Integration of non-synchronous generation into the Australian National Electricity Market

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I. INTRODUCTION

Currently the electrical power system that makes up the National Electricity Market (NEM) in Australia is being transformed by the increased penetration of wind and solar generation, at the same time as synchronous generation is being retired. As a result a number of technical issues are beginning to emerge, the most urgent of these being the potential for power system instability with lower fault levels in some parts of the network, and high rates of change of frequency which reduce the effectiveness of the emergency frequency control schemes.

The AEMC is working with stakeholders to determine the required changes to market and regulatory arrangements necessary to facilitate the appropriate technical solutions. These arrangements are not specific to any technology but define the market mechanisms or regulatory obligations, including cost recovery and incentives, most likely to effectively deliver efficient levels of investment by participants in the NEM.

II. CONTEXT OF THE NATIONAL ELECTRICITY MARKET

In the early 1990s the Council of Australian Governments (COAG), which includes the Commonwealth and State and Territory governments, recognised the need for micro-economic reform including greater inter-regional competition co-ordination on energy matters so they agreed to form the National Electricity Market (NEM). These reforms involved:

- introducing a uniform single wholesale energy-only electricity market across eastern and southern Australia
- disaggregating the vertically integrated state government owned utilities into competing generators and retailers, and monopoly transmission and distribution network service providers
- harmonising the laws and regulations in each participating jurisdiction
- establishing the energy market institutions to manage changes to market rules and the network access regime, for economic regulation, compliance and the operation of the NEM power system and market.
- facilitating customer choice in their electricity supplier across the NEM.

The characteristics of the NEM can be described as a market where:

- an energy only spot market determines wholesale energy prices, with integrated markets for frequency control ancillary services
- power system security and reliability is generally managed using market mechanisms, with an independent system operator having intervention powers when the market does not deliver security and reliability
- investment and divestment decisions are made by market participants (not governments) based on market prices
- competition facilitates consumers making their own decisions regarding energy products and services (not networks, regulators or government)
- the economic regulation of the monopoly transmission and distribution businesses aims to replicate the incentives of a competitive market
- generator access is open with shallow connection costs and technical performance negotiated with the network businesses, within the requirements of the National Electricity Rules
- the network businesses cannot operate in retail markets.

The infrastructure that supports the NEM has largely been privatised although government ownership remains in

certain areas. Most of the generation in the NEM has been privatised excluding significant capacity in Queensland and Tasmania where government owned corporations own or control the majority of capacity. In addition, generators and retailers have tended to vertically integrate, to form 'gentailers', to manage the risk of price volatility in wholesale energy markets.

III. GOVERNANCE

The governance structure for the Australian energy markets was designed to separate decisions on policy, rule-making and market development; regulation and compliance; and operations to deliver effective competition, clear accountabilities and support investment certainty in the energy sector.

A. Policy

The COAG Energy Council brings together energy and resources Ministers from the Commonwealth, states and territories to pursue a common set of objectives and coordinate priorities for the development of national energy and resources markets.

B. Rule-making and market development

The Australian Energy Market Commission (AEMC) is responsible for rule-making and energy market development at the national level. In making and amending rules, the AEMC's focus is on developing market and regulatory frameworks that are flexible and adaptable to market and technology changes, while allowing industry investment decisions to be guided by consumer preferences. The AEMC also undertakes reviews and provides advice to the Energy Council on improvements to the regulatory and energy market arrangements.

C. Regulation and compliance

The Australian Energy Regulator (AER) is the national energy market regulator. It is responsible for the economic regulation of transmission and distribution networks, and retail markets (other than retail pricing), at the national level. It also enforces the energy laws, regulations and rules.

D. Market and system operation

The Australian Energy Market Operator (AEMO) is responsible for the day-to-day operation and administration of the power system and electricity wholesale spot market in the NEM and the settlement of retail electricity markets. It coordinates the operation of the national electricity grid and delivers strategic planning advice and forecasting to guide long-term investment and resource management.

E. National Electricity Objective (NEO)

In carrying out their respective functions, the market bodies (the AEMC, the AER and AEMO) must have regard to the NEO, which aims to achieve the economically efficient investment in, operation and use of energy services (rather than assets) in the long-term interests of consumers. The long-term focus does not refer to a particular period of time but rather to when the capital or fixed components can be changed.

The unique nature of Australia's rule change process means stakeholders are not only allowed, but also expected, to participate in the reform process through submitting rule requests and being involved in the development of solutions.

