CT Lab supplementary submission to the House Standing Committee on the Environment and Energy.

This supplementary submission to the Standing Committee is to focus attention on the importance of real-time monitoring and control of the national electricity market (NEM) networks (the subject of our initial submission) and that *it should be considered in the light of an expanded role for the Australian Energy Market Operator (AEMO) in order to provide assurance of system strength maintenance and improvement*.

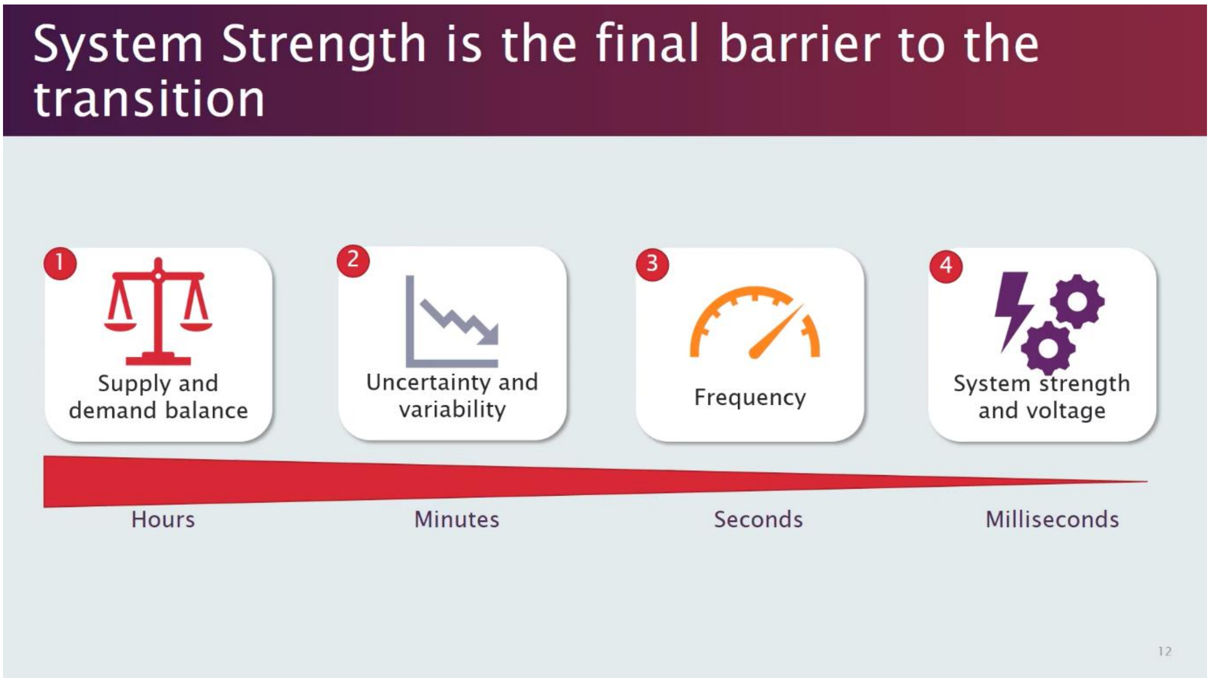
"System strength is the final barrier to transition"
Dr Alex Wonhas, AEMO Chief System Design and Engineering Officer
November 2020 webinar on system strength

In order for AEMO to provide control of system strength, it should have the power to mandate that Australia's network systems including distribution (distribution network service providers—DNSP), transmission (transmission network service providers—TNSP) and generators provide it, on a permanent basis, with appropriate data streams of live, short-interval visibility, electrical parameter data, capable of correlation across the NEM networks, such data structure to be in accordance with AEMO specifications. DNSPs, TNSPs and generators would be free to contract with various suppliers of technologies who comply with AEMO specifications.

