FORTESCUE ALINTA SOLAR GAS HYBRID PROJECT

Annual Performance Report 2021 - 2022

Date: 1/9/2023



*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

| | |
|---|---|
| AC | Alternating Current |
| AEE | Adjusted Expected Energy |
| APG | Actual Plant Generation |
| ARENA | Australian Renewable Energy Agency |
| BESS | Battery Storage Energy System |
| CHSF | Chichester Solar Farm |
| DC | Direct Current |
| EPC | Engineering, Procurement, Construction |
| Fortescue | Fortescue Metal Group |
| GJ | Gigajoule |
| MET | Meteorological measurement (station) |
| NAIF | Northern Australia Infrastructure Facility |
| O&M | Operation and Maintenance |
| OEM | Original Equipment Manufacturer |
| PCS | Power Conversion System |
| PF | Power Factor |
| Project | Chichester Solar Gas Hybrid Project |
| PV | Photovoltaic |
| PVSyst | Simulation software for Solar system modelling |
| SCADA | Supervisory control and data acquisition |
| SF | Solar Farm |
| SoC | State of Charge |

## 1. Executive Summary

This report details the annual performance of the Chichester Solar Farm (CHSF), for the 2021/2022 period. The report leans on the system forecasting developed during the design stages of the project and compares it to the measured data during the inaugural year of operation. To provide context to the data, the initial section of the report explains the background of the project, and the lessons learned during various stages of the project.

The system forecasting details the datapoints used to measure the performance of the system, and details the assumptions made when determining the expected energy yields of the Solar Farm (SF). The initial system constraints used to forecast expected yield, underestimated areas around system uptime, arraying soiling, and active power curtailment. However, the SF exceeded the forecast energy yield at periods over summer, which was due to optimal conditions and high system uptime.

Environmental conditions also factored into the SF performance and the overall network stability. Clouding events during peak SF generation resulted in significant reductions in generation (up to 60MW) over a short period of time. The integration of the SF in Chichester and the battery energy storage system (BESS) in Newman can be considered a success. Data shows a clear correlation between the clouding events at the SF, and the BESS in Newman dispatching power to cover the shortfall in generation. This operation is critical to maintaining network stability and providing instantaneous support if thermal generation needs to come online.

Optimization of the dispatch is an ongoing process and finding the additional incremental improvements continues on the SF. The lessons learned indicate that further integration work is need, to reduce the Active Power curtailment of the SF during low loading periods.

Increasing the BESS capacity to support a larger amount of clouding events. The results showed that a 10MW increase in BESS could result in 80% of clouding events being supported by renewables.

Operational lessons learned have also identified key areas around inspections and maintenance that require innovative solutions. Improvements to the components on site is necessary to reduce the downtime of inverters for maintenance.

## 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**) has provided funding support of $24.2 million for the Project as part of its Advancing Renewables Program. The Northern Australia Infrastructure Facility (**NAIF**) has 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 report outlines key performance indicators of the Chichester Solar Farm (CHSF) throughout the first year of operation and provides technical and operational lessons learned to benefit future renewable projects and improve efficiencies.

## 3. 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 BESS has 35 (MW) of storage, with a primary function of providing spinning reserve capability for the Newman Power Station.
- Alinta's Roy Hill diesel generators;
- Fortescue's Christmas Creek diesel generators;
- Fortescue's Cloud break diesel generators; and

- Alinta's Solar PV facility;

  and 4 load centres:

- Alinta's Newman BESS;
- 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 physically 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 lines 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.

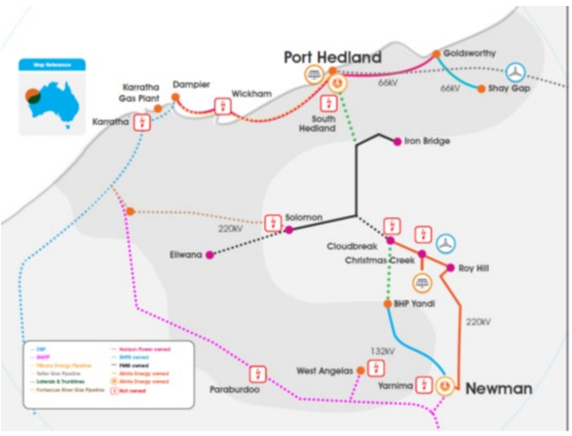



Figure 1 Project Location Overview

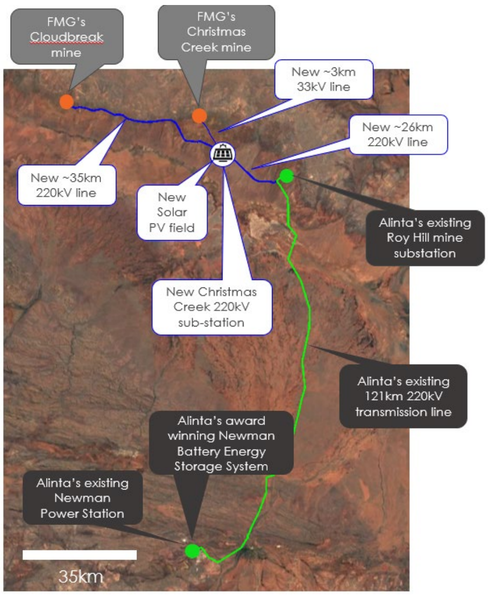



Figure 2 Detailed Project Location

# 4. Annual Performance

The following CHSF performance results are 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. The report then discusses operational and environmental conditions that influenced the annual outcomes.

## 4.1. Energy Yield Assessment (Forecast)

### 4.1.1. Forecast Assumptions

- The Energy Yield assessment uses PVSyst to model the expected system performance throughout the first year of operation. The environmental inputs used MET station data to provide average hourly inputs into PVSyst. The irradiance was modelled using the Perez transposition model, which is a calculation of the incident irradiance on a tilted plane using horizontal irradiance data.

- The soil in Chichester is composed of red loamy earths, red deep sandy duplexes, and stony soils. The soiling on the panels was estimated to be an average of 3% over the period between array cleans.

- The Solar Field Auxiliary Loads cover: Tracker Motors and Controllers, Met Stations, PCS stations self-consumption, PCS Auxiliary Loads Transformer losses. The Solar Facility Loads cover: Control room, O&M room, workshop room, Lighting & Security Systems and Auxiliary transformer. The combined CHSF auxiliary loads were estimated at 950 (MWh)/yr.

- Solar farm uptime is 100% for the year zero, and 99% for years 1 to 25.

