DeGrussa Solar Project

KNOWLEDGE SHARING REPORTS

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KNOWLEDGE SHARING REPORT

2 (a) Site Construction Works

Project Name	DeGrussa Solar Project

Knowledge Category	Technical
Knowledge Type	Construction
Project Stage	Construction

i. INTRODUCTION

The construction of the DeGrussa Solar Project consisted of civil, mechanical and electrical works of a 10.6MWp Solar PV System and 6MW Battery Storage System. Each element of the construction works were not particularly "pioneering", however the system as a whole (coupled with site specific requirements) was complex. The key challenges and lessons learnt from the site construction related to:

- Site Geotech;
- Brownfield Project Construction;
- Utilising Existing Capability Sets in New Environments;
- Solar Inverter Works;
- Battery Station Works.

The learnings of the above items are further explained below.

ii. SITE GEOTECH

Key Learnings

During early stage development the geotech was identified to be challenging due to the 3.5-5.5Mpa "hard pan" located 200-1,000mm below the topsoil. This significantly affected all works requiring ground disturbances below this depth, including cable trenching, drilling/piling and fencing. In order to plan and develop the schedule and costings, juwi undertook the following:

- Pre-construction tests on drilling and piling, including pull-out testing of multiple types of piers at multiple locations on the site;
- Utilised trenching contractors who have previously completed works on site and who were experienced with the geotech;
- The racking foundation installation required the augering of a 150mm hole followed by the piling of the H-beam foundation. Even with the preparation, the piling works took approximately twice as long as expected due to the ground hardness. The following adjustments were made as a result:
  - Piling contractor manning: changed from 10hr working days to 12hrs;
  - Piling contractor equipment: project started with two piling rigs and one auger drill rig; then finished with three piling rigs, one auger drill rig and two hammer drill rigs.

Figure 1: Rock-saw Trenching Machine

Figure 2: Auger Drill Compared with Hammer Drill

Figure 3: Drilling and Piling Progress

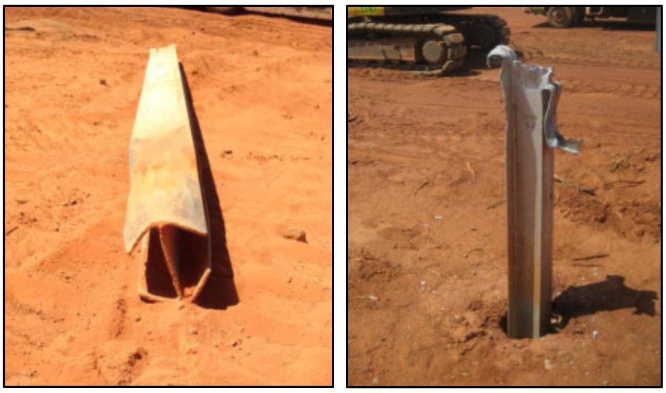

Figure 4: Effect of Hard Pan on Piers. (a) Pier deformation after removal. (b) Pier removal attempt with 6kN vibratory hammer.

Implications for Future Projects

Ideally, the exact equipment proposed for use throughout the project should be used for the pre-construction testing to ensure that time and cost planning is accurate.

The piling s-curve is quite linear for sites with difficult geotech (in comparison to other works), which is driven by machine capabilities and piling processes. If targets are not being hit early in the project, either the processes need to change immediately or larger/different machines should be sourced.

Knowledge Gap

The challenges associated with geotech are typically specific to each site and the required technical solution is unknown until a suitable level of due diligence and testing is undertaken. Prior to this, the variability of the foundation design, supply and installation costs would remain high.

iii. BROWNFIELD PROJECT CONSTRUCTION

Key Learnings

Many of the Mine requirements, processes and procedures are setup for Brownfield mining operation rather than greenfield construction of power generation equipment. As a result there was some challenges surrounding the implementation and use of documentation and processes.

Being remote had the expected challenge and costs associated with:

- Personnel mobilization and accommodation: Limitations on mobilization days and number of available flight seats/beds, additional administrative load for both contractors and the Mine;
- Component supply lead time: Being in a "rural" area additional inspections required at the port of entry to Australia, any components have a minimum 1-3 day lead time if available from the nearest supplier;
- Equipment availability: Equipment approval and inspection required prior to entering site, minimum 1-3 day lead time if available from the nearest supplier.

