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Australia's Opportunity To Plan Ahead for a Secure Zero-Emissions Electricity Grid

Towards Ending the Reliance on Inertia for Grid Stability

Executive Summary

Australia's National Electricity Market (NEM) is at the forefront of the transition from thermal power generation to renewable energy. With planning and reforms currently in development, there is now an opportunity to define the end-state of the transition, resulting in a grid that is future ready.

In the past, the large spinning masses of the national coal generator fleet were always there providing the inertia to smooth out disturbances and faults that affect grid frequency, and which might otherwise lead to instability and potential blackouts.

Now that renewables are on the rise and coal plants are being squeezed out of the market, there is less inertia in the system, and grid security has become a primary concern for grid operators and planners.

To address this concern, energy agencies are establishing a new market for procurement of inertia. Wind, solar and batteries are connected to the grid with power electronics and do not provide inertia, but they can be configured to emulate the inertial response of spinning machines, and therefore provide the same stabilising services. As the generation mix shifts, this so-called 'virtual' inertia will contribute to grid stability through participation in the inertia market, alongside traditional synchronous inertia from thermal generation plants, hydro plants, and other sources and loads that are synchronously connected to the grid. However, technologies that provide 'virtual' inertia have substantially different operational characteristics compared to traditional power plants.

There will need to be fundamental changes in the way the grid is planned, designed, built and operated.

To make way for the necessary renewable energy future, there will need to be fundamental changes in the way the grid is planned, designed, built and operated. Along the way, as the grid becomes more distributed and flexible, synchronous machines will become increasingly difficult to accommodate. In fact, the technologies that allow renewables and batteries to replace physical inertia, if correctly designed and controlled, would lead to a more reliable, secure and higher-performing power system that does not rely on inertia at all.

With 225 gigawatts (GW) of proposed renewable and battery projects in Australia[1], capital markets and project developers are lining up to deliver the next generation of energy infrastructure. Sustained investment will rely on broad national acceptance of a future grid framework that is substantially different to the grid of today – one highly automated and based on non-synchronous renewable energy generation.

We recommend that current planning and design should consider a scenario that involves shifting to a new grid framework that does not rely on traditional inertia.

Decarbonising Australia's Electricity Sector

The impending impact of climate change on global economies has further heightened public awareness and political debate on the issue of decarbonisation.

The power sector is currently the largest bulk source of carbon emissions globally, accounting for about 36% of total emissions across advanced economies.[2] Transport, industry and agriculture make up the balance.

Although the electricity sector is considered by many to be the easiest sector to decarbonise, the pace of the transition to cleaner more sustainable energy has tended to be slowed down by the legacy of political, financial and ideological barriers from past eras. However, the world is moving on, and these incumbent forces now appear to be diminishing under the weight of economics that favour a clean energy future, and a growing consensus among public, corporate and many government voices, that the age of fossil fuel power generation is all but over.

The age of fossil fuel power generation is all but over.

In the context of Australia's National Electricity Market (NEM), the transition to clean energy is slowly overcoming the drag forces of unsettled national climate and energy policy and the excessive concentration of market power by a small number of large generator-retailers (gentailers).

[1] RenewEconomy. Australia's battery and hydrogen storage pipeline jumped by massive 20GW in 2020. 19 February 2021.
[2] International Energy Agency. Global CO2 emissions in 2019. February 2020.

The increased uptake of wind and solar over the last decade verifies the economic viability of these sources, and new grid-scale battery projects suggest that storage is now considered an investible asset class, together heralding the beginnings of a flexible future grid powered by renewables.

The energy sector needs to re-think how the electricity system will operate in the future, beyond the next 15 years. A grid that is supplied primarily by renewable energy will require substantially different physical and operational designs.

Taking a step-by-step approach to the energy transition runs the risk of creating a grid that does not meet future requirements.

The energy sector needs to re-think how the electricity system will operate in the future.

This paper considers the potential for a new grid framework to enable grid security as renewable generation increases towards 100%.

The Changing National Electricity Market

Despite the growth of renewables, the NEM today is still dominated by fossil fuels, with over 77% of generation coming from coal and gas during the period from July-September 2020.[3] This is expected to change in coming years.

