Clements Gap BESS

Voltage Control Strategy

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Contents

Revision History

Table 1: Revision history

Rev.	Date	Prepared By	Reviewed By	Description
1-0-0	16/05/2025	Jared Geere	Ben Kearney	Initial release

This document uses *Semantic Versioning for Documents* for revision numbering.

Given a version number *MAJOR-MINOR-FIX*, the

- *MAJOR* is incremented when the document has undergone significant changes
- *MINOR* is incremented when new information has been added to the document or information has been removed from the document, and
- *FIX* is incremented when minor changes are made (e.g. fixing typos)

Where appropriate, several revisions may be represented in one table entry with all notable changes described in the *Description* column.

1. Summary of Voltage Control Strategy

The Clements Gap Battery Energy Storage System (CGBESS) is a $\pm 60MW/120MWh$ Battery Energy Storage Project, located 170km North of Adelaide in South Australia. As part of this project, the existing 132kV line between Red Hill substation and Clements Gap Wind Farm will be converted to a Designated Network Asset (DNA), after which both the existing wind farm and CGBESS will connect to the wind farm end of the line.

Clements Gap BESS (CGBESS) will include twenty five (25) SMA Sunny Central 3.6 MVA (SCS 3600 UP) inverters which will be connected to a 132/33kV, 70 MVA transformer through the 33kV reticulation system. Each inverter will have a dedicated 33/0.63kV, 3.78 MVA step up transformer.

CGBESS will operate in voltage droop control mode by default, controlling the 132kV connection point with a 2% droop on a 23.7 MVAr base.

The proposed maximum capacity of CGBESS at the connection point is $\pm$ 60 MW at ambient air temperatures between 25°C and 50°C.

Table 1.1: Connection Overview

Connection Overview	Description
Project Name	Clements Gap BESS
Technology	Battery
Geographical location	Approximately 170km North of Adelaide and 15km from Redhill substation
Connection point	Clements Gap Wind Farm end of the 132 kV line between Clements Gap Wind Farm and Redhill substation
Control point	The connection point as described above
Network Service Provider	ElectraNet
Maximum capacity at the CP	$\pm$ 60 MW and $\pm$ 23.7 MVAr [25° C to 50° C]
Units	25 x SMA SCS 3600 UP inverters
Rated capacity at the generating unit terminals	90 MVA [25°C]
Maximum operating temperature	50°C
Default Control Mode	Voltage Droop Control
Available Modes	Voltage Droop Control, Reactive Power Control and Power Factor Control
Expected Target Reference	1.0227 pu (132kV base)
Expected Normal Voltage	132 kV
Q Base	23.7 MVAr

Table 1.1: Connection Overview

Connection Overview	Description
Droop %	2.00% on 23.7 MVAr base
System Strength at the POC	510 MVA (N-1) and 1068 MVA (N)
Owner Contact Details	TBD
24/7 Operator Contact Details	TBD

CGBESS uses as closed loop PID controller - the SMA Hybrid Power Plant Controller (PPM), to control the point of connection to desired active and reactive power setpoints. The Power Plant Manager (PPM) receives these setpoints from the sites's Energy Management System(EMS) controller and dispatches the battery inverters accordingly. The power quality meter providing feedback to the PPM receives its current transformer (CT) inputs from CTs located at the high voltage side of the main transformer while voltage transformer (VT) inputs are from a VT located on ElectraNets side of the projects delineation boundary.