However, the benefits of undertaking works on a brownfield site included:

- Daily delivery trucks from Perth to site (weekdays only);
- Flights direct from Perth to the sites aerodrome;
- Support personnel and equipment available from the Mine i.e. lifting equipment, emergency services;
- Water and other utilities available from the Mine at nominal cost;
- Concrete available on site from the Mine's batch plant;
- Camp services already available.

Being on a brownfield mine, the exposure to site personnel resulted in a significant amount of engagement. This was evident in the consistent positive support for the project and queries around the progress.

Due to the remoteness of the site and the lack of local resources, a fly-in-fly-out (FIFO) roster was used for site personnel. Similar to other construction projects, this incurs and additional workload to the administrative and planning teams from both the contractors as well as the Mine. The workforce was manageable for the duration of the project, however there were two instances where challenges arose:

- Extensive first-time mobilization requirements (medicals, internal approvals, mine approvals, flight and accommodation bookings) coupled with high turnover of labor due to the type of work (repetitive tasks in the heat of summer) resulted in a significant amount of administrative tasks;

- The solar-hybrid experts involved in system commissioning required very particular skill sets of which there were limited resources working on the project. As a results of the fatigue management policies relating to FIFO workers, commissioning activities were affected due to these personnel being off-site or unavailable. Also, if urgent tasks came up when these personnel were off-site, the completion times of these tasks were also dependent on the mobilization process.

Implications for Future Projects

Expectations and requirements from the Mine regarding processes and procedures are to be defined prior to mobilization to ensure that there are no delays during construction. This includes reporting and documentation as well as operational requirements. Pre-construction planning workshops are pivotal in ensuring that all stakeholders have an understanding and agreement on each parties requirements relating to documentation deliverables and site processes.

Knowledge Gap

The processes and procedures implemented at brownfield mines are based around operational methodologies, which are tailored to maximize production through disciplined adherence to the standard practices and firm control of changes to process, design and technologies utilised. With the introduction of a non-core process construction project (integration of a Solar Hybrid System) there is a level of learning throughout the construction and operation phases to ensure that the project can be successfully delivered. Prior to this point, only planning can be undertaken to determine what/how the processes and procedures will be developed.

iv. UTILISING EXISTING CAPABILITY SETS IN NEW ENVIRONMENTS

Key Learnings

All stakeholders had relevant experience. However, as the project was a first of its kind, none had experience constructing a "large scale Solar-Hybrid System on a mine site". As such there were inefficiencies due to the level of 'new development' required for documentation, processes and procedures.

As an example, the construction contractor was experienced in remote construction of mining camps (large scale civil/mechanical/electrical projects) however had not previously undertaken a utility scale solar PV construction project. This resulted in key learnings specific to the solar and battery installation activities.

Implications for Future Projects

If a contractor does not have the same experience elsewhere, additional selection criteria should be assessed prior to contract award in conjunction with additional planning and management during construction. Focus should be put to:

- Contractor project organisational chart i.e. good management and a sufficiently resourced project team (based on other similar projects);
- Experience with managing the regulatory and documentation requirements for mining operations;
- Experience with managing projects of similar nature is beneficial:
    - Solar Array: large scale repetitious work e.g. mining camps;
    - Solar/Battery Inverters: large drives and other electrical equipment;
    - Control System/Integration: other forms of power station integration i.e. diesel/gas.

Knowledge Gap

As the solar-hybrid industry in Australia matures and more contractors/suppliers become experienced, there will be a greater selection for projects. There are still a very limited number of contractors in the utility scale and remote/off-grid solar industry with the appropriate experience. This effects project risk, cost, schedule and in turn the projects likelihood of proceeding.

v. SOLAR INVERTER WORKS

Key Learnings

ABB battery inverters and control technology were selected for the project after which it was decided to also procure ABB solar inverter stations to retain one point of responsibility. Due to the high labor cost on site, the preferred option for the solar inverter stations was a pre-fabricated 40ft container which included DC board, solar inverters, controls, transformer and switchgear in the one unit. After further investigation, it was determined that this solution was unlikely to meet the required Australian Standards and Site Standards. As a result, the standard ABB 20ft solar inverter station (DC board, solar inverters, and controls) with external HV substation (transformer, switchgear) was selected.

Figure 5: ABB transformer station and ABB 20ft Solar PV Station

Implications for Future Projects

Inverter stations which include an enclosed transformer and switchgear should be preferred to minimise on-site construction works and overall costs. However, particular attention must be made to Australian Standards, local building regulations and site specific requirements to ensure that there are no conformances issues.

