of these closures was Hazelwood Power Station in early 2017. Large generator retirements will continue and the next expected withdrawal is Liddell in 2022.

Currently there is a rush to connect new wind and PV generators in the NEM. Within the next two years a total of 3,500 MW[ii] of new renewable capacity is expected to be commissioned. Some of these projects will benefit from the final years of the Renewable Energy Target. But the main driver for the new renewable capacity is the current high level of wholesale prices. These prices have recently achieved levels that have not been seen before in the history of the NEM.

The Victorian and Queensland governments each have Renewable Energy Targets that will incentivise a significant build of new wind and PV projects. If these energy targets are achieved in full, it would see at least 11,000 MW[iii] of additional renewables added to the NEM by 2030.

Large pumped hydro projects are also proposed for the future NEM. The Snowy Hydro 2.0 project will see 2,000 MW of additional hydro capacity added in 2024[iv]. The Tasmanian "battery of the nation" initiative could add up to 2,500 MW[v] of pumped hydro projects into the system. The viability of these storage projects depends on the future within-day prices and an adequate arbitrage opportunity being available. This also applies to utility scale batteries such as the Hornsdale Power Reserve in South Australia.

2 Dispatch Modelling

Making a prediction of future generation and price outcomes requires a market model that reproduces the dispatch process. The PROPHET dispatch model is one of a limited number of forecasting models that has the ability to reproduce these market outcomes.

In the NEM generators submit supply-side offers to the market operator (AEMO) for dispatch. AEMO aggregates these price offers as part of the merit order "bid stack" and dispatches plant to meet demand. The offers, as well as the regional energy demand and available transmission capacity, are used to determine the regional wholesale prices. PROPHET simulates this merit order process over a future period and produces projections of wholesale prices. But how accurate are these projections? To calibrate its model IES regularly performs back-casts to check the accuracy of the price and generation outcomes. The following figures show the price results from a PROPHET simulation for the period between June 2017 and February 2018 compared to actual values.

Figure 1 Average Regional Prices (Peak Period)

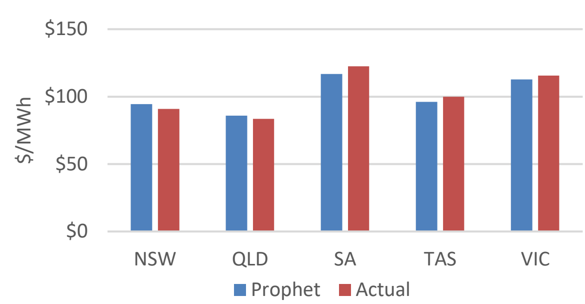
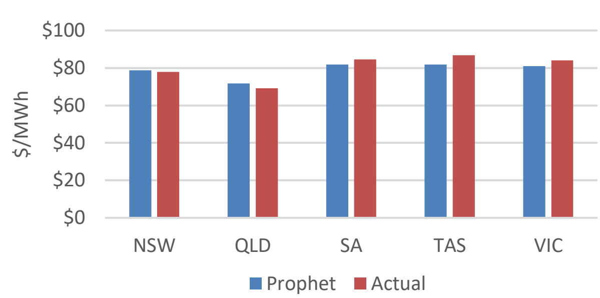


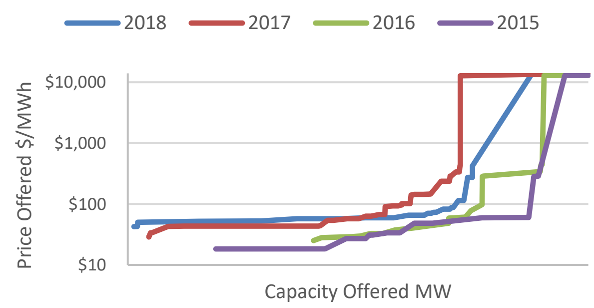
Figure 2 Average Regional Prices (Off-peak Period)



3 Generator Offers

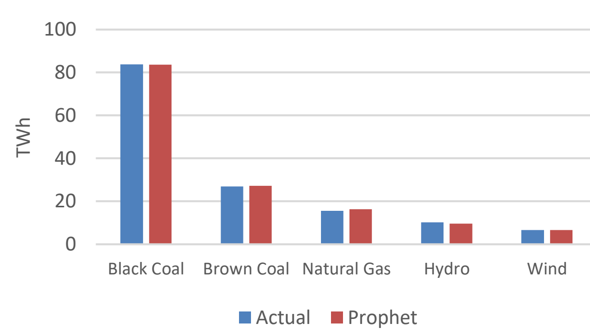
Understanding generator price and volume offers[vi] is a key aspect of modelling dispatch in the NEM. All scheduled generators are required to submit offers to AEMO at 4am each day. These are structured as ten price and volume bands. Most generators will re-bid the volume that they have available on any given day. This ensures that their generation capacity is dispatched efficiently given movements in demand. Generator bidding patterns have been subject to significant change over the last 18 months. This reflects increased fuel costs and a tightening supply-demand balance in the period following the Hazelwood closure. More recently however, the generator bidding has moved closer towards historical averages. The following figure shows (as an example) how the supply curves for one large NEM generator have changed over the last four summer periods.

