Firming A Renewable Energy Zone with Batteries

Introduction

As intermittent generators continue to penetrate the electricity system, firming capacity is required to stabilize the system to compensate for sudden reductions in intermittent, weather dependent electrical energy.

The NSW Electricity Infrastructure Roadmap (the Roadmap) is promoting the establishment of 3 Renewable Energy Zones (REZ) in regional NSW. The New England REZ is planned to have the largest capacity of 8GW. The REZ will need firming. The Roadmap promotes the use of Pumped Hydro as Pillar 2 of the Roadmap and proposes the use of batteries and gas as a source of dispatchable energy for firming the REZ. Gas is a fossil fuel and its use under current policies is likely to be short lived and as Pumped hydro is likely to be over a decade away, it appears that batteries are the most likely source of firming power and energy.

It might also be noted that Australia's Chief Scientist advised that battery storage is still decades away from being able to support a renewables-dominated grid.[1]

Firming the New England REZ.

According to the records of the Australian Electricity Market Operator (AEMO), wind droughts of up to 30 hours duration frequently occur across the whole of SE Australia, where little or no wind blows. Therefore, to compensate for a complete or partial loss of wind generated electricity, we need to "firm" (back up) wind farms power and energy supply during periods of little or no wind.

The performance of the Sapphire Windfarm, commissioned in October 2019 and located close to the New England REZ, can be used as an example to indicate the size and number of batteries that will be required to firm wind generation in the REZ during a wind drought of 30 hrs.

The data below, from the AEMO, confirms the problem with intermittent generation for the 270 MW Sapphire wind farm and will be the basis for our analysis of battery firming.

Sapphire Wind farm Data

Table 1 below provides a summary of the intermittency of energy supply from the Sapphire Wind farm

Performance as % Dispatch for 270 MW	Max (%)	Mean (%)	Min (%)
Maximum Output (See blue line in Graph)	97.5	78.3	0.5
Mean Output (See green line in Graph)	95.2	34.3	-0.7
Minimum Output (See red line in Graph)	94.5	4.8	-1.6

Table 1 Sapphire Wind generator Performance Summary for 2020 year

Figure 1 demonstrates the intermittency of wind generation.