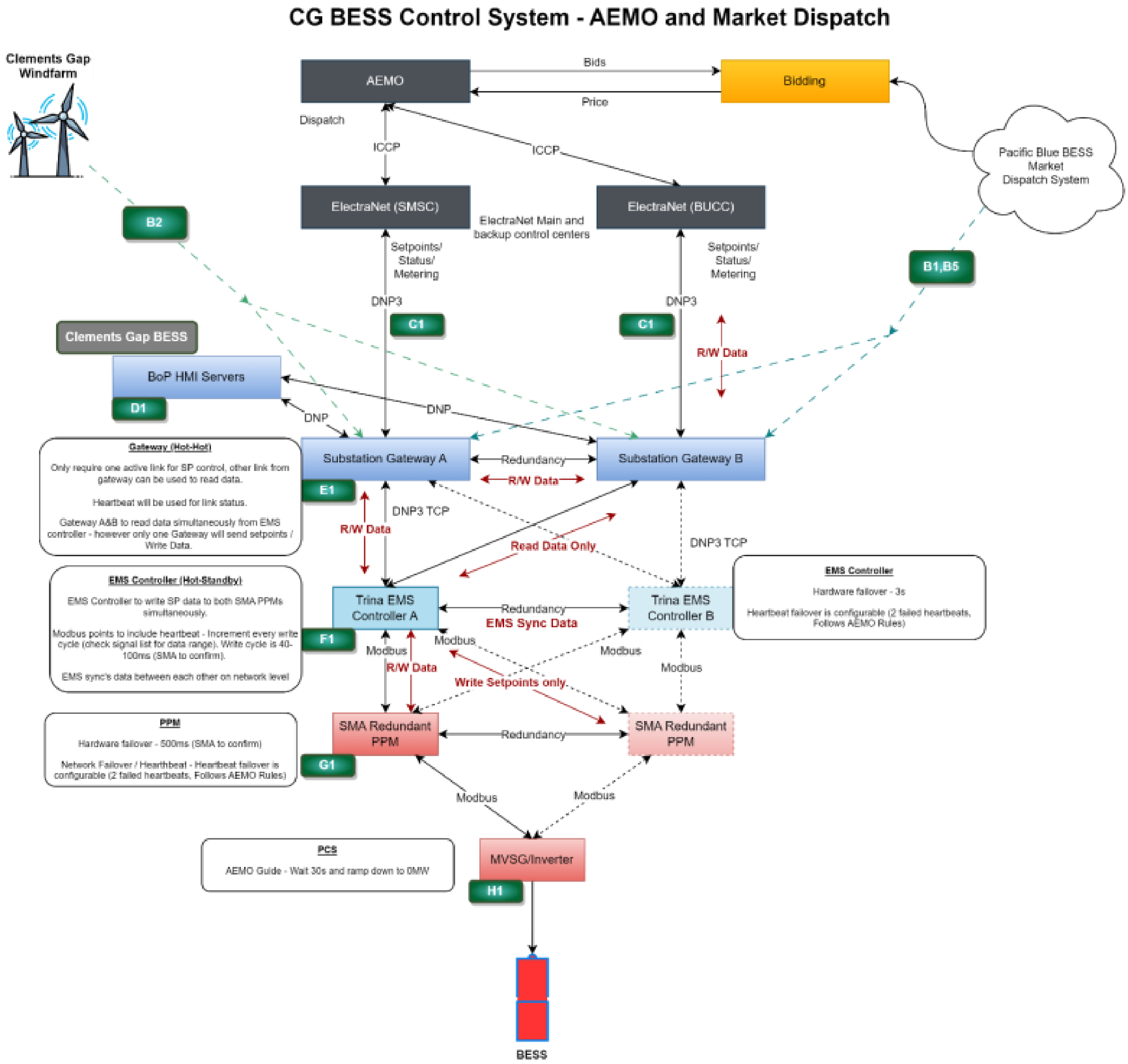


Figure 1.1: CG BESS Control Scheme

2. Remote Voltage Control

Table 2.1: Reference Change Series of Events

Action	By	Description	Response By
1.	NSP or AEMO	Voltage Reference Setpoint Change at 132kV POC of Clements Gap BESS	NSP or AEMO
2.	Owner	Clements Gap BESS EMS controller receives the voltage setpoint from NSP/AEMO and issues a change in setpoint to the PPM. The PPM then determines a droop adjusted reactive power setpoint and determines an appropriate control value to be issued to all inverters.	Generating system
3.	Owner	Completes the fast response	Inverters
4.	Owner	Main transformer tap changer regules the voltage at the 33kV terminals with the voltage deadband.	Main transformer OLTC
5.	Owner	Completes the slow response	Main transformer OLTC

The PPM receives the voltage setpoint signal from the site's EMS - which is responsible for triaging setpoints received from various sources eg. NSP, AEMO, the dispatch system or the plant operator. Once a setpoint is received, the controller calculates a droop adjusted reactive power target based on the error between the measured voltage at the POC and the voltage reference setpoint. The controller then issues a reactive power target to each inverter based on the error between the measured reactive power output and the droop adjusted reactive power reference.

The relationship between the droop adjusted reactive power reference and the error between the voltage reference and the measured voltage at the POC ($V_{error,poc}$) is given by the chart below. This characteristic reflects a 2% voltage droop on a reactive power base of 23.7 MVAr. Therefore, we expect that the generating system will target a reactive power output of $\pm$ 23.7 MVAr whenever $|V_{poc} - V_{vref}| \geq 0.02$.

