Essential Power System Services with Very High Levels of Renewable Energy, with Principles for DER Interaction

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Solar and wind generation in the National Electricity Market (NEM) was curtailed due to power-system considerations more than 6% on average over 2019, more than any previous year (AEMO 2020). Ancillary service costs rose to more than $300m in Q1 of 2020 alone, due in part to the SA separation event of February 2020, but also from the growing need for system services arising from increased penetrations of Variable Renewable Energy (VRE) – large-scale wind and solar photovoltaics (PV) farms and distributed roof-top PV.

Approaching 50% of instantaneous demand in the NEM in 2019, AEMO's Central Scenario forecasts VRE regularly meeting 75% of instantaneous demand by 2025 (Figure 1), with Step Change scenarios – what Australia is currently tracking along – predicting 100% of instantaneous demand frequently being met by VRE by 2025 (AEMO 2020a).

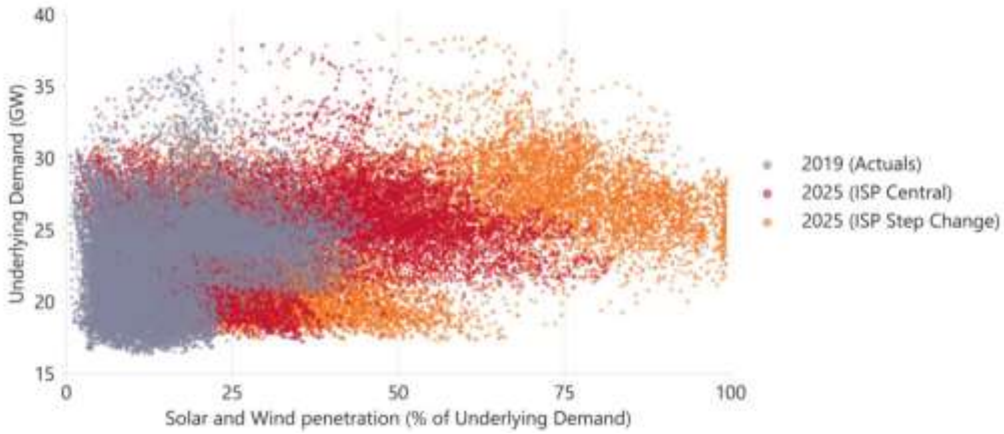

Figure 1. Australian National Electricity Market half-hourly wind and solar generation divided by the underlying demand, actual and forecast (AEMO Integrated System Plan). Source: Future Energy Systems, AEMO 2020.

Whilst the energy of existing traditional thermal (coal and gas) synchronous generators may be easily replaced by that from inverter based resources (IBR) of wind and solar PV, as the proportion of variable inverter-based renewable energy generation in electricity systems increases from minority to majority of total supply, the complexity and cost of providing ancillary system services increases in parallel (Chuang and Schwaegerl 2009). Australia is transitioning now from the third most carbon intensive electricity sector in the world to having world-leading penetrations of VRE, IBR and distributed energy resources (DER). To guide this transition, The Council of Australian Governments (COAG) established an independent Energy Security Board (ESB) to develop a long-term, fit-for-purpose electricity market framework that could apply Post-2025.

In this paper we outline the pioneering work exploring new technical, economic and regulatory options being developed as part of the Essential System Services market-design initiative of the ESB's Post-2025 program. We identify the emerging challenges in defining, procuring and providing system strength and its interactions with the provision of fault-current and inertia, and the characterisation of Essential System Services as 'Common Pool Resources' and not 'Public Goods', being non-excludable but rivalrous (Billimoria et al. 2020, Dietz et al. 2003), with associated governance principles (Ostrom 1990). The reduction of inertia (Figure 2a) and rapidly growing ramp events (Figures 2b,c) are explored with the seven rule-change requests regarding system security currently under consideration by the Australian Energy Market Commission (AEMC 2020).

