Lord Howe ISLAND BOARD

Jacobs

PHOTON ENERGY

Lord Howe Island Renewable Energy Project

System Design Report

August 2021

Disclaimer and Funding Acknowledgment

The views expressed herein are not necessarily the views of the Australian Government. The Australian Government does not accept responsibility for any information or advice contained within this document.

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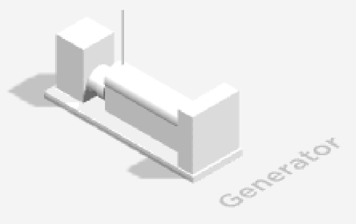
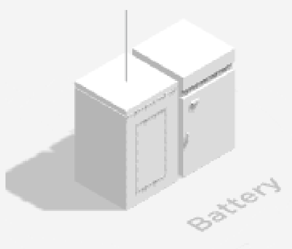
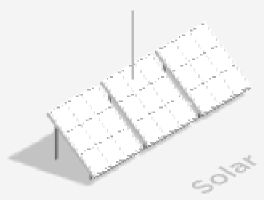
Contents

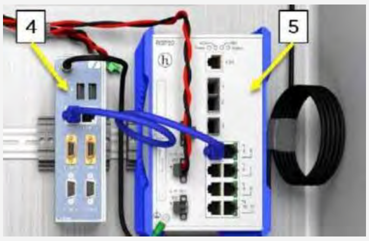
Executive Summary

The Hybrid Renewable Energy Project (HREP) set out to reduce Lord Howe Island's reliance on Diesel power generation by at least 67%, thus reducing fuel costs and the reliance on fossil fuels.

The design to achieve this goal, currently proven by simulation and modelling, incorporates a 1.3MWp solar PV array and a 1MW/3.7MWh Battery Energy Storage System (BESS) integrated with the existing Diesel generation (DG) system via a Tesla Microgrid controller (MGC).

System Elements

	Diesel Generation 3 x 280kW Existing Diesel generators with upgraded controllers for system integration and compatibility with the new MGC.
	Battery Energy Storage System A 1MW/3.7MWh battery system is the grid forming entity in the microgrid. The battery is always online and supplements the DG to supply LHI load and also due to its fast reaction times stabilises the grid. The battery stores excess solar energy during the day and discharges at night to service LHI night load demand.
	Solar Generation A 1.3MWp DC / 1MW AC fixed tilt (20°) solar PV array provides the energy source for the BESS. The design opted for the utilisation of string inverters to provide the solar AC power and integrate to the distribution system.
	SCADA HMI & Remote Monitoring performance management tools provide operator viewing via web and smart phone apps. Automated performance reporting, allowing real-time and remote monitoring and performance monitoring of the power system.

	Tesla Micro Grid Controller coordinates and dispatches generation automatically to ensure reliable power and maximum diesel fuel savings.

The Design considerations of the Project included: -

- Maintaining reliable power supply to the Island.
- Integrating with the existing generation and electrical infrastructure
- Complying with specific Consent Conditions regarding fauna and flora requirements

The project has been successfully constructed and commissioned. It is currently within its 24-month performance testing period.

1. Introduction

The Lord Howe Island Board (LHIB) and the local community Sustainable Energy Working Group (SEWG) had been investigating options to reduce the reliance on imported diesel fuel for electricity generation at Lord Howe Island for a number of years. The HREP has a long history with initial feasibility activities starting as early as 2011. In 2016 an initial application, based on a design combination of solar PV, battery storage and wind generation, did not achieve developmental approval. The less than aesthetic nature of wind turbines on a UNESCO world heritage listed Island was the main driver behind not achieving consent. Consent was given for the use of solar PV and battery storage, and the project team embarked on a journey to develop a solution that would succeed in achieving a minimum renewable energy fraction of 67% using only the combination of solar PV and BESS.

Once the system and financial modelling proved that Solar PV and BESS was feasible the LHIB engaged industry in a competitive tender process. In June 2019 the LHIB entered into a contract with Photon Energy Pty Ltd for the execution of the Hybrid Renewable Energy Project (HREP) through an Engineer, Procure and Construct (EPC) Contract.