Large-scale renewable energy development plans announced by state governments[4], partially underpinned by the Australian Energy Market Operator's (AEMO) Integrated Systems Plan 2020 (ISP), signal a somewhat incongruent yet persistent movement away from legacy thermal generation to flexible renewable generation. When overlaid with the Australian Government's Technology Roadmap, and with the Energy Security Board (ESB) working to implement recommendations from the 2017 Finkel Review[5], the physical power system and financial settlement market are becoming increasingly complicated and inefficient, with no clear objectives or governance for achieving necessary decarbonisation.

The pending early retirement of the thermal generation fleet from the NEM, and inevitable replacement by variable renewable supply firmed by storage, imposes a challenge that is already confronting the NEM.

According to the ESB[6] as of December 2020:

> "*System security remains the most concerning issue in the NEM. Maintaining the electricity system within the required parameters for*

[3] Australian Government. Australian Energy Update 2020.
[4] For example, the NSW Electricity Infrastructure Roadmap 2020, and the Victoria's Renewable Energy Action Plan 2020.
[5] Dr Alan Finkel AO et al. Independent Review into the Future Security of the National Electricity Market. 2017.
[6] Energy Security Board. The Health of the National Electricity Market. 2020.

frequency, voltage, inertia and system strength becomes harder as variable renewable generation increases its presence in the NEM."

The issue of system security has already risen to the top of the pile when renewable supply is still at modest levels. As thermal generation exits, likely at an accelerated pace, the system security challenges will become even more acute.

Future Electricity Market Picture Unclear

The ESB is presently working on Post 2025 Market reforms, many of which are being designed to provide reliability and stability in the grid during the transition, although it is not clear exactly what the NEM is transitioning towards.

Stakeholders would agree that a stable transition of the grid, from fossil fuels to renewables, is essential. Current reform planning involves introducing new markets and mechanisms for Essential System Services (ESS) such as frequency response, inertia and system strength.

It is not clear exactly what the NEM is transitioning towards.

AEMO's ISP offers a viable roadmap for the transition, including specification of an *optimal development path* for the most cost-effective solutions that meet the NEM's reliability and security requirements, but it is based on supporting legacy technology put in place decades earlier.

In all ISP scenarios, synchronous generation, mainly from fossil-fuel generators, forms the basis for grid stability all the way out to 2042 and beyond. This reliance on legacy assets is likely to limit future possibilities, and there is a risk of preserving a synchronous grid model in a system that is moving rapidly away from synchronous generation.

If the reliance on synchronous inertia were to be reconsidered, then new grid paradigms would become possible, with the potential for reliable and secure supply from 100% renewable energy at lower cost. It has already been established that renewables are the cheapest form of new power[7], so the cost to consumers in the long run should be minimised under scenarios that work towards 100% renewable energy supply.

This paper proposes an alternative grid paradigm – one that is reliable, secure, affordable, and with zero emissions.

[7] CSIRO/AEMO. Gencost 2020-21 Consultation Draft.

An Historical Reliance on Synchronous Inertia

Originally, electricity grids in Australia were set up for one-way power flow, from a small number of centralised coal-fired generators to a large number of distributed power consumers.

That model largely remains in place today. All of the coal-fired generators involve very heavy machines rotating at a precise speed that electro-mechanically matches the 50Hz frequency of AC power across the grid. The mass and speed of these rotating machines represent a large store of kinetic energy, which gives them significant inertia.[8] This inertia has always been there providing stability to the grid. For example, if a large generator suddenly trips out, then there will be a sudden imbalance between supply and demand in the grid. Kinetic energy from synchronous inertia will automatically and instantaneously make up the deficit, but the machines will slow down slightly, and since they are synchronous, the grid frequency will drop. The inertia slows down the rate that the frequency drop, such that the system can generally remain stable for a short time until Primary Frequency Control mechanisms can be applied to restore the balance. It is this first response that is critically important to maintaining grid stability, which is why the inertia of turbines has always been important in the past.

Wind, solar and batteries are connected to the grid with power electronics units, called inverters. Although wind turbine rotors do have some inertia, they spin at variable speeds and are electro-mechanically separated from the grid (i.e. asynchronous), so do not provide instantaneous inertia like synchronous machines. Solar plants and batteries do not have any inertia. Typically, these Inverter Based Resources (IBRs) operate by sensing the grid frequency produced by synchronous machines, and then producing power that follows this frequency. They are 'grid-following' devices.

As more and more IBRs enter the market, displacing synchronous generation, the overall inertia in the grid is declining, leading to challenges in maintaining frequency stability with traditional methods and markets.