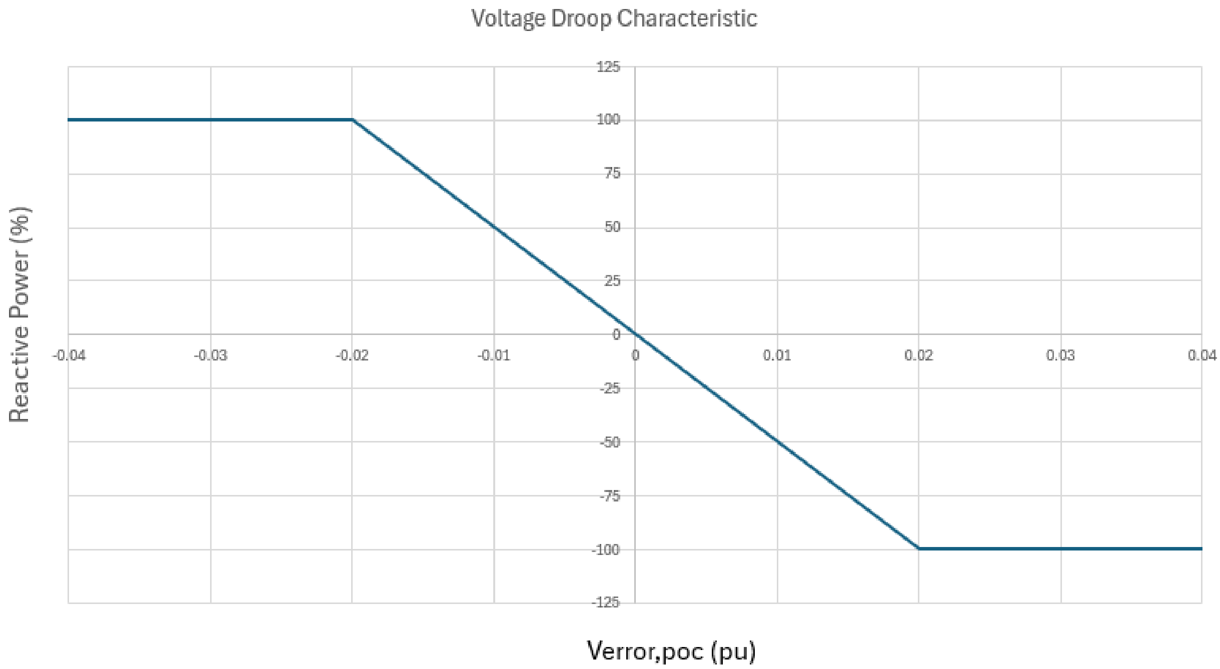


Figure 2.1: CG BESS Voltage Droop Characteristic

3. Remote PF Control

Table 3.1: PF Reference Change Series of Events

Action	By	Description	Response By
1.	NSP or AEMO	Power Factor Reference Setpoint Change at 132kV POC of Clements Gap BESS	NSP or AEMO
2.	Owner	Clements Gap BESS EMS controller receives the power factor reference setpoint from NSP/AEMO and issues a change in setpoint to the PPM. The PPM then calculates a reactive power setpoint and determines an appropriate control value to be issued to all inverters.	Generating system
3.	Owner	Completes the fast response	Inverters
4.	Owner	Main transformer tap changer regules the voltage at the 33kV terminals with the voltage deadband.	Main transformer OLTC
5.	Owner	Completes the slow response	Main transformer OLTC

The PPM receives the voltage setpoint signal from the site's EMS - which is responsible for triaging setpoints received from various sources eg. NSP, AEMO, the dispatch system or the plant operator. Once a power factor setpoint is received, the controller calculates a reactive power target based on the measured active power and the power factor setpoint. The controller then issues a reactive power target to each inverter based on the error between the measured reactive power output and reactive power reference.

4. Remote Reactive Power Control

Table 4.1: Reactive Power Reference Change Series of Events

Action	By	Description	Response By
1.	NSP or AEMO	Reactive Power Reference Setpoint Change at 132kV POC of Clements Gap BESS	NSP or AEMO
2.	Owner	Clements Gap BESS EMS controller receives the reactive power reference setpoint from NSP/AEMO and issues a change in setpoint to the PPM. The PPM determines an appropriate control value to be issued to all inverters based on the error between the measured reactive power and the reference.	Generating system
3.	Owner	Completes the fast response	Inverters
4.	Owner	Main transformer tap changer regules the voltage at the 33kV terminals with the voltage deadband.	Main transformer OLTC
5.	Owner	Completes the slow response	Main transformer OLTC

When in Reactive Power Control (Q Control), the PPM may receive a change in reactive power setpoint via the site's EMS - which is responsible for triaging setpoints received from various sources eg. NSP, AEMO, the dispatch system or the plant operator. Once a reactive power setpoint is received, the controller then issues a reactive power target to each inverter based on the error between the measured reactive power output and reactive power reference. The reactive power output at the point of connection is limited to $\pm$ 23.7 MVAr.

5. Reactive Power Capability

Clements Gap BESS is capable of providing $\pm$ 23.7 MVAr ($0.395 * P_{base}$) at the generating system point of connection, for active power outputs of $\pm$ 60 MW and ambient air temperatures up to $50°$C. This is demonstrated by the reactive capability curves below. This assessment has considered continuous uninterrupted operation and whether the inverters are capable of providing sufficient reactive power at steady state for voltage disturbance steps from 1.0 - 1.1 pu and 1.0 - 0.9 pu at the point of connection.