Important Note:

Appendix A to this supplementary submission provides committee members with an overview of renewable technologies and with a graphical oversight of their growth and influence on unserved electrical energy projections, the most important parameter in judging the effectiveness of state and federal government policies designed to 'keep the lights on'. The worn out discussions regarding "keeping the lights on when the wind doesn't blow or the sun doesn't shine", need to be replaced with a new mantra: Maintaining Australian System Strength (MASS). It is MASS that requires vigilance as that will provide assurance of supply and dictate economical network design and investment, as well as connection of new generators and schedules for the closure of others.

AEMO should have millisecond by millisecond network control responsibility.



The many options that present themselves all lead Australia towards an accelerating adoption of inverter-based resources (IBR) as these are the interface with transmission and distribution networks, whether we are considering wind, solar or batteries or other non-synchronous sources.

The nub of our supplementary submission is that in recognition of this reality, augmentation of the responsibilities of AEMO is urgently needed because IBR have particular network disturbance influences on distribution and transmission grids as demonstrated by AEMO in its various network studies.

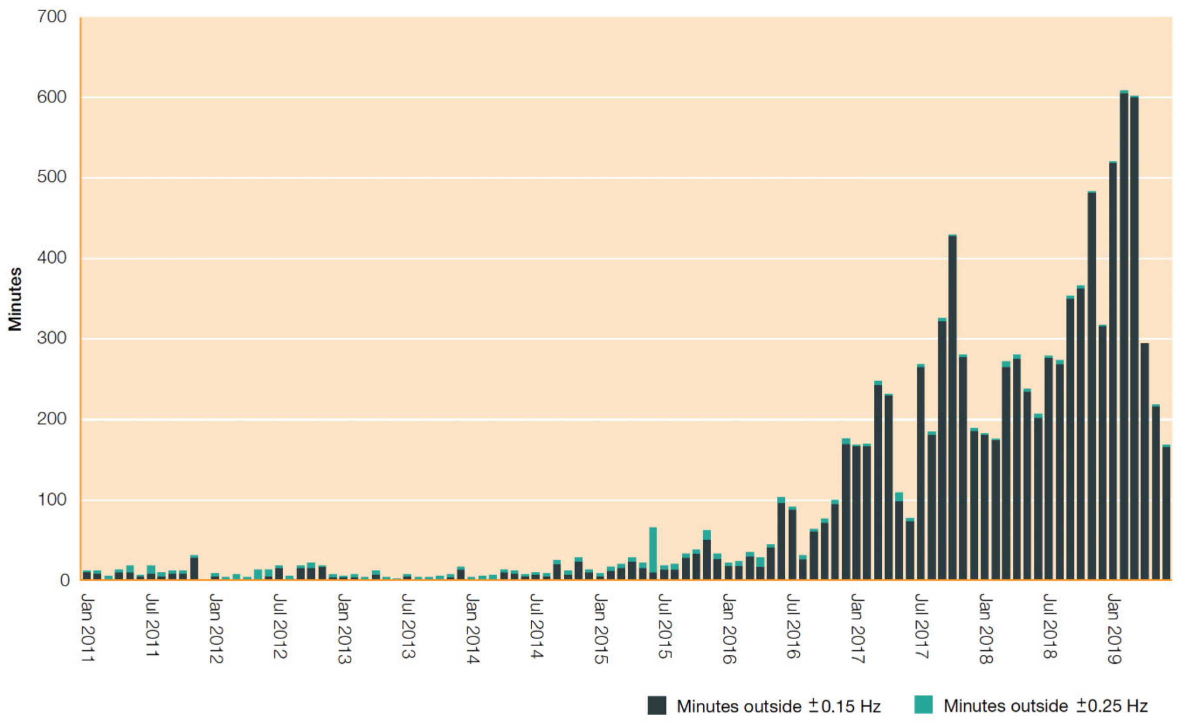
System strength—the only way of keeping the lights and power on.

There is, in effect, no direct market for system strength in the national grids.

