Darlington Point Energy Storage System

Lessons Learnt Report D4.2

Project Name:	Darlington Point Energy Storage System
Contract Number:	2020/ARP05
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Darlington Point Energy Storage System has received funding from ARENA as part of ARENA's Advancing Renewables Program.

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Executive summary

Edify Energy (Edify) has developed the Darlington Point Energy Storage System (DPESS) which is a 25MW / 50MWh Battery Energy Storage System (BESS) system located adjacent to the 275MW Darlington Point Solar Farm in NSW. DPESS comprises advanced grid forming inverters with the ability to provide system strength services to the NSW electricity network. The performance of the plant is being verified through an agreed Testing Plan. This Testing Plan was developed in consultation with Transgrid and AEMO and includes a combination of power system studies, commissioning tests, and ongoing performance monitoring. The findings of the Testing Plan and any other key learnings will be disseminated though knowledge sharing outputs.

This Knowledge Sharing Report is issued at Milestone 4, Commercial Operations Commenced. The report specifically addresses lessons learnt in the registration, testing and commissioning process and the approach for an advanced grid forming inverter plant compared to a traditional grid following plant.

The key lessons learnt for this project are as follows:

- While there are challenges to the connection of grid forming inverters in each of the connection application, registration and commissioning and testing phases, the overall process and timeline for these stages is similar to grid following technologies.
- Similar to grid following technologies, the connection process becomes easier with precedence of similar projects in terms of both the formation of appropriate GPS clauses and the familiarity and confidence in power system models of the grid forming inverter controls. The biggest risk to the initial timeframes relates to the additional time in the due diligence process for parties to become familiar with new models.
- The grid forming controls have created no observable difference from a market and trading perspective for the BESS.

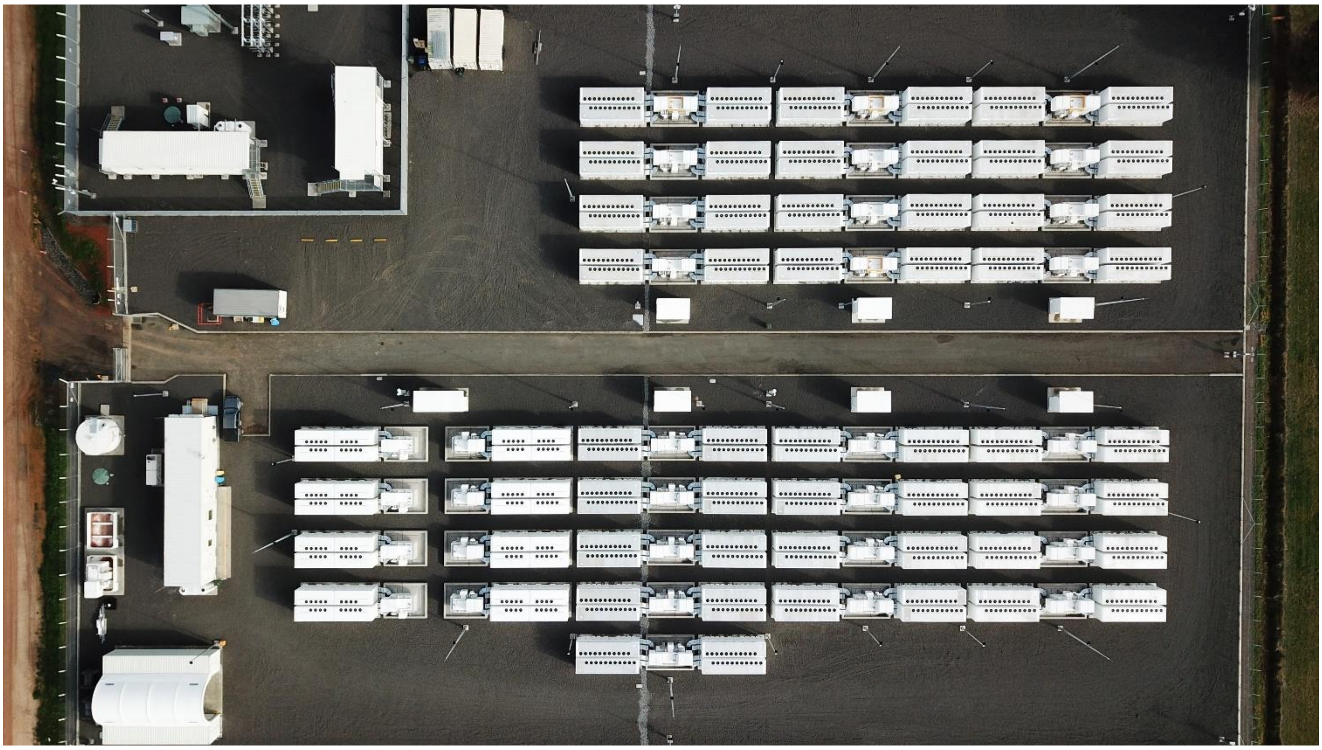
Overall, we believe that this project has helped to create precedence for future BESS to be connected with grid forming controls and shown there is little impediment to implementing grid forming BESS compared to grid following, provided that the supplier’s control systems are in a suitable state of readiness. When this is balanced with the benefit of this technology to the network there is a strong case for the majority of future BESS to use grid forming controls which, with the current forecast BESS deployment in the NEM, could have a material positive impact on system strength and network stability.

