FORTESCUE ALINTA SOLAR GAS HYBRID PROJECT

Final Project Report

Date: 06/09/2023

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*This project received funding from the Australian Renewable Energy Agency (**ARENA**) as part of ARENA's Advancing Renewables Program.*

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List of Abbreviations

ARENA	Australian Renewable Energy Agency
BESS	Battery Energy Storage System
EPC	Engineering, Procurement, Construction
FIFO	Fly In Fly Out
Fortescue	Fortescue Metal Group
FY	Financial Year
GJ	Gigajoule
HAZOP	Hazard and Operability study process
HSE	Health, Safety and Environment
kV	Kilo Volt
NAIF	Northern Australia Infrastructure Facility
PPA	Power Purchase Agreement
PPR	Principals Project Requirement
Project	Chichester Solar Gas Hybrid Project
PV	Photovoltaic
SF	Solar Farm
SoC	State of Charge
WA	Western Australia

1. Executive Summary

The Chichester Solar Gas Hybrid Project was a successful initiative by Alinta Energy to provide low emission renewable energy to large, islanded networks in the Pilbara region of Western Australia. The project involved the construction of a new 60 MW solar generation facility at Fortescue's Chichester Hub iron ore operations and a 60 km transmission line linking the Fortescue's Christmas Creek and Cloudbreak mining operations. This line then connected to Alinta's existing 220 kV transmission line running between Roy Hill mines and Alinta Energy's Newman gas-fired power station and 35 MW battery facility.

In terms of performance the first year of operation the Solar Farm met the expected energy yield for each month (98 % +). It has contributed to the reduction in fossil fuel generation, by reducing the amount of spinning reserve required at Newman Power Station. The Newman battery has also performed well, providing network support during intermittent clouding and outages. The solar facility and battery integration has shown that high penetration renewables can be a reliable energy source for mining operations, providing a clean energy pathway for the future.

Throughout the project, there were several valuable lessons learned. One key lesson learned was the importance of effective communication and collaboration between all stakeholders, including Alinta Energy, Fortescue and local communities. Another lesson was the importance of clear and accurate system studies, which provides the foundation for thorough planning and risk management. This would ensure that any potential challenges were identified and addressed early on.

Looking forward, improvements to the battery dispatch will ultimately reduce spinning reserve requirements of the Newman Power Station. This could tie in with feasibility studies, to determine if increasing battery storage at Newman Power Station is worthwhile. Generally, the solar farm will see significant improvements in output if soiling can be managed effectively and improvement to filtrations systems can be made.

Overall, the Chichester Solar Gas Hybrid Project has been a success and serves as a model for future energy projects in the Pilbara region.

2. Introduction

Alinta has completed the construction of its Chichester Solar Gas Hybrid Project (the **Project**) in the Pilbara region of Western Australia (**WA**). On behalf of the Australian Government, the Australian Renewable Energy Agency (**ARENA**) provided funding support of $24.2 million for the Project as part of its Advancing Renewables Program. The Northern Australia Infrastructure Facility (**NAIF**) also provided a loan of approximately $90 million for the Project. A condition of the funding support from ARENA is that Alinta provides a series of reports summarising the lessons learnt from each stage of the project lifecycle.

This report has been prepared in accordance with Alinta's knowledge sharing obligations under the Funding Agreement reached with ARENA. The final report closes out the Project stages of reporting, outlining the lessoned learned during each project phase and comparing expected performance against key performance indicators of the Chichester Solar Farm throughout the first year of operation.

3. Previous Lessons Learned Reports

The previous lessons learned reports focused sequentially on a specific lifecycle phase of the Project.

3.1. Lessons Learned Report 1: Inception to Financial Close

This report has been issued and accepted by ARENA. It covers the period from project inception to financial close, which occurred on 27 November 2019. The report was issued in April 2020.

3.2. Lessons Learned Report 2: Design and Construction Phase

This report has been issued and accepted by ARENA. It covers the period from financial close to commencement of commissioning. The report was issued in January 2022.

3.3. Lessons Learned Report 3: Commissioning and Testing Phase

This report has been issued and accepted by ARENA and covered the energisation, commissioning and testing phase which occurred for each separable portion of the project prior to the commencement of operations. The report was issued in August 2022.