- Active Power Limitation was assumed to be 60 (MW) up to 35°C, and 54 (MW) at 50°C and linier curtailment from 35°C to 50°C.

### 4.1.2. Forecast Results

Table 1 shows a monthly breakdown of the expected system performance during the first year of operation. Data has been sourced from WSP technical Due Diligence Revision 6 – 19/11/2019.

**Table 1 Energy Yield Forecast (Year 1)**

| Energy Yield Forecast (Year 1) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Total** |
| Solar Farm Availability | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% | 99% |
| Irradiation kWh/m² | 277 | 253 | 251 | 232 | 209 | 172 | 199 | 253 | 290 | 311 | 315 | 314 | 3,076 |
| Metered Energy (MWh) | 14,283 | 13,406 | 13,246 | 12,557 | 11,786 | 9,910 | 11,484 | 14,095 | 15,669 | 16,351 | 15,980 | 15,933 | 164,700 |
| Specific Yield (kWh/kWp) | 211 | 198 | 195 | 185 | 173 | 146 | 169 | 207 | 231 | 242 | 238 | 236 | 2,431 |
| Performance Ratio | 76.40% | 78.10% | 77.70% | 79.50% | 83.10% | 84.60% | 84.70% | 82.20% | 79.70% | 77.70% | 75.40% | 75.30% | 79.00% |

#### 4.1.3. Data Sources

CHSF has 2 weather stations that monitor irradiance, ambient temperature, rain fall, and soiling percentage. The weather station is also fitted with cloud cam, to monitor clouding events.

The Power Plant Controller and PCS units monitor and control:

- AC measurements:
  - Active power
  - Reactive power
  - Power factor
  - Phase Voltages
  - Phase currents
- DC measurements
  - Voltage
  - Current
  - Power
- Current values from each DC input
  - Inverter temperatures

- Inverter alarms
- Inverter status

#### 4.1.4. Energy Yield Measured Results

Table 2 is a summary of the CHSF annual performance.

**Table 2 Energy Yield Measured (Year 1)**

| Measured Energy Yield (Year 1) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | **Dec-21** | **Jan-22** | **Feb-22** | **Mar-22** | **Apr-22** | **May-22** | **Jun-22** | **Jul-22** | **Aug-22** | **Sep-22** | **Oct-22** | **Nov-22** | **Dec-22** |
| Solar Farm Availability MWh) | 98.5% | 86.0% | 78.3% | 88.0% | 79.2% | 78.0% | 79% | 88.7% | 93.3% | 96.9% | 99.0% | 86.0% | 97.0% |
| Solar Generation (MWh) | 16,864 | 13,790 | 10,039 | 11,321 | 8,927 | 6,017 | 7,307 | 8,376 | 10,364 | 13,310 | 17,024 | 13,105 | 15,251 |
| Forecast Energy (MWh) | 15,933 | 14,283 | 13,406 | 13,246 | 12,557 | 11,786 | 9,910 | 11,484 | 14,095 | 15,669 | 16,351 | 15,980 | 15,933 |
| Soiling Loss (MWh) | 624 | 551 | 445 | 588 | 719 | 412 | 870 | 2,648 | 1,423 | 1,031 | 1,097 | 1,454 | 1,182 |
| Constraint (MWh) | 450 | 1,032 | 2,088 | 526 | 87 | 1,022 | 31 | 167 | 800 | 517 | 954 | 2,587 | 587 |
| **Inverter Downtime (MWh)** | 338 | 2,400 | 2,570 | 1,784 | 2,214 | 1,641 | 1,876 | 1,188 | 972 | 333 | 155 | 256 | 231 |

### 4.2. Energy Yield Findings

As seen in figure 3, the forecast and measured trends vary, depending on the time of year. It was seen that December 2021 and November 2022 the SF exceeded the forecast values. This was due to favourable solar conditions above the long-term average, low inverter down times and reduced constraints on the solar farm. The uptime of the inverters used in modelling the system performance was 99% for the life cycle of the system. These values were not reflective of the actual uptime seen on site. Routine maintenance, improved safety procedures and environmental factors resulted in longer than expected outages. The environmental and operational factors that impacted the system performance are detailed in section 6 and 7.

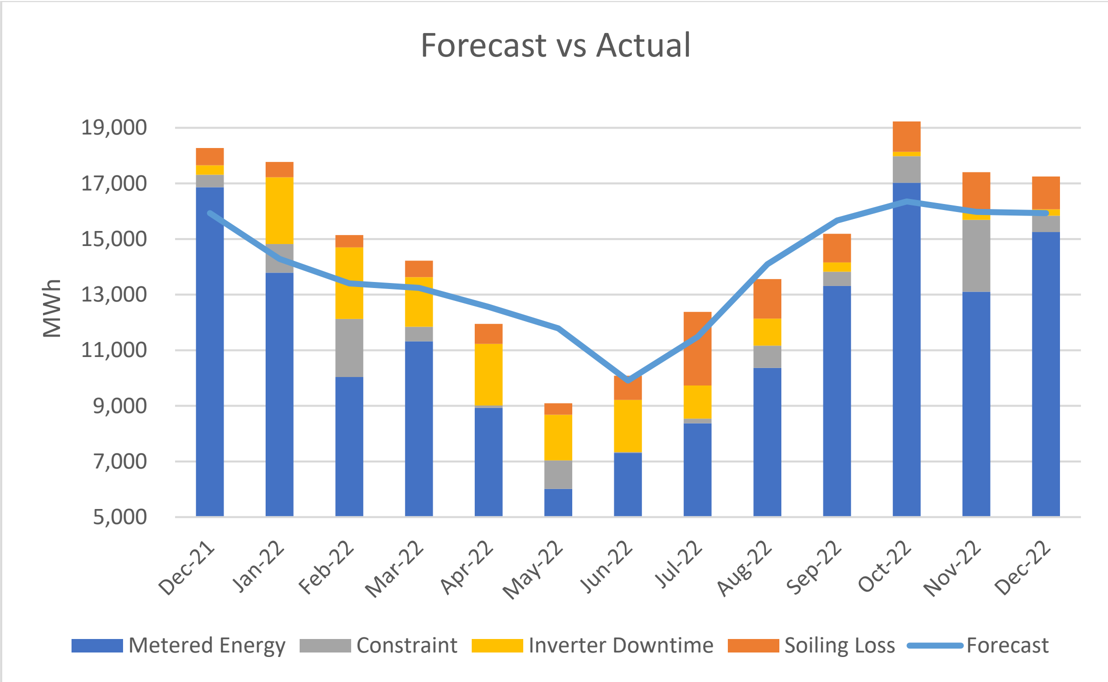



**Figure 3 Energy Yield Forecast Vs Measured**

### 4.3. Energy Yield Test

Once Practical Completion of the Solar Farm was achieved, the Contractor was required to commence a 12-month energy yield test which may be completed during the 24-month defects liability period.