The overall inertia in the grid is declining.

The energy transition is inevitable, so the challenge of operating large grids with very low or zero inertia will become more confronting. As we explain below, the transition to IBRs will actually reduce the need for inertia. It will become less and less important, and eventually it will be irrelevant.

We suggest that current planning and design should consider a zero-inertia grid as a possible future scenario for the NEM.

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[8] Inertia is the resistance of a physical object to a change in velocity. It is the subject of Newton's 1st law of motion.

Today Inertia Levels Are Decreasing

The growth in rooftop solar installations in Australia since 2007 is accelerating (39% year-on-year increase in 2020[9]), and is predicted to continue.[10] In 2025, forecasts by Green Energy Markets suggest that rooftop solar PV capacity will exceed the capacity of the national coal-fired generation fleet.[11] When combined with utility-scale solar, this will exacerbate the decline of coal and outdated baseload gas power plants in the electricity market due to minimal daytime demand, potentially triggering exits earlier than expected. Modelling by IEEFA suggests that 3-5 coal-fired plants in the NEM could have negative EBIT[12] by 2025.[13]

The AEMO Renewable Integration Study (RIS) indicates that by 2025 the NEM could operate with up to 75% instantaneous supply from wind and solar under the ISP Central scenario and at times up to 100% under the ISP Step Change scenario.[14] Inertia levels could drop by 35% by 2025 and would presumably decrease further as coal-fired generators retire.

One of the challenges is to maintain a minimum level of synchronous inertia as coal-fired generators are displaced.

The operation of the NEM is based on a legacy configuration with frequency stability provided by synchronous generation from coal, gas and hydro plants. As the NEM invariably shifts to rely more on IBRs than on synchronous generation, the disjointedness of the grid becomes greater.

The operation of the NEM is based on a legacy configuration.

Much of the planning and policy development occurring now seems to focus on the burden of accommodating IBRs and on patching the system such that it remains operational under the synchronous generation framework.

For example, the AEMC rule change request submitted by Delta Energy in July 2020, calling for a 'Capacity commitment mechanism for system security and reliability services'[15], seeks to establish an ancillary market to "*provide a payment to non-peaking dispatchable generators to remain online at their minimum safe operating level (MSOL) should they be needed for system security or reliability purposes*". Under such as rule change, consumers would be expected to

[9] RenewEconomy. Rooftop-solar-market-ends-tricky-2020-by-smashing-records-surpassing-13gw-total-capacity. January 2021.
[10] Small-scale Technology Certificates, Updated Forecast 2020-2024, Green Energy Markets report to Clean Energy Regulator.
[11] AFR. Rooftop solar will eclipse coal-fired power in 2024. January 2021.
[12] Earnings Before Interest and Taxes (EBIT) is an indicator of a company's profitability.
[13] IEEFA Australia. Coal plant closures imminent as renewable energy surges.
[14] AEMO. Renewable Integration Study. 2020.
[15] AEMC. Capacity commitment mechanism for system security and reliability services. July 2020.

pay for coal-fired plants to idle in the background, waiting for when they may be needed.

One way or another, the "market" will fill the vacant capacity with the lowest cost form of new supply, which is wind and solar and storage. All of this new supply will provide power to the grid in a very different way to the thermal generation that it displaces because it is variable, distributed, asynchronous, and does not provide any inertia.

Somehow, the system will need to accommodate a large percentage of zero-inertia inverter-based renewables, and still provide reliable and secure power.

By moving more quickly to a system that does not rely on synchronous inertia, the NEM could be operated more flexibly and efficiently, which would minimise cost to consumers.

Weaning the Grid off Synchronous Inertia

At present, the NEM relies heavily on synchronous generation.

In November 2019, Hydro Tasmania submitted a rule change request to the AEMC for adding a payment for synchronous services (inertia, voltage control, system strength) into dispatch.[16] This rule change, if created, will provide financial incentives to synchronous generators, potentially allowing them to operate profitably for longer. However, equivalent services as provided by IBRs should be included in any change of this type, and a broader approach to system services should be considered.

A broader approach to system services should be considered.