Market interventions: in 2019/20: AEMO issued 178 directions to deal with actual or potential supply shortages or system security issues, representing a ten-fold increase over the past three years. The majority (65) were issued to maintain system strength in South Australia when the state was separated or 'islanded' from the rest of the NEM.

As is evident, the interventions by AEMO are concerned with energy balance as well system strength. Although, at present, South Australia's renewable penetration impact is unique within the NEM, Victoria, New South Wales and Queensland with their own highly ambitious renewable targets, can be expected to follow and to stress intervention frequency beyond the practicable level. A real-time control mechanism is therefore needed in parallel with emergency reserve trader (RERT) interventions.

Figure 1.12
NEM mainland frequency excursions

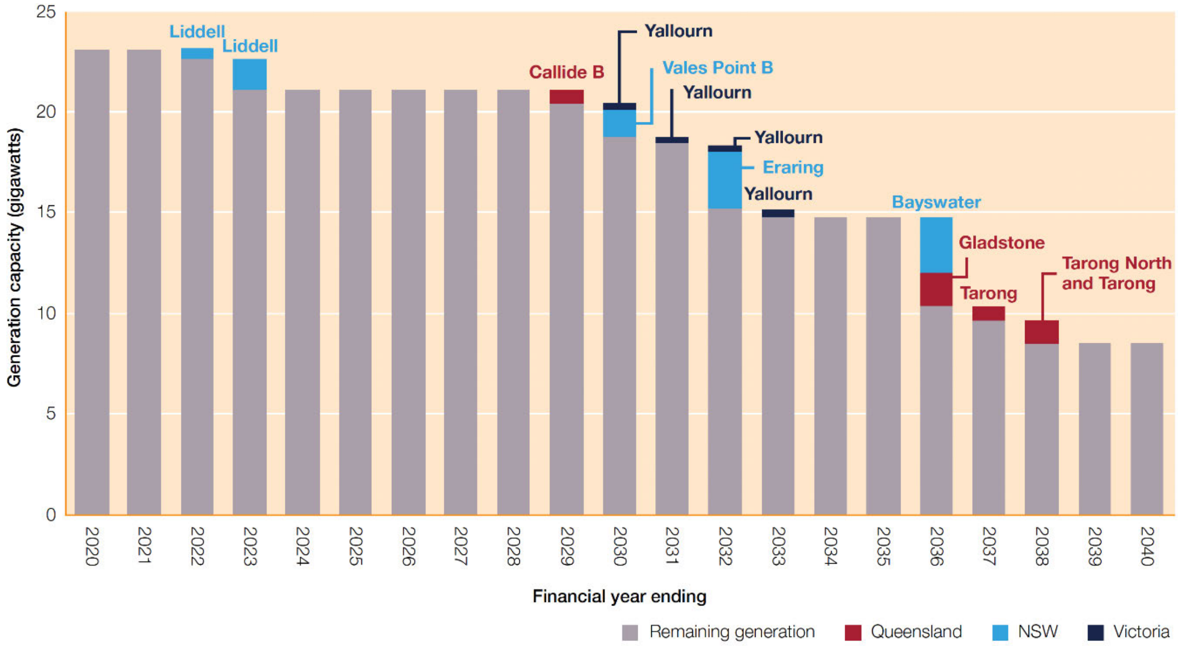


Hz, hertz.
Source: AEMC Reliability Panel, *2019 annual market performance review, Final report,* March 2020.

Although subject to wide fluctuation, frequency stability limits are on average, widening substantially, a worrying trend likely to be exacerbated as more renewable solar and wind generation connect to the NEM. Voltage stability in transmission grids will also require a much stricter and short interval control mechanism as distributed solar generation, primarily rooftop, reduces power flow in transmission lines.