Value engineering during the design phase consolidated the Solar PV layout by relocating two (2) separate solar arrays, to form a single array near the existing powerhouse. This removed the requirement for High Voltage distribution and offered savings to the project with the removal of equipment including transformers and switchgear. These savings were reinvested in the procurement of additional solar panels and increased battery storage. The new design provided a renewable energy penetration of 69% which was accepted and approved for construction.

Figure 1.1: HREP Aerial perspective

2. Project Overview

2.1 Project Scope

The Hybrid Renewable Energy Project (HREP) was undertaken to achieve the objectives of the project which are listed below in order of importance:

- Achieve a more environmentally sustainable electricity generation for the Lord Howe Island community by replacing at least 67% or two thirds of the Island power generation with renewable energy whilst maintaining a high-level quality and reliability of supply.
- Improve the Lord Howe Island community's self-sufficiency by reducing the Island's reliance on imported diesel fuel and NSW Government funding used for electricity supply.
- Protecting the Island's World Heritage and tourism values by reducing the risk of a fuel spill by decreasing the diesel fuel imported to the Island and reducing the impacts (atmospheric pollution, traffic and noise) of the use of the diesel for power generation.
- Seek the lowest long-term cost of energy production and reduce the potential for rises in the cost of energy if the diesel fuel price escalates (diesel price shock).
- To build on the current high levels of community support and provide a pathway through which other innovative energy management technologies can be introduced to support the local community.
- To install a system that can be maintained and operated by the LHIB electricity generation team with minimal external input for regular operation and maintenance
- Provide a showcase of what is possible in a remote community when solar, storage and conventional diesel generation are integrated.

2.2 Project Summary

The primary driver for the project, as with many islanded micro-grid projects, is to reduce reliance on fossil fuels by displacing diesel with renewable generation. The challenge is to integrate variable renewable energy, while maintaining power quality and system security. As the renewable contribution increases, so does the need to carefully manage the wider power system, including diesel generators, feeders, and auxiliary systems to effectively integrate the variable renewable energy sources without putting supply security at risk.

The HREP project is set to displace 69% of the energy required to service the Island electrical load with energy generated from renewable sources.

A new Micro Grid Controller (MGC) in combination with a 1.3MWp Solar PV plant and a 1MW/3.7MWh BESS integrated with the existing Diesel generation system was designed constructed and commissioned to deliver this outcome. A new Supervisory Control and Data Aquation (SCADA) system provides monitoring and supplementary control of the new system

The existing Diesel generator's control system was upgraded to utilise the Woodward easYgen 3200XT generator controller which is compatible with the Tesla MGC.

2.3 Project Outcomes

The HREP system has proven to be very effective in servicing Island load and has achieved a full 24hour renewable energy day. The Homer simulation model indicates that this is expected to happen up to 5 times a year.

Figure 2.1 below shows the Diesel Generation power in khaki green, the Solar power in yellow, the Island load in Dark blue, the BESS power in light blue and BESS State of Charge in purple.

Diesel generators start when the BESS state of charge reaches 5%, in the absence of adequate PV output, this ensures that the BESS has enough energy remaining to respond to network contingencies.

Figure 2.1 below shows that during the morning of March the 5th 2021, at a time when the system would typically have called for diesel generation, the BESS was still at 10% state of charge, and as there was adequate PV output the BESS went into charge mode and the PV serviced Island load.

Figure 2.1: 24 Hour renewable energy period.

3. System Design and Contracting Approach

The project was considered viable on a guarantee to achieve at minimum a 67% renewable energy fraction of the island's power generation mix utilising a combination of Solar PV and Battery storage. With value engineering at the beginning of the project, the management team was able to reinvest project savings and increase the PV and BESS capacities and renegotiate a guarantee of 69%.

For this target to be achieved all parties worked from a common baseline, in the case of the HREP the Contractor used 2011[1] load and meteorological data to develop a PVsyst model for the solar farm which was used in the Homer model by combining Battery and Diesel generation over an annual period to determine the achievable renewable fraction.

This Homer model forms the basis of the contractual guarantee.

To test HREP plant performance, the PVsyst model will be updated with actual measured meteorological data and imported into the Homer model which will be updated with the actual load data over the same period (12 months). The Homer model will then predict the target renewable fraction for the system. A manual calculation using the raw measured data will determine actual system performance.