This is backed by a U.S. National Renewable Energy Laboratory (NREL) study in 2020[17], which concluded that IBRs (wind, solar, and batteries) can quickly detect frequency disturbances and respond to contingency events by rapidly injecting power into the grid. In fact, these electronic-based resources can be configured to respond many times faster than the traditional mechanical response from conventional generators, thereby reducing the need for inertia. Further, by introducing IBRs and shifting to a distributed network made up of smaller generators (relative to large thermal plants), the need for inertia becomes less.

As noted by NREL:

> "*First, these resources decrease the amount of inertia available. But second, these resources can reduce the amount of inertia actually needed—and thus address the first effect. In combination, this represents a*

[16] AEMC. Synchronous services markets.
[17] NREL. Inertia and the Power Grid: A Guide Without the Spin. Technical Report. NREL/TP-6A20-73856. May 2020.

paradigm shift in how we think about providing frequency response."

In addition, a new class of IBRs based on "grid-forming" inverters can create the voltage waveform and provide system strength for grids that are operating in synchronous mode with low inertia. According to Matevosyan *et al*[18], if nominally 10-30% of IBRs are based on grid-forming inverters, then the balance of generation can be passive grid-following inverters.

The long-term future of the NEM will involve millions of distributed IBRs and very few, if any, large synchronous machines. Therefore, it would not make sense to design and build the next-generation NEM around a synchronous inertia paradigm, as there will be a high risk of stranded assets and sub-optimal grid operation.

For now, and in the near future, there would seem to be no other way to maintain grid security other than to ensure there is enough inertia in the system. This is being pursued through new market mechanisms, and by requiring network service providers and new generators to 'do no harm' to the grid, which may involve them investing in long dated pumped hydro storage or synchronous condensers[19]. These investments, and the market structures that incentivise or necessitate them, should be scrutinised.

Large-scale inertia infrastructure will be superfluous in a future post-transition grid.

Large-scale inertia infrastructure, such as synchronous condensers, developed for the purpose of providing system security, will be superfluous in a future post-transition grid that has little or no synchronous inertia, and can be managed entirely with power electronics and low-latency digital communications.

Managing the power system will be challenging as inertia is reduced, primarily at the far end of the energy transition when fast-frequency-response IBRs are able to operate stably and flexibly but are still beholden to a few remaining slow-responding synchronous generators. The two types of systems will not work well together due to different time-response characteristics.

The entire transition may be akin to a weaning process, but there is no other way to do it as consumers need the power system to operate reliably, securely

[18] IEEE Power and Energy Magazine. Will Grid Forming Inverters be the Key for High Renewable Penetration? December 2019.

[19] Synchronous condensers are large spinning machines that do not generate active power but do provide inertia. They are installed to help with grid stability. ElectraNet in SA has procured four new synchronous condensers, which are expected to be operational in 2021. The $180 million cost of these units will be recovered from consumers over their 40 year operational life, but these costs should be offset by reducing the costs incurred by AEMO in compensating gas plants that would otherwise be called upon for system services.

and affordably as the changes happen. Some contribution from inertia markets, synchronous generators, and synchronous condensers will be needed up until new technologies, control methods, and grid architectures are developed and implemented.

As stated by Ackerman et al[20]:

> "*In the near to medium term we will require a managed balance of inertia-providing and non-inertia-providing devices, the choice for each device being made with consideration to the properties of the energy source connected. However, in the long-term a more holistic system planning approach is needed. Band-aid solutions applied in the interim by system operators world-wide to maintain reliability may inadvertently limit further integration of inverter-connected devices.*"

Eventually, if and when the entire network migrates to non-synchronous generation, grid operation may be more distributed and flexible, and security will increase under a new grid paradigm.

Re-Imagining the Next Generation NEM

Much of the energy planning and policy development work occurring today focusses on the transition period, during the next 10 to 15 years. It seeks to shore up security by ensuring there will be enough inertia available to stabilise the system at all times.

The planning should also consider the foundations of a next-generation NEM – one that will provide a platform for a fit-for-purpose grid after the transition to renewables is more or less complete in 10 to 20 years. Stakeholders will need to form a shared vision for the future grid that extends beyond this timeframe.

The status quo option is to move forward on the basis of maintaining more-or- less the same operating paradigm, as established in the past for synchronous generation, and to manage the transition to high penetration of IBRs by ensuring there is enough inertia and operating reserve in the market. This is the option currently in development by the ESB.

The future grid will be as much a digital communication system as it is an energy management system.