4. The Project

Alinta has constructed a 60MW AC Solar Photovoltaic (**PV**) power station with interconnecting infrastructure in the Pilbara to supply electricity to Fortescue Metal Group's (**Fortescue**) Chichester Hub mining operations. Fortescue is Alinta's second customer on its Pilbara inland power system, the first being Roy Hill's Iron Ore mine. The Project is the first example of large-scale renewables in both low inertia grids and remote mining operations in Australia. Alinta's Pilbara inland power system now includes seven sources of generation:

- Alinta's Newman gas turbines;
- Alinta's Newman 60MW natural gas fired reciprocating engines which were commissioned during the solar operational reporting period;
- Alinta's Newman battery;
- Alinta's Roy Hill diesel generators;
- Fortescue's Christmas Creek diesel generators;
- Fortescue's Cloud break diesel generators;
- Alinta's Solar PV facility;

and 4 load centres:

- Alinta's Newman battery;
- Roy Hill Iron Ore's mine;
- Fortescue's Cloudbreak mine and
- Fortescue's Christmas Creek mine.

The complete power system integrates PV cells, lithium-ion batteries, diesel and gas fired reciprocating engines and gas turbine technologies across five geographically distributed locations.

The project is in the Pilbara region of Western Australia, near the Chichester Ranges, approximately 150km North of Newman. Refer to figure 1 and figure 2 below for an overview of the location of the infrastructure. The distance from Alinta's Newman

Power Station to the Roy Hill substation is 121km. The new 220kV transmission line which feeds power to the Christmas Creek and Cloudbreak mines are 26km and 35km respectively. The total line distance across the network therefore spans approximately 182km.

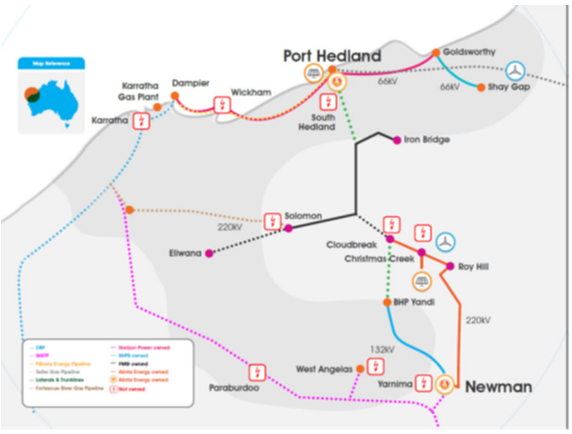

Figure 1 Project Location Overview

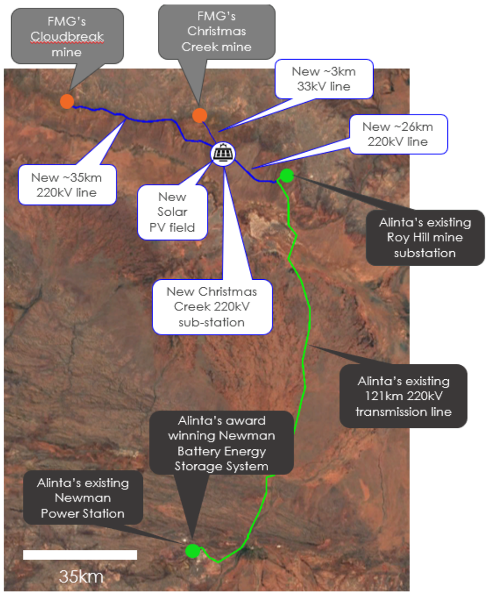

Figure 2 Detailed Project Location

4.1. Project Inception

In 2017, Fortescue, in a public forum in WA, expressed its intention to explore the possibilities of displacing existing diesel and gas-fired power generation with renewable generation sources for mining operations at its Chichester Hub in the Pilbara, Western Australia.

Alinta was already supplying electricity to Roy Hill Iron Ore mines from its gas turbines and battery storage facility at Newman power station. Newman power station is connected to Roy Hill Iron Ore mine via a 120 km, 220 kV transmission network. Alinta proposed extending the 220kV network from Roy Hill mines to Fortescue's Chichester Hub and constructing a solar PV plant at Christmas Creek. This would then supply all electricity requirements for Fortescue's Chichester hub operations under a Power Purchase Agreement (**PPA**).

Fortescue agreed on the concept proposed by Alinta and the Project was developed by Alinta in close cooperation with Fortescue and other stakeholders. The Project reached the financial close on 27 November 2019.