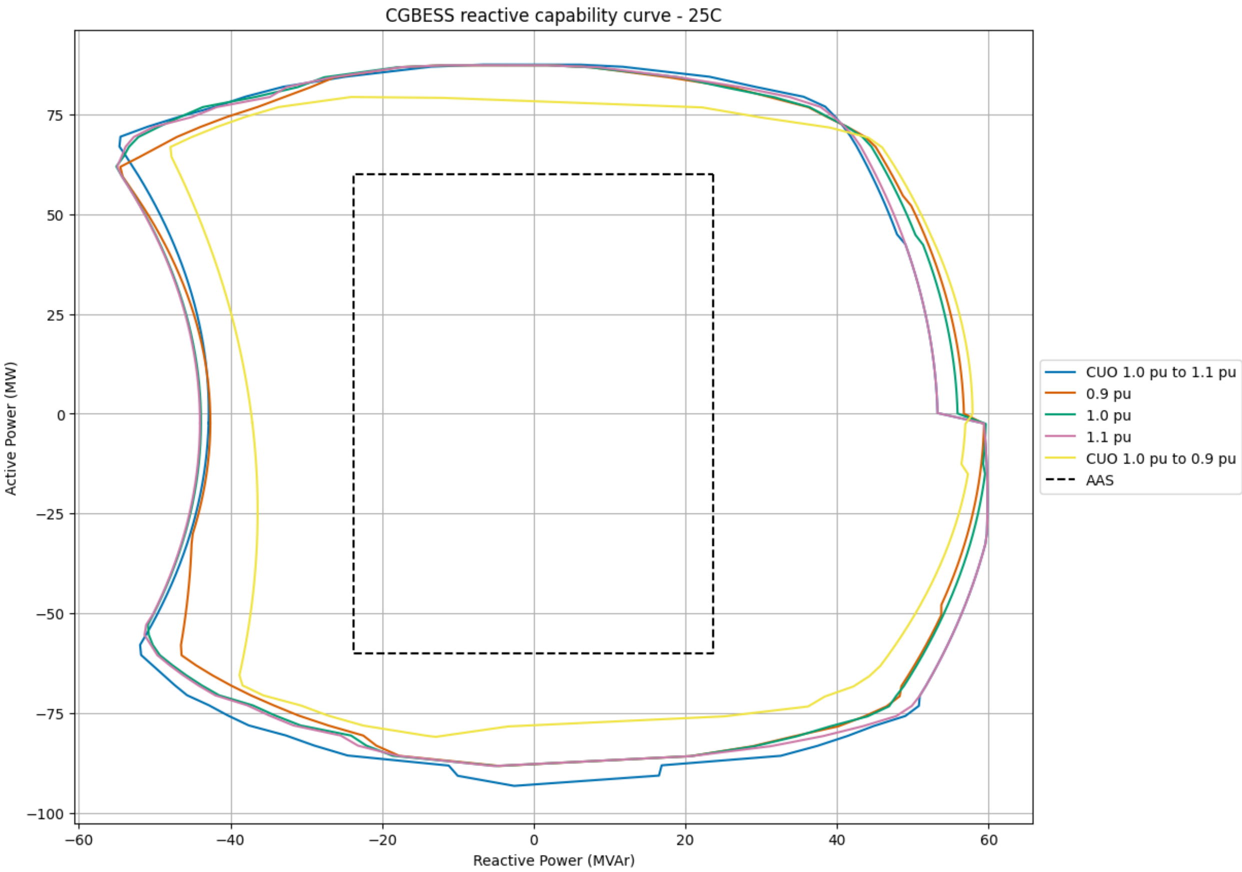


Figure 5.1: CG BESS Reactive Capability Curve at $25°$C

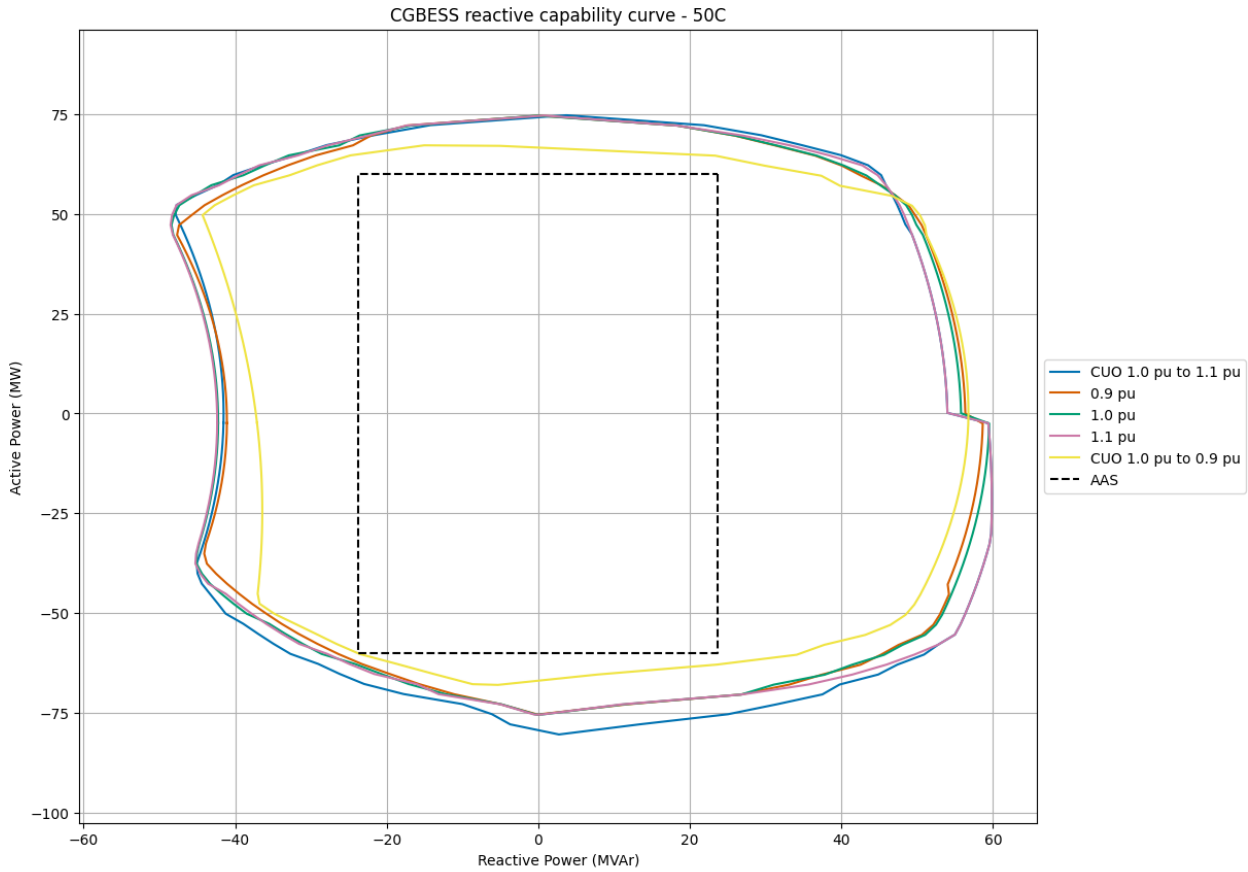


Figure 5.2: CG BESS Reactive Capability Curve at $50°$C

The capability of the generating system at the POC was determined as a function of the individual capability of the SMA SCS 3600 UP inverters. These have been provided for reference below.

