Lessons from the implementation of market systems for utility scale batteries in the NEM
Dr. Harley Mackenzie
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Slide 1

HARD software develops operations and trading solutions for renewable generation in the NEM and implemented the first semi-dispatched system that came into the NEM at Clements Gap in 2009 and we are now managing about 40 different sites in the NEM; managing their Energy and FCAS dispatch, showing operations and trading people what's happening in the market, what constraints are effective and those sorts of things that they need to know.

But, today I am talking about the Hornsdale Power Reserves Project. Why did we need the Hornsdale Power Reserve? Most of the people here will be familiar with the circumstances in SA so I won't spend a whole lot of detail on that, but it's more also interesting to explore what the political climate was around the project at the Hornsdale project at the beginning, the impetus to get it done in a very short amount of time, as we have seen for subsequent projects, other battery systems have struggled to meet anywhere near the timeframes that that was achieved for the Hornsdale Power Reserve and I'll discuss why that has happened.

So, there were a number of significant challenges, so we are going to be looking forward to future projects on the basis of what happened to real projects when they get implemented and then at the end of the talk, we will briefly discuss what are the future challenges? Some of those challenges are being resolved, some of them will be familiar to you, some maybe not and also I will finally conclude with, "What is the most significant challenge we are facing for storage and renewable in the NEM at the moment?" and that is the issue that not many people are presently talking about.

Slide 2

We won't spend too long on the events in SA that led to the project as this is pretty familiar territory to industry people in Australia. There was always a recognition that as increasing amounts of renewables happened in South Australia there was a vulnerability in the amount of inertia on the system at the time. This was amply demonstrated by nature, given the incident that happened in September 2016 which caused a lot of political problems and also a lot of technical angst about how we maintain the integrity of the South Australian market.

Slide 3

Couldn't happen again, could it? Well, it nearly did. Also, this is soon after the blackout on 3 March 2017 and this time no one could blame the wind producers because they had addressed the issue of maintaining fault ride throughs on their systems . Obviously, there were a lot of other factors that caused the SA blackout but wind generator shutdown is the one the politicians seemed to focus on.

What we had was on the 3 March, a capacitor blew up in the switch yard of the Torrens B, smoke took out the other unit of Torrens B and we can see that in that highlighted red area, so we see both of those units coming off. That caused the Pelican Point gas turbine to come off which is a combined cycle so also what happened is that affected their steam turbine in a later time period and we can see all that happening in that top highlighted red rectangle. As the gas turbines and diesels were receiving signals to start generating, we can see the interconnector flow, which is that red line down the bottom, coming up. Luckily there was higher voltage than the blackout incident and also the interconnector was only running at about 400 to 500 MW at the time so it was able to compensate for the low frequency problems and went up over 900MW when it should have tripped. You can see the interconnector flow got to about 923 MW and the only reason is didn't trip was we believe a setting was not correct in the Heywood connector control system. If it had tripped, and this is all detailed in the AEMO report, there would have been another blackout because we could not have recovered from the frequency drop at that time.

Slide 4

So, what was the collective thinking before the Hornsdale project happened? Well, let's quickly dwell on this and we are not here to accuse anybody of not being forward. The generally accepted principle was that it was, if you look at this graph from about 2012, we can see again in that red triangle, the maximum size of a Li-ion battery in 2012 was considered to be sort of a maximum of about 1 MW.

Slide 5

Also related with that idea is that we had some publications, again by the Minerals Council of Australia, so we have a little scepticism on this, that large-scale utility scale batteries were expected, if you look at that top figure in that red triangle, to take about 3 years from conception to actual implementation. They did get the scale that it was possible to install 20MW which probably at that time was a reasonable figure but again, long timeframes and small capacities.

Slide 6

This isn't to accuse anybody of not doing their jobs, but this was the prevailing theory at the time was that we are a long way away from batteries actually having an impact on the grid in a meaningful way. Obviously, things happened very quickly after this. The South Australian blackout happened, there was a lot of public discussion. You had the heady mixture of politicians, silicon valley rock stars, billionaire software entrepreneurs in Australia coming together, a lot of public debate, a lot of media scrutiny and the formation of this idea of a large utility scale battery could happen and it would have to happen in a quick amount of time.