The Project:

- was planned as a high-penetration, renewable hybrid project for supplying reliable energy for mining operations;
- was developed in collaboration with the energy users (Fortescue and Roy Hill Iron Ore mines);
- was underwritten by a long-term PPA for 10 years offtake of the solar farm energy between Fortescue and Alinta; and
- will replace current fossil fuel fired power generation of Fortescue.

The Project dispatches solar, gas, diesel and battery storage to meet the continuously varied load demands of both key users, Roy Hill mines and Fortescue Chichester operations. Successful operation of the system is measured by maintaining network stability and security whilst maximising the renewable generation.

4.2. Technical Scope

The scope of the Project comprises:

1. A single circuit 220kV overhead transmission line between the existing Roy Hill 220kV substation and a new 220/33kV substation at the Christmas Creek mine;
2. Augmentation of the existing Roy Hill 220kV substation to accommodate the new transmission line;
3. A new Christmas Creek 220/33kV substation;
4. A 33kV transmission line to a new 33kV/11kV transformer at the Christmas Creek Mine Power Station and a 11kV underground cable connection to the Christmas Creek Mine Power Station 11kV distribution board;
5. A fully operational 60MW AC Solar Farm connected to the Christmas Creek 220/33kV substation;
6. A new single circuit 220kV interconnecting overhead transmission line between the Cloudbreak 220kV substation and the Christmas Creek 220kV substation, and the interfacing with Fortescue Cloudbreak mine facility; and

7. A new 220 / 11kV Cloudbreak Substation. and a 11kV overhead and underground cable connection to the Cloudbreak Mine Power Station 11kV distribution board.

4.3. Key Objectives

Key objectives of the Project are to demonstrate:

Project Objectives	How this was achieved
Significant penetration of an intermittent renewable energy source for mining operations;	High loading periods throughout the day allowed the SF to export at capacity for large durations of time. This was then supported by the Newman battery energy storage system (**BESS**), which picked up solar shortfalls during clouding events.
The ability of solar and battery storage to meet 100% of the load for Fortescue's mining operations; and	During optimal conditions, the SF can export approximately 60MW. This allows the SF to meet customer demand during the day when conditions are favourable.
Improved system security and reliability in a low inertia grid with intermittent renewable generation and battery storage.	The SF is designed to follow customer loading profiles based on the frequency of the Newman Power Station. During high frequency periods, the SF reduces export to maintain minimum spinning reserve. Conversely, during low frequency periods the SF operates at 100% export. The BESS provides the network stability, by providing instantaneous power during clouding events. This gives the Power Station time to bring additional generation online, if required.

The Project also aims to demonstrate that:

- A mining operation can run solely on solar power with battery storage during the day;
- Miners can operate in a "business as usual" manner when being supplied by an intermittent renewable generation source along with battery storage; and

- Integration of renewables into an existing generation portfolio can facilitate further electrification of diesel-powered auxiliaries.

The Project displaces Fortescue's current aging fossil fuel fired (diesel) fleet of generators. The diesel generators are only be utilised in abnormal circumstances such as black start, network support or outages.

Data extracted from Fortescue's FY22 Climate Change report indicated that Diesel usage had been reduced by 80 million litres during FY2022 when the solar project was being commissioned and this was expected to be at a level of 95 million litres in a full year of operation. Fortescue also reported that increased use of renewable electricity from Alinta Energy's Chichester solar-gas project has led to an overall emissions intensity of electricity falling from 3.50 to 3.32 CO_2/Mt ore processed.

Emissions intensity in electricity generation (CO_2/Mt ore processed)

The Project optimally dispatches solar, gas, diesel, and battery storage to meet the continuously varied load demands of both key users while maintaining network stability and maximising the renewable generation.

Figure 3: New Christmas Creek Substation

5. Summary of Key Lessons Learnt (until Practical Completion)

The following are key lessons learnt from each phase of the project up to and including practical completion. For a complete list the reader is directed to the individual reports.

- System studies should be conducted with an accurate, reliable and calibrated system model with simulation of multiple scenarios for understanding of the static and transient performance of the system.

- System study results would assist in economic evaluation of optimised dispatch of different generators on the network with due considerations of the customer loads, generation efficiency, generator operating hours, start/stop of generators, contingencies, solar generation curtailment and how many generation units should run.