Knowledge Gap

The selection of equipment that is new to the Australian market incurs a level of risk associated with regulatory compliance and suitability to the site conditions. Due diligence is therefore required to minimize the level of delay and in-country rework.

vi. BATTERY STATION WORKS

Key Learnings

The construction of the battery station involved the landing and electrical connection of two 40ft battery inverter containers, two 40ft battery containers (with external HVAC units), one transformer kiosk, one HV switchgear kiosk and the associated electrical balance of systems. From a civil works and mechanical works perspective, the construction was quite standard, with the key challenges arising out of the electrical cabling between the containers. With each battery inverter container having a peak output of 3.0MW at 400V, the cabling between the AC cabinet of the container and the transformer kiosk was required to carry ~4,300A. Utilizing traditional cabling in cable tray for this would have posed constructability and operational complications, so it was decided that bus duct would instead be utilised. This was a very good solution as the installation was fast and efficient and the end result was more reliable. The cost of this, including design, component supply and installation, was also similar to that of the traditional cabling method.

Figure 6: Battery Station Layout

Implications for Future Projects

Similar to the solar inverter recommendations, the ideal solution in terms of constructability is to have the battery racks, battery inverters, transformer and HV switchgear in the one container. In particular for remote sites with high labor rates, this will minimize costs as the site construction works and on-site electrical testing will be minimised.

Knowledge Gap

With each Solar-Hybrid System being unique due to the differing locations, off-taker risk profile, power station integration and other general requirements, the battery station design can change drastically from site to site. As such, there will continue to be unknowns with the required battery station until advancements in technologies produce cost effective, robust solutions that can be applied to many different applications.

vii. SUPPORTING DOCUMENTATION

Construction Time-lapse - https://www.youtube.com/watch?v=S3Fh4R_fqbA

KNOWLEDGE SHARING REPORT

2 (b) Interaction with Mining Operations

Project Name	DeGrussa Solar Project

Knowledge Category	Technical
Knowledge Type	Off-taker Inputs and Planning
Project Stage	Construction

i. INTRODUCTION

When comparing the execution of a solar PV project for a mining operation to that of a regional and more standard construction project, fundamental differences can be seen with regards to regulatory requirements, personnel management, logistics and system design. A different approach must be made to ensure the following items are managed:

- Project Involvement from Mine Operation;
- Solar-Hybrid System Commissioning.

The learnings of the above items are further explained below.

ii. PROJECT INVOLVEMENT FROM MINE OPERATION

Key Learnings

Any scope with interaction between the project works and the Mine's operations required additional planning, time and resources. This included physical interactions (cable running, vehicle movements etc.), hybrid integration (operational changes, energisations etc.), electrical integration (planned shutdowns, HV switching) and regulatory requirements (processes, procedures etc). The Mine had allocated resources to assist with aforementioned items relating to the project with the main goals of these managers being to ensure the Mine's procedures were adhered to and ensure minimized production loss of the Mine's processing facility. Figure 7 identifies the site areas of interactions the respective descriptions outlined below:

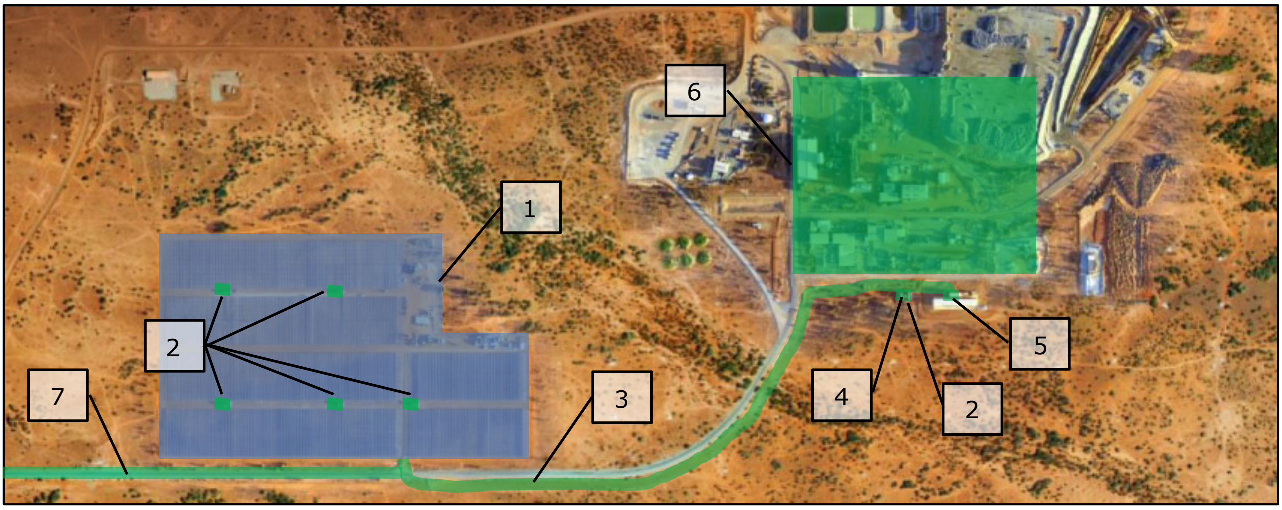

Figure 7: Site Map of Project Interfaces

1. Solar Array: The solar array area was setup as a Lease under the mine lease. The location allowed for segregation from the mine site, however the Mine remained involved with safety management, equipment inspections and construction/commissioning supervision;
2. Solar/Battery HV Substations: Trained electrical personnel from the Mine are the only personnel authorized to undertake HV switching, whether planned or unplanned. This enabled the Mine to control any HV network works but did require additional commitments for the switching of the Solar-Hybrid System equipment;
3. HV Cable Run: The HV cable ran from the solar array to the Diesel Power Station adjacent to the existing main road and overhead power lines. The construction works affected vehicle movements, walking track movements and overhead/underground cable routes in the outlined area. The Mine was involved throughout the design, planning and construction phases to ensure that impact on Mine personnel and infrastructure were minimised;

4. Battery Station: Being within close proximity to the Mine's site facilities, Mine personnel were involved with the design, planning and construction phases to ensure that impact on Mine personnel and infrastructure were minimised;
5. Diesel Power Station: The diesel power station was both a physical and operational interface with the Solar-Hybrid System works. It was also the equipment that was most influenced by the implementation of the project, and as a result required the most amount of design and planning resources. This impact included:
    a. Design and planning of system integration;
    b. Connection of HV cables to allocated feeders;
    c. Changes/additions to internal electrical and controls equipment;
    d. Changes to generator loading during operation.
6. Mine Processing Facility, Camp, Administration and Underground Operations: Planned shutdown of site power station was required to complete critical component installation and testing.
7. Mine Access Road: An additional loading on the access road was required for the personnel vehicles (to and from mining camp each day) and delivery trucks required for the project.

On top of the above items, commissioning and testing works that could possibly have affected the Mine's site operations were required to be completed during the Mine maintenance days. These required a significant amount of input from the Mine from a technical and logistical perspective during these times to ensure minimal impact on the other work fronts during the shutdown. On top of the unavailability of the Mine's personnel in this time, other challenges included the limited accommodation availabilities and flights to and from site.

Implications for Future Projects

Due to the challenges experienced with the above items, it is clear that the interfaces between project activities and mine operations should be minimized. This will reduce the additional workload on the mines operation to undertake the project, but also ensure that the contractors remain in full control of the works on site. Key recommendations for future projects include:

1. Where possible, the project works should be physically and contractually segregated from the mining operations. As an example, constructing the solar array off the mining lease will qualify standard building code requirements to be used rather than the mining act. However this option could be prohibitive due to the high voltage cable connection costs;
2. Of any preconstruction works, the design and planning for electrical connection, energization and hybrid control/integration has the largest impact on the project works. Clarifying and agreeing to design requirements and integration plans prior to construction is key to ensuring that the process runs smoothly.

Knowledge Gap

All mining operations are unique in how they are managed so the solution for minimizing the interfaces between the stakeholders will be project specific. The technical solution also evolves as the detailed design is completed during the delivery phase of the project. Until this is completed the interface requirements for the integration/connection are not fully determined.

iii. SOLAR-HYBRID SYSTEM COMMISSIONING

Key Learnings

The commissioning and testing plan was developed prior to project construction and further developed throughout the project as new information was provided. The commissioning tests for the Solar-Hybrid System were broken down into the following categories:

- Individual Component/Container Operational Tests;
- Communication Testing Between Equipment;
- System Active Power Management Tests;
- System Reactive Power Management Tests;
- Mine site Operating Condition Tests;
- System Performance Test.