The system will pass its performance test if the manually calculated renewable energy fraction is equal to or greater than the predicted value (Homer model) within an agreed contractual tolerance.

This method provides an equitable means to protect both LHIB and the Contractor from variable weather and Island load conditions. [1]

[1] The 2011 data was used since it was the most recent data set available prior to the introduction of private rooftop PV installations on the Island.

4. System components

The system consists of four (4) main components which are, the existing diesel generation system, a Solar PV plant, a BESS and the electrical integration and control of the HREP system. Each of these components is discussed in the sections below.

4.1 Diesel generation system

The Island's existing diesel generation system consists of three (3) 300kW Detroit Series 60 generating units supplying the 415V Powerhouse Main Distribution Board (MDB). The three (3) units provide a combined generating power of 840kW (280kW per machine). The HREP included an upgrade of the generator controllers to the Woodward easYgen 3200XT which established compatibility with the MGC controller.

4.2 Solar PV plant

The HREP relies on a PV solar farm for the provision of renewable energy. The solar farm's array configuration covers an area of 12250m^2 installed at a fixed 20° Tilt.

The total installed PV power is 1328.4 kWp DC with a combined AC output of 1000kVA.

Table 4.1: Solar Farm technical specifications

Description	Value/Quantity
CANADIAN SOLAR HIKU CS3W – P410-415Wp PV Panels	3240
SMA CORE1 STP50-40 Inverters	20
PV Modules per string	18
Number of strings per inverter	9
Number of inverters per AC combiner box	2-3

4.3 BESS Energy Storage System (BESS)

The BESS supplied by TESLA provides the grid forming performance in the HREP system. The Powerpack unit is installed externally adjacent to the HREP Distribution Board for efficient 415V AC integration with the system.

Table 4.2: BESS Technical Specification

Description	Value/Quantity
TESLA INVERTER 544kVA	2
TESLA POWERPACK 232 kWh	16

5. System Integration

5.1 400V AC integration

The new system integrates with the existing at 415V, the voltage is then stepped up to 6.6kV for distribution to the Island grid. The existing Powerhouse MDB (415V) was provided with two (2) spare 800A feeder panels allocated to future renewable expansion which were utilised in the HREP. A cable connection between these two (2) circuit breakers and the new HREP DB feeder breakers electrically integrates the HREP system to the existing electrical infrastructure. Refer to Fig 4.1 for the general system single line diagram (SLD).