#### 4.3.1. EPC Contract Requirements

Satisfaction of the Energy Performance Test requires that the Actual Plant Generation is equal to, or greater than the Energy Yield Guarantee over a twelve-month period commencing on a date after Practical Completion. The Energy Yield Guarantee is equal to 98% of the Adjusted Expected Energy in MWh over the same period. Definitions of Actual Plant Generation and Adjusted Expected Energy are as follows:

**Actual Plant Generation** means the sum of all energy exported for each non-zero data line entry for the number of days for the Energy Yield Test.

**Adjusted Expected Energy** means the output of the Energy Model adjusted for the hourly Availability, monthly soiling loss figures and PF adjustment when PF < 0.9.

Requirements of the Energy Yield Test are stipulated in the EPC Contract as follows:

- The Contractor is responsible for carrying out the test.
- The test must be carried out over 365 continuous days.
- The test may be completed within the Defects Liability Period.
- Actual Plant Generation readings are taken from the tariff meter at the connection point in MWh (AC).
- The contractor shall record all relevant data required to perform the Energy Model evaluation.
- The evaluation for the energy yielded during the Energy Yield Test shall use data line entries of one minute duration each.
- Each one-minute data line shall be zeroed should the following occur:
    - irradiance less than 100 W/m2;
    - any grid contingency event such that the grid is operating outside the normal operating range of the NWIS;
    - anytime the grid is operating below the voltage p.u. of the Energy Model;
    - export constraint outside the responsibility of the contractor;
    - an event that is the result of a direction by the principal; and
    - an event that was the result of an action or event outside the contractor's responsibility.
- If the data line entry has one of the above events occurring, then that data line shall be zeroed for all results.
- Data line entries are input into the Energy Model to determine the Adjusted Expected Energy.

- The Adjusted Expected Energy results for each one-minute data lines are summed to determine hourly, daily, and monthly results.

#### 4.3.2. Yield Test results

The Solar Farm monthly energy yield assessment occurred between 24 November 2021 and 23 November 2022 based on the PVSyst model energy yield prediction and actual plant generation data. The monthly results show the Solar Farm is meeting the guaranteed expected energy yield for each month (98% +) and the full 12 months as per the table below.

**Table 3 Actual Energy Yield**

| Period Start | Period End | Period (Days) | Adjusted Expected Energy (AEE) | Actual Plant Generation (APG) | APG/AEE Ratio | AVG Soiling Loss (%) |
|---|---|---|---|---|---|---|
| 24-Nov-21 | 31-Dec-21 | 38 | 21,285.00 | 21,018.00 | 98.7% | 2.10% |
| 1-Jan-22 | 31-Jan-22 | 31 | 14,187.00 | 13,985.00 | 98.6% | 1.76% |
| 1-Feb-22 | 28-Feb-22 | 28 | 7,652.00 | 7,752.00 | 101.3% | 1.62% |
| 1-Mar-22 | 31-Mar-22 | 31 | 9,545.00 | 10,015.00 | 104.9% | 3.21% |
| 1-Apr-22 | 30-Apr-22 | 30 | 8,279.00 | 8,788.00 | 106.1% | 4.56% |
| 1-May-22 | 31-May-22 | 31 | 4,545.00 | 4,712.00 | 103.7% | 2.83% |
| 1-Jun-22 | 30-Jun-22 | 30 | 7,156.00 | 7,188.00 | 100.4% | 6.58% |
| 1-Jul-22 | 31-Jul-22 | 31 | 8,127.00 | 8,165.00 | 100.5% | 21.40% |
| 1-Aug-22 | 31-Aug-22 | 31 | 8,080.00 | 8,310.00 | 102.8% | 12.37% |
| 1-Sep-22 | 30-Sep-22 | 30 | 11,160.71 | 11,414.25 | 102.3% | 6.00% |
| 1-Oct-22 | 31-Oct-22 | 31 | 13,040.00 | 13,167.00 | 101.0% | 4.50% |
| 1-Nov-22 | 23-Nov-22 | 23 | 6,254.51 | 6,214.02 | 99.4% | 7.20% |
| | | | | **Annual (12 Month) Average** | **101.6%** | |

As per previous lesson learnt reporting this yield test was flawed due to incorrect allocation of unplanned outages in the EPC contract meaning the Contractor was excused of all unplanned outages.

# 5. Solar Performance

### 5.1.1. Clouding Events

The following analysis details clouding events for the CHSF over a period covering Dec 2021 to Dec 2022. The data uses a 10 second sample rate, which compares the pervious time stamped value to determine changes in solar output (MW). The data points collected are:

- The starting position of the of the solar farm prior to the shading event (MW)
- The total solar loss (MW), which is the maximum decreased change of the solar array during a clouding event
- Rate of change is the (MW) loss over a 1-minute period

If the solar output is trending downwards over a period, the accumulated sum of the reduction in solar is calculated. This sum will continue until the reduction in solar has stopped for greater than 1 minute.

Table 4 below, is an example of the number of clouding events that occur during a 12-hour period, when the array is generating. This table only includes events where the decrease in solar is greater than 30 (MW).

Note: The time intervals are based on Perth time (UTC+8).

**Table 4 Daily Shading Events < 30 MW**

| Time | Change MW/min | Maximum Change MW | Starting Output MW |
|---|---|---|---|
| 10:41:30 AM | 9.7 | 37.3 | 56.4 |
| 12:08:00 PM | 12 | 35.9 | 59.4 |
| 1:18:30 PM | 7.6 | 35.4 | 59.4 |
| 1:40:30 PM | 11.3 | 47 | 59.9 |
| 2:40:40 PM | 10.2 | 44.3 | 60 |
| 3:01:30 PM | 6.3 | 37.1 | 60.8 |
| 3:36:20 PM | 9 | 40.7 | 57.5 |

### 5.1.2. Findings

During the period between Dec 2021 and December 2022 there were:

- 647 clouding events greater than 30 (MW)

- 367 clouding events that exceeded the BESS's capacity 35(MW) to dispatched 100% renewables.
- This required thermal units to provide the generation deficit for events exceeding 35 (MW)

The data used in figure 4 shows that 280 clouding events (43.28%) were supported by the BESS. This is subject to the duration of the shading event and the state of charge of the battery at the time. There remaining 56.72% of clouding event required BESS + thermal generation supporting.