The outlook for continued manufacture of turbines and synchronous generators is restricted by the inroads batteries and inverter-based resources (IBR) are making in the marketplace. The recent collapse of a turbine-generator at Callide C power station, and the advice from the turbine manufacturer, Toshiba, that it had ceased manufacture is a sign of the times. This is not to imply that Australia can rely on purely renewable generation and battery sources as the only form of energy—at present that is an impossibility. Not only do we require conventional synchronous energy generation at present, we also need to follow an evolutionary rather than revolutionary path towards our aim of an eventual, 100% renewable electrical energy supply system.

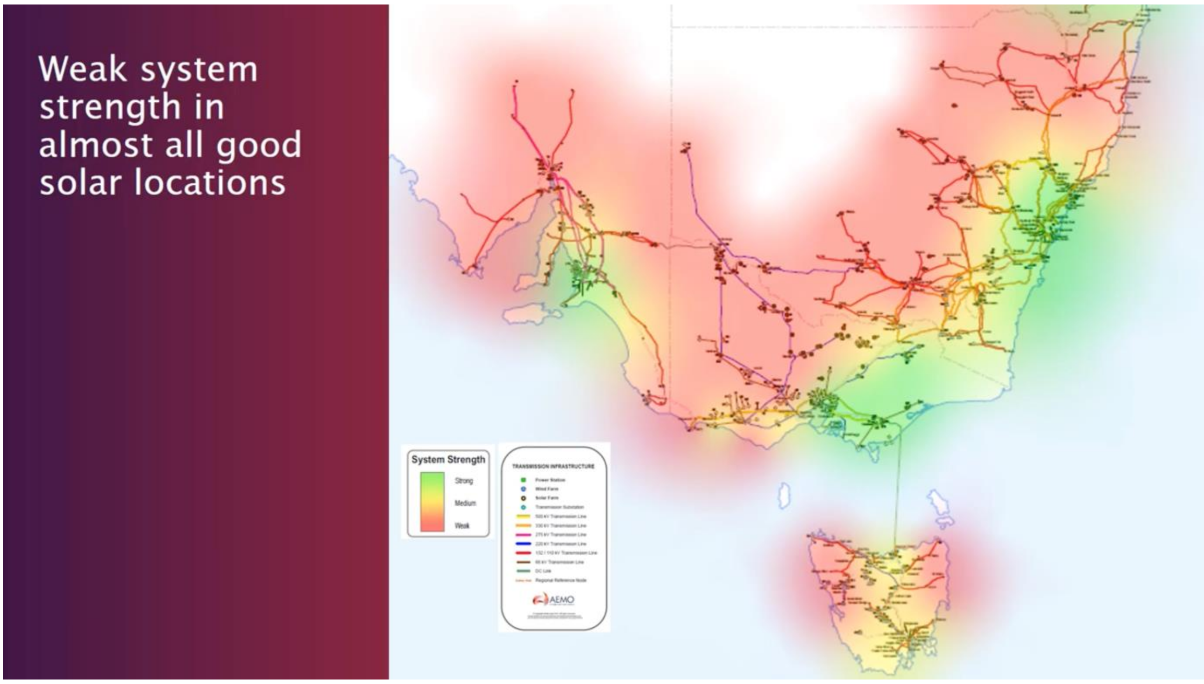
Figure 1.4
Scheduled closure profile of coal fired generators



Source: AEMO, *Draft 2020 integrated system plan*, December 2019.

AEMO technical operations, underlying its integrated systems plans (ISP), conduct simulation studies based on increasing penetration of inverter-based resources (IBR) forming connection to the grid of large-scale wind and solar (VRE) as well as large-scale batteries. These simulation studies are revealing the very different time response features differentiating traditional synchronous power sources from IBR.

An explanation as to the essence of the influence of IBR on our national networks is appropriate in order to underscore the basis of our supplementary submission. The map below indicates the spread of the grid throughout the south eastern states, with coloured areas indicating the strength of the networks.