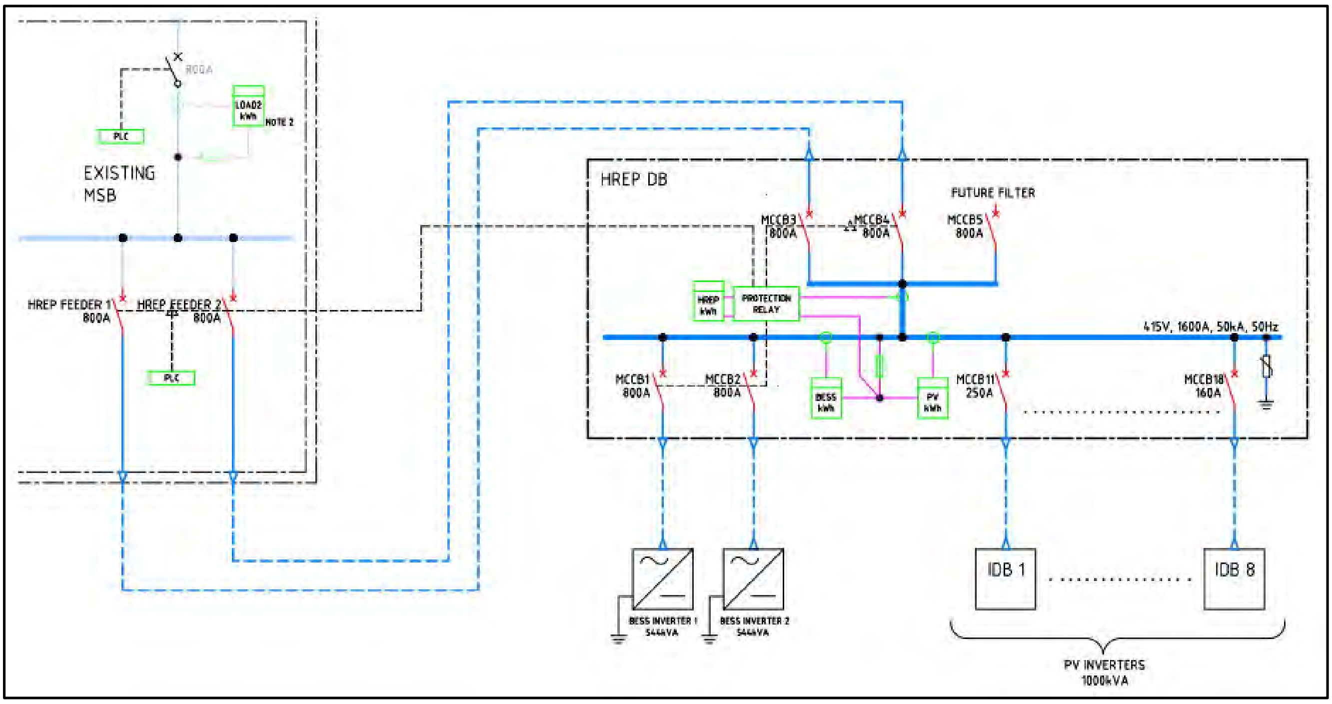


Figure 4.1 AC System integration.

MCCB 3 and MCCB 4 are electrically interlocked and operate together, HREP Feeder 1 and 2 also has the same ability via external shunt trips. This function is to ensure that the full 1000kW is transferable between the two (2) distribution boards without the risk of losing a single feeder and overloading the remaining feeder. This cable link is in effect an extension of the 415V existing MSB Bus to the HREP DB.

5.2 Control system

With multiple sources of generation i.e. diesel, solar PV and BESS an overarching controller is required. The Tesla Micro Grid Controller (MGC) included in the HREP performs this function. The MCG communicates with and manages the Tesla Powerpack inverters, SMA solar string inverters, and Diesel generator controllers. The control system manages the operation of the DG units and starts and stops the units based on pre-set criterion discussed in more detail in Section 6.

It is important to note that the BESS is the primary grid forming[2] entity in system. The system has two (2) mechanisms to control the output of the other generating sources:

[2] Source that provides the reference voltage amplitude and frequency for other generators to synchronise with.

1) Control by the MGC through a HREP wide communication network.
2) In the event of communication loss between the MGC and PV Inverters or DGs, the BESS can adjust the level of generation by changing system frequency and in doing so manages output of the diesel generators and the PV plant by means of pre-loaded Power-Frequency droop settings.

Monitoring of the solar PV array is achieved via regular polling of the Modbus register values by a Beijer Box2 Protocol Converter. The Box2 hosts an OPC server, which converts the hardware communication protocol into the industry standard OPC protocol. The OPC client is accessed by the SCADA server via a Local Area Network (LAN) connection to transfer data or send commands to the generators.

A Human Machine Interface (HMI) including monitors, keyboards and pointing devices, running on an industrial grade PC in the Powerhouse control room, provides real-time monitoring of PV inverter, BESS and Diesel generator performance. Parameters are averaged and stored at regular intervals in an on-site historian server for later retrieval and report generation.

As previously stated, the BESS, is controlled by the Tesla MGC. The operation and monitoring of the BESS battery cells is handled autonomously by the BESS battery management system, which forms an integrated part of the BESS and which is not reliant on outside communication for safe operation.

6. System Operation

The plant is automated with minimum operator intervention for normal operation. The Microgrid Controller integrates and operates the BESS, PV System and existing Diesel Genset assets with the necessary interfaces to support normal operation.

For black start, maintenance, testing and commissioning purposes, the individual assets are operated in manual mode. Safe operator control is achieved when in manual mode as while switched into this mode the MGC does not control the diesel generators, Manual mode is selected through a rotary switch provided for each generator's control panel.

In automatic mode (normal mode of operation) the MGC controls the scheduling and staring of Diesel generation as follows:

- Generator Start at Low Battery State of Energy (SOE) (5%)

  The MGC will start a diesel generator as the BESS approaches its minimum SOE. The generator with the highest priority (as set on the HMI), will start first. Multiple generators will be started if necessary.

- Starting multiple generators

  If one or more generators are already active and the load reaches the generator maximum capacity, the MGC will start another generator to meet both load and spinning reserve requirements.