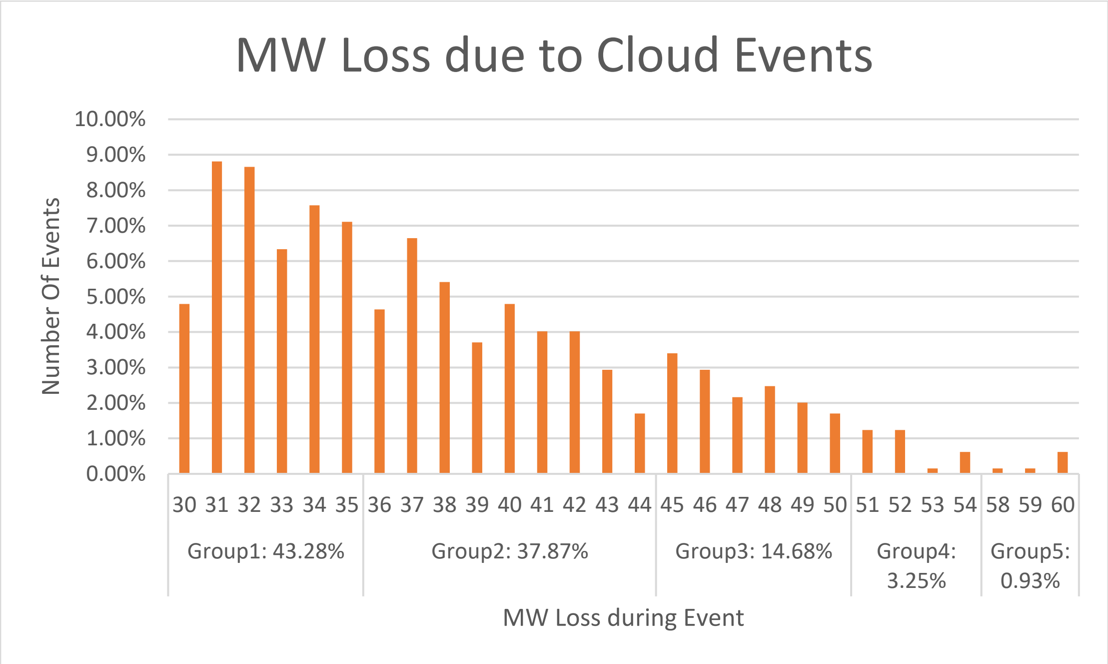



**Figure 4 Clouding Events Vs Losses**

Referring to figure 4, of the remaining 57.72% of clouding events

- **Group 2:** 245 clouding events (37.87%) required less than 10(MW) thermal generation.
- **Group 3:** 95 clouding events (14.68%) required between 10(MW) - 15(MW) thermal support
- **Group 4:** 21 clouding events (3.25%) required greater than 15 (MW), but less than 20(MW) thermal support

- **Group 5:** 6 clouding events (0.93%) required thermal generation greater than 20 (MW)

**Note:** Group 1: 280 clouding events (43.28%) were within the BESS capacity

From this data it can be seen that although one of the project goals was to operate only on solar with battery backup, due to cloud cover events there is a need to maintain some thermal spinning reserve unless the battery is of sufficient size to supply the full amount of solar output.

#### 5.1.1. Soiling Effects

The data from December 2021 to January 2022, showed that the average Solar Farm Soiling Percentage was 9.4%. This is significantly higher than modelling estimates of 3%. The active mine sites, and the ground type around the solar farm has resulted in an accumulation of heavy dust build up on the panels.

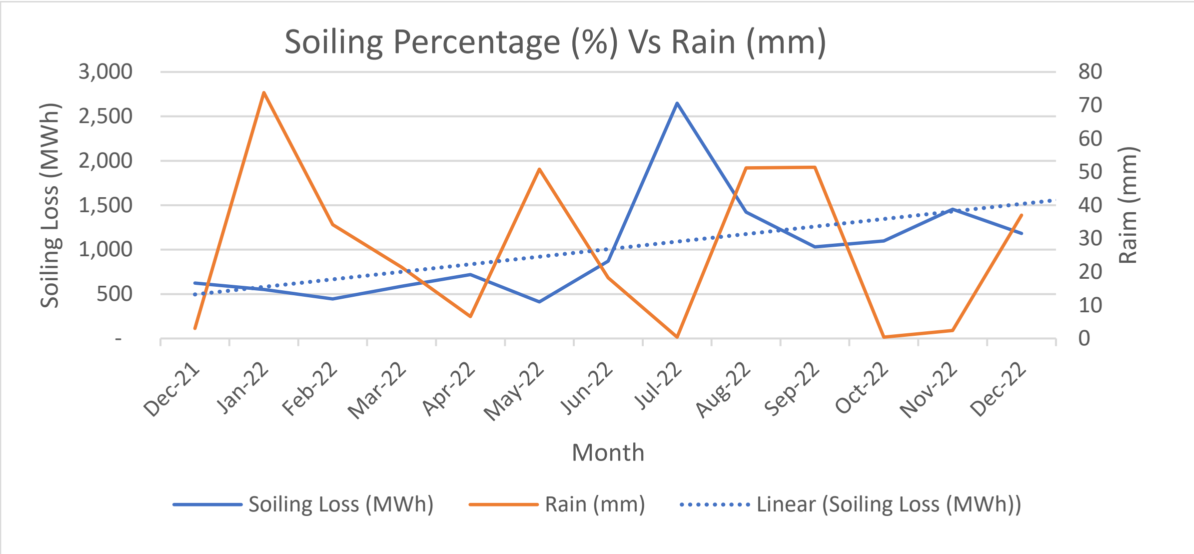



**Figure 5 Soiling Vs Rainfall (Dec 21-Dec 22)**

In December 2021 the soiling derating was 3.7%, only slightly higher than the modelled values expected. Figure 5 shows the soiling percentage only increased over the year, despite heavy rain fall improving monthly results. Conversely, the driest month of July received 0.4mm of rain. This resulted in the array soiling increasing 20% on the previous month or ~1700 MWh of generation.

The original assumption of the project was that no mechanical cleaning would be required during operation. The data from the first operating period has shown that in lower irradiance months when there is no rain events cleaning may be required to maximise solar production. Alinta Energy will review this requirement over the next 12 months of operation.