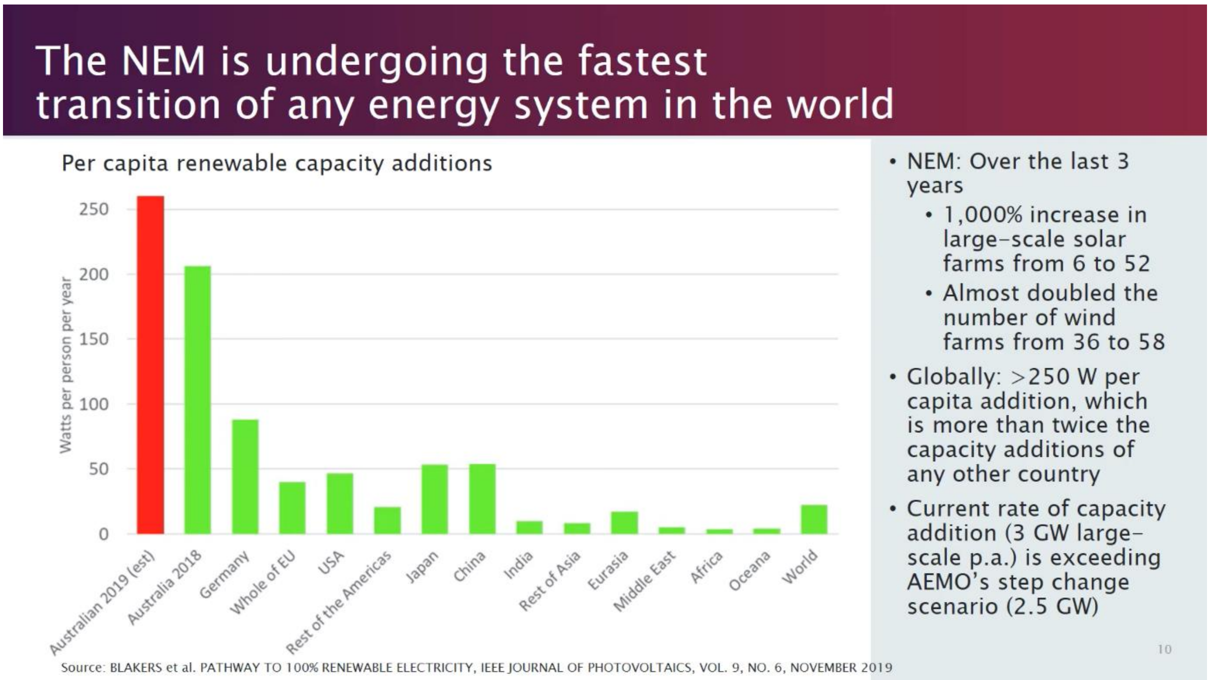


System strength relates to limits imposed on power transmission, which when exceeded, causes instability. It should be noted that weak networks (red zones) respond differently to synchronous generation than to IBR. The latter are responsible for heightened voltage and frequency instability, requiring AEMO to carry out special studies (electromagnetic transient—EMT studies) on most networks prior to connecting IBR to remote energy zones (REZ). However, the enormous computer power required to carry out such studies in real-time (i.e. during operation of IBR) requires a tailored approach to the monitoring and information system which is part of our initial submission. An AEMO-compliant network visibility systems would rapidly lead to stable incorporation of IBR, this being particularly important in light of declining synchronous capacity.

Appendix A

Facts and strategies concerning development of the NEM with increased renewables:

Australia is in the vanguard of renewable adaption (and most often quoted as the world's testbed)