During normal operation, the solar plant generates power during daytime commensurate with solar irradiance levels and forms the primary source of the energy in the island grid. Excess power production is utilised to charge the BESS during the day.

The available rate of charge of the BESS decreases as individual battery modules reach full charge, this could lead to a scenario where the solar PV delivers more instantaneous power than the combination of the island load and BESS charging can accommodate. When this happens the system frequency will rise and unless controlled will ultimately trip at its maximum set threshold. To manage this the MGC systematically curtails excess solar production when the BESS reaches 90% State of Energy, gradually reducing the power generation from the solar plant until 95% SOE is reached.

The solar PV inverters will enter standby mode as irradiance decreases to zero during the night.

The BESS will be the primary source of energy during the night. When the BESS is nearing depletion (5% SOE), diesel generation will be started in preparation to supply the Island load, the BESS always remains grid forming[2] i.e. providing the frequency sync signal for the generators. Real power sharing between the BESS and one or multiple generators is actively managed by coordinating frequency-power droop curves. The Woodward easYgen controllers handle starting and stopping of the generator engines and synchronising to the common 415V bus. The various modes of operation are detailed in Table 6.1 below.

Automatic Mode / Control Hierarchy		PV Plant	BESS	Diesel Generators
Sufficient Solar Radiation Present	Status	On	On/Grid Forming	Off
	Function	Servicing Island Load Charging BESS	Charging Ancillary Services	Stand-by
Sufficient Solar Radiation Present BESS Charged (95%)	Status	On/Curtailed	On/Grid Forming	Off
	Function	Servicing Island Load (Load following)	Ancillary Services	Stand-by
Insufficient Solar Radiation BESS SOE (95%-5%)	Status	Off	On/Grid Forming	Off
	Function	Stand-by	Servicing Island Load Ancillary Services	Stand-by
Insufficient Solar Radiation BESS SOE (5%)	Status	Off	On/Grid Forming	On
	Function	Stand-by	Ancillary Services	Servicing Island Load

Table 6.1: System Automatic operating modes

7. Technical Design Challenges

7.1 Fencing

The Solar PV system was located adjacent to the existing powerhouse, which provided significant technical advantages and the site is one of a very few open areas on the Island, which the Lord Howe Island Board has access to.

This area (Plot 203) of land is also situation next to a section of woodland, where a colony of Flesh Footed Shearwaters breed seasonally.

The project works are in proximity to this breeding area as such the Project Technical Specification (RT019500-GN-SPC-0001_Rev0) and the Conditions of Consent required that any fence, constructed by the project, not contain any barbed wire and provide clearance at the base (150mm) to avoid entrapment of fauna (particularly ground dwelling birds) to allow breeding parents, which happen to land within the fenced area, the freedom to migrate back to the woodland.

The Technical Specification also required adherence to AS5033: Installation and safety requirements for photovoltaic (PV) arrays. This standard requires restricted access for this specific installation since the DC array voltage exceeds 600V.

Restricted Access is defined by AS5033 Clause 1.4.61 as follows:

- Access restricted by a barrier (e.g. by a perimeter fence or barrier with access only via a padlocked or equivalently secured gate or door); or
- by location (e.g. a commercial roof where there is no fixed ladder or other ready means of access).

This definition requires the construction of a fence or barrier that is effective in restricting entry to the facility or access to the equipment via authorised access points that can be locked or closed to such an extent that only a key or the use of a tool will allow access.

There exists, therefore, a contradiction between the requirement for restricted access as per AS5033 and the requirement for freedom of movement for ground dwelling birds since the Conditions of Consent required a 150mm minimum gap at the bottom of the fence. A 150mm gap would allow access to the premises with minimal force, little effort and without the use of a tool.

This contradiction caused the project team to re-evaluate the use of the typical perimeter fence.

Following detailed risk assessments, the provision of a series of system hardening initiatives was found acceptable to satisfy the intent for “restricted access” within AS5033.

a) Solution

AS5033 clause 3.1 states: “*For non-domestic installations, at the Power Conversion Equipment (PCE) where the DC array voltage exceeds 600 VDC restricted access of the array cabling is satisfied where the cabling is in heavy duty conduit or is fully enclosed in an equivalent electrical enclosure which is not accessible without the use of a tool up to and including the PCE input. If in accessible areas, the associated protection and isolation devices shall also be fully enclosed and not accessible without the use of a tool*.”