#### 5.1.2. Inverter Derating

Chichester has an extremely arid and hot climate for majority if the year, where the average temperatures exceed 35 °C on a regular basis. Figure 6 is the weather station data between 2021 and 2022, which shows the hottest months are between November and April where the average was 30.7°C.

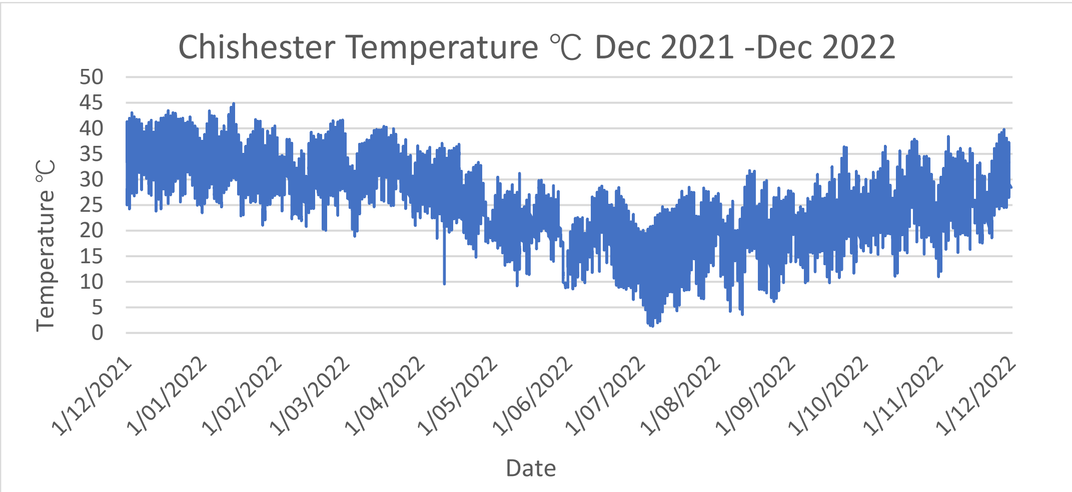



**Figure 6 Chichester Annual Temperature**

These high temperatures have an adverse effect on the solar farm inverters, which must derate when the ambient temperatures get too high. This capacity is made up of reactive and actual power and as reactive requirements are fixed for the site the reduction due to temperature will directly affect solar power production. Figure 7 shows that when the air temperature exceeds 35°C the inverter will reduce the operating capacity. The inverter will continue to reduce capacity until the operating temperatures are at a maintainable level. It is noted that Figure 7 represents an hourly average, whereas 1 second data shows that the inverters will ramp up and down multiple times per hour as the internal temp of the inverter fluctuates.

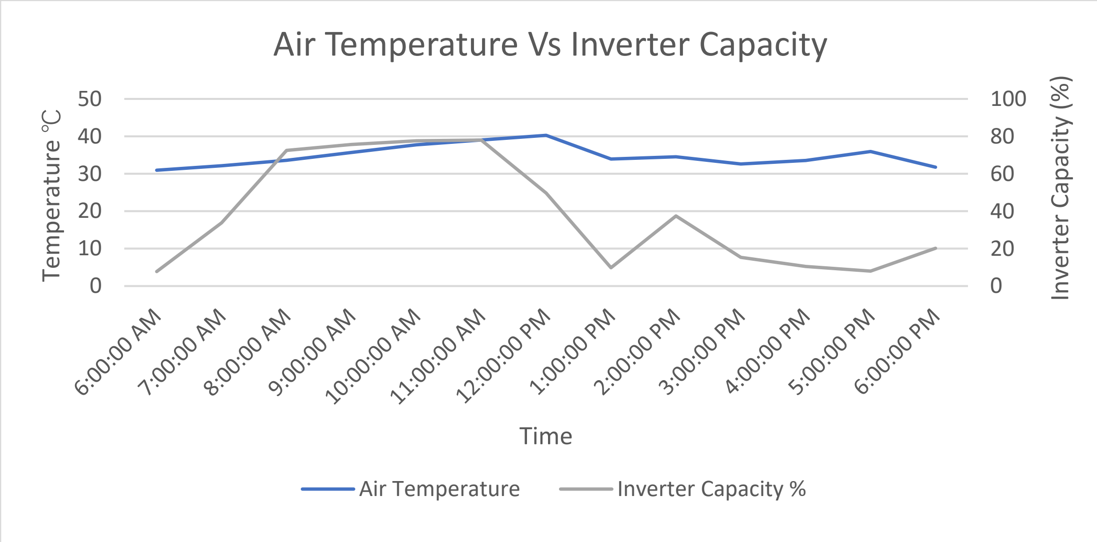



**Figure 7 Inverter Derating**

This reduction in MW output results in loss of renewable penetration and increases thermal generation. This was a known characteristic of the inverter and the original forecast did take into account this effect particularly during the summer months.

### 5.2. Battery Performance

The 35 MW/11.4 MWh BESS primary function is to provide virtual spinning reserve. This reserve is for events where there is loss of generation or significant load shedding, resulting is a sudden load change. Now the CHSF is commissioned, the BESS provides additional network support during clouding events.