There were certain representations in the media making about delivery in 100 days and all those sorts of things. Probably really the underlying thing was South Australia had to do something about their problem and they had to do something quickly. So, the real lesson here is that when there is this real cooperation between industry, government support and

AEMO, because of the serious issue of stability in the SA system, you can get a lot done in a very small amount of time.

Slide 7

This was the parameters that were going to happen for this and a lot of this information was confidential at the time of the project and a lot of the information that I'm sourcing from here is now being publicly disclosed because Neoen has got a public share offering and prospectus, we are able to get a lot more than we could have about a year ago.

The project was the largest one in the world and I think it still is. There are proposals for larger batteries, but I think it's the only one installed and working. One hundred days from signing of the contract took quite a while, but there was a drop-dead date of the 1st of December 2017 for the project. That was the date that everybody on the project knew about and that sort of technically was 62 days after the contract was signed. There was South Australian government involvement as 70MW of the plant was for the South Australian System Protection Scheme so that part of the battery doesn't participate in the energy market per se, as it provides FCAS services with contingency services and 30MW of the battery was proposed to be a commercial operation and the details between Tesla and Neoen are confidential about how that's structured between themselves.

HARD software's involvement was basically that we had a lot of experience in the NEM, being around for twenty years, and the question was put to us…"Well, we need to have some software that takes Tesla's offers and operators need to have some sort of engagement, we need a system to do all that, it has to be done by the 1st of December (this was in September 2017), and no there is no requirement specification. "Can you do it?" and we said, "Sure." One of those things that you can live to regret but it certainly was a serious challenge to get that system delivered.

Slide 8

Basically, what did we have to deal with here? The slide shows what the project had to deal with very quickly. There was no chance of any rule changing to come in to effect within the time frames that we are talking about. At the start of the project, no one was aware of things like that the dispatch engine for AEMO cannot handle any negative generation for a generator. That limitation was a discovery in the early stages of the project. The limitations of the existing market technology were starting to have some impact on the project. Everyone knows about these limitations now, but they didn't know about them at the start of the project.

Obviously, we had to use all the existing NEM infrastructure for generators, there was no possibility for doing anything different. The system had to produce both energy and ancillary services, the revenue model was for both, so there are arbitraging opportunities, ancillary service contingency markets and regulation all to consider. We also had to work out how we organise coordinating all the different parties. Neoen were the actual customer. We also had to deal with Tesla who were the people providing the optimised offers and also a direct financial interest in the operation of the battery that we also had to take into account. How did we do all this when the specification wasn't completed and delivered until about late October? A lot of things were happening in parallel. This involved getting project teams who design user interfaces up to scratch on how the electricity market works and we were able to implement a system.

Slide 9

What were the specific rules that caused problems? Some of these issues have been fairly well articulated before but I will just go over them briefly. I spoke before about not being able to handle negative generation, that means your battery is split into two, you've got a generator and a dispatched load. As things worked out, it was shown that it was best to have all the raise ancillary services on the generator, all the lower contingency services and regulation on the load. I don't think you had to do that, but it just makes your life easier to make sure you've got consistency and you're not bidding in both of those services on both the generator and the load.

So, you've got two offer / bids that go to AEMO. Obviously, the co-optimisation happens from AEMO's market perspective, to make sure that energy is co-optimised with ancillary services for the market, but from the generator perspective, that doesn't mean that your revenue is optimised. So, there is a fair bit of work spent with Tesla working out how the energy market really works, as opposed to just reading the rules out of the rule book and what people's market responses are likely to be, and there is no fast frequency response market designed for a fast response unit such as a battery. The NEM contingency markets were all designed around the technology that was installed at the time, which was gas, hydro and coal units.

Everybody is probably aware of the five minute and the trading price interval averaging that happens. This is bad news for anybody with fast responding plant and this is obviously a market limitation that has been flagged for a whole lot of other reasons. Batteries are one of the reasons for changing the rules here and it's going to be changed in 2021, but obviously not for this project in the initial implementation and now.

What does a fast frequency response market look like? Well again, not many people are talking about his stuff. They are saying there is a market for fast frequency response, but they are not coming up with what does it possibly look like?

Slide 10

In 2017 I was part of a paper that presented what a fast frequency response could look like. We are not saying we have all the answers, but what we are saying this is one possible solution. The idea is that you base all of your contingency and regulation market services about the physical capability of plant and measured frequency response rather than assuming the unit delivering the FCAS service is a gas, coal or a hydro unit. If people are interested in that, I can give them the further details of that paper or provide a reprint if you see me after the presentation.

