The Advantages of Digital Twin Microgrid Controllers in Distributed Energy Resources

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***Abstract*—It is clear that the rapid energy transition in Australia and overseas is not progressing smoothly. Energy market regulators, operators, generators and network service providers contend with an ever-changing complexity of rules in attempts to compensate for a lack of inertia, with wind and solar farms being deployed far from the population centres of highest demand.**

One solution now being considered by energy utilities around the world, is for a significantly increased use of localised Distributed Energy Resources (DERs) closer to the consumers.

This paper explores the efficient and flexible use of digital twin microgrid controllers to better manage the design, engineering, operation and automation of DERs to support the grid in populated areas, or provide an alternative to the main grid in remote areas.

In a vast but sparsely populated country like Australia, some electrical utilities have already identified the benefits of removing poles and wires transmitting power to remote areas, and providing local microgrids to supply power to their consumers.

***Keywords*—digital twin, microgrid controllers, distributed energy resources, energy management.**

I. Introduction

In Australia, the main entities for ensuring safe, reliable and affordable energy and enabling the energy transition for the benefit of all Australians include the Energy Security Board (ESB), the Australian Energy Regulator (AER), the Australian Energy Market Commission (AEMC) and the Australian Energy Market Operator (AEMO).

The ESB has set out a range of reform initiatives as part of its integrated Consumer Energy Resources (CER) Implementation Plan. By 2030, AEMO expects around 50 per cent of consumers, including large businesses, to use some form of consumer energy resources to participate in the demand side of the national electricity market [1]. AEMO's DER Program aims to ensure a smooth transition from a one-way energy supply chain – starting with large-scale generation units to consumers – to a decentralised, two way energy system.

This then begs the question, if numerous participants, EPCMs, subcontractors and investors have fled the renewables wholesale market in Australia due to significant losses and delays, how will those charged with managing the energy transition manage this new challenge that will essentially be at a more decentralised retail level ?

II. Distributed Energy Resources

A. What are DERs ?

Energy market operators need to manage the available supply to match the demand every minute of every day.

Distributed Energy Resources – or DERs – are consumer-owned devices that, as individual units, can generate or store electricity or have the 'smarts' to actively manage energy demand.

When aggregated and operating together at scale through micro-grids and virtual power plants (VPPs), these devices have huge potential to exchange consumer value by contributing to a reliable and secure energy supply [2].

B. Types of DERs

DERs can be fossil fuel driven generators or renewable generation assets, including:

- Diesel generators utility or commercially owned
- Fuel cells
- Rooftop solar PV arrays, residential or commercial
- Battery Energy Storage Systems (BESS)
- Smart appliances
- Electric vehicles

C. Challenges of High Level Integration of DERs

While DER usage by Australia consumers has increased dramatically over the last decade, no doubt driven by skyrocketing electricity costs, we are still a long way from a "decentralised, two way energy system.".

Challenges under consideration by the market entities include:

- Distribution Network Service Providers (DNSPs) state of readiness
- Customer access and conditions
- Customer reward pricing and management
- System security and reliability
- Integration and interoperability standards

III. Microgrids

A. What is a Microgrid ?

A Microgrid is a cluster of interconnected DERs and loads. It can be operated in either grid-connected or islanded modes. A Microgrid requires a supervisory control system to manage and control DERs. This is sometimes referred to as a

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Microgrid Management System, or a Distributed Energy Resources Management System (DERMS).

B. *Microgrid Benefits in Remote Areas*

Microgrids have been used in remote locations, where the DNSPs often do not reach. The Australian Grid is nowhere near as meshed as say, Europe.