Another option is to manage the transition under the synchronous model, as an interim measure, but to start considering how to go about a fundamental transformation of the network, in parallel, such that it can be essentially switched over to a new operational model once the legacy generators have exited.

The future grid will be as much a digital communication system as it is an energy management system.

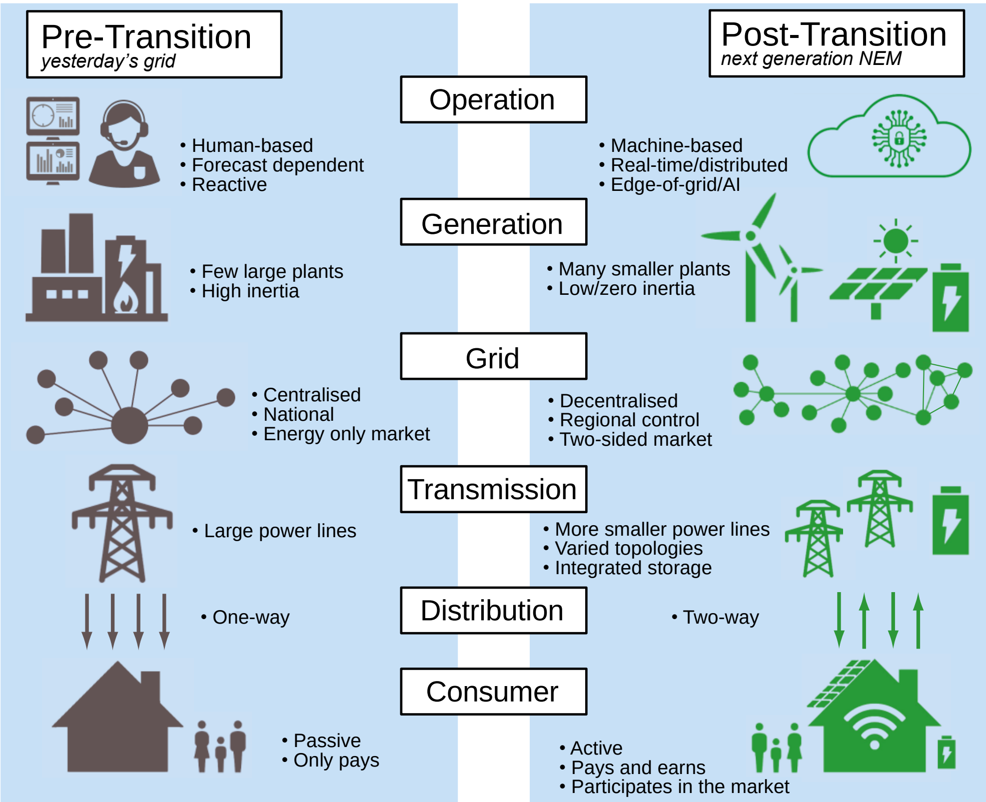
[20] Ackermann et al. A future without inertia is closer than you think. 2017.

Rather than thinking about energy being generated, transmitted, distributed and consumed, it is possible to start imagining a network with generation and consumption more localised and interdependent, with the grid functioning as a tapestry of highly-interconnected regions. Generation, storage and load would be optimally controlled via low-latency digital communications networks, edge-of-grid regional control methods, with real-time distributed computing, all orchestrated with artificial intelligence. This will require that the digital and data systems are developed in tandem with energy systems, starting now.

The regulatory frameworks and market structures are also likely to be quite different to those that are currently being developed, so planning for future alternatives should be on the table in the current discussions.

As outlined in Figure 1, the next generation NEM could be substantially different from the grid of the past and will require fundamental changes at every level. Just building on top of what we have today will not deliver the best outcomes for the post-transition power system.

Figure 1: The Difference Between Yesterday's Grid and the Next Generation NEM



Source: Tim Finnigan.

At present, the NEM is a long thin interconnected system, with bulk power and frequency control ancillary services (FCAS) transferred between regions via inter-connectors. This configuration seems to be taken for granted as the best one for the future, and it is rarely questioned. While technologies that connect to the grid are rapidly advancing, the transmission and distribution system itself does not appear to be evolving at the same pace.