This report addresses some of the key lessons learnt in developing and executing the DPESS project.

Project details

Project overview

Edify developed the DPESS project which is a 25MW / 50MWh BESS located adjacent to the 275MW Darlington Point Solar Farm in NSW (also developed by Edify). DPESS commenced construction in July 2022, completed construction in May 2023 and began commercial operations in September 2023.



DPESS connects to Transgrid's 132kV network at Darlington Point Substation and involves the use of advanced inverters set to 'grid forming mode' (also known as 'virtual machine mode'), which is a unique feature that can provide system strength services to the grid.

Project objectives

DPESS principally aims to demonstrate that a BESS with advanced inverters can reduce the cost of connecting variable renewable energy projects to weak grids by offsetting (fully or partially) the need for synchronous condensers (or other reactive plant) in future projects.

DPESS aligns with the objectives and desired outcomes of ARENA's Advancing Renewables Program (ARP)[1] as successful completion of DPESS will contribute to technical, regulatory and commercial outcomes that are of high priority for ARENA. DPESS will contribute to all five of the ARP objectives and outcomes, which are:

a) reduction in the cost of renewable energy;
b) increase in the value delivered by renewable energy;
c) improvement in technology readiness and commercial readiness of renewable energy technologies;
d) reduction in or removal of barriers to renewable energy uptake; and
e) increased skills, capacity and knowledge relevant to renewable energy technologies.

BESS projects using advanced grid forming inverters offer several key benefits to the electricity network, as follows:

a) **Reduce the need for synchronous condensers**: BESS projects with advanced grid forming inverters can remove the need for synchronous condensers or other measures to be installed with renewable energy projects. Synchronous condensers are complex and expensive machines. Therefore, removing the need for such machines significantly reduces the cost and risk profile associated with connecting renewable energy projects in weak grids.
b) **Provide system strength services**: BESS projects with advanced grid forming inverters provide system strength remediation services (i.e. frequency and voltage stabilisation, fast disturbance event

[1] https://arena.gov.au/assets/2017/05/ARENA_ARP_Guidelines_FA_Single_Pages_LORES.pdf

response, etc.) with much faster response times than other energy storage or generation technologies. These services can allow nearby renewable energy projects to operate with fewer constraints or without constraints to their output, increasing the value of these projects and improving the utilisation of the network.

c) **Multi-use technology**: BESS projects with grid forming inverters can also provide all the beneficial services that have been observed and well reported from other BESS projects (such as charging during periods of low demand / price, dispatching into high demand / volatile price periods and providing market ancillary services) making them a multi-use market and technical service technology, in contrast to single purpose technologies such as synchronous condensers.

These benefits combine to support the further commercialisation of BESS and advanced grid forming inverter technology, further development of renewable energy projects and increased economic, environmental and social benefits to Australian consumers.

BESS technology is relatively new and as such there are significant learnings from every project. Key learnings to date from DPESS are detailed in the following section. These learnings are already being applied to other renewable energy and BESS projects in Australia.

Key lessons learnt

Lesson category: regulatory – connection / registration process

Detail

In order to export to the network, a generator needs to successfully navigate the multi-stage connection application and registration process, that is managed by a combination of the relevant Network Service Provider (NSP) and the Australian Energy Market Operator (AEMO). The relevant NSP for DPESS is Transgrid.

During its development stage, a project proponent must submit a connection application pack to agree a set of generator performance standards (GPS), which define the limits within which the generator must operate at all times. This is referred to as the Connection Application stage.. The Connection Application stage culminates in an offer to connect and the issuing of 5.3.4A and B letters which allow entry into a connection agreement based on the agreed GPS. Edify understands that DPESS was one of the first projects to negotiate a GPS for a plant using grid forming inverters.

This process is followed by the registration stage during which models are updated and submitted based on the project's detailed design and procurement. This is intended to assess whether the 'as built' project will have any adverse impact to network stability compared against its original models and the agreed GPS.

Key lessons learnt

Importance of precedent projects in the connection process

Over the past 5 or so years there has been a significant number of inverter-based projects connect to the NEM. While this in itself has presented some challenges, one observation that can be made is that the connection process has benefited from precedent projects using the same technology. The benefits include:

- There are pre-existing agreed GPS clauses which adequately capture the performance of the generator which can be used to quickly agree the GPS. This removes uncertainty about the acceptability of GPS clauses and the approach to tuning of inverters.
- The power system modellers as well as the NSP and AEMO in conducting due diligence have experience with the inverter model being used and know the parameters which can be tuned to alter the performance.
- Problems have been encountered and previously fixed with the resolution known.