- Managing interfaces in a brownfield project, particularly the interfaces with the existing assets of the customer, are challenging. Interface schedules should be developed with all relevant drawings and information and such information should be included in the Principals Project Requirement (**PPR**) to define the scope of work of the EPC contractor.

- Specific aspects of some Australian standards related to the installation of solar power infrastructure are not applicable for utility scale solar plants and/or are at odds with the electrical specifications required under mining legislation. Exemption from specific aspects of Australian standards should be agreed with the EPC contractor and incorporated in the PPR.

- Construction in any mining lease in WA requires compliance with the *Mines Safety and Inspection Act 1994* (WA) and related regulations. Contractors are more familiar with the requirements of *Work Health and Safety Act 2020* (WA) applicable for construction in non-mining industries. The selection of an EPC contractor experienced in construction under *Mines Safety and Inspection Act 1994* (WA) is beneficial to the project. The requirements of the relevant safety legislation should be clearly articulated in the PPR.

- Significant time and resources are required to obtain the statutory and regulatory approvals. It may take over a year, after approvals from traditional owners are received, to obtain all necessary regulatory approvals required for the financial close of a project.
- Tenure granted under different legislation will have different benefits and constraints. A detailed assessment of the specific activities required against the constraints of different tenure types is necessary in order to optimise the project development timeline.
- ARENA's requirements of information for funding are different from other financiers. Significant investment of time and resources are required to satisfy the condition precedents for financial close of ARENA funding. Early and deep engagement with ARENA is required to understand requirements for conditions precedent and an agreement on how the requirements shall be implemented in practice. Involving a person with prior experience working with ARENA would prove beneficial.
- When constructing new equipment in the vicinity of operating assets, ensure that requirements and constraints imposed by the operator are well understood from the outset of the design process. A fully comprehensive safety in design process must be followed and all affected stakeholders must be represented at each stage of design review and the associated Hazard and Operability study (**HAZOP**) processes.
- For projects undertaken within mining sites, engage at least one full time site based HSE specialist from first mobilisation through to the completion of physical works. The complexities in dealing with tenure, mining legislation and mining policies warrants this investment.

Once assets became electrically connected to the network, they fell under the health and safety systems of the operations team. Ensure that as few defects, omissions and incomplete works remain as possible as it becomes an unnecessary drain on operations resources to be implementing permits for outstanding construction works.

- Engage a dedicated Commissioning Manager as early as possible to manage the interactions between stakeholders. Keep the Commissioning Engineers focussed on the technical aspects of the process as far as practicable.
- Develop a series of pre-commission bench tests to develop a deep understanding of the control systems which are to be integrated. Use this bench testing to fine tune the control systems prior to integration and to minimise the risk of delays caused by unexpected results during functional control system testing.
- There was a lack of appreciation for the effort and time required to configure/tune the forecasting system. It is recommended that the system is made operational as soon as physically practicable, with temporary power supplies and communications if required to allow for data collection and tuning.
- The asset owner should have the ability to engage directly with cloud forecasting equipment suppliers during design, installation and commissioning, in parallel with the Contractor. Optimally, the Contractor should be required to install and make the system operational at least 3 months prior to grid connection.

6. Battery System

6.1. Newman BESS

In 2018 a 35MW/11.4MWh BESS was installed and commissioned at Newman Power Station. The primary function of the BESS was the provision of 35MW of virtual spinning reserve. Thus, the BESS acted as a ready reserve in the event of the loss of generation when a turbine tripped or in the event of significant customer load shedding; the BESS could absorb significant energy so as to increase the step response capability of the facility. The BESS was also capable of operating in virtual generator mode, supplying up to 35MW of energy if there is only a single gas turbine in service at the time that gas turbine trips.

The BESS is configured in a highly modular configuration providing substantial system redundancy. The BESS is comprised of:

- 1 x 50MVA 33/66kV step up transformer
- 1 x 33kV switchroom/control room
- Control and communications equipment
- 5 x modules providing 7MW at 33kV to the BESS switchboard
- Each module contains
  - 1 x 8 MVA 715/33kV dry type coupling transformer
  - 1 x inverter container containing 72 x ABB PCS 90 inverters
  - 1 x Battery container containing 2.28MW of Kokam NMC high discharge rate Li ion batteries in 4 separate banks – including fire detection and a salt-based fire suppression system

The BESS was designed and installed to be expandable to 50MW with the addition of 2 modules. The underground conduits and switchboard installed during the initial construction are capable of accommodating this future expansion if required.