Under a future scenario whereby the grid is populated with millions of non-synchronous IBRs, as both sources and loads, different grid architectures may be more suitable. In fact, it could be beneficial to modularise the grid, and link smaller regions together with DC connections, allowing for the potential to island grid patches or sub-regions in a coordinated manner to support system wide stability.[21] Indeed, as noted by Kroposki et al[22] for example, micro-grids have been operating reliably for years with zero inertia, and allowing different parts of the grid to operate under different inertia and frequency control scenarios could be one way to manage the hybrid grid as it evolves deep into the energy transition.

Micro-grids have been operating reliably for years with zero inertia.

As NREL concluded in a recent study[23], it is looking increasingly possible that grid frequency can be maintained with grid-forming inverters "even in systems with very low or zero inertia." Kroposki *et al* goes further to say that:

> *"…With proper control considerations, inverter-based systems can not only maintain or improve grid stability under a variety of contingencies but also dramatically improve the response characteristics of power systems and increase operational stability*."

Further technological advancements are expected to enable a new grid paradigm, whereby millions of generators and loads are orchestrated flexibly and automatically, with two-way power flows being modulated between demand response, storage devices and renewable sources, with artificial intelligence that is configured to deliver the optimal services at lowest cost.

It is worth giving serious consideration to such developments in the planning processes and market reforms underway now for the NEM. Whilst it is not known precisely what grid architectures or operational frameworks will be optimal at the other end of the transition, it is very likely that they will be substantially different to those of today.

The Turning Point

For Australia to achieve an optimal outcome from the energy transition, reforms should enable dynamic operating envelopes that support local control of DER, and by extension, a flexible grid architecture that is dominated by IBRs.

The ISP forecasts that 6-19GW of new dispatchable resources is needed to support the inherently variable nature of distributed and large-scale renewable

[21] See for example, Reimagining the Grid, White Paper by Edison International. December 2020.
[22] IEEE Power and Energy Magazine. Kroposki et al. 2017. March 2017. 15(2):61-73.
[23] NREL. Inertia and the Power Grid: A Guide Without the Spin. May 2020.

generation. These dispatchable resources comprise of utility-scale pumped hydro, large-scale battery energy storage systems, distributed batteries, Virtual Power Plants (VPP) and other demand side participation. Together, these resources will operate along-side legacy plants during the next 10-15 years under the existing national synchronous grid configuration.

The risk with current planning approaches is that the NEM evolves to a state in which say 90-100% of generation is from variable renewable sources, and the supply/demand balance is achieved by buffering from large storage units, and by active management of DER and demand response. We would be running a system with inherently very low (or zero) inertia in a grid environment and market framework that is constrained by the rigid frequency stability requirements of a traditional synchronous system.

It would be prudent to stretch the imagination now and plan for a system that goes beyond the 19th century notion of synchronous inertia.

Internationally, some power system stakeholders are beginning to envisage new operational regimes for grids that are supplied with up to 100% inverter-based renewables.