DPESS was negotiating a GPS at a time where the NSP and the responsible team at AEMO had not yet agreed a GPS which reflected the performance of grid forming inverters. Our approach to this was to propose deviations from the minimum access standards early including wording which captured what was considered an appropriate response of the plant. This primarily related to the response to a fault where it did not make sense to specify thresholds and rise and settling times as required by the minimum access standards for asynchronous machines. It took a number of months to reach agreement on the wording of the relevant clause (clause 5.2.5.5), which had the potential to delay the project. This was due to the need to negotiate an acceptable GPS clause which didn't fit in with the currently defined performance standards for asynchronous grid forming plant, as by design, the response of grid forming inverters is more akin to synchronous machines. Given the limited experience with grid forming inverters, it took time to demonstrate that while it was theoretically possible to tune the inverters to meet existing asynchronous generators standards, this was not the best outcome from a network perspective as the voltage disturbance would be larger and take longer to return to stable conditions following a fault using these settings. The final GPS clause described the performance similar to synchronous machines which was deemed to be a higher level than the asynchronous standard and accommodated the grid forming response characteristics.

Key outcomes

DPESS was able to successfully negotiate a GPS which allowed for the grid forming controls and we believe this is in the best interest of network stability.

Implications for future projects

We believe that this and other projects which have now connected with similar technology have created sufficient precedence such that this issue will not be encountered by future projects. Edify has already experienced the benefit of this when negotiating a GPS for a subsequent BESS connection application. It is also noted that this project and others using similar technology are increasing the familiarity of people in the industry with these models and their characteristics which should also make future connections easier.

Lesson category: technical – testing and commissioning

Detail

Generator testing and commissioning is undertaken to demonstrate that the actual plant performance is compliant with the GPS and that it aligns with the power system models of the generator. Checking the alignment with models is an important step as much of the assessment of the impact of the generator on the network is assessed using these models. This practice is reliant on the assumption that the models accurately represent the actual performance of the plant in the given scenario.

Over the past 5 years we have observed that there has been a significant focus to improve the accuracy of the power system models of asynchronous generators as it became clear that this would be the dominant generator technology connected in the future. With the new control systems for these advanced inverters, it is possible that similar accuracy issues may be identified during the testing and commissioning processes to those initially found with asynchronous generators.

Key lessons learnt

- During testing and commissioning we observed that the commissioning process for the BESS was very similar to how we would have anticipated the process with grid following inverters. There were no additional tests required due to the grid forming nature and there was generally good alignment between the actual performance and models.
- The one unexpected issue which was encountered was due to the false operation of current transformer (CT) failure detection for the project during testing. CT failure detection is implemented to enable the plant to detect a failure of a CT which could lead to unstable operation of the generator in the event that it were undetected. While a number of methods of CT failure detection exist, one such method is by monitoring negative sequence current. This method has proven effective for grid following plants as high magnitudes of negative sequence currents only occur due to CT faults as the plants don't try to correct phase imbalance. One feature however of grid forming inverters is that they will try to correct for imbalance between phases. This is desirable from a network perspective as this will reduce phase imbalance, however this response was observed to lead to false triggering of CT failure detection during times of high imbalance in the network. As a result, it is observed that the utilisation of negative sequence current monitoring is not a suitable means of CT failure detection for grid forming BESS as it is for grid following BESS. Alternative means of CT failure detection based on comparison of phase currents are being investigated.

Key outcomes

- It was observed that there are no additional requirements for the commissioning and testing of grid forming BESS and there does not appear to be a higher risk of model inaccuracy as a result of the use of grid forming inverter controls.

- Use of negative sequence current monitoring is an unsuitable means of CT failure detection for grid forming BESS, which resist network phase imbalance and alternate means shall be used.

Implications for future projects

We believe that testing and commissioning of grid forming BESS does not materially differ in risk profile to grid following BESS and that future projects should not consider this as an impediment to adopting the technology.

Lesson category: technical – operational aspects

Detail

One question that is often raised with respect to grid forming BESS is whether there is a material operational impact on the BESS. Concerns often relate to aspects such as:

- Deviation from dispatch targets which may create compliance issues, potentially impact revenues or attract causer pays costs.
- Increased cycling of the BESS via numerous small charges and discharges.
- Impacts on ability to participate in FCAS markets.

Key lessons learnt

- Overall, the experience has been that the use of grid forming inverter controls has had no discernible impact on the operation of the BESS or the participation in any of the conventional energy and FCAS markets.
- Responses due to the grid forming controls are by and large very small in nature and are dominated by reactive power and so there has not been a detectable difference in active power import or export attributable to the grid forming controls.
- While the grid forming controls do provide an inertial response to frequency deviations, these responses are very small and short term in terms of timeframe. These responses are insignificant compared to the frequency droop control of the plant which is enabled the majority of the time as the plant participates in FCAS markets or provides the mandatory primary frequency response. We estimate that the grid forming control action would represent less than 1% of the energy exported or exported as a result of frequency droop control. The frequency droop control is identical for grid forming and grid following plants.
- The ability of the BESS to be registered for FCAS markets has not been impacted in any way by the grid forming controls.

Key outcomes

The project has demonstrated that concerns about the operation of the BESS due to grid forming controls are not occurring in practice.

Implications for future projects

The project has shown that concerns about the impacts of operations are not an impediment to selected grid forming BESS when compared to grid following BESS.