6.2. Change in Service

Essentially the Newman BESS continues its role as a virtual spinning reserve source with the addition of the solar farm. By its design it offers some frequency control and inertia capability as well but due to the small storage capability it offers no real load shifting capability.

The virtual spinning reserve capability gives an initial support for short duration cloud events allowing enough time for thermal generation to be started to support the network if the cloud cover and solar reduction is sustained.

6.3. Overall Performance

The following section is extracted from the Annual Performance Report 2021 - 2022 detailing battery performance and key lessons learnt concerning the integration of a virtual spinning reserve BESS to a significantly sized solar farm.

Table 1 Details of BESS Performance (Annual)

Month	SoC Ave (%)	SoC Max (%)	SoC Min (%)	Charge +Aux (MWh)	Discharge (MWh)
Dec-21	79.01	79.87	58.48	433	54
Jan-22	79	79.8	40.04	414	42
Feb-22	79.07	83.04	55.23	359	30
Mar-22	79.07	80.22	39.97	391	36
Apr-22	78.6	80.3	39.9	363	38
May-22	79.8	86.6	40.1	361	39
Jun-22	79.4	80.6	55.2	337	32
Jul-22	79.9	80.4	0	349	31
Aug-22	79.8	80.6	39.9	349	29
Sep-22	79.8	81.2	48	351	35
Oct-22	79.8	81.4	39.9	379	41
Nov-22	79.8	81.3	40	372	37
Dec-22	79.7	80.3	55.5	433	63

Figure 4 below illustrates the BESS response to clouding events well. It shows that the BESS is supporting the network when there is a loss of solar. Reducing the required spinning reserve and reducing fuel consumption. For events greater than 35 (MW) the BESS will support the system up to 35MW, past this point some thermal generation is required to maintain system stability. The BESS is also restricted by its minimum State of Charge, which is 10% of rated capacity (3.5MWh).

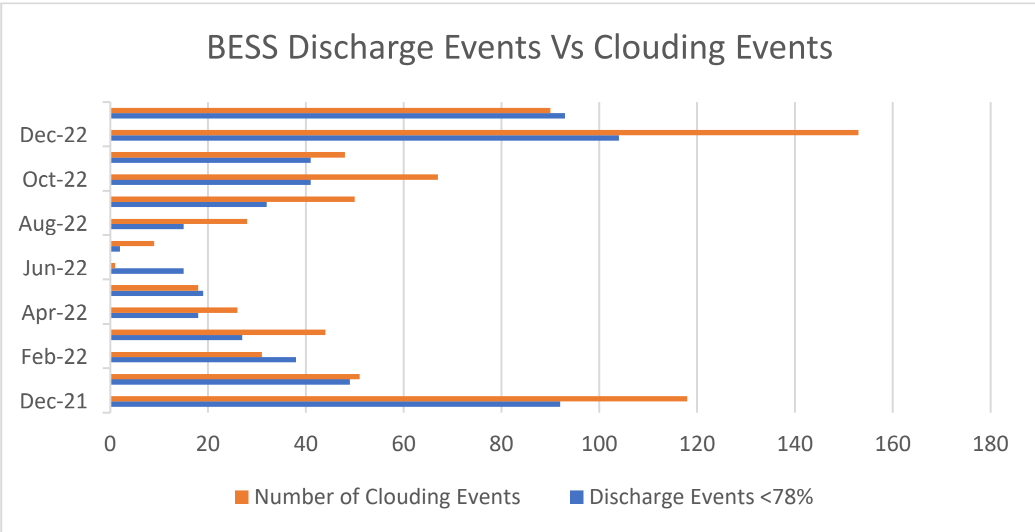

Figure 4 BESS Discharge Vs Clouding Events

6.1. Dynamic Response

The ability of the BESS to respond to a loss of generation in the form of synthetic inertia is critical for the operation of the Chichester grid. A specific example is displayed below of an event where the Solar Farm instantaneously lost 50MW due to a generation trip event.