Using this definition, the project team developed and designed a series of access barriers to prevent human contact with high risk elements, either intentionally or inadvertent, without the use of a tool. This process was focused on satisfying clause 3.1 by the definition of Clause 1.4.61 - collectively known as system hardening. Table 1 includes the key high-risk plant elements and the associated hardening initiative.

PLANT ELEMENT	HARDENING INITIATIVE
Panel wiring and Panel junction boxes	Installation of a 450mm wide cable tray including tray lid running continuously under each row which will house the panel wiring, associated connectors and will cover all PV panel junction boxes.
Tesla Inverter DC Isolator	Fix staple to the BESS inverter door to enable the DC isolator handle to be locked in the "ON" position by means of padlock. (Addition approved by supplier)
SMA Inverter DC Isolator & installation	Modify inverter to allow the DC isolator to be locked via padlock in the "ON" position. All incoming and outgoing cables to be installed in heavy duty conduit. (Modification approved by supplier). All cables AC and DC running from or to the inverters will be covered with bespoke metal cable channels and covers.
HREP Distribution Board	The HREP distribution board is fitted with an outer shell for compliance with IP requirements. These doors can be locked by means of a barrel lock arrangement installed on each door.

Table 7.1: HREP System Hardening Initiatives

The hardening initiatives satisfies the intent of "restricted access" as described within AS5033 as any access to potentially live parts can only be gained using a key or a tool.

b) Conclusion

A Solar PV and BESS installation of the size and nature designed for the Lord Howe HREP would typically be surrounded by a 1.8m high cyclone fence with no gap at the bottom and three (3) strands of barbed wire at the top. Such a fence will satisfy the barrier requirements as described in AS5033 but would not have met the environmental impact, specifically related to the threatened Flesh Footed Shearwaters breeding on the Island.

In lieu of a fence a set of system hardening initiatives was designed and implemented to satisfy the requirement for a "barrier" and the requirement for the use of a tool or key to gain access to potentially dangerous equipment or operate equipment in any way.

It is the position of the Lord Howe Island Board that the system hardening initiative complies with the general intent of AS5033 with specific reference to restricted access. The design was not intended to be vandal proof. A “traditional” perimeter fence while “keeping honest people honest” would not deter a vandal. The proposed initiatives provide a barrier to prevent inadvertent contact of potentially live system elements and mandates the use of a tool or key for access.

It is noteworthy, however, that vandalism on Lord Howe Island is extremely low, due to high reliance on tourism, coupled with the pride the community feel for the Island and its natural appearance.

This culture of respect for the island in a small community notably reduces the likelihood of the risks discussed in this memorandum materialising.

7.2 System Electrical Protection

Inverter based generation produces low short circuit currents during fault conditions. As such protective systems normally provided on circuit breakers sized for nominal current and overload protection would not be able to safely protect by tripping, during three phase faults or single phase to ground faults within an acceptable time.

A generation scenario when only the two 544kVA BESS Inverters are online i.e. with no DG operating, typically at night, produces a short circuit current of a magnitude that would trip the 800A BESS MCCBs in 13s which is unacceptable and unsafe.

a) Solution

To provide a fault clearance time required to appropriately protect the electrical system under fault conditions, an Intelipro protection relay was installed in the HREP DB. This relay monitors voltage and current will trip both BESS MCCB’s and the HREP DB Main MCCB’s in the event of a fault.