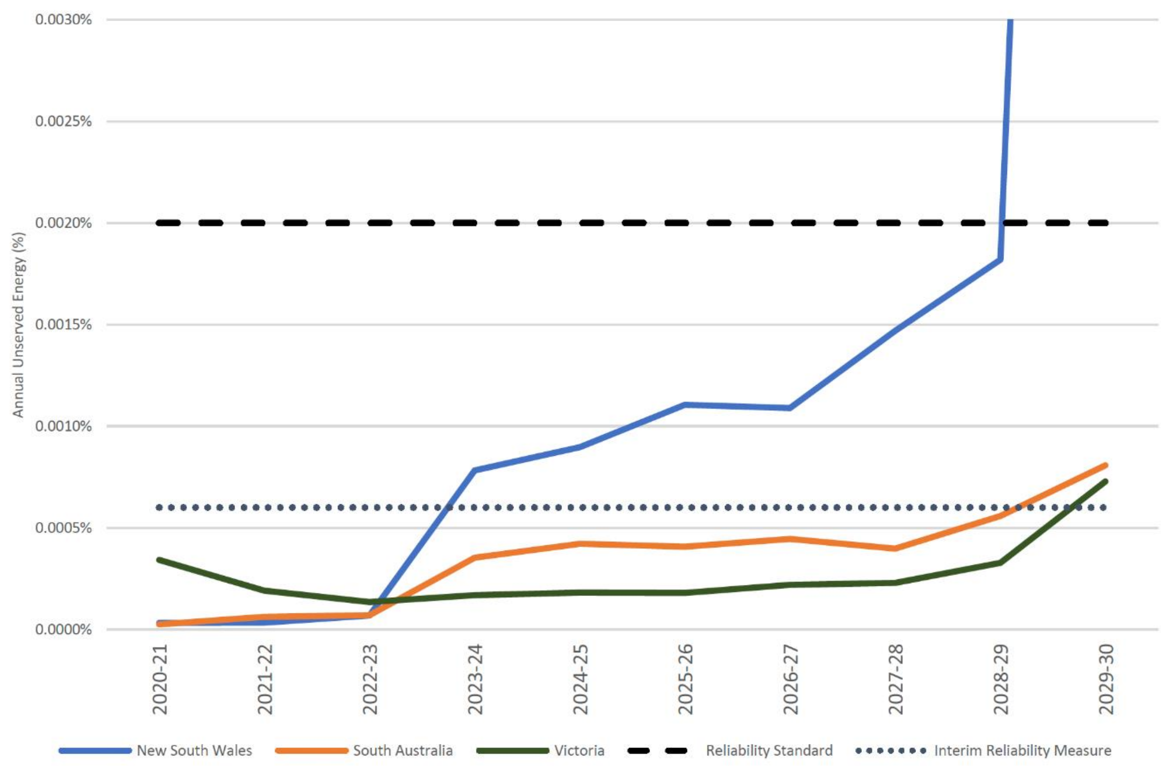
Is a 100% Renewable Energy Source Grid a Reality?

Yes, but Maintaining Australian System Strength (MASS) is the 'here and now challenge!

A 100% renewable electrical supply system can be a reality; however, it depends on the technology mix. For example, a mix of hydro, or politically more controversial nuclear generation, and wind, solar and batteries is in principle a sound system.

A 100% renewable electrical supply system comprising of only wind, solar and batteries has not yet been demonstrated on any realistically practical scale. It is, however, a field in which much academic research is taking place. For example, ESIG (USA-based Energy Systems Integration Group), EPRI (USA-based Electrical Power Research Institute) and NREL (USA-based National Renewable Energy Laboratory) are involved in renewables integration studies.

FIGURE 22 FORECAST UNSERVED ENERGY OUTCOMES



SOURCE: AEMO, ELECTRICITY STATEMENT OF OPPORTUNITIES, 2020

Australia is the developed world's unique testbed for system strength—and it is system strength maintenance that is the overriding responsibility of electrical engineers. The AEMO 2020 system strength graph projections (in terms of unserved electricity) is the very thing Federal, State and Territory Governments should be very concerned about because AEMO's integrated systems plan (ISP) is in 'step change' mode (AEMO terminology for 'runaway' adoption of solar and wind generation). Without MASS, the lights will not stay on!

Europe and the UK are not a template for Australia.