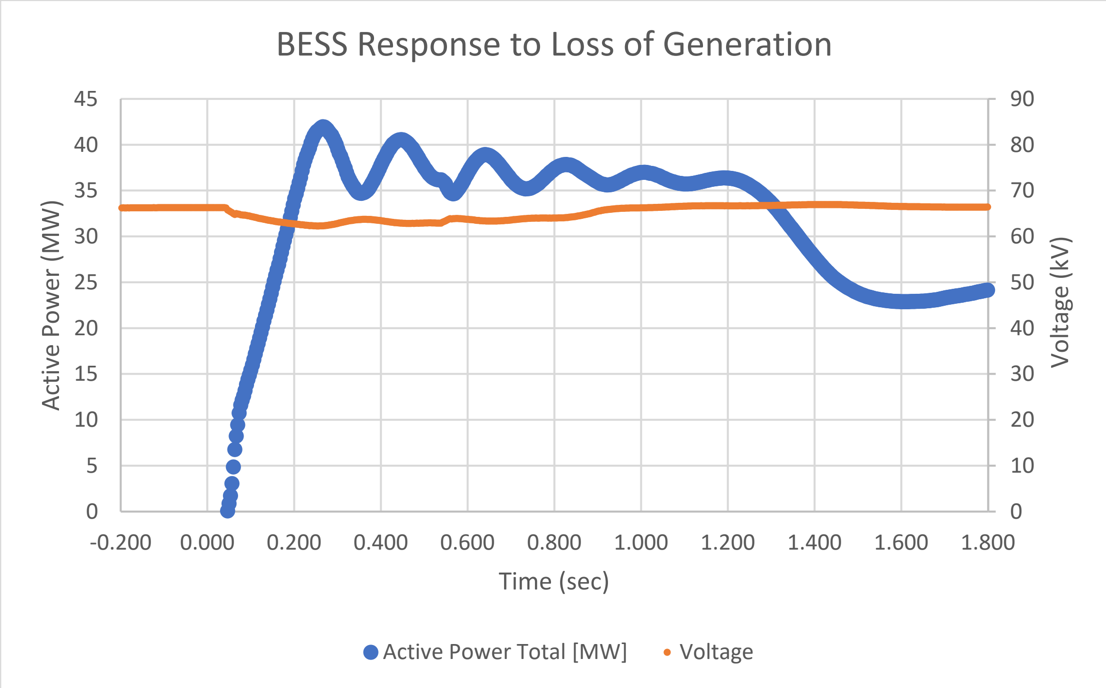

Figure 5 BESS Response to loss of Generation

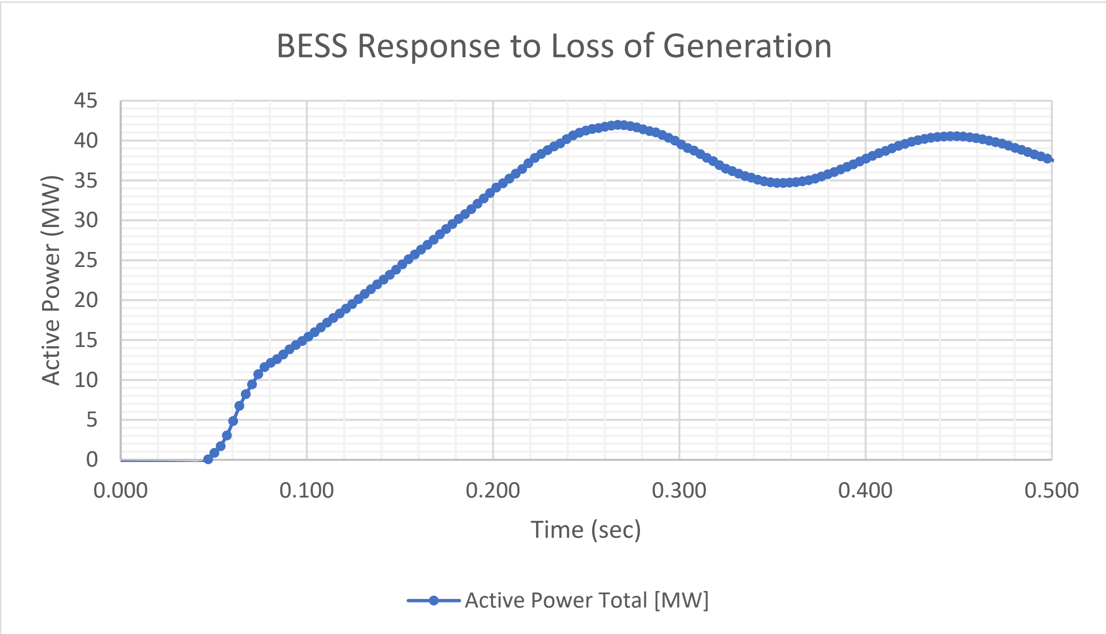

Figure 3 first 500ms response of BESS

As can be seen in Figure and Figure 3 with no thermal generation responding the battery responds to its full output within 240ms with minimal disturbance to the voltage of the system. It should be noted that the size of the generation loss was