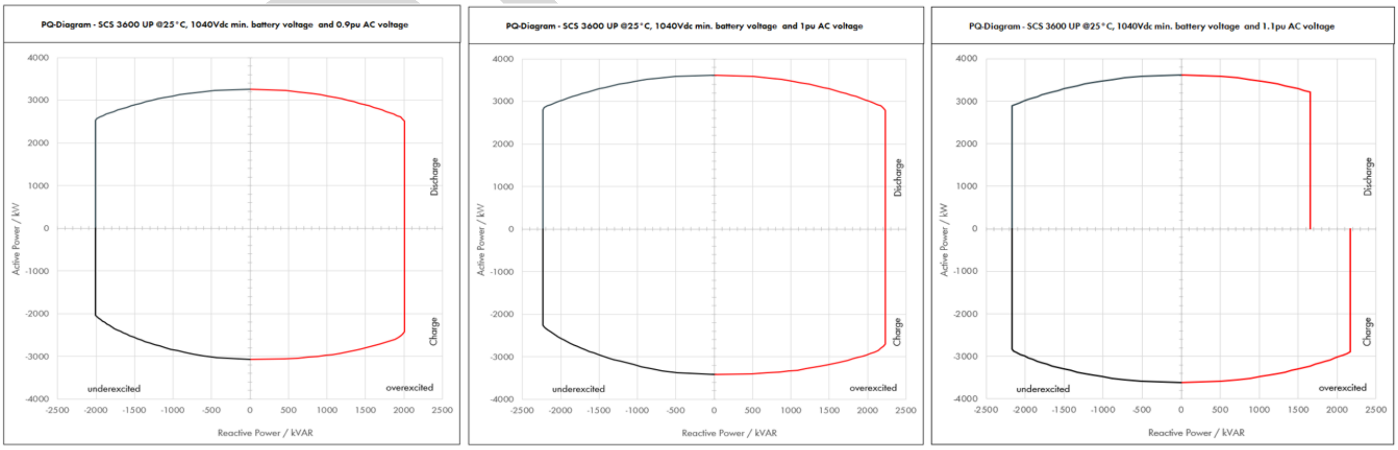


Figure 5.3: SMA SCS 3600 UP Reactive Capability Curve by terminal voltage at $25°$C

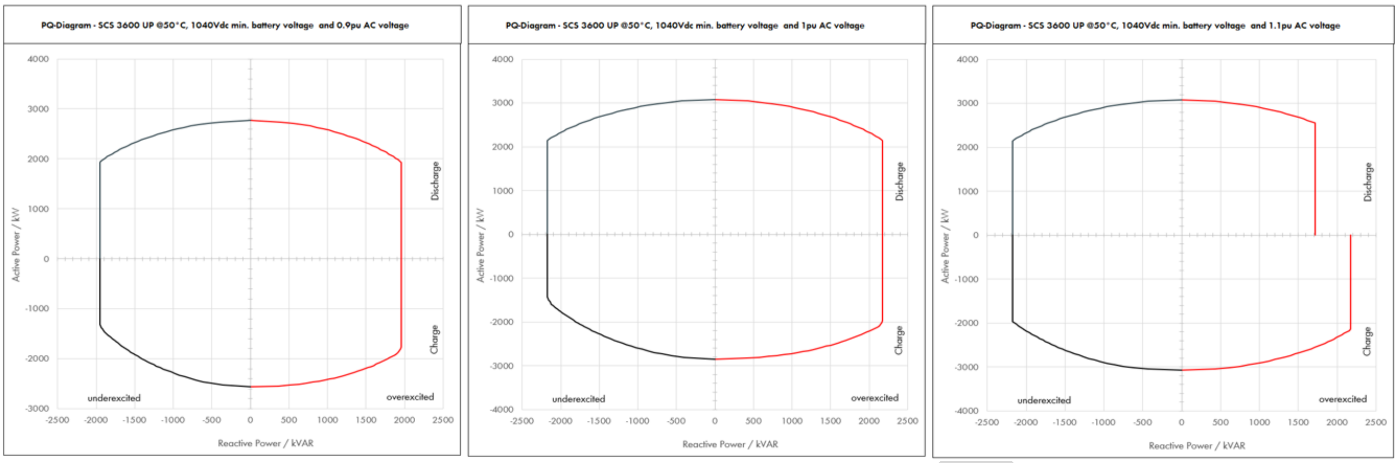


Figure 5.4: SMA SCS 3600 UP Reactive Capability Curve by terminal voltage at $50°$C

6. Physical Equipment

The substation single line diagram (SLD) is illustrated in Figure 6. This diagram outlines the electrical configuration of primary plant as well as the CTs and VTs used for metering.

Significant primary plant for this generating system are as follows

- 1 x 132kV/33kV 70 MVA main transformer
- 5 x 33kV collector feeders
- 25 x SMA SCS 3600 UP inverters
- 2 x 33kV HF filter banks (12MVAr + 3 MVAr)
- 5 x 500 kVA collector auxiliary transformers
- 1 x 315 kVA auxiliary transformer

ELECTRANET LINE BAY (+D01-T11)				
ID	CORE	RT	CLASS	BURDEN
CT7088	1	800/1A	PX	860V, RCt ≤ 1.8Ω
	2	800/1A	PX	860V, RCt ≤ 1.8Ω
	3	800/1A	PX	860V, RCt ≤ 1.8Ω
	4	800/1A	PX	860V, RCt ≤ 1.8Ω
	5	400/1A	0.2S	10VA
	6	400/1A	0.2S	10VA
	7	400/1A	0.2S	10VA

TRANSFORMER BUSHING - HV SIDE (+T01-T11)				
ID	CORE	RT	CLASS	BURDEN
CT01	1	400/1A	0.2s	10VA
	2	400/1A	0.2s	10VA
	-	-	-	-

TRANSFORMER BUSHING - HV NEUTRAL SIDE (+T01-T12)				
ID	CORE	RT	CLASS	BURDEN
CT02	1	800/1A	PX	860V, RCt ≤ 1.8Ω
	2	800/1A	PX	860V, RCt ≤ 1.8Ω
	-	-	-	-

TRANSFORMER MV NEUTRAL SIDE (+T01-T14)				
ID	CORE	RT	CLASS	BURDEN
CT03	1	1600/1A	PX	Vk>450V, RCt ≤ 10Ω
	2	1600/1A	PX	Vk>450V, RCt ≤ 10Ω
	-	-	-	-

