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Decentralisation Framework: An approach to mapping power system transition

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Power systems worldwide are undergoing a once in a generation transition. The urgent need to decarbonise, combined with increased opportunities for consumers to engage with their energy use are two critical catalysts driving this transition. The shift towards renewable energy, and increased decentralisation are impacting all aspects of the power system, presenting challenges and opportunities across technical, social, regulatory and policy-making spheres.

Decentralisation of the power system is particularly challenging, as it fundamentally changes the physical operation of the system. Simultaneously, it introduces more decision makers and increases system complexity. This complexity means it is difficult for an individual, or organisation, to manage and respond to changes. Ultimately, this can make transition harder, potentially more costly and less just. Australia is experiencing rapid decentralisation due to the high uptake of distributed photovoltaics (DPV) and is therefore a good case study. However it is not alone as power systems world-wide are becoming more decentralised and common impacts are emerging.

This work defines decentralisation of the power system and offers a framework for comprehending decentralisation. The framework is based on foundational observations developed through an international review that involved interviewing stakeholders across parts of North America (Hawaii, California, Colorado) and the UK. This review was supported by the Australian Institute of Energy (AIE) Youth Scholarship. The underlying observations are as follows:

- There are three key physical elements of the power system: end use, generation and networks. These three physical elements exist across 'continuums' of scale, and decentralisation is changing the balance of these continuums.
- Decision making plays a key role in the electricity system and decentralisation is substantially increasing the number of decision makers.

Our aim in proposing this framework is to assist researchers, policy makers and industry participants in grappling with decentralisation by providing structure. Additionally, to assist with identifying gaps in collective efforts to support and manage the transition. It is important to note that the framework is not a complete picture of decentralisation, instead it is intended as a tool that can be adapted and extended.

1 Definition of Decentralisation

The proposed definition is stated in terms of the three key physical components of an electricity system: end use, electricity networks, and generation (depicted in Figure 1). Broadly, an increasingly decentralised power system is defined as a system in which at least one of the following is true:

- **End users** – end users are more 'actively' participating in the power system (including distribution connected end users).
- **Networks** – 'active' participants are increasingly connected in the distribution network and electricity flow is increasingly bidirectional.
- **Generation** – generators are reducing in size (generator capacity) and increasing in number, with the number of owner/operators also increasing.

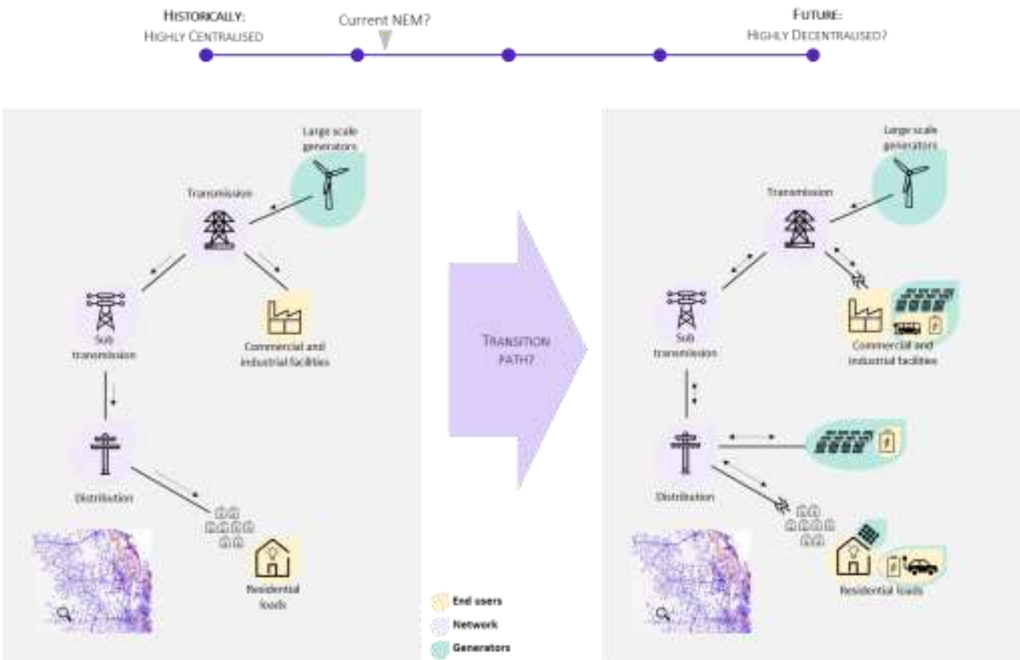

Figure 1. Stylised depiction of the transition to a highly decentralised power system

2 Mapping decentralisation

2.1 Physical continuums of scale

Historically these three key physical elements of the electricity system have been divided into segments, largely based on size and/or voltage level. Often there have been differences in the 'rules' that apply to different segments. For example, connection requirements for utility generators (≥5MW) are different to small generators (<5kW). Historically this segmentation and lack of coherence may have been appropriate. However as decentralisation continues in some cases it is becoming problematic. We propose that each of these three elements of the power system should instead be considered as 'continuums', rather than as segments.

As observed above, decentralisation is changing the physical infrastructure of the power system. Particularly through increasing volumes of distribution connected generation. This trend is exacerbating differences in rules, or 'lack of coherence' across each continuum. These continuums and the lack of coherence across each, are the first core element of the proposed framework.

2.2 Decision making regimes

Decentralisation is also leading to a substantial increase in the number of decision makers in the electricity system. Considering decision making in a structured way is therefore valuable. The second core element of the proposed framework is therefore the decision making regimes proposed by Outhred [1] and adapted by Sue [2]. These decision making regimes are summarised in terms of their respective goals in Figure 2, and also described (in italics) through framing the electricity system as a game.