50MW well above the capacity of the BESS and some load shedding was required to maintain frequency within the required range.

6.2. Lessons Learnt

The key lesson learnt from BESS integration is as follows:

- To completely avoid the use of thermal energy for solar operation during cloud cover events the battery must be of sufficient size in output and energy delivery to ensure 95% of cloud cover events can be dealt with. Whilst a battery increase would have a positive impact on the renewable percentage of the network, additional data is still required over the coming years of operation to determine the size of the BESS required.
- The BESS is able to respond to its full output with minimal disturbance to the voltage of the system.
- The BESS is able to respond to a loss of solar generation event (e.g. cloud cover) at a quicker rate than thermal generation but only up to it's to the maximum capacity.

7. Summary of Chichester Solar Farm Performance

The following is a summary of Chichester Solar Farm performance results for the period spanning from December 2021 to December 2022. The review looks at the forecast annual yield results and compares them to the measured output of the solar farm. For a more detailed analysis including a discussion of operational and environmental conditions that influenced the annual outcomes please refer to the Annual Performance Report 2021 - 2022.

7.1. Energy Yield

7.1.1. Forecast Assumptions

The energy yield forecast assumptions were based on environmental and operational conditions. The environmental factors included, but not limited to:

- Irradiance levels throughout the year, considering the array is single axis tracking.
- Derating of components due to temperature, soiling, and seasonal events.

Operational limitations were also considered fundamental in understanding how to balance the system with the introduction of renewable sources. Key operational considerations were:

- Active power curtailment, due to minimum loading on the thermal generation units
- System down time, due to scheduled maintenance and planned outages.

7.1.2. Energy Yield Measured Results

The Annual Report 2021-2022 shows the SF availability was based on a 99% uptime; this equates to 87.6 hrs of allowable system downtime per year. Whilst some months the SF hit the 99% target, routine maintenance, planned, and unplanned outages resulted in the average uptime being approximately 88% over the year. It was also seen that soiling losses can severely impact the SF output during the winter months, accounting for 11% of losses on average.

However, there were months during the summer periods where the SF exceed the forecast yields. This was due to:

- High penetration of solar over a sustained period
- High customer loads
- High SF availability.

7.1.3. Yield Test results

This was also reflected in the Solar Farm monthly energy yield assessment which showed the Solar Farm is meeting the guaranteed expected energy yield for each month (98% +).

7.2. Fuel Savings

Figure 7 summarises the estimated reduction in gas driven thermal generation after one year of the SF being operational. Since the commissioning of the SF, it is estimated that 1,878,465GJ of gas have been saved. This was reflective in Fortescue's diesel consumption reducing by 80 million litres annually. This saving is expected to increase to 95 million litres in 2023. The seasonal changes significantly influence the SF production and the resultant gas savings. The gas savings during summer are 2 times higher than in the winter months, this is due to the sun's low positions in the sky and the shorter days.