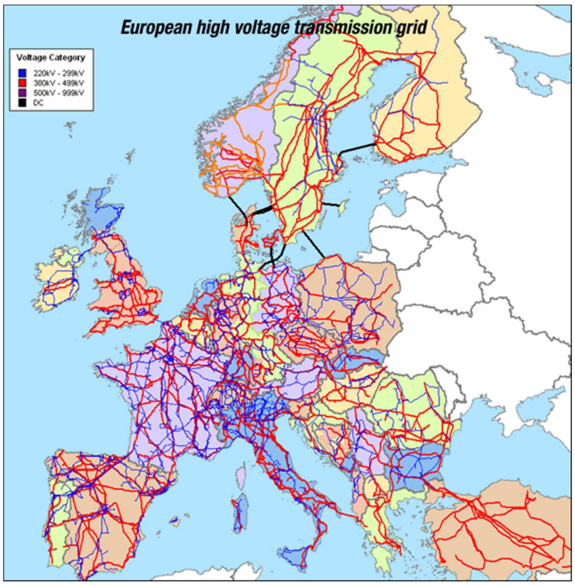

Fig. 1. European HV Transmission Grid

By contrast, the Australian HV Transmission Grid leaves many remote regions without supply options. This has become increasingly apparent, when proponents of new commercial-scale renewable installations, such as solar and wind farms seek connection to the grid from areas far away from the population centres of major cities.

These two maps are on approximately similar scales. Due to the tyranny of distance in Australia, grid lines often reduce in size towards the periphery.

Even if the grid does reach close to the new renewable sites, often the transmission line capacity is insufficient, and the full capacity of the new installation cannot meet the grid connection requirements without further enhancements.

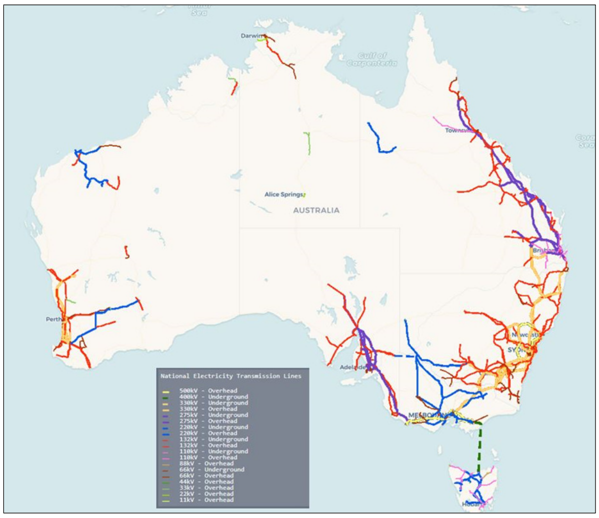

Fig. 2. Australian HV Transmission Grid

Western Power, the primary Network Service Provider (NSP) in Western Australia, has one of the largest isolated electricity networks in the world. Their installation of some 4,000 stand-alone power systems comes with the progressive decommissioning of approx 15,000 kms of overhead powerline.

They find these Microgrid installations more reliable, and cheaper to maintain. The added reduction of bushfire risks with fallen power lines is also welcome.

C. *Microgrid Benefits in Built-up Areas*

With the slow progress in the energy transition, many commercial users are considering alternatives. Embedded generation offers not just reliability options, but with the potential for excess generation, further benefits in the near future to export back to the grid and sell the energy.

Microgrid controllers with flexible capacity to connect in either grid-connected or islanded modes, are ideally placed to provide continuous power supply during grid issues such as “unserved energy events”, and also to benefit from exporting higher energy market prices when demand is high and supply is low.

D. *Energy Market Reliability*

To meet the federal government’s Net Zero target for 2030, “Australia must install 22,000 500-watt solar panels every day for eight years along with 40 seven-megawatt wind turbines every month – backed by at least 10,000 kilometres of additional transmission lines [3].”

According to Clean Energy Council data, in the first quarter of 2023, eight renewable energy projects commenced construction. This construction activity was overshadowed however, with no renewable generation projects reaching financial close in Q1 2023.

Fortescue Future Industries Director and Former Deputy Governor, Reserve Bank of Australia, Guy Debelle, suggests that “Building enough transmission to transport renewable energy to households and businesses is Australia’s biggest energy challenge [4].”

Origin Energy chief executive Frank Calabria agreed calling “delays to the build-out of the transmission grid… the single biggest hurdle to Australia’s energy transition [5].”