European examples of countries such as Denmark having at times 100% (and higher) renewable generation are misleading if translated as practical examples for Australia. Western Europe is part of a large interconnected grid in which renewables are much smaller fraction than is the case for Australia.
The UK is connected to France and the Netherlands, with more interconnectors to France being planned. Ireland, an example quoted by ESIG, is connected to Scotland. Ireland has limited its wind power to 50% in order to preserve system strength.

Australia has a skinny grid which, when the NEM was conceived, comprised of essentially independent State and Territory based power systems that were 'synchronised' by way of a few interconnectors. A skinny grid is one in which generators are at long physical (and electrical) distances from one another. Electrically, this poses technical challenges when interchanging power flow between erstwhile independent regions.

Built-in redundancy for security can be very costly.

From 2007 onwards the at first very gradual penetration of large-scale wind and solar, did not affect the basic reliability of the national grid. Now, the penetration is, depending on the State (South Australia can approach 80% and higher) a serious challenge to stability and security.

Solutions for system control to provide stability, resilience and security include the 'belt and braces' approach. This means more hydro, more gas-fired generation and more interconnectors, effectively building in redundancy to provide security. Hydro and gas, and a second interconnector to Tasmania are providing a balance against higher penetration of renewables. These major infrastructure investments must be met by (a) increased debt, (b) increased tax and/or (c) increased charges to energy users.

Experimentation can be costly and impair reliability.

The NREL of the USA predicts that 100% renewables would require at least 70% additional capacity by way of batteries (note: this a theoretical model-based prediction in which all renewables and batteries connect to the grid via inverter-based resources (IBR)).

The current State-based renewable targets may well be, electorally speaking, attractive but in terms of currently available IBR technology, will require more gas and hydro as coal-fired generation diminishes. It must be understood that the term 'grid-firming' when applied to battery resources, although of itself not misleading IF there is synchronous generation capacity available, does not imply that grid-firming battery resources can replace synchronous generation entirely. In practical terms the IBR technology that could possibly replace traditional synchronous generation is as yet unavailable and untested other than as mathematical equivalents in mathematically modelled networks.

A new approach to the integration of renewables is needed.

The current, fragmented approach to integrating more renewables, in the absence of a centrally-based engineering plan, with supervision and control based on a contiguous, live database monitoring all generation, transmission and distribution, will result in impaired security and/or in an ad hoc approach, propping up the system as problems such as the blackout in South Australia in 2016 occur. It is to be noted that Australia would be pioneering monitoring and control systems to manage its increasing penetration of renewables. However, it would provide opportunities for a local technology base as well as export potential for many companies working in conjunction with academia. Much published work is available from Australian academic sources that address required control schemes. This knowledge could be exploited in conjunction with a technology base including contributions from CT Lab's Australian operations, planned to be in place early 2022.

AEMO and its role.

AEMO has the expertise to be a driver of a central control approach. Indeed, it is well aware of the problems associated with the rising level of renewable penetration. AEMO carries out highly sophisticated modelling based on electromagnetic transient (EMT) analysis of networks including those of remote energy zones (REZ) where renewables are situated. These studies reveal the challenge renewables are posing in terms of stability and grid strength. However, AEMO's visibility of distribution grids where the largest impacts of rooftop solar are felt, is basically non-existent other than on a previous 24-hour timelapse basis. An integrated, contiguous, synchronized monitoring and data base (meaning that all events and disturbances on the entire network stretching from Queensland to South Australia, and all distribution network zones are capable of correlation) would provide AEMO with the basis for comprehensive control.

At present, other than for Reliability and Emergency Reserve Trading (RERT interventions and curtailment interventions, there is no direct control exercised, therefore jeopardizing system strength. This is a major concern of the ESB as system strength is increasingly affected. Distribution networks with their millions of rooftop solar systems take no part in system strength, in fact, negatively because during periods of strong sunlight, transmission demand can drop to such low levels as to cause excessive voltage on transmission lines. Voltage control during periods of low demand is of increasing concern to AEMO.