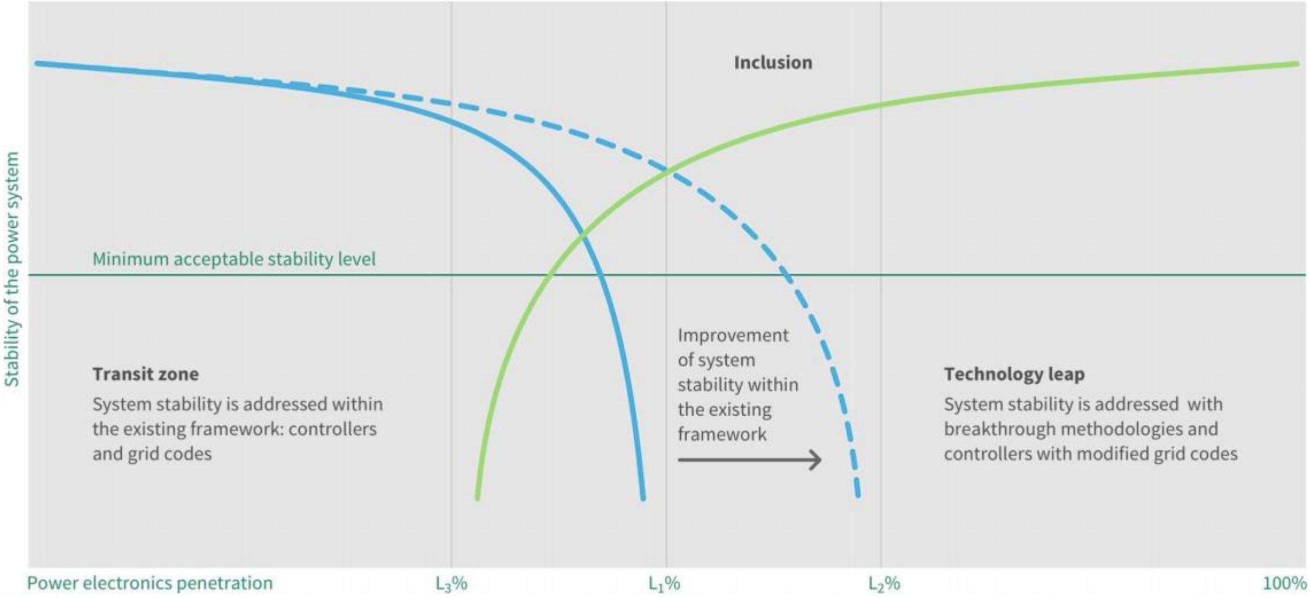
In Europe, member countries of the pan-European transmission system recently completed the multi-year Horizon 2020 MIGRATE project that investigated challenges and solutions for the transition of a continental-scale transmission grid from synchronous machines to 100% inverter-based generation and load.[24] The study considered all power system needs that would enable a reliable, secure and cost-effective grid solution without synchronous machines.[25] The project claimed to have developed solutions to increase the share of IBRs into the European grid from around 30% in 2016 to a potential 90%, and it proposed further new concepts to enable a 100% renewable energy supplied grid. Such concepts involve new market rules, grid operation structures, advanced control methods, high-speed communications, grid-forming inverters, and region-specific grid topologies. The actual grid-scale solutions are complex and require significant investment in further research and development, simulation, trials, and planning.

In the European MIGRATE study it was noted that maintaining stability in a grid with a high penetration of inverter-based renewables would be more challenging than maintaining the stability of a 100% inverter-based grid.

This presents a challenge for the transition. At what point could the entire grid be migrated from a tightly controlled synchronous mode, as required for traditional generators, to a more flexible mode dominated by non-synchronous sources? Figure 2 suggests a staged approach whereby grid-forming inverters and control techniques progressively take over, and with careful planning the grid operation could be updated over a limited timeframe to enable the new regime, before stability in the hybrid power system becomes a critical problem.

[24] Migrate.
[25] Refer to report D3.1, and other reports, accessible at Migrate.

Figure 2: Changing From Existing Framework to Next Generation Grid



Source: H2020 MIGRATE.
Note: Indicative decrease in stability as power electronics (IBRs) increase under existing framework (blue), followed by increasing stability with further power electronics penetration under new system framework (green).

Whether the change happens incrementally, or abruptly at some pre-determined date, the turning point will come. At some stage the NEM will operate with up to 100% inverter-based resources and will require substantially different markets, rules, and operating regimes.

There is a risk that planning aimed at preserving legacy inertia and building new sources (e.g. synchronous condensers) and markets for inertia will slow down the transition and result in a sub-optimal system.

A whole new way of thinking about grid reliability and security is needed, and it should be integrated with the current planning.

Investors Likely to Support the New Grid Paradigm

In 2020, the world invested over half a trillion U.S. dollars in the energy transition – including wind, solar, batteries, pumped hydro, electric vehicle infrastructure and DER technologies.[26] This represents an increase of 9% on the previous year, despite the global economic turmoil due to COVID-19.

All indicators suggest that global capital markets are in the midst of a shift away from fossil fuels and towards clean energy. Fossil fuel divestment by institutional investors[27] (notably led by Blackrock[28]) and record low demand for

[26] Bloomberg New Energy Finance. Energy Transition Investment Hit $500 Billion in 2020 – For First Time. January 2020.
[27] See IEEFA's divestment tracker.
[28] BlackRock. Sustainability as BlackRock's New Standard for Investing.

oil, gas and coal resources underpin the movement of capital into future-oriented energy investments.

IEEFA has previously noted that Australia is exposed to the energy disruption occurring globally, with the rapid deflation in the cost of renewable energy and storage, and the shift in capital flow towards clean energy.[29]

There is recent eye-opening evidence of market sentiment, highlighted by the steep rise in the valuation of Tesla and NextEra Energy during 2020, and the concurrent collapse in value of the likes of ExxonMobil and Peabody Energy. Investors are banking on a future that is powered by renewable energy, storage, and digital technologies.