Table 5 is a summary of the BESS annual performance

**Table 5 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 8 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.

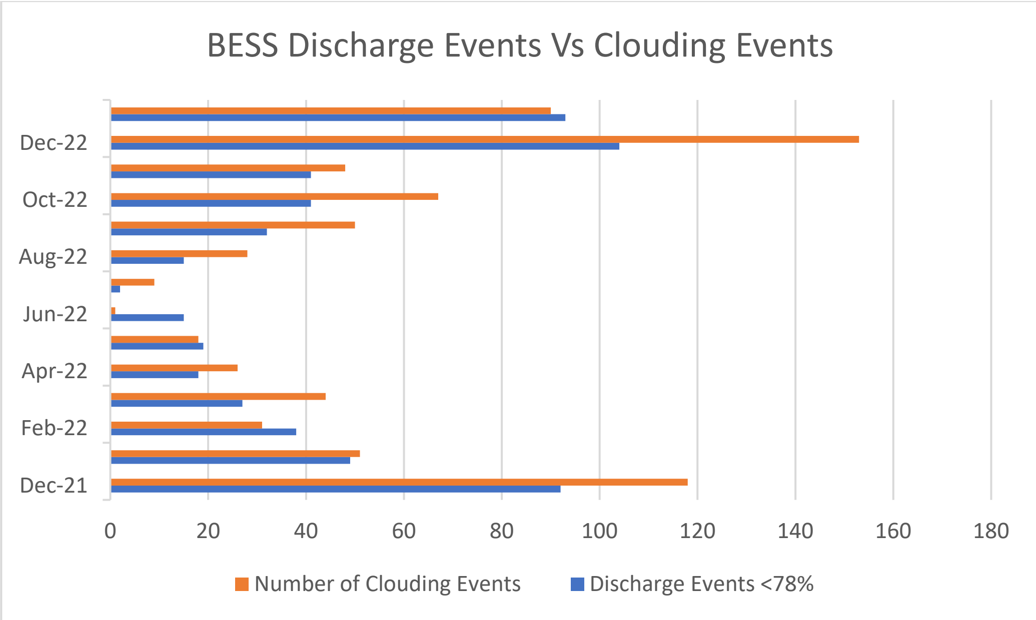



**Figure 8 BESS Discharge Vs Clouding Events**

### 5.2.1. Solar Smoothing

Solar smoothing is a key performance indicator of the BESS performance. It is the ability of the BESS to supplement loss in solar generation during a clouding event. The aim of the BESS is to reduce the amount of spinning reserve required through thermal generation, via instantaneous response to shading events.

Figure 9 shows a clouding event where the network load was 92 (MW). The CHSF was generating 47(MW) and the remaining load 45(MW) was met via thermal generation. During the clouding event, the Solar Output reduced (green trend) by ~39MW or 80%. This reduction occurred at a rate of >25MW/min. The BESS (blue trend) responded to the loss in solar generation, providing 20.7 (MW) in less than a minute of the clouding event occurring.

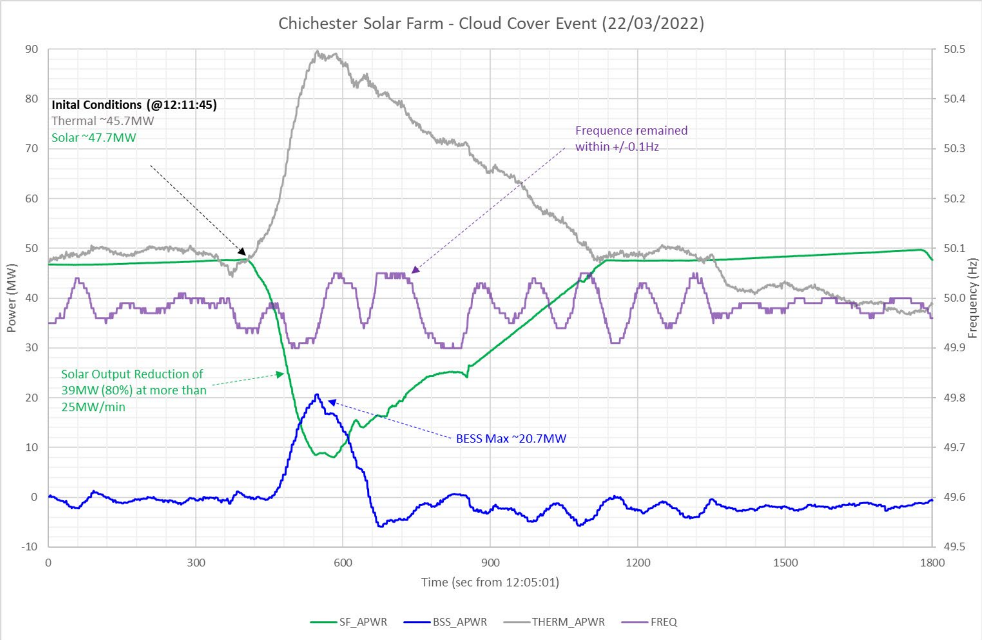



**Figure 9 BESS Response to Cloud Event**

### 5.3. Fuel Savings

Figure 10 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 1,878,465 (GJ) have been saved. 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.

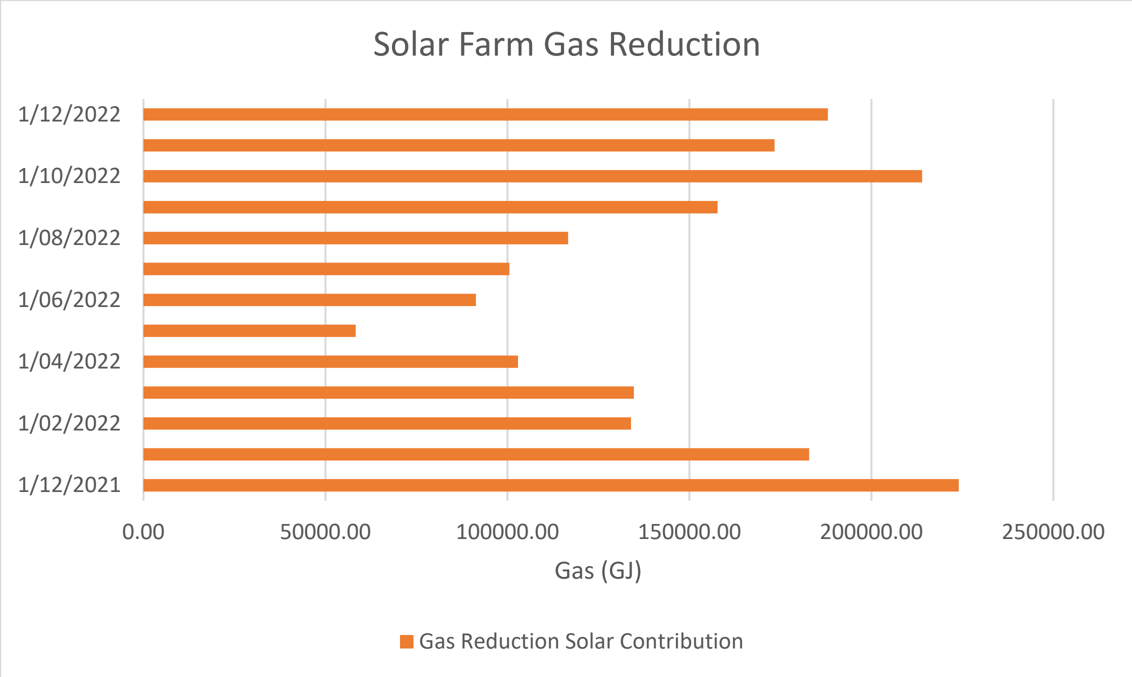



**Figure 10 Estimated Gas Reduction**

## 6. Operation Issues

### 6.1. Inverter Performance

The inverter performance has a significant impact on solar production and is measured by Alinta Energy through inverter availability. Inverter availability is the percentage of time that all 48 units at CHSF are online and operating.