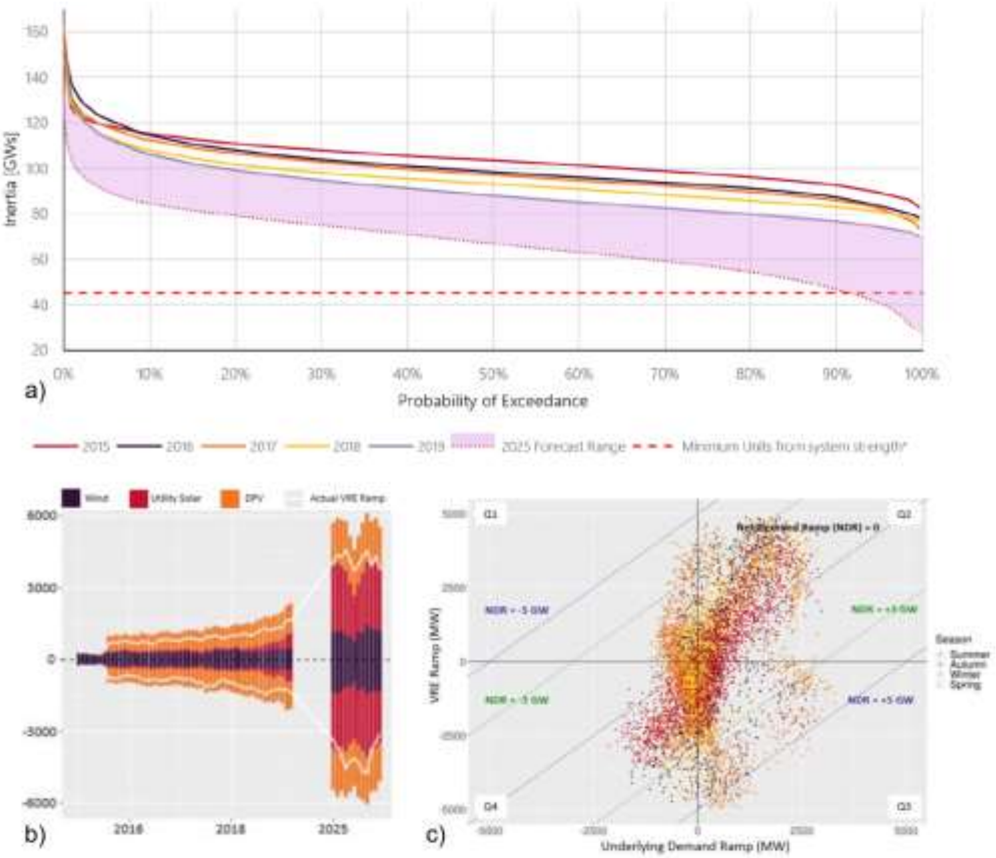

Figure 2. a) Inertia duration curves – historical (actual) and future range (forecast) of NEM mainland inertia. b) Butterfly plot: monthly top 99th percentile upward and downward 1-hour VRE ramps in the NEM. c) 2025 Forecast Net Demand Ramps in the NEM. Dotted lines represent the locus of net demand ramps. The black line indicates a net demand ramp of zero. The green and blue lines show ±3 GW and ±5 GW changes in net demand, respectively. Source: Future Energy Systems, AEMO 2020.

We present the application of the concept of demand curves and 'nomograms' to the procurement of essential system services, and emerging design principles for frameworks in facilitating the evolution from default provision of system services by synchronous generation, to co-optimisation of services through unit commitment mechanisms, to independent provision of services through inverter based resources (Hogan 2002).

We also explore the characteristics that may be required by future renewable energy resources (encompassing DER, solar PV and wind farms) including advanced ride-through capability, the provision of synthetic inertia by grid-forming inverters, and advanced grid-support capability to provide system restoration capability for secure, resilient and island-able grids.

Finally, we explore the interaction of system security and essential system services with DER, and the emerging policy principles of i) symmetric treatment with large-scale generation and load and ii) the right to access self-generated electricity; this latter principle, explored via its potential expression in an optional 'self-consumption clause' (Figure 3) in the Australian Standard for Grid-Connected Inverters AS 4777.2, currently under revision.

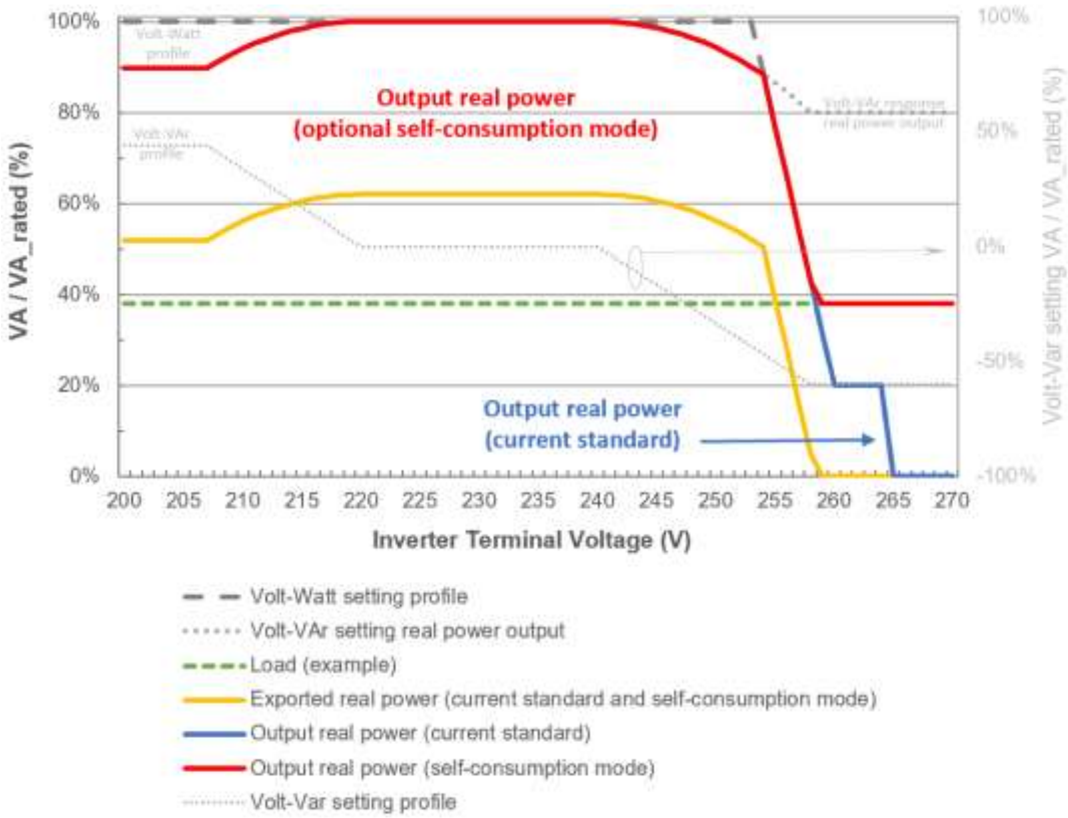

Figure 3. An optional self-consumption mode (Red) for the grid-connected inverter response profile with Volt-Watt and Volt-Var modes of AS 4777.2, allowing the ability for DER owners to self-consume electricity to not be curtailed due to i) high-voltages on the distribution network, or ii) generation shedding mechanisms for security.

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