These tests were completed in accordance with the contracts and included additional items that had been determined as necessary during the commissioning planning. When potential risks were identified during commissioning, additional constraints and process were put in place. This resulted in complications with the commissioning planning and time overruns with the schedule.

Some tests were determined to have a risk rating too high for them to be completed during normal operation e.g. full trip of the solar HV feeder at full solar output and diesel-off mode operation. Some tests were completed at later stages of commissioning once the system was proven further and some processes were changed to enable the tests to be completed during a shutdown.

The system performance tests required the most amount of review and rigor from project stakeholders due to the impact that they had on the Diesel Power Station i.e. output ramping, trip tests etc. Key tests which were required to prove the system performance included:

- Battery Storage System response to Solar PV System Ramp-up/Ramp-down;
- Battery Storage System response to Solar PV System Step Load;
- Solar Hybrid System response to loss of diesel generator;
- Battery Storage System 6MW Peak Output Test;
- Dynamic Spinning Reserve Response, Voltage Stability and Frequency Stability Checks (during all tests);

The trend below in Figure 8 and Figure 9 shows a normal day of operation following commissioning where the solar smoothing function (ramp-up and ramp-down of solar PV) was demonstrated. The solar PV output (green curve) reduces by ~3.5MW as the cloud covers the array (see yellow curve for irradiance), then increases back to its original level as the sun returned. In response, the battery output (grey curve) ramps up to cover the drop in generation to ensure the network remains stable as can be seen with the Diesel Power Station output (brown curve).

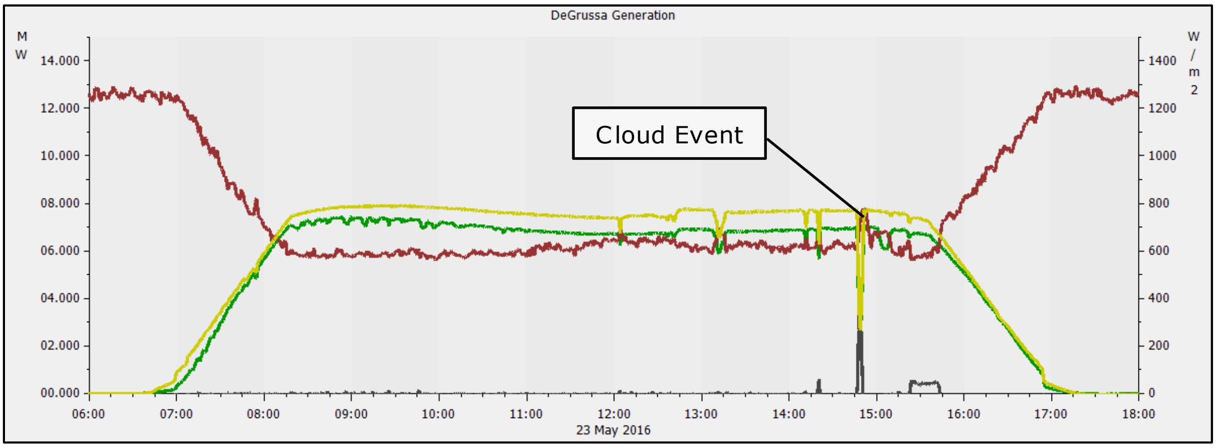

Figure 8: Demonstration of Solar Smoothing Function (whole day)