#### 6.1.1. Inverter Availability

The inverter availability is the "uptime" of the system, which can be impacted by:

- Routine maintenance on the system
- Faults on the inverter units that require an isolation
- SCADA faults that result in the inverters being offline
- System updates and testing

The Chichester Solar Array has had a number of technical issues that has resulted in reduced inverter availability. Improved safety procedures during scheduled maintenance require isolation of the PCS, which was not accounted for during the initial forecasting. Inverters require a weekly shutdown for inspection as well as a monthly inspection and clean. These routines where not accounted for in the initial forecast and due to the fine dust particles on site, the duration of the outages are longer to facilitate weekly filter changes and extended cleaning at the monthly outage.

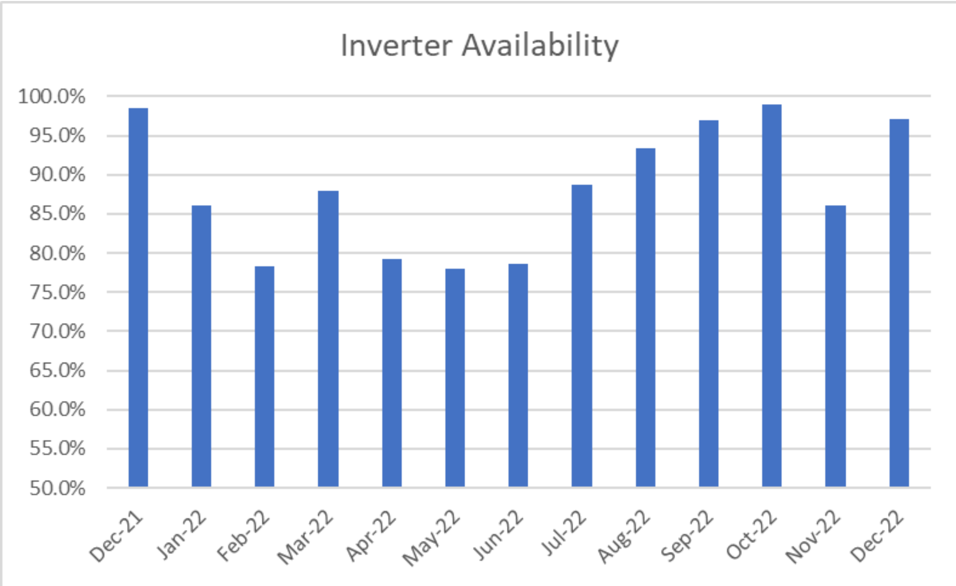



**Figure 11 Inverter Availability**

During the first operational period the inverters have had a number of faults that the OEM has worked with Alinta Energy to rectify with the aim to maximise availability. This lower-than-expected availability of 99% has had an impact on solar production. Although there is a trend of improvement due to ongoing maintenance requirements and a level of breakdowns the availability of inverters is expected to be approximately 97% in future years.

### 6.2. Active Power Curtailment

The CHSF can currently produce approximately 60% of the network load at full generation, requiring the remaining load to be provided by thermal generation. To maintain optimum efficiency and longevity of the thermal generation they have minimum load requirements as well as limitations on cycling from on to off. Consequently, during low network loading, the solar farm is required to reduce generation to ensure thermal generation required for meeting total customer load is held at its minimum load. This has resulted in significant constraints during the operating period which was not built into the original forecast. These levels of constraints have further been increased due to Alinta Energy completing commissioning of the 60 MW gas reciprocating engines at Newman Power Station which required significant curtailment of the solar farm in November and December 2022 to ensure the new equipment had a fixed load for reliability proving. This activity was not included in the original forecast.

### 6.3. Array Performance

#### 6.3.1. PV array Availability

The PV array performance is largely controlled by systems upstream, such as the inverter availability. However, a drone survey was completed in January 2021 aimed to identify solar panel defects that result in a loss of generation. The table below is a summary of defect type and resulting losses on the system.

**Table 6 Solar Panel Defects**

| Fault Type | Quantity | Loss (kW) | Loss (MWh/yr.) |
|---|---|---|---|
| Total diode faults | 70 | 11.3883 | 49.88 |
| Total String Faults | 2 | 27.7200 | 121.41 |
| Total Multicell Faults | 65 | 0.0000 | 0.00 |
| Damages Panels | 3 | 1.4850 | 6.50 |
| Total | 140 | 40.5933 | 177.80 |

These defects have a small contribution to the overall output of the solar farm. Inverter availability and panel soiling during the winter period were the main contributors to loss in production. However, the overall forecast constraints did not correctly consider all these variables.

### 6.4. Efficiency Improvements

#### 6.4.1. Newman BESS

The Newman BESS is a dynamic system, where dispatch setpoints and control is optimized based on learnings and environmental conditions. The findings in section 6.1.2 indicate that an increase in the BESS capacity would reduce the amount of thermal generation required during clouding events. An increase of 10 MW to the BESS could reduce 40% of clouding events that require thermal generation to support renewable losses (see Group 2 from figure 4), therefore resulting in 80% of clouding events being supported by renewables.

#### 6.4.2. Drone Inspections

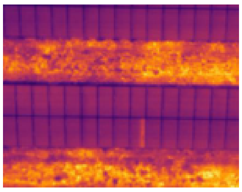
The drone service would be a contractor-based agreement which includes.

- Initial construction and commissioning on site
- Development of drone missions and scheduled flights
- Drone training
- Operation and maintenance of drone hub and auxiliary services
- Management and reporting of data collected on site

The drone inspections can be incorporated into daily tasks, reducing manual fault finding and inspections. The drone would fly predetermined missions developed by the contractor from a base area on site. The data collected on site is automatically uploaded from site to the contractor servers, where the data is analysed, and reports are published to Alinta. The reports identify PV panel defect type and severity, based on thermal imaging.  As seen in the figure 12, the difference in colour corresponds to a variation in temperature (5°C to 10°C). The lighter colour cells correspond to higher temperatures, this indicates an increase in current resulting in hot spots on the panels.