Figure 3 Aggregated Supply Curves for a Large Generator



IES analyses the bidding behaviour of each scheduled generator in the market. As part of the PROPHET model calibration, all bids and re-bids are segmented and tabulated by hour of the day and time of year. Working weekdays and weekends are treated separately given that demand (and therefore the bidding behaviour) changes during the week. Seasonality is also important since demand is higher in summer and winter compared to other times of year. Plant availability trends are captured on a similar basis as most generating units regularly update these values. When producing forecasts, segmented bidding tables can be adjusted for any expected variations of generator fuel prices. The approach used on aggregating historical bidding data ensures that PROPHET achieves a good fit between the modelled dispatched energy and actual market results. This is demonstrated in the following figure which shows the generated energy results of a recent PROPHET back-cast.

Figure 4 Total NEM Generated Energy (June 2017 – Feb. 2018)



4 Renewables

The new renewables projects arriving in the next 10 years will significantly impact the generation dispatch mix and wholesale price outcomes. A key question for the future NEM is: how will the wholesale price change throughout a typical day as a result of these new renewables? Wind turbines and large PV projects are generally price takers in the AEMO dispatch process. This is because these facilities have a low marginal cost of production and can offer their output at negative prices to ensure they are dispatched[vii]. Under the market rules the wholesale prices have a minimum level of minus $1,000. Negative prices can occur at the moment in SA when its wind generation is at full output.

IES has extensive data repositories of all existing wind and large PV facilities. Actual half-hourly generation profiles for wind and PV are used in PROPHET to produce forecast generation trends from variable sources. PROPHET's use of generating unit bidding tables ensures that new renewables are modelled effectively. The merit order process is run for each half-hour over the forecast term and captures generation intermittency and the time of day impact on price. This includes negative price events. The price and volume offer settings prioritise the order in which any surplus energy may need to be curtailed.

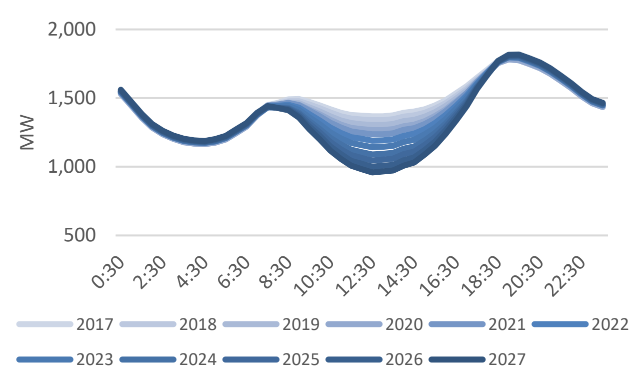
5 Energy and Water Storage

Utility scale energy storage and pumped hydro facilities have the ability to flatten out any supply irregularities from renewables. The PROPHET dispatch model can be used to investigate the operating characteristics of new storage projects. These projects require a price arbitrage opportunity to be economically viable. This means that price for charging (or pumping) must be significantly less than the generated energy. Generating and charging (or pumping) bids can be entered into PROPHET to represent the minimum required operating margin for a project. The results of the dispatch modelling will determine the number of running hours and the typical operating regime of the project. It also establishes the amount of energy dispatched and used as load. As an alternative, fixed generating and load profiles for a storage facility can be pre-loaded into PROPHET. The project then becomes a "price taker".

6 New Energy Technologies

New energy technologies located behind a customer's meter can include rooftop PV, electric vehicles or residential energy storage. These are taken into account in PROPHET as the net impact to system demand. Half-hourly profiles that represent the load and generation of these new technologies ensures that the time of day variations and captured. The following figure shows how rooftop PV take up for South Australia is likely to impact the regional average system demand.

Figure 5 South Australian System Demand with Rooftop PV



7 Transmission Constraints

The existing NEM transmission interconnectors are taken into account in PROPHET market simulations. They are defined as constraint equations which set the upper capacity limit plus other dependences (such as voltage, plant outputs, or other system limitations). As more renewable projects are installed across the NEM, additional interconnectors may be required to avoid transmission network congestion. The PROPHET dispatch model can include proposed interconnectors and assess their impact on regional prices as part of a market benefits assessment.

Transmission constraints also occur within regions. These may be due to voltage stability requirements or transmission line limits. The PROPHET model can accommodate intraregional constraint equations and determine the market value impact and the extent that they bind across a forecast period.

8 Conclusion

Understanding the evolving NEM has never been more important for market participants, investors and policy makers. If planning decisions aren't informed then inefficient outcomes will occur with unfavourable price impacts.

While this discussion has focused on the NEM, PROPHET can be applied to other markets that use a merit order dispatch process, such as Western Australia's WEM. The IES team regularly models electricity markets in PROPHET and has experience in the issues addressed in this article.

CONTACTS

Bill Nixey

+61 (0)2 8622 2224 +61 (0)2 9436 2555

bnixey@iesys.com www.iesys.com

[i] AEMC Annual Market Performance Review 2017 Final Report

[ii] Source: AEMO. Includes projects for which formal commitment has been made for construction or installation. They also either satisfy all of the AEMO *generation project commitment criteria* or have commenced construction.

iii Assuming a 40% generation capacity factor with no energy curtailment of the new plant. Queensland has a 50% renewable energy target for 2030 and Victoria has a 40% target for 2025. Future regional generation requirements are as forecast by AEMO.

[iv] Snowy Hydro Feasibility Study Summary

[v] Hydro Tasmania website

[vi] The term "offers" and "bids" are used interchangeably.

[vii] Semi-scheduled plant can be constrained off but typically due to network considerations