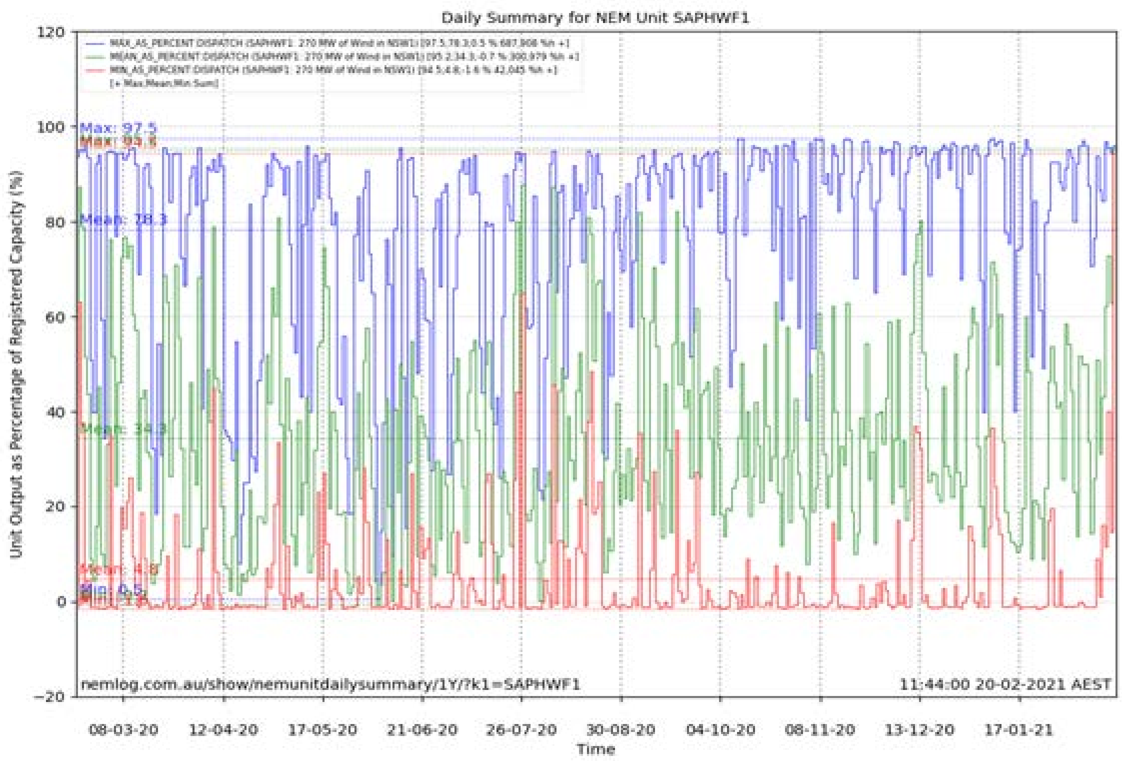

Figure 1 Sapphire Wind generator Performance for 2020 year

The capital cost to build Sapphire wind farm was $590 million i.e. $2.185million/MW.

Cost of Large Batteries

The Hornsdale battery in South Australia was constructed in two phases. Table 2 summarises the costs of the two phases and calculates the differences in costs per MW for the nameplate power ratings.

Phase 1 Specifications and Costs	
Power	100 MW
Energy	129 MWh
Cost	$90 million
Cost per MW ($90 million/100 MW)	$900,000
Phase 2 Specifications and Costs	
Power	150 MW
Energy	194 MWh
Cost	$71 million
Cost per MW ($71 million/50 MW)	$1,420,000
Final Hornsdale Specifications and Costs	
Power	150 MW
Energy	194 MWh
Cost	$161 million
Average Cost per MW ($161 million/150 MW)	$1,073,333

Table 2 Cost calculations for Hornsdale battery

The Phase 2 specifications and

costs above show a significant increase in the cost per MW over Phase 1. This contrasts with the frequent claims by advocates of "big batteries" that the price is plummeting. Since these are the most recent cost data that has been made public, they will be used in the cost calculations for the battery firming required for Sapphire Wind Farm. Note also that it might be safely assumed that most of the infrastructure supporting the battery (land, cabling etc) purchased and constructed during Phase 1 would be common to Phase 2, which should actually reduce the cost.

Firming Battery System Cost

Table 3 summarises the data for the battery storage system and the cost to firm sapphire wind farm for both Power and Energy. Both are required as it is necessary to match the characteristics of a firmed wind farm with that of a fossil fuel or nuclear power station.

Item	**Description**	**Quantity**	**Comments**
1	Battery nameplate Energy rating	194 MWh	Equivalent to Hornsdale battery in SA
2	Battery nameplate Power rating	150MW	Equivalent to Hornsdale battery in SA
3	Loss of available energy during wind drought	2778MWh	(270 MW * 34.3% * 30h)
4	Loss of Power during wind drought	270 MW	
5	Number of Hornsdale size batteries required to compensate for loss of electrical energy for 30 hours	Approx 14	(2778 MWh/194 MWh)
6	Number of Hornsdale size batteries required to provide Mean Maximum Demand (95% of 270 MW).	Approx 2	.(0.95*270 MW/150 MW)
7	Time for supply at Mean Maximum Demand	1.4hrs	(2*194/270)
8	Number of Hornsdale size batteries required to provide Mean Maximum Demand for the full wind drought	Approx 43	(30/1.4*2)
9	Total capital cost for 43 batteries	$9.16 billion	(43 * 150*1,420,000.00 million) This is more than the cost of **3** HELE coal fired power stations.

Table 3 Calculations to determine number of batteries and cost required to firm Sapphire wind farm

Energy Required to Charge the Battery Bank

Assume a round trip efficiency of 80% for Li-Ion batteries to recharge the battery bank.