Household and communal batteries—the future role of rooftop solar.

Household and communal batteries, of use in preventing excessive infeed of rooftop solar energy and certainly proving of economic benefit to energy consumers, play no role in grid strength maintenance. Bespoke solutions to control solar output such as those being implemented by South Australia's ElectraNet and earlier experimentation with so called grid support by means of virtual power plants (VPP) based on household batteries as initiated by AGL in 2016 have proven to be of limited value to distribution networks, and to have no positive effect on network strength.

As renewables, both large scale (VRE) and small scale, distributed energy resources (DER), chiefly solar, in distribution networks continue to grow, an impasse is being reached. Curtailment of household solar as well that as already practiced from time to time for VRE, would have to be implemented to conserve grid strength. Currently some distribution networks are experimenting with solar inverter control but that is for voltage control within the distribution networks and not for NEM grid system strength.

A new approach revisited.

Australian governments should urgently contemplate extension of AEMO's charter for the management of system strength. In many ways we have avoided grasping the nettle, for example by rule change proposals to the AEMC, such as Transgrid's (see below). Using these forms of rule change, although by themselves reasonable, ultimately result in a pastiche with all manner of special conditions—a highly complicated mosaic, inimical to comprehensive management of system strength.

Draft rule determination

The draft rule proposes three main elements, which we have described as being relevant to the supply, coordination and demand for system strength:

- ***Supply side:*** *System strength services will be supplied through a TNSP (transmission network service provider) led procurement of system strength. TNSPs, working closely with AEMO, would be responsible for providing efficient levels of system strength on a forward looking basis over the given timeframe. The TNSP would provide system strength as a prescribed transmission service, with the TNSP required to meet a system strength planning standard at certain locations on its transmission network.*
- ***Coordination:*** *The system strength mitigation requirement, which would provide connecting parties with IBR a choice between paying to use the system strength provided by the TNSP or providing their own system strength by remediating their impact. This mechanism would mean that while customers would bear some of the initial cost of providing system strength services, over time this cost will be recovered from connecting parties.*
- ***Demand side:*** *New access standards, to ensure that connecting parties with IBR would only use the efficient volumes of this valuable common pool resource. The new access standards also underpin the coordination measures, by allowing generators to undertake actions to reduce the amount of system strength they require.*

Of course, access standards for VRE to transmission grids require rules designed to facilitate system strength, but as AEMO's studies of EMT phenomena make clear, a future national grid without very tight, short interval, real time measurement and control is inconceivable. The yellowed area in the above rule change proposal is in effect blind to the effect of even short-term disturbances in an environment where mainly IBRs connect to the grid and participate in energy delivery. The red print in the proposed rule change assumes that contingency analyses will be sufficient for determining the level of remediation (whether by the connecting energy source, or the network or a cost sharing arrangement, i.e. this goes to the economics rather than the assurance of stability, short term or long term).

At present we manage by retaining synchronous generation sourced from existing plant and restraining plant closures, as well as building new gas fired plant. However, as more IBR enter the grid, the more we will have to rely on fast, real time monitoring and control.

Australia should remain in the vanguard

Australia is in the vanguard as early adopter of renewables in its grids. It is also very likely to suffer grid instability and grid strength issues as a result of being an early adopter, as it continues to essentially control its new fleet of generation that is steadily replacing legacy generation, with legacy monitoring and control. CT Lab, which provides South Africa's ESKOM national grid with thousands of synchronous monitoring points and Big Data system amassing real time data, is proposing to collaborate with other Australian technology providers and academia in a new commercial venture to be in place by early 2022. The new company would design and implement, where directed, for example by AEMO, synchronized monitoring and secure Big Data throughout the NEM while designing a number of inverter-based resources (IBR) and network control paradigms for testing and evaluation. However, as mentioned in our submission, the field for monitoring and control systems would be opened up to potentially many other technology participants and does not imply exclusivity to CT Lab technology.

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