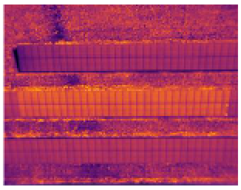
**Diode** Severity : MINOR

A bypass diode provides a current path around a faulty cell or module. A diode anomaly indicates as activated bypass diode, typically 1/3 of module



**Offline String** Severity : MEDIUM

A string consists of an individual set of modules connected in series. A string anomaly shows fault in contiguous modules matching the string layout



**Combiner** Severity : CRITICAL

A combiner combines many strings into a larger flow of DC (direct current). A combiner anomaly shows a fault in contiguous strings matching the combiner layout

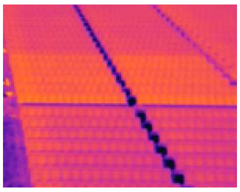


**Figure 12 Diode Fault**

The reports produced from the drone inspection also detail vegetation height and locations, allowing for management of vegetation to be prioritized based on the severity, as seen in figure 13 & 14.

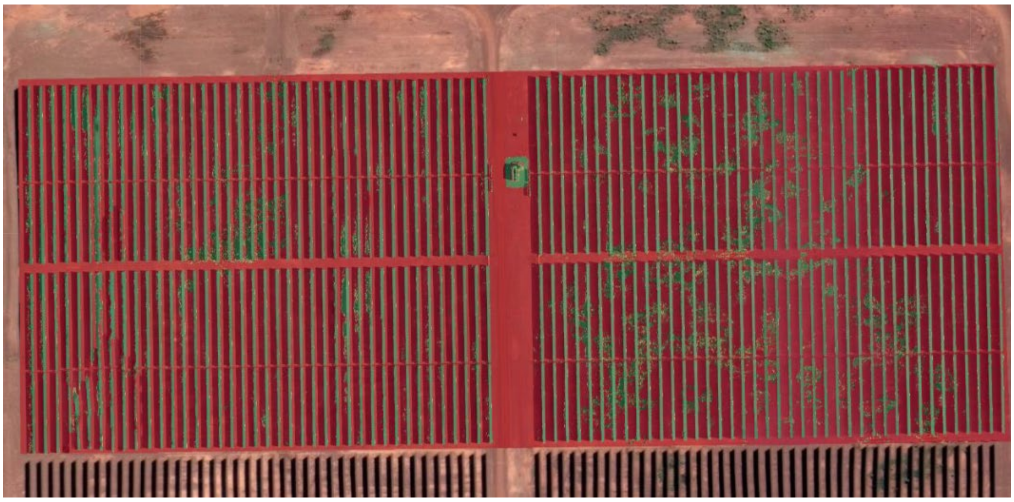


**Figure 13 Vegetation Imaging**

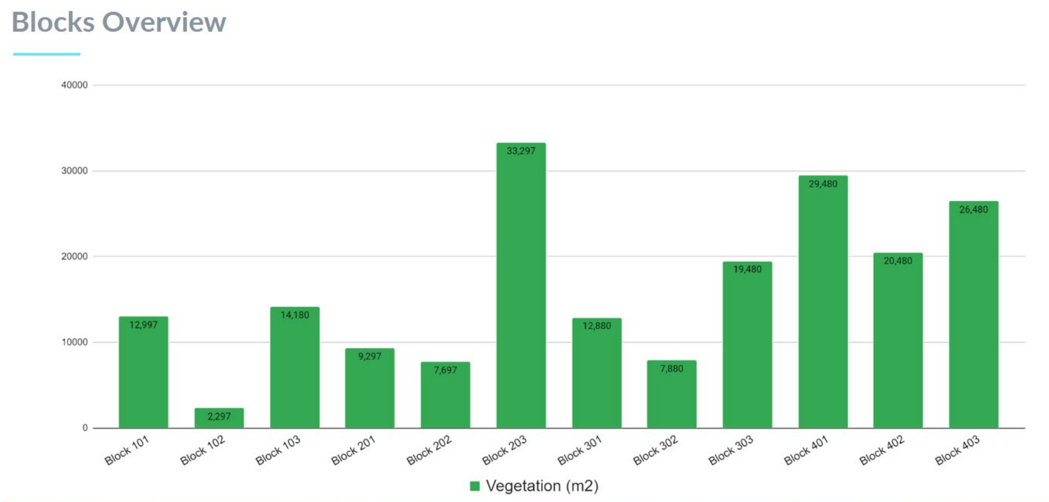



**Figure 14 Vegetation Reporting**

### 6.4.3. Microgrid and supporting technology performance

Alinta Energy measure the performance of its micro grid by availability and impact to customers for unexpected events. The results for the operating period area follows.

For the BESS which acts as the virtual spinning reserve there was one planned outage to complete HV inspection work during the period so the BESS availability was 98.9%, It should be noted that during the BESS planned outage the thermal unit operation was adjusted to ensure customers were not impacted.

The other key component of the grid is the transmission line which during the operating period achieved an availability of 99.6%. This availability level includes 3 planned outages to complete line works during low or no customer offtake periods so no impact to customers occurred.

Four unplanned customer outages occurred during the operation period the cause and duration of these events are recorded in the table below.

**Table 7 Unplanned outages**

| Event No | Duration (hrs) | Cause |
|---|---|---|
| 1 | 0.5 | Lightning strike causing line trip |
| 2 | 1.1 | Operation error during routine testing of protection resulting in trip |
| 3 | 1.2 | Lightning strike causing line trip |
| 4 | 1.0 | Lightning strike causing line trip |

Line and BESS availability and customer outage events are within expected outcomes for the operation of the grid during this operating period.

## 7. Lessons Learned

Key lessons learnt during the first phase of operation include:

- 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.

- Forecasting of solar yield must include a realistic assessment of inverter downtime, soiling and customer curtailment rates to ensure a high accuracy of expected yield.

- Use of drones fitted with infrared camera technology is an effective method to determine solar panel health.

- Although washing of panels may not be required setting up of the farm to facilitate efficient washing with machinery is advisable in case soiling is at an unexpected level.

- Microgrids can achieve a high availability even with long transmission lines in a storm prone area.

- Improvements to filtration of the inverter units need to be considered to reduce maintenance requirements.

## 8. Conclusion

Throughout the first year of operation the SF 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.

Key areas that have constrained the SF output have been identified in detail. Soiling, inverter availability, and active power curtailment were considered. However, the extent of the constraints was initially underestimated. These will be areas of focus moving into the next year of operation.

Using the lessons learned over the past year Alinta will continue to optimize the system. Increases in BESS capacity can further reduce thermal generation and improve network stability. Changes to O&M, through the introduction of new technologies can provide a safer and more effective outcomes for the SF.