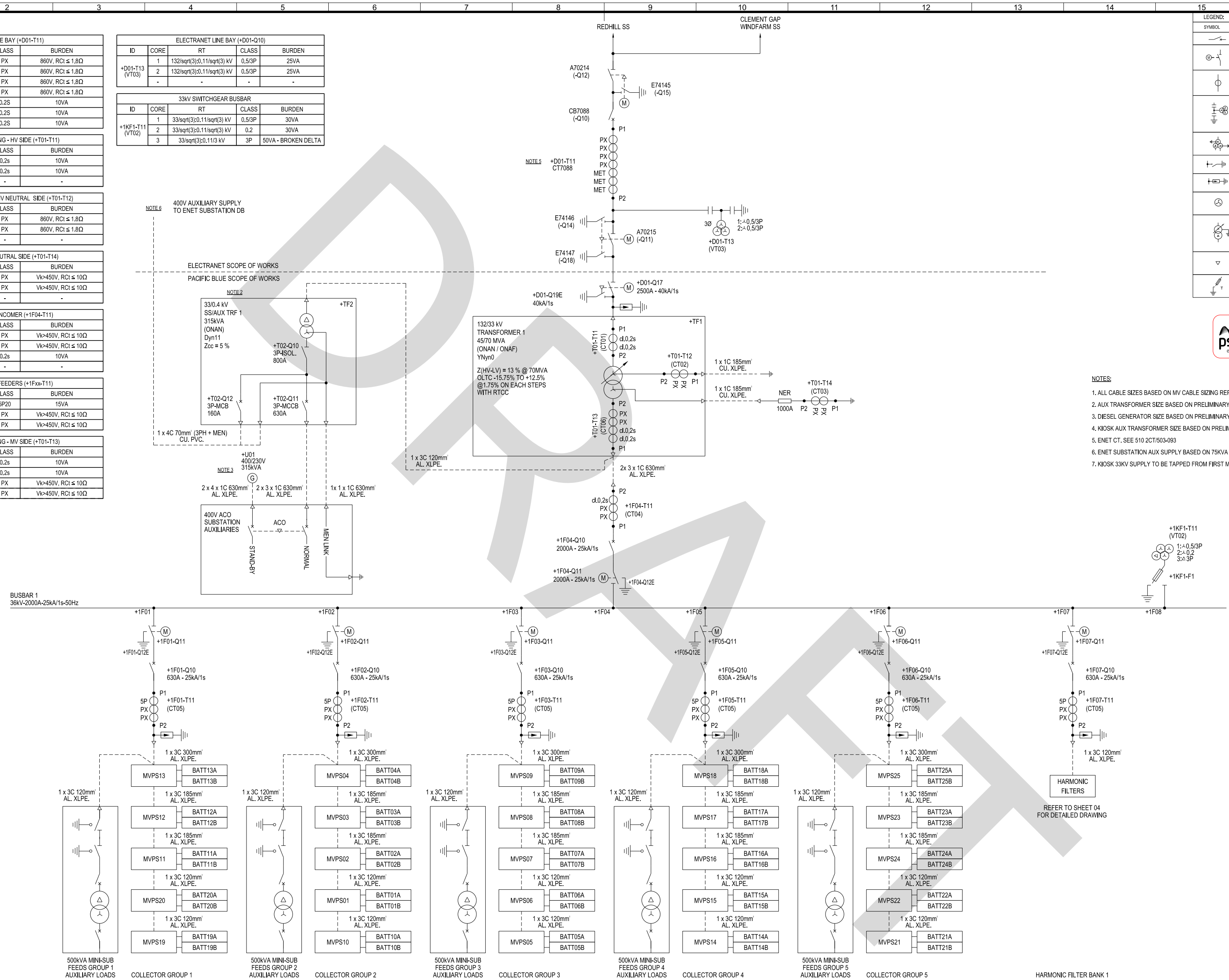
33KV SWITCHGEAR INCOMER (+1F04-T11)				
ID	CORE	RT	CLASS	BURDEN
CT04	1	1600/1A	PX	Vk>450V, RCt ≤ 10Ω
	2	1600/1A	PX	Vk>450V, RCt ≤ 10Ω
	3	1600/1A	0.2s	10VA
	-	-	-	-

33KV SWITCHGEAR FEEDERS (+1Fxx-T11)				
ID	CORE	RT	CLASS	BURDEN
CT05	1	600/1A	5P20	15VA
	2	1600/1A	PX	Vk>450V, RCt ≤ 10Ω
	3	1600/1A	PX	Vk>450V, RCt ≤ 10Ω

TRANSFORMER BUSHING - MV SIDE (+T01-T13)				
ID	CORE	RT	CLASS	BURDEN
CT06	1	1600/1A	0.2s	10VA
	2	1600/1A	0.2s	10VA
	3	1600/1A	PX	Vk>450V, RCt ≤ 10Ω
	4	1600/1A	PX	Vk>450V, RCt ≤ 10Ω

ELECTRANET LINE BAY (+D01-Q10)				
ID	CORE	RT	CLASS	BURDEN
+D01-T13 (VT03)	1	132/sqrt(3):0.11/sqrt(3) kV	0.5/3P	25VA
	2	132/sqrt(3):0.11/sqrt(3) kV	0.5/3P	25VA
	-	-	-	-

33kV SWITCHGEAR BUSBAR				
ID	CORE	RT	CLASS	BURDEN
+1KF1-T11 (VT02)	1	33/sqrt(3):0.11/sqrt(3) kV	0.5/3P	30VA
	2	33/sqrt(3):0.11/sqrt(3) kV	0.2	30VA
	3	33/sqrt(3):0.11/3 kV	3P	50VA - BROKEN DELTA