If the energy transition is embraced, Australia will have plenty of infrastructure and technology investment opportunities to offer local and international investors. It has been estimated that around $400 billion[30] will need to be invested in new generation and storage technologies in the NEM over the next 30 years. When residential installations and transmission costs are included, estimates are as high as $888 billion.[31]

In recent weeks, there have been several announcements for world-leading storage projects in the NEM, including a 1,200 megawatt (MW) battery system in the Hunter valley by CEP Energy at a cost of $2.4 billion[32], and a $500 million pumped hydro project by ATCO.[33] These announcements confirm that the proponents have confidence in the access to capital for new ground-breaking energy infrastructure.

Proponents have confidence in the access to capital for new ground-breaking energy infrastructure.

These investment trends are positive, but without a clear pathway to a future grid paradigm, capital markets will be less supportive. Stringent regulations that require new inverter-based generation to adhere to traditional inertia frameworks could stifle investment.

Requirements for new generation to provide essential grid services, by using grid-forming inverters[34], could be considered. Renewable energy generation and DER are likely to grow substantially if markets point towards a future that does not rely on traditional synchronous inertia.

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[29] IEEFA. Energy transition presents high risks and big opportunities for Australia. February 2020.
[30] AFR. We must reverse course from energy failure. October 2019.
[31] CSIRO/ENA. Electricity Network Transformation Roadmap. April 2017.
[32] Australian Financial Review. Hunter set for 'world's biggest battery'. 5 February 2021. Page 15.
[33] Australian Financial Review. ATCO takes $500m dive into NSW pumped hydro. 1 February 2021.
[34] Synthetic inertia can be provided by wind turbines and virtual inertia can be provided by solar PV and batteries, using power electronics to inject power into the grid in response to contingency events.

It is imperative for governments and agencies to create a vision for the future NEM to underpin long-term investment in infrastructure and technologies that will form the basis of the future grid – one that is distributed, digitalised, and compatible with a zero inertia and zero emissions paradigm.

Conclusion

Australia is well-positioned to chart a clear path towards a future national electricity system that does not rely on traditional synchronous generators and delivers reliable and secure power with zero emissions, at an affordable price.

The transition from thermal generation to renewable energy is reducing available inertia in the NEM. This is a problem, but only one of transition – as we shift from the outdated legacy grid system of the previous century to the modern two-way smart grid of the future. The inverter-based resources that are replacing synchronous generators can respond to contingency events and system imbalances much faster than mechanical synchronous machines. If appropriately designed and controlled, inverter-connected technologies can alleviate any issues associated with reduction in grid inertia due to coal-fired generator closures.

The future grid is expected to be powered primarily, if not completely, by renewable energy sources and battery storage systems. All of this capacity will be electronically controlled, inverter-based, and capable of coordinated fast frequency response. Advancements in grid-forming inverters and low-latency computation and digital communication are opening up the potential for large grids to operate reliably with up to 100% renewable energy and low or zero inertia.

The NEM is currently undergoing a process of reform and re-design. With strong support from state governments, project developers are mapping out nationally significant renewable energy and storage projects. It remains unclear if the roll-out of new projects is coordinated under a long-term forward-looking plan that goes beyond the immediate needs of the NEM during the next 10 years or so.

It remains unclear if the roll-out of new projects in the NEM is coordinated under a long-term forward-looking plan.

It makes sense to consider the grid of the future – one that will serve the country after the bulk of the energy transition is complete. A significant planning effort, involving coordinated risk-based studies, will be required.

There is a risk that current planning and reforms continue to rely on the inertia and operating frameworks of legacy systems, thereby holding back progress towards a highly electronic and digitalised system, which will be the standard of modern economies in a few decades.

The energy transition will not be complete until the reliance on inertia has ended.

About IEEFA

The Institute for Energy Economics and Financial Analysis conducts research and analyses on financial and economic issues related to energy and the environment. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy.
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Tim Finnigan is an independent consultant with 20 years of experience in the renewable energy sector as an engineer, academic, entrepreneur, business executive and company director. He is an engineering physicist, with a PhD in environmental fluid mechanics, and is a member of Engineers Australia and the Australian Institute of Company Directors. Tim was founder and CEO of BioPower Systems, a globally significant marine energy technology company, and has held senior leadership roles in both the private and public sectors, most recently as Director of Energy at the CSIRO.

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