IV. RECENT TRENDS IN THE NEM

Australia's energy system is undergoing changes driven by rapidly evolving technology due to changing price signals and government policy, including:

- The Commonwealth Government's renewable energy target (RET), as well as other state specific policies to drive investment in renewables, which are encouraging large scale wind and solar generation to enter the market.
- Generous feed-in tariffs for solar PV introduced by governments, but also rising wholesale electricity prices, are leading to an increased take-up of distributed generation and a growing interest in storage technologies.
- Forecast grid-supplied electricity to remain flat for the next 20 years, despite projected 30% growth in population and average growth in the Australian economy.
- Some older coal-fired generators making commercial decisions to retire.
- Policy uncertainty in relation to future emissions reduction policies impacting market driven investments in technologies not captured by the existing RET or directly supported by government.
- Wholesale retail prices which have risen significantly.
- Increased concern about power system security following the black system event in in South Australia in September 2016.[1]

V. IMPLICATIONS FOR POWER SYSTEM SECURITY IN THE NEM

These trends in the NEM present challenges for the market and regulatory arrangements as the amount of synchronous generation has reduced while the majority of new generation is power electronic connected wind and solar. This has meant that the inertia of parts of the NEM, particularly in South Australia and Tasmania, has significantly reduced and other technical challenges have emerged. In response to these emerging challenges, the following four immediate issues were identified:[2]

1) managing extreme power system conditions – new emergency frequency control schemes and special protection systems will be required as increasing rates of change of frequency (RoCoF) are reducing the ability of existing under frequency load shedding schemes to operate effectively.

2) maintaining frequency control – market or regulatory mechanisms will be required to ensure minimum

[1] "Black system South Australia 28 September", AEMO, March 2017.

[2] "Future power system security program, progress report", AEMO, August 2016.

levels of inertia will be maintained as most new generation has little or no inertia.

3) managing low fault levels – market or regulatory mechanisms will be required to ensure minimum fault levels (referred to as system strength) will be maintained as most new generation contributes little to the fault level, resulting in voltage control and protection issues in the networks as well as generator instability.

4) maintaining visibility of the power system – increased information is required for distribution connected generation such as rooftop solar photovoltaic (PV) and batteries, in addition to a general need for more detailed system models due to assess system security and generator connections at reduced fault levels and inertia conditions.

Fig 1 shows the joint AEMC and AEMO System security market frameworks review that considered the first three issues. In addition, other AEMC and AEMO processes are considering the issue of invisibility through information on distributed energy resources.

VI. Managing extreme power system conditions.

In March 2017 the AEMC made a final rule determination to address emergency frequency control that included:[3]

- a framework for AEMO to regularly review current and emerging power system frequency risks
- an enhanced process to develop more sophisticated emergency frequency control schemes
- a new classification of specific low probability but high impact event (a protected event) that allows power system security to be managed by using a combination of ex-ante solutions, as well as some limited generation or load shedding.

VII. Maintaining frequency control

Historically, the physical inertia provided by the large synchronous generators has dampened the effects on frequency of any sudden imbalances in supply and demand such as due to the tripping of a major generator, load or transmission line. This has meant that the frequency control services and the automatic under frequency load shedding schemes have been able to effectively control the frequency.

More recently levels of inertia in the NEM have been dropping as synchronous generators retire. This is occurring more in some regions and creates particular challenges when electrical islands form, such as when the Heywood interconnector from Victoria to South Australia trips, as the frequency may not be controllable which could result in major supply disruptions or black system conditions. Therefore, the AEMC considered a range of mechanisms to provide additional inertia including:

- an obligation on new generators to provide a minimum amount of inertia (either physically or by contracting with a synchronous generator)
- a market signal for inertia (based on the incremental value of the inertia)
- an obligation on AEMO or the transmission network business to acquire inertia.

Following analysis and stakeholder consultation on these options, the AEMC is considering the introduction of an obligation on transmission network businesses to provide minimum required levels of inertia, or alternative equivalent services (eg synthetic inertia), to allow the power system to be maintained in a secure operating state following an islanding event.[4]

The provision of inertia by transmission network

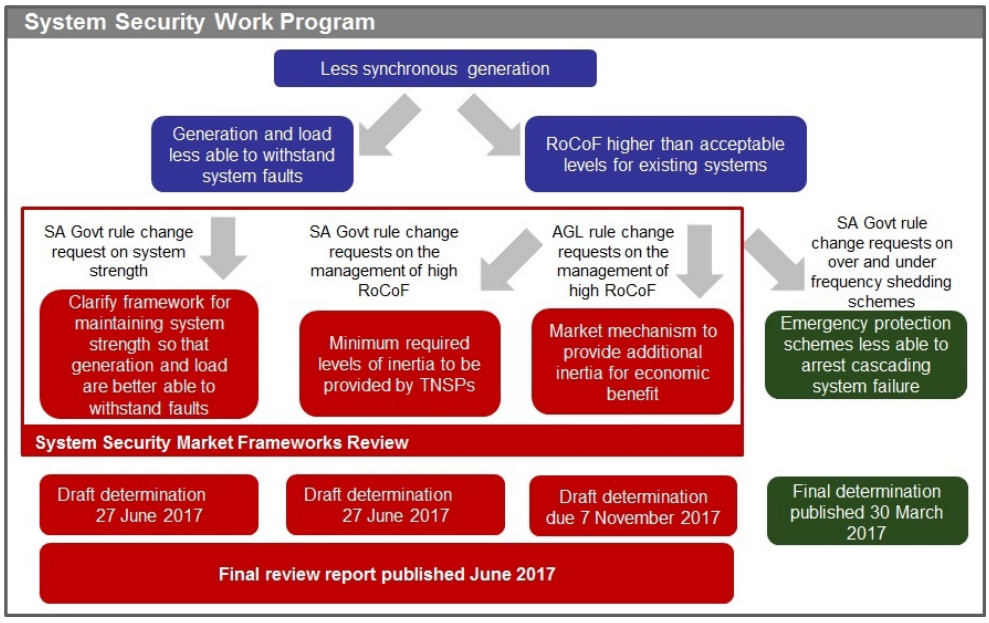


Figure 1 AEMC System Security Work Program

[3] "Emergency frequency control schemes", AEMC Rule determination, 30 March 2017.