LEGEND:

SYMBOL	DESCRIPTION
	CIRCUIT BREAKER
	MOTORIZED DISCONNECTOR
	CURRENT TRANSFORMER (CT)
	CAPACITOR VOLTAGE TRANSFORMER (CVT)
	VOLTAGE TRANSFORMER (VT)
	EARTH SWITCH
	SURGE ARRESTOR
	EARTHING TRANSFORMER
	POWER TRANSFORMER
	MECHANICAL INTERLOCK
	FUSE SWITCH DISCONNECTOR

psd energy ISSUED FOR CONSTRUCTION S.H 29.11.2024 Initials Date

NOTES:

1. ALL CABLE SIZES BASED ON MV CABLE SIZING REPORT.
2. AUX TRANSFORMER SIZE BASED ON PRELIMINARY AC SIZING REPORT.
3. DIESEL GENERATOR SIZE BASED ON PRELIMINARY AC SIZING REPORT.
4. KIOSK AUX TRANSFORMER SIZE BASED ON PRELIMINARY BESS AUX LOADING DATA.
5. ENET CT. SEE 510 2CT/503-093
6. ENET SUBSTATION AUX SUPPLY BASED ON 75KVA REQUIREMENT IN SPECIFICATIONS.
7. KIOSK 33KV SUPPLY TO BE TAPPED FROM FIRST MVPS RMU IN EACH COLLECTOR GROUP.

0	ISSUED FOR CONSTRUCTION	EL	KT	SH	11/24
D	ISSUED FOR REVIEW - 80% DESIGN	EL	KT	SH	08/24
C	ISSUED FOR REVIEW - 80% DESIGN	EL	KT	SH	07/24
B	ISSUED FOR REVIEW	EL	KT	SH	05/24
A	ISSUED FOR INFORMATION	EL	KT	SH	05/24
REV	DESCRIPTION	RVD	CKD	APD	DATE

PacificBlue enzen psd energy

SIZE A1	SCALE NTS
PROJECT	CLEMENTS GAP BESS
STATUS	FOR CONSTR.
TITLE	132/33kV SUBSTATION OVERALL SIMPLIFIED SINGLE LINE DIAGRAM
SHEET No.	01 OF 04
DRAWING No.	PSD1834-110-001-001
REV	0

7. Transformers

7.1 Inverter Transformers

Clements Gap Bess contains twenty five (25) 3.6 MVA 33/0.63 kV three-phase two-winding inverter transformers with parameters given in Table 7.1. These transformers are fitted with an off-load tap changer and are typically configured at the nominal tap position. Please refer to [1] which illustrates the electrical configuration of the medium voltage power station. Please refer to the medium voltage transformer datasheet [2].

Table 7.1: 3.78 MVA Inverter Transformer Details

Parameter	Value
Nameplate Voltage (kV)	33/0.63
Rated Power (MVA)	4.2 MVA at $35°C$, 3.78 MVA at $50°C$
Vector Group	Dy11
Tap Ratio Range	0.95 to 1.05
Tap Changer Type	Off-load
Number of Taps	5
Nominal Tap	3 (1.0 pu)
Tap Size	2.5% (at 33kV)
No Load Losses (W)	3780
Load Losses (W)	36900

7.2 Main Transformer

Clements Gap Bess contains a single 70 MVA three-phase two-winding main transformer with parameters given in Table 7.2. This transformer is fitted with an on-load tap changer (OLTC) with seventeen (17) taps, where the nominal tap is tap 10 (1.0 pu). Please refer to the datasheet for the main transformer [3] and the substation sld [4] which illustrates the electrical configuration of the main transformer.

Table 7.2: 70 MVA Main Transformer Details

Parameter	Value
Nameplate Voltage (kV)	132/33 kV
Rated Power (ONAN/ONAF)	45/70 MVA
Vector Group	YNyn0
Positive Sequence Leakage Reactance (pu)	0.13
Zero Sequence Resistance (pu)	0.0073

Table 7.2: 70 MVA Main Transformer Details

Parameter	Value
Zero Sequence Reactance (pu)	0.1298
No Load Losses	$\leq$ 39.9 kW
Load Losses	$\leq$ 260 kW
Tap Changer Type	On-load
OLTC Number of Taps	17
OLTC Nominal Tap	10
OLTC Tap Size	1.75
OLTC Tapping Range	0.8425 to 1.1225
OLTC Voltage Deadband (pu)	0.015
OLTC Voltage Setpoint (pu)	1.0
OLTC Tapped Winding	132kV side
OLTC Total Time Between Taps	10s

The OLTC voltage set point is expected to be set to a fixed value of 1.0 pu, independent of the level of generation. The OLTC auto-voltage regulation (AVR) relay utilises a dead band ensuring that the target is achieved to within $\pm$ 0.015 pu. An initial tap change in response to a voltage deviation beyond the control dead band is undertaken after a defined delay of 10 seconds. This is commonly understood as an AVR constant time program. If after a single tap change operation the voltage is still outside the deadband, another tap will be expected after an additional ten seconds. This delay of ten seconds is representative of the total tapping time - that is it includes any mechanical delays of the OLTC and wait times configured in the AVR. This time delay has been selected to ensure no unwanted interference between primary and secondary control loops while ensuring it is fast enough to ensure the generator maintains continuous uninterrupted operation for a variety of network disturbances. Please refer to the TAPCON 230 AVR manual [5] and OLTC switching datasheet provided [6].