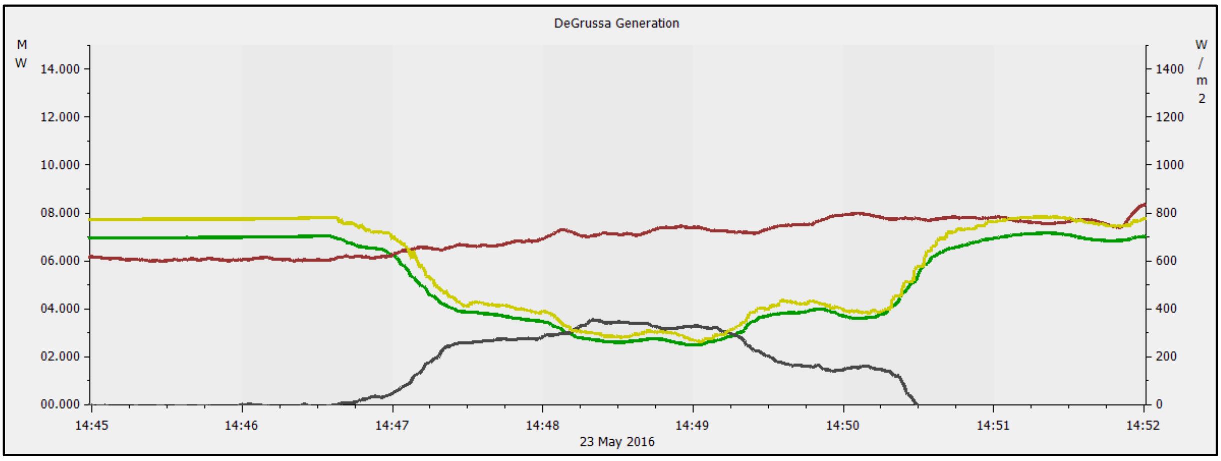

Figure 9: Demonstration of Solar Smoothing Function During Cloud Event (7 minute period)

Implications for Future Projects

The implementation and commissioning of the DeGrussa Solar Project has proven that a utility scale solar-hybrid system can successfully be integrating with a mines critical operational load. This has provided the industry with a reference case for future mine developments looking to implement renewable energy systems.

As Vince Algar, Managing Director of Australian Vanadium, concluded, "Sandfire has had a knock-on effect and almost everybody developing a mine is looking at putting (in) PV and Storage" (Energy and Mines, 2016). The stakeholders (primarily contractors and suppliers) involved with the project will have the most amount of experience to be transferred to other projects; however the industry as a whole can now investigate this solution knowing that it is feasible.

Knowledge Gap

The commissioning process requirements are dependent on the site infrastructure, system design/functionality, site operational requirements and stakeholder risk profiles. This combination results in a complex planning process requiring input from both the mine and project developer commercial/technical personnel. This process is manageable, however with the lack of precedence in the industry and data surrounding operations from other mines and suppliers, the perceived risks are increased, which further complicates the process. Once suppliers and contractors alike become more experienced with "large scale Solar Hybrid Project on mine sites", the risks and technical challenges of commissioning will be further understood and reduced.

iv. SUPPORTING DOCUMENTATION

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2 (c) SOLAR-HYBRID SYSTEM INTEGRATION

Project Name	DeGrussa Solar Project

Knowledge Category	Technical
Knowledge Type	Network connections
Project Stage	Commissioning and Operation

i. INTRODUCTION

The key challenges surrounding the execution of the DeGrussa Solar Project related to the integration of the Solar PV System into the diesel power stations network and the implementation of the associated Battery Storage System. Innovation was required from all project stakeholders, with particular challenges and learnings seen in the following items:

- System Design;
- Battery Storage System Energisation;
- Additional System Functionalities;
- Effect on Diesel Network During Commissioning Operation.

The learnings of the above items are further explained below.

ii. SYSTEM DESIGN

Key Learnings

The key purpose of the Solar-Hybrid System was to reduce daytime diesel consumption of the mine, with the operations continuing to be primarily reliant on the Diesel Power Station. From a high level perspective, the Solar PV System was installed to generate the renewable electricity and the Battery Storage System was implemented as an enabler to ensure grid stability was maintained and solar PV output was maximized.

Key functionalities and constraints of the system allowed for in the design included:

- Site Load Profile - consistently (24/7) between 11MW and 13MW;
- Minimum Diesel Generator Loading Range – between 50% and 100%;
- Dynamic Spinning Reserve Management - requirement from battery and diesel of 1MW plus 85% of solar PV output;
- Ramp Rate Control / Solar Smoothing - Maximum ramp rate at a pre-determined kW/s.
- Frequency Control – site frequency must be maintained;
- Reactive Power Control – site PF must be maintained;

Throughout the early design process, designs were made based on the limited data and information provided. Pre-manufacture design reviews were undertaken after which equipment was delivered and installed. During the commissioning process, the designs were re-assessed by new and existing project participants which resulted in some re-work which added cost and impacted the schedule.

Implications for Future Projects

To ensure that the preliminary design is accurate in the development stage, sufficient data and operational resources must be provided to the design team. By investing time in this initial design process to confirm the key inputs and getting an understanding between the stakeholders, time and costs will be saved in the back end of the project through minimization of rework, redesign and operational underperformances.

