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Storage and "Super Grid": the Key to 100% Renewable Energy

Bin Lu, Andrew Blakers, Matthew Stocks, Cheng Cheng and Anna Nadolny

The Australian National University, Canberra, Australia
E-mail: bin.lu@anu.edu.au

Numerous studies have demonstrated that full decarbonisation of energy sectors can be achieved through large-scale adoption of renewable energy in electricity sector, primarily solar and wind, along with direct or indirect (e.g. renewable electro-fuels) electrifications of heating, transportation and industry. However, due to the nature of intermittency in renewable energy production, large-scale integration of solar and wind energy will bring significant challenges to system security and reliability, especially to the energy systems which are isolated from neighbouring network such as the Australian National Electricity Market. To facilitate high penetration of solar and wind energy in electricity system, a synergy of energy storage (energy time-shifting) and stronger inter-regional transmission (energy geo-shifting) is required (Blakers et al., 2017; Lu et al., 2017).

Pumped hydro energy storage constitutes more than 99% of the global energy storage market. It is capable of grid-scale energy time shifting and a variety of ancillary services, which can facilitate large-scale integration of variable renewable energy in electricity systems. Short-term off-river energy storage (STORES), which refers to closed-loop pumped hydro systems located away from rivers and thus has little environmental impacts, offers vast opportunities to access cost-effective mass energy storage. A world-first high-resolution global atlas of pumped hydro energy storage has been developed at the Australian National University, which discovered more than 600,000 cost-effective STORES sites around the world (Stocks et al., 2019; Lu et al., 2018). In addition to pumped hydro energy storage, distributed energy storage located behind the meter such as electric car batteries and thermal energy storage within buildings can also contribute significant storage capacity as well as large demand flexibility to the future energy system. Enabled by smart energy system, these distributed energy resources allow energy and power deficiency due to low availability of renewable energy to be effectively mitigated through active demand-side management.

Modern high-voltage direct-current (HVDC) technology, with either line-commutated converter or voltage-source converter, enables efficient delivery of gigawatts of electric power over thousands of kilometres with relatively low transmission loss (3% per 1,000 kilometres). The world's most powerful HVDC project, the Changji-Guquan ±1,100 kV HVDC link in China, is capable of transferring 12,000 megawatts of electricity over a distance of 3,000 km. A hypothetical "Super Grid" across the National Electricity Market is envisaged as shown in Figure 1, which connects major load centres and renewable energy zones using HVDC transmission with three potential extensions to Far North Queensland, the Northern Territory and Western Australia.

In this presentation, the significant roles of storage and "Super Grid" in large-scale integration of solar and wind energy in Australia will be discussed. It will be demonstrated that energy supply and demand balance can be effectively maintained in 100% renewable energy scenarios through a synergy of stronger interconnection between electricity grids, energy storage, and demand-side management enabled by distributed energy resources and smart energy system.

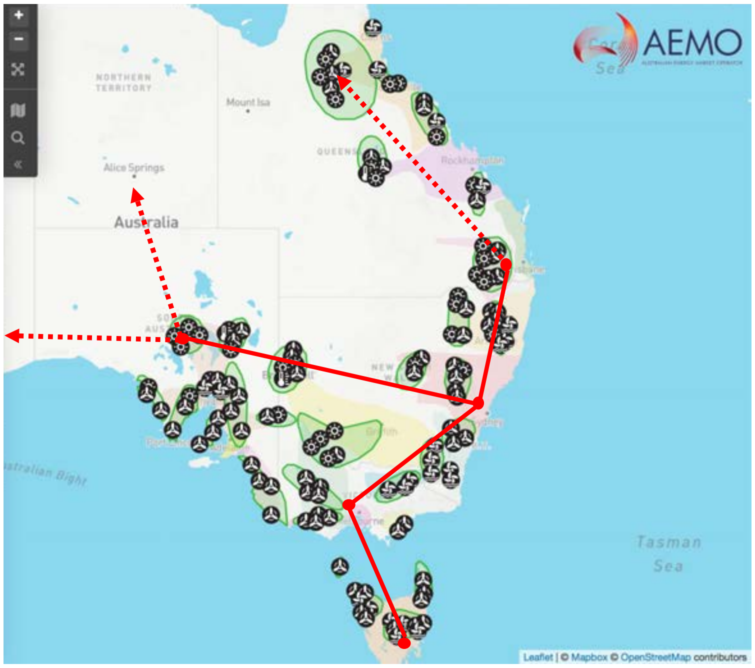

Figure 1. A hypothetical high-voltage direct-current backbone (red lines) in Australia.

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