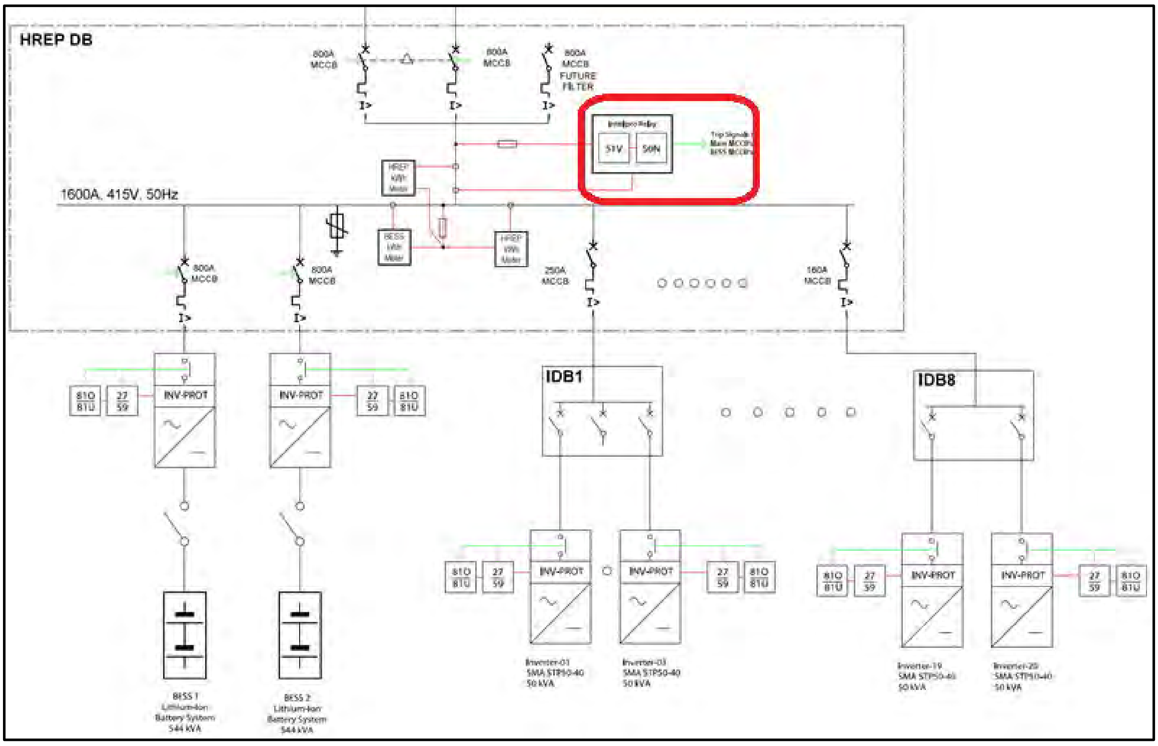
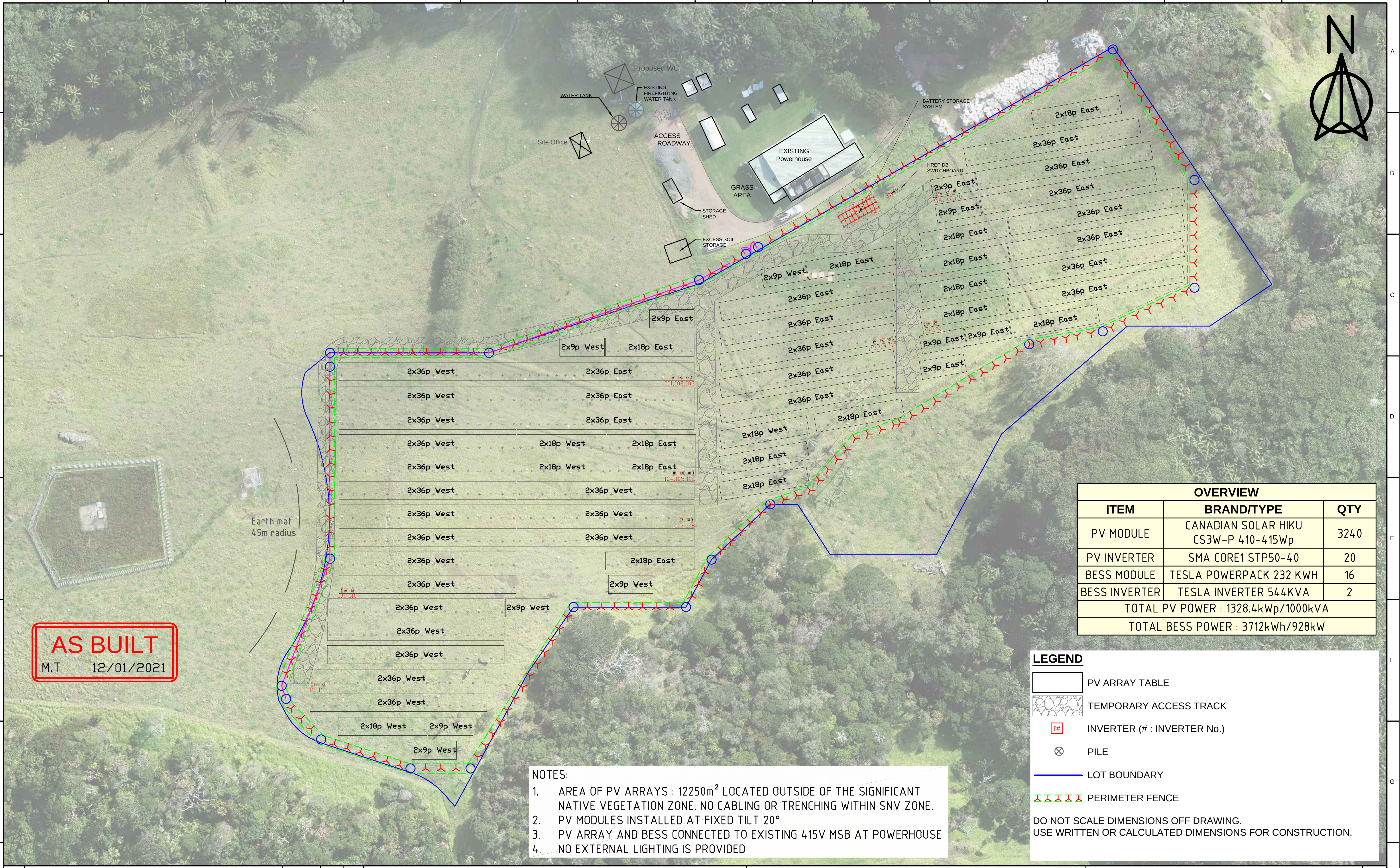