Knowledge Gap

There are a significant number of additional design requirements for Solar-Hybrid System compared with a standard grid connected system. These types of systems have been developed and implemented for many years, however there is limited industry experience for renewables integrated into systems powering the critical load of mine sites. Due to the higher risks associated with this type of system and the limited number or reference sites or industry experience, mine operations are hesitant to progress with such a solution.

On a project specific level, the designs are based on the capabilities and operating strategy of the Diesel Power Station. On a large scale, there is little operational data to show how integrated renewables affect the short and long term operation of the diesel generators. Because of this knowledge gap, the Diesel Power Station owners and in turn the mine operators are very conservative when determining the system constraints around minimum diesel loading, minimum number of generators online, maximum ramp rate of solar PV, and the minimum spinning reserve allowance. Being conservative with these factors incurs additional design/control requirements (see below) on the system which results in system cost increase, LCOE increase and/or solar PV output reduction:

- Larger battery storage;
- More complex control systems;
- Additional curtailment i.e. limited solar PV penetration.

The maximum expected drop in output due to cloud cover is also an uncertainty at new sites due to the lack of weather data and how available data can be used to calculate the expected drop. This input drives the spinning reserve requirement to cover a drop in solar PV output and in turn determines the battery storage sizing. If more solid data was available from similar sites around Australia, a more efficient battery storage size and control philosophy could be developed.

iii. BATTERY STORAGE SYSTEM ENERGISATION

Key Learnings

The Battery Storage System area required electricity to complete pre-commissioning, battery installation (HVAC) and testing works prior to HV energisation. LV circuits were energised through temporary diesel generators on site with a spare backup genset.

The single 5MVA battery transformer was larger than other transformers onsite and therefore had the potential to impact the network upon energisation.

Figure 10: Battery Station Prior to HV Energisation

Implications for Future Projects

If possible, the low voltage power required for Battery Storage System pre-commissioning, auxiliaries and battery HVAC should be provided from existing diesel power station rather than temporary generators.

Having a comparatively larger transformer on a microgrid has the potential to cause high transients upon energisaiton. This can be mitigated through the use of multiple smaller transformers for the installed equipment i.e. similar to the solar inverter setup of one transformer/RMU for each inverter station.

Knowledge Gap

Each microgrid is different and until the first energisation of equipment occurs (particularly transformers), there will not be full certainty around what impact it may have on the network. This uncertainty can be minimised though good design and a well-planned energization/commissioning processes.

iv. ADDITIONAL SYSTEM FUNCTIONALITIES

Key Learnings

The key purpose of a Solar-Hybrid System is to reduce diesel consumption of the site. However, there are other possible benefits that have been observed since implementing the Solar PV and battery system at the DeGrussa mine. These include:

- Voltage and frequency support from solar inverters (improved power quality);
- Voltage and frequency support from battery inverters (improved power quality);
- Supply of Reactive Power from battery inverters;
- Additional spinning reserve from battery inverters (reduced diesel generator runtime, increase overall site reliability).

The benefits of these functionalities were not able to be quantified prior to project commencement. All stakeholders were aware of these secondary benefits but they were not leveraged to provide additional revenue for the project.

Implications for Future Projects

The benefits of voltage support, reactive power control, frequency support and spinning reserve are difficult to quantify in the planning stages of the project and as a result the financial impacts cannot be included in the financial models. If enough data was generated from DeGrussa to quantify the benefits, there is a possibility that similar projects could benefit in the future.

Knowledge Gap

Data is pivotal in determining how a system such as this can have a positive impact on the grid power quality and reliability. If high resolution data was available during development phases of the project, contractors and suppliers could assess the data and provide informed estimates of the additional benefits that could be generated. Unfortunately this data is rarely available as it is generally not required for normal operation of a mine.

Data from the operational phase of DeGrussa is being captured and will be assessed to confirm the actual impact of the Solar PV System and Battery Storage System on the Diesel Power Station. Until this occurs, there will be limited firm information on how successful the system is in actually realizing the benefits of these functionalities.

v. EFFECT ON DIESEL NETWORK DURING COMMISSIONING/OPERATION

Key Learnings

It was planned that the integration of the Solar PV and Battery system at DeGrussa would require at least 6 hours of total mine downtime for construction and commissioning. The actual impact on the diesel network during the integration and operation is outlined below.