[4] "System security frameworks review", AEMC, June 2017.

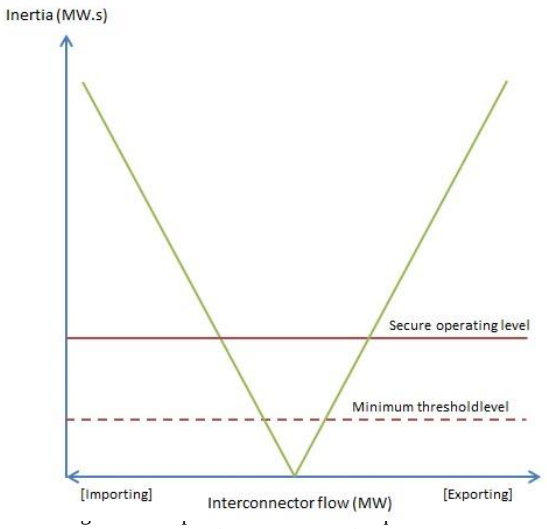
businesses would offer certainty that the minimum required levels would be made available, either through investment in network equipment or by contracting with third party providers. Under network regulation arrangements, these businesses have financial incentives to minimise the costs associated with meeting their obligations. They would also have the ability to coordinate inertia provision with the more locational requirements of maintaining fault levels.

The AEMC is considering introducing a market-based mechanism to realise market benefits that could be obtained through the provision of inertia above the minimum obligation on transmission network businesses. For example, additional inertia may allow greater pre-contingent interconnector flows when islanding is a credible contingency or a protected event. This is because the potential RoCoFs following islanding that would otherwise result could lead to the system frequency collapsing before the under frequency load shedding scheme could operate. This collapse could also be further compounded if some generation trips due to the high RoCoF.

A market-based mechanism is preferred for providing this additional inertia as it would put a price on inertia so that it can be traded off against the additional energy trading available when the interconnector is less constrained.

Fig 2 shows the absolute minimum threshold level of inertia (broken red line) and the secure operating level of inertia (solid red line) in comparison to the level of additional inertia that would allow for increased flows on the interconnector (green line).

VIII. MANAGING LOW FAULT LEVELS



ia and additional inertia for market benefit

Historically fault levels have tended to increase as load growth has driven increased (synchronous) generation and network reinforcement. However, as discussed above, more recently load growth has abated, synchronous generation is operating less or retiring, and levels of non-synchronous generation have increased.

The potential technical solutions to low fault levels include:

- increased use of synchronous condensers at selected locations to maintain minimum fault levels at key locations in the network
- contracting with existing synchronous generation to operate more to restore fault levels
- redesigning affected protection and voltage control systems
- constraints on the output of potentially unstable non-synchronous generation at times of low fault levels
- reinforcement of the network to increase fault levels to non-synchronous generation.

However, while the network businesses are responsible for maintaining the effectiveness of their protection and voltage control systems, the regulatory framework is less clear who is responsible when fault levels reduce and generation can no longer meet the required technical performance such as stability and fault ride through. Therefore, to reduce the risk of cascading outages on system security, the AEMC is developing new arrangements in the rules including:[5]

- an obligation on transmission network businesses to maintain fault levels in order to manage the risk of cascading outages
- an obligation on new connecting generators to do no harm to the ability of existing generators to remain stable and ride through faults
- AEMO, as the independent system operator, to manage this operationally.

IX. FURTHER ENHANCEMENT TO THE NEM SYSTEM SECURITY FRAMEWORKS

Throughout the *System security frameworks review*, and the assessment of the associated rule changes, a number of additional issues have been identified and will be progressively progressed by the AEMC or AEMO. These include:

- A *Frequency control frameworks review* that includes an assessment of primary frequency control in the NEM (including whether mandatory governor response should be introduced) and the changes necessary to the existing frequency control ancillary service arrangements necessary to accommodate the rapid frequency response services potentially available from inverter connected generation and storage.[6]
- A review of the frequency operating standards that apply on the NEM mainland and in

[5] "System security frameworks review", AEMC, June 2017.

[6] "Frequency control frameworks review", AEMC, on-going.

Tasmania (which is connected to Victoria via HVDC).[7]

- A rule change from AEMO that proposes to revise the technical performance requirements for connecting generators, including a potential requirement for all new generation to provide either inertia or a fast active power control capability. The proposed rule also proposes minimum short circuit ratio requirements for all new inverters and related items of plant within grid-connected generating systems.[8]

[7] "Review of the Frequency Operating Standard", AEMC Reliability Panel, on-going.

[8] "Generator technical performance standards", AEMC rule change process, on-going.