Figure 7.1: HREP DB Protection SLD

Appendix A. System Layout



OVERVIEW

ITEM	BRAND/TYPE	QTY
PV MODULE	CANADIAN SOLAR HIKU CS3W-P 410-415Wp	3240
PV INVERTER	SMA CORE1 STP50-40	20
BESS MODULE	TESLA POWERPACK 232 KWH	16
BESS INVERTER	TESLA INVERTER 544KVA	2
TOTAL PV POWER : 1328.4kWp/1000kVA		
TOTAL BESS POWER : 3712kWh/928kW		

LEGEND

- PV ARRAY TABLE
- TEMPORARY ACCESS TRACK
- INVERTER (# : INVERTER No.)
- PILE
- LOT BOUNDARY
- PERIMETER FENCE

DO NOT SCALE DIMENSIONS OFF DRAWING.
USE WRITTEN OR CALCULATED DIMENSIONS FOR CONSTRUCTION.

NOTES:

1. AREA OF PV ARRAYS : 12250m^2 LOCATED OUTSIDE OF THE SIGNIFICANT NATIVE VEGETATION ZONE. NO CABLING OR TRENCHING WITHIN SNV ZONE.
2. PV MODULES INSTALLED AT FIXED TILT 20°
3. PV ARRAY AND BESS CONNECTED TO EXISTING 415V MSB AT POWERHOUSE
4. NO EXTERNAL LIGHTING IS PROVIDED

REV	DETAILS OF REVISION	DATE	CHK	APP
0	FOR CONSTRUCTION	20/05/2020	Z.V	G.K
1	LAYOUT CHANGE	02/11/2020	Z.V	G.K
2	REVISED AND UPDATED	02/12/2020	Z.V	G.K
AB	AS BUILT	12/01/2021	M.C	E.N

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CLEAN ENERGY COUNCIL APPROVED SOLAR RETAILER

CLIENT	LORD HOWE ISLAND BOARD
PROJECT	HYBRID RENEWABLE ENERGY PROJECT (HREP) LORD HOWE ISLAND
TITLE	SITE LAYOUT
DRAWING No.	PEA-16-146-C-DWG-120
REV	AB
DRAWN :	M. TAGHIZADEH
CHECKED :	Z. VALA
APPROVED :	G. KLINGBERG
SCALE:	1:750 @ A3
STATUS:	AS BUILT
ISSUE DATE:	09/09/2019

Appendix B. System Photos