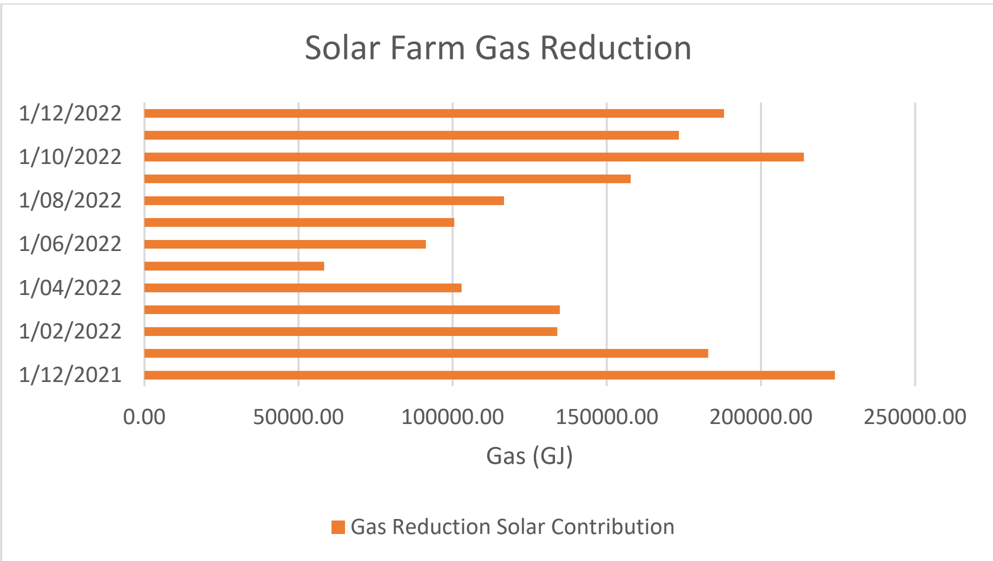

Figure 7 Estimated Gas Reduction

Figure 8 shows the equivalent reduction in carbon dioxide based on the gas reduction seen in figure 7.

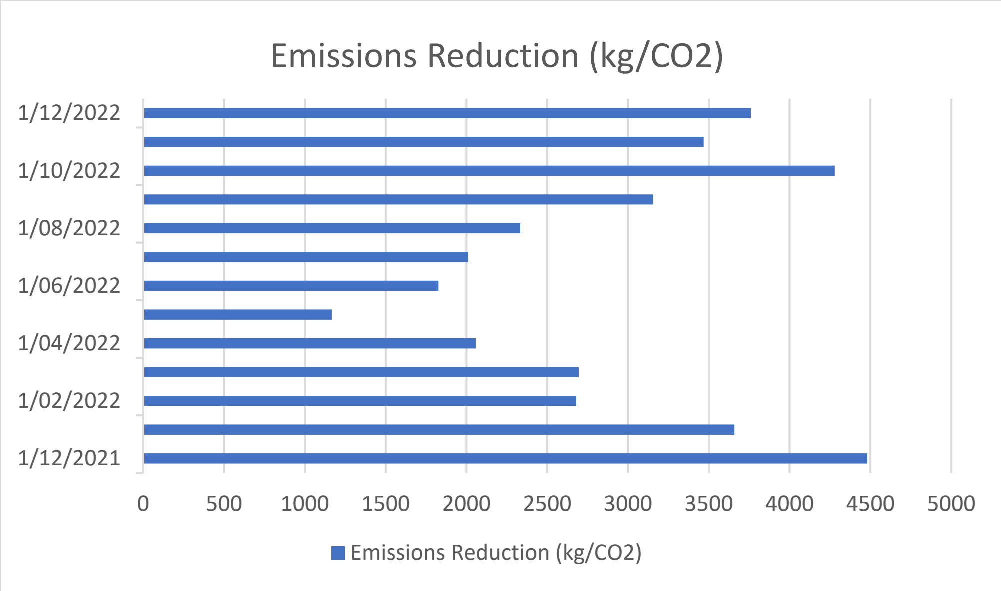

Figure 8 Emission Reduction

8. Local Skills development

Due to the location of the solar farm inside the active mine site of Fortescue that operates as a FIFO location there is no immediately local labour pool for skills development. Consequently, Alinta Energy considers the Newman area to be the local labour pool.

Over the operational period local labour has been used and therefore developed skills in the following areas:

- Solar farm ground maintenance including vegetation management in and around the solar plant.
- Isolation and replacement of solar panels in an active solar farm
- Cleaning and regular maintenance of solar inverters

9. Conclusion

Alinta has successfully completed installation and commissioning of the Chichester SF, with the aim of continual optimization and improved renewable penetration.

To date, the SF has met the guaranteed expected energy yield for each month (98% +). It has contributed to the reduction in thermal generation, by reducing the amount of spinning reserve required at Newman Power Station. The system has also performed well with the BESS, supporting the network during clouding events and outages.

Using the lessons learned over the past year Alinta will continue to optimise the system. Increases in BESS capacity can further reduce thermal generation and improve network stability. These optimisation steps will be detailed in the Annual Performance Reports.