Item	Works	Approx. Outage	Notes
1	High Voltage connection to power station	zero	Connection completed with power station still operating.
2	Implementation of duel protection setting at the Diesel Power Station	20 min (three feeders)	Pre-planned work to three individual feeders with little to no impact on production.
3	5MVA Battery transformer energization	10 min (mill motor)	A trip of the mill motor occurred around the time as the initial battery transformer energisation. The motor was restarted with minimal/no impact on production.
4	ComAp Control Software	10min	A fault in the ComAp Intelisys Bridge software occurred when an individual genset ComAp controller was unplugged which resulted in incorrect communication between the ComAp and ABB control system. An existing firmware update addressed/rectified the fault.

The most significant impact on the diesel network was item #4 which occurred in October 2016. The Diesel Power Station operator was performing scheduled maintenance on a diesel generator and isolated the power from that particular generator controller as part of the standard generator O&M procedure. Disconnection of the particular generator controller caused an unforeseen intermittent communications failure which led to the solar and battery generation systems eventually overpowering the diesel generation system. The root cause of this has been identified as "the ongoing intermittent communications failure caused the system to go in and out of Diesel Off Mode, which eventually caused the diesel generators to trip on reverse power. This in turn caused a under voltage and frequency trip which caused the HV Breakers to open".

There were several significant contributing factors relating to different stakeholders in this event. Details are as follows:

- The project owner was unaware of any maintenance activities at the Diesel Power Station. The management of the interface between the Diesel Power Station and the O&M Contractor was an identified risk in the Project Operations Sandfire risk workshop held following project construction;
- The testing of communications under the specific scenario seen pre-event was an oversight by all stakeholders during the project. Despite all of the engineering input during testing, no one thought to test the behavior of the system with a communication loss between the individual generator controllers on the generators and the Solar-Hybrid controller bridge. Despite the intermittent communications problem that stemmed from the activities performed by Diesel Power Station Owner, the control system remained in a stable enough state to continue the control and delivery of power to the mine for 25 minutes.
- The PV system began a steady rise in output that remained on a linear increase until the event. This was because the Solar-Hybrid control system saw the visible diesel generators above minimum loading due to the intermittent communications between the generator controller and the Solar-Hybrid controller bridge.
- Due to both the Battery Storage System and the Diesel Power Station trying to control frequency, the two systems started working separately instead of in unison due to no load sharing between these two sources. The two sources then modulated their outputs due to them both increasing and decreasing frequency independently;
- Eventually due to the combined continued increase in solar PV output and the Battery Storage System increasing output independently of the Diesel Power Station, the diesel generation was driven into reverse power and tripped. At this point the HV Breakers tripped due to an under voltage and under frequency event.
- It was discovered after the event, during the diagnostics period, that the Solar-Hybrid controller bridge had out dated firmware that contained a bug.

Following the blackout the diesel generators were brought back online within 7 minutes and the re-energisation of the site followed. Throughout the entire event, there was no damage caused to site equipment or infrastructure, however there was loss of production of both the mine and Solar-Hybris System during this time period.

In order to ensure that such an event does not occur in the future, the following control measures were implemented:

- Firmware updates to the relevant control system components with the required bug fixes;
- Testing of lost communications between the control components and confirmation of the required responses;
- Personnel completing works on relevant equipment must notify all stakeholders prior to commencement of the works;

- Remote monitoring personnel to be provided further training to assist with remote response to alarms and faults.

Implications for Future Projects

Each Diesel Power Station commissioning tests need to be defined through a robust process of workshops and reviews to ensure that all operational conditions and events can be allowed for. In this process, many risks can be defined, which assists in developing the specification for the hybrid integration solution. This proactive approach ensures the integration deliverables for the project are as mature as possible to minimize reactive changes.

The outage at DeGrussa illustrated that even after all reasonable due diligence and rigor during system design and commissioning was undertaken, implementation of a complex 'industry first' has some risk.

Knowledge Gap

The current knowledge gaps associated with the integration of high penetration systems are for the most part project specific and as a result need to be managed through the design, commissioning and operation processes. Through ongoing development of integration system smarts by industry experts and product/service providers, hybrid systems will continue to be improved to enable the management of more integration scenarios with less project specific design.

vi. SUPPORTING DOCUMENTATION

Project Presentation Video - https://www.youtube.com/watch?v=9ljiQ86L78Y&feature=youtu.be