Figure 2. Decision making regimes overview, as proposed by [1] and adapted by [2]

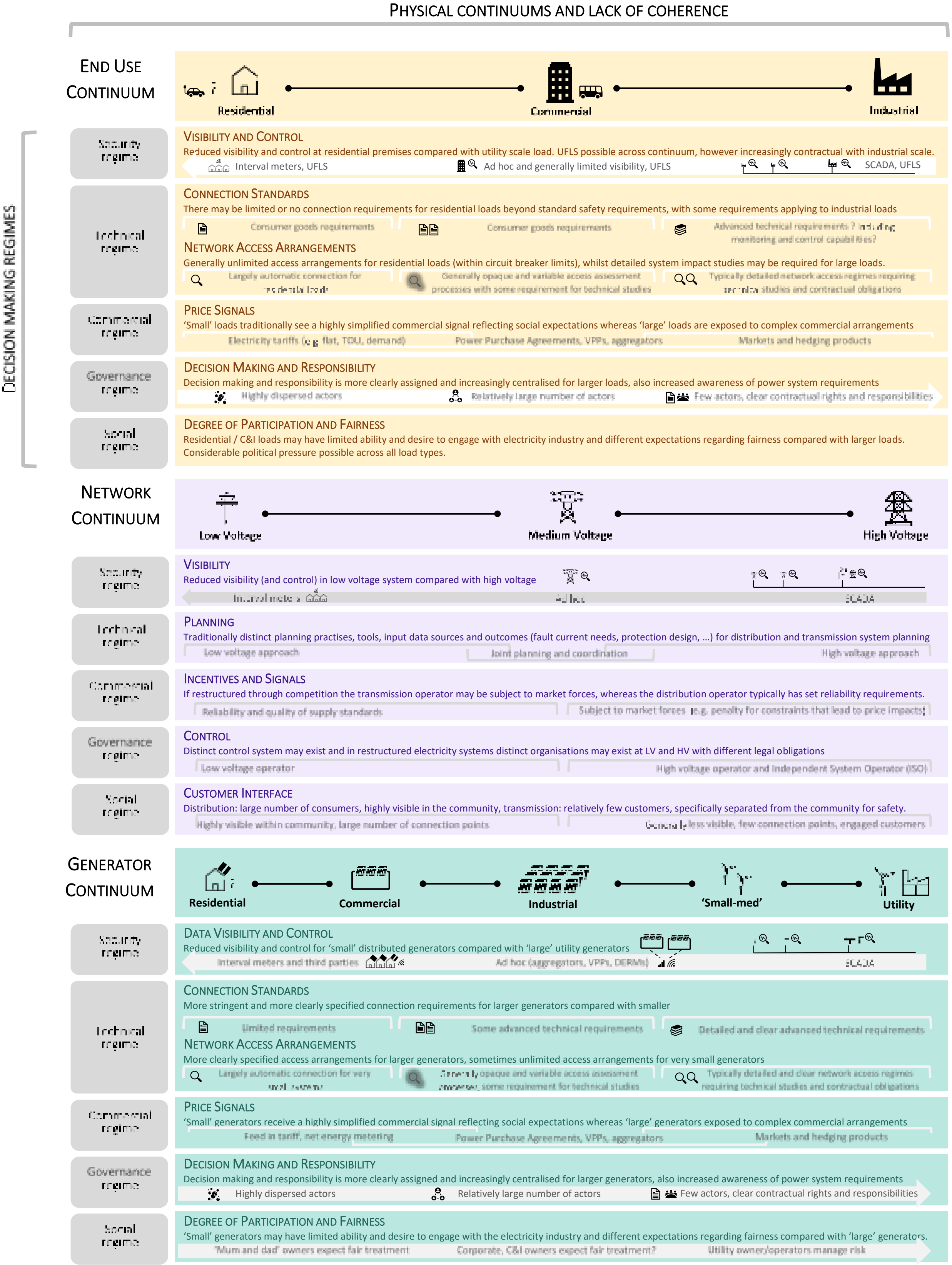

Figure 3. Proposed decentralisation framework

2.3 General framework

Combining these components of 1) physical continuums and 2) decision making regimes yields the proposed decentralisation framework, as shown in Figure 3. A specific lack of coherence is identified for each decision making regime, and each physical continuum. It is important to note that this analysis is not exhaustive and is intended to be extensible.

2.4 Generator connection standards case study

Generator connection standards is a useful a case study (at the intersection of the generation continuum and technical decision making regime in Figure 3).

Typically, small distribution connected generators are subject to minimal connection standards whereas utility generators are expected to meet detailed requirements. This approach has been historically appropriate; if small generators were required to meet utility requirements then it is unlikely that many would be installed given the high costs involved.

However there is now sufficiently high levels of inverter connected DER (and particularly DPV) in the power system that the behaviour of these systems can threaten power system security [3]. Therefore small, distribution connected generator requirements are evolving to become more coherent with utility scale requirements. This trend has been observed in Hawaii [4], California [5], the UK [6] and Australia [7].

3 Conclusion

The shift to a more decentralised power system is presenting challenges and opportunities around the world. The fundamental changes to the underlying physical power system coupled with increased number of decision makers is resulting in a highly complex transition, set against the backdrop of the urgent need to decarbonise. The framework presented in this work has been developed through examination of international experience. It is intended to provide structure so that researchers, policy makers and industry participants are better able to identify how their own work fits into the broader transition, and to identify gaps in collective efforts to manage decentralisation.

4 References

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