Item	**Description**	**Quantity**
1	Round trip battery efficiency	80%
2	Battery energy capacity (43 * 194 MWh)	8342 MWh
3	Energy required from the grid to recharge the battery bank (8342 MWh/0.8)	10428 MWh

Table 4 Energy required to charge the battery bank

Time to Recharge the Battery Bank

It is difficult to calculate the time required to recharge the battery bank from the grid as the charging energy available is a function of the grid demand, the available generating capacity and the electrical and thermal characteristics as well as the degradation behaviour of the batteries.
However, if we assume that maximum power used to recharge the batteries equals the maximum power output, Table 5 illustrates the time to charge.

Item	Description	Quantity
1	Maximum output power of Batteries	150 MW
2	Maximum Battery charging power	150 MW
3	Energy required to recharge the battery bank	10428 MWh
4	Minimum Time required to charge	69.5 hours (10428 MWh/150 MW)

Table 5 Time to recharge battery bank.

This means that after an outage of 30 hours the battery storage system is unavailable for at least 69.5 hours depending on the intermittent energy available during the recharging operation. Of course, the wind farm's output could be transmitted to the grid, but that would leave the battery bank uncharged and the system vulnerable to the next reduction in wind energy.
This raises the question "Where does the firming power and energy come from while the batteries are being recharged?"

Renewable Energy Zone in a Wind Drought

The Renewable Energy Zone to be established by the NSW Government in the New England area (NEREZ) is planned to provide 8000 MW of RE generation. As demonstrated by the AEMO wind data wind droughts affect large areas of the country at the same time. Thus, there is a foreseeable risk that wind power from the RE Zone at New England will not be available for periods up to 30 hours and possibly greater. Table 6 below details the capital cost requirement to firm wind generation for 30 hours in the New England RE Zone based on 50 % of the desired name plate output of 8000 MW.

Item	Description	Quantity	Comments
1	Wind Nameplate Output	4000 MW	50% of NEREZ output
2	Capacity Factor	34%	As for Sapphire Wind farm
3	Capital Cost of wind farms	$8.74 billion	4000*$2.185 Million
4	Wind drought duration	30 hrs	
5	Required Energy from Batteries	40800 MWh	4000 MW*30*0.34
6	No of Battery systems required for energy	Approx 210	40800 MWh/194 MWh. Based on battery system at Hornsdale
7	Capacity required from Batteries	3800MW	4000 MW*0.95
8	No of Battery systems required for capacity	Approx 25	3800/150
9	Capacity duration for 25 Batteries	1.3 Hrs	25*194/3800
10	No of Battery systems required for capacity for 30 Hrs	Approx 577	30/1.3*25
11	Cost of 577 battery systems to provide 3800 MW of Capacity for	$122.9 billion	577*150*$1,420,000/MW

	30 Hrs		
12	Total capital cost for Firmed Wind farms	$131.64 billion	(122.9+ 8.74)

Wind Farms

Conclusions

The capital cost to build and firm wind generation in the New England REZ with batteries is nearly $132 billion.

The comparable capital cost for a HELE USC coal fired power station is in the order of $2,75 billion for a 1000 MW plant. Four of these will cost $11 billion and provide dispatchable power for their life. There is no requirement for FCAS and a correctly maintained HELE USC plant can be expected to operate with a minimum of 95% operational availability.

The technical life of a HELE USC coal fired power station is 50 years, while the technical life of a wind farm is about 25 years.

The technical life of a large battery is about 15 years, based on the warranty period for the SA Hornsdale battery.

Hence the life cycle capital cost of wind farms firmed with batteries is significantly amplified by their constrained technical lives.

For the New England REZ to match the power and energy output of 4 in no 1000 MW HELE USC coal fired power stations with an operating life of 50 years, the capital cost would be in excess of $263 billion ($131.64*2) compared with $11 billion for coal.

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[1] https://www.pv-magazine-australia.com/2020/05/28/chief-scientist-says-big-batteries-are-not-ready-to-fast-track-energy-transition/