Slide 11

How did we structure a solution? Obviously, HARD software had to divide the problem up and make sure that we only have loosely coupled and tightly defined interfaces between all the parts and the bit in the middle is software that we developed which is a web API that brings together the user interface, battery status and handles the optimised results from whatever optimiser is used. We don't necessarily have to use a Tesla optimiser, as it can be anybody's offer and the web API handles turning those into the plain text offer formats that AEMO have had around since that start of the market and also take into account SCADA or battery data from an API so that we can display what the battery state is, the amount of the charge and other relevant data.

The most significant competing requirement is that you cannot just fully optimise and run your battery, you must have some sort of oversight or ability to interrupt automated offers as there are NEM participant obligations and one of them is that a generator may be directed by AEMO and you must be able to respond to their direction. A real person has to physically pick up the phone and has to be able to do something when directed to do so by AEMO.

Plus, there was the added consideration that nobody knew how well the Tesla optimiser would perform at the start of the project. No one had done one before in the market with a battery. Tesla had never done one quite like it before either so there was a lot of uncertainty that we needed some sort of oversight to make sure that the optimiser wasn't producing silly results, which didn't happen in reality, but there was a lot of speculation about "is it possible to provide a good NEM optimised solution for a battery?"

Slide 12

As an illustration of how the battery works with a zero-energy dispatch target, (the big orange line in the middle) we can see that the battery is providing both contingency services when we go outside the frequency band (bottom part of the graph in green) and also providing the ongoing regulation services when there are both frequency excursions and when there are no contingency requirements. You can see that the battery provides a very fast response rate. In fact, one of the lessons that was leant is you have to reduce this response rate and make sure that your unit doesn't respond too fast a ramp rate, as the battery is physically able to respond much faster than you probably want in as stable electrical system or otherwise you will also cause issues for frequency stability.

Slide 13

A quick summary of the performance of the HPR battery. South Australia wasn't islanded when NSW connector got hit by lightning and it prevented any load shedding, in SA. The HPR has been to date, very profitable. There's an early adopter advantage here in that they are the only ones in the market for the moment, so they are the ones who are capturing about 10% of the FCAS raised service revenue in the whole of the NEM. Interestingly as other batteries have come into the market, their proportion of the FCAS market has been about the same. The other batteries have taken up extra parts of that FCAS revenue, so that's a shift in the market revenue away from the traditional generation towards storage solutions.

Slide 14

So, what are the lessons that we learnt form the project? Obviously, we are going to need batteries and other storage solutions to get 100% renewable generation in the NEM. You can't just set up a battery and expect it to run on its own. It's going to need some oversight and whether that means that oversight is continuous or whether it is event based is up to the generator but that is obviously a significant part of the cost of the operation of the battery. Optimised offers certainly have a place in the market because arbitrage requires the battery to respond quickly to opportunities in the market. You also need to make sure your offers are providing the FCAS capabilities and that those physical battery state capabilities actually match what your energy and FCAS offers are accepted in the market.

The market rules change over a long period of time and there seems to be little appetite for serious market reform, and we are seeing this a lot in the market, not just in batteries but we are also seeing it in renewable generation. Generators are complaining about large loss factors in the market as loss MLFs are a very blunt market instrument. Loss factors are a one-year averaged figure, determined from power flow studies from AEMO and have their limitations, especially with regard to shifting start dates for significant renewable and transmission projects.

What I believe is the most significant current challenge for storage and for renewable generators, is that we are not talking about fundamental market reform. When we started this market, the industry always imagined the market would develop and yet one of the interim solutions that we had of averaging five-minute dispatch interval prices and metering to a trading interval half hour is now only being removed 20 years after the market started.

No one is talking about implementing nodal pricing, which is a much-improved dynamic matching of the physics of the power system with the economics and therefore providing better market signals to people who are investing money. The reason we can't implement serious market reform is that we now have so many incumbent players. When we started the NEM, we had state owned utilities and not many of them, who had broadly aligned goals. Now we have hundreds of participants all with their own investments, all with their own financial positions and I think the real challenge, which I would like to leave everybody thinking about is, how do we implement significant market reform when there are so many different interests in the market. How do we make the NEM match the power system more closely so that real effective markets signals work and provide the proper economic results for people to make good future investment decisions?

Slide 15

Presentation concluded