On 21 February 2023, AEMO issued an update to their 2022 Electricity Statement of Opportunities (ESOO) report, including this warning: “Reliability gaps begin to emerge against the Interim Reliability Measure from 2025 onwards. These gaps widen until all mainland states in the National Electricity Market (NEM) are forecast to breach the reliability standard from 2027 onwards, with at least five coal power stations totalling approximately 13 per cent of the NEM’s total capacity expected to retire [6].”

E. *What does a Microgrid Management System do ?*

The Microgrid Controller performs supervisory functions, including:

- Dispatching Microgrid DERs
- Managing transitions from grid connection to islanded
- Optimising DER utilisation
- Miniming operational cost

- Demand management
- Provision of operator interface
- Reporting operation,
- Managing setpoints

F. *Generic Microgrid Controllers*

A common design practice with generic Microgrid Controllers commences with an engineering expert writing logic and designing settings for the project specific DERs. This level of bespoke development requires individual verification and validation with hardware-in-the-loop modelling (HIL) and a complex level of testing. Set-ups are not repeatable for the user.

Any changes to the DERs, for example, addition of a Battery Energy Storage System (BESS), will require further engineering and development by the engineering experts, and revalidation with HIL modelling.

This rework can result in higher costs and longer timeframes to execution and implementation.

G. *Digital Twin Model Microgrid Controller*

By utilising a model-based digital twin controller design, the user finds a controller with more than a blank slate to commence design. Ratings and connectivity is available in the model, as well as built-in functions with all levels of required controls.

The simplification for configuration over programming, and a shared model from design to controller, allows the user to make changes and then verify with integrated software-in-the-loop (SIL) simulation. Benchmark scenarios can be retested as situations change.

This simplified update process can be performed with off-line modelling, controller upload, and verification, then deployed in the field with hot-swap of settings.

IV. Conclusion

The actual roll out of the new transmission grid system to transport renewable energy to households and businesses is not nearly on target. Regulator warn of “unserved energy events” (colloquially known as “blackouts”) within the next two years.

Microgrids offer two potential solutions for NSPs and their consumers. Replacing long transmission lines to remote areas to supply access to energy with all of the high costs of maintenance and risks of fallen lines and possible bushfires, also improves reliability and reduces total cost of ownership, reducing consumer prices.

Secondly, Microgrids can provide those consumers with access to the grid, an alternative source of supply for increased reliability with the likelihood of critical grid failures, as well as a commercial opportunity as NSPs seek to manage demand and supply

Aggregation at scale through micro-grids and virtual power plants involving electric vehicle chargers and batteries, residential PV and commercial embedded generation of all types is going to provide further challenges.

Clearly, in countries with sparse populations like Australia, the utilisation and management of smaller microgrids and DERs closer to the consumers will require much greater supply and demand data granularity than currently exists in the market.

The role of model-based digital twin Microgrid Controllers to manage and adapt to this level of detail will be critical in ensuring a smooth transition from a one-way energy supply chain to a decentralised, two way energy system.

V. Acknowledgment

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VI. References

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VII. Biographies

Mick Weston

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Mick’s career spans more than 40 years in the electrical industry. From Distribution System Operator for SEQEB, (now Energex), to sales and service management roles in global companies such as Toshiba and Schneider Electric, Mick is well known throughout Australia and SE Asia for delivering engineering services and solutions to the region’s leaders in consultant engineering, mining, resources and industrial infrastructure.

Mick developed the new Schneider Engineered Services division in Queensland supporting clients' needs for HV switchgear and protection systems installation testing and commissioning. Following implementation of Schneider’s first SF6 switchgear end-of-life management program as National Manager for Special Projects, he is regarded as a leading authority on SF6 emissions and safe gas management within the electrical industry, with his program adopted by Schneider France as a global solution.

Mick's role at Voltex as General Manager combines all of his skills and technical knowledge of HV systems, from design to operation and automation. With responsibilities for business development, tendering, risk management, regulatory and legal compliance, he has secured and managed the company’s delivery of major projects on three continents, including Lihir MOPU in PNG, QCLNG gas plant in Australia and Cobre Panama for First Quantum Minerals in Panama.