8. Reactive Plant

As part of R1 a harmonic emissions assessment has been undertaken and two C-Type filter banks have been proposed in order to address harmonic emmissions at the point of connection and to ensure compliance with S5.2.5.2 of the generator performance standard. These filters are connected to the 33kV bus and supply a total of 15 MVArs of passive reactive power when in service. Please refer to the harmonic emissions assessment [7] and substation sld [4] which details the connection point of the filter banks.

Table 8.1: C-Type Filter Details

Name	Type	Rated Reactive Power	Tuning Order	Quality Factor
HF1	C - Type Filter	12 MVAr	4.8	0.6
HF2	C - Type Filter	3 MVAr	30.5	7.5

9. Control Block Diagram

Detailed control block diagrams have been provided directly to AEMO by SMA as they are confidential in nature.

10. Control Mode Switching

Clements Gap BESS is capable of operating in three main reactive power control modes

1. Voltage droop control
2. Power factor control
3. Reactive power control

The generating system EMS is responsible for ensuring that switching between these modes, whether by a local operator or remote party, is bumpless - that is to say that there will not be large changes in reactive power output (resulting in voltage steps) when transitioning between reactive power modes.

Please refer to the SCADA Control Philosophy [8] for a summary of the CG BESS control system design and the active and reactive power AEMO/TNSP control schemes applicable to this site.

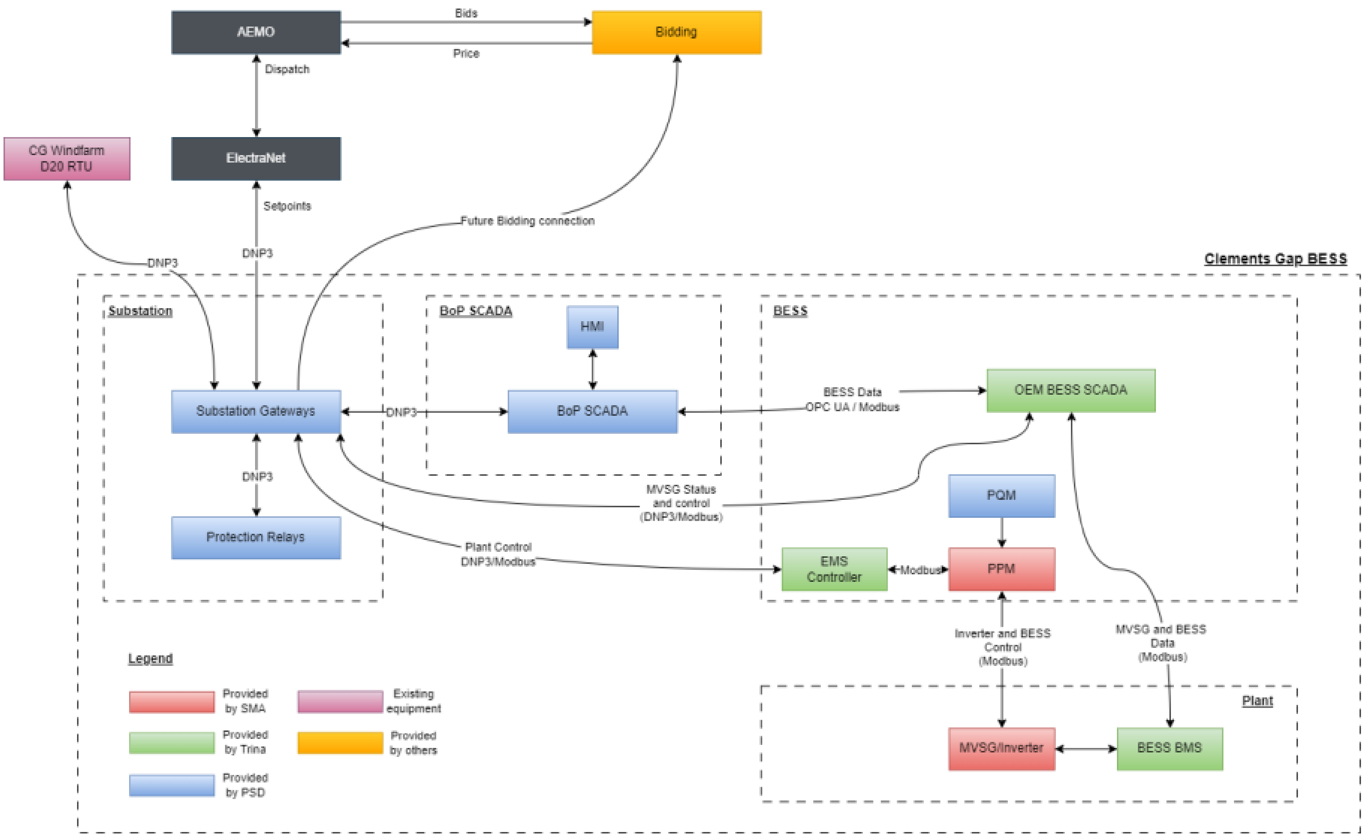


Figure 10.1: Control Scheme Overview

11. Inverter Level Controls

The inverters at Clements Gap BESS are equipped with a voltage-dependent reactive power control (CArCtlVol) mode. This voltage control scheme allows the inverters to provide additional reactive power based on the inverter AC voltage. This mode supports an external set point *VolNomSpt* that will effectively shift the Q-V characteristic left-ward or right-ward. The Q-V characteristic for this mode with a voltage setpoint of 1.0pu has been included below. For this site, the AC voltage setpoint is initialised with a value of 1.0 pu (as per the parameters *VArCtlVol_VolNomSptMod* and *VArCtlVol_VolNomSptInit*). Please refer to the PSCAD RUG included in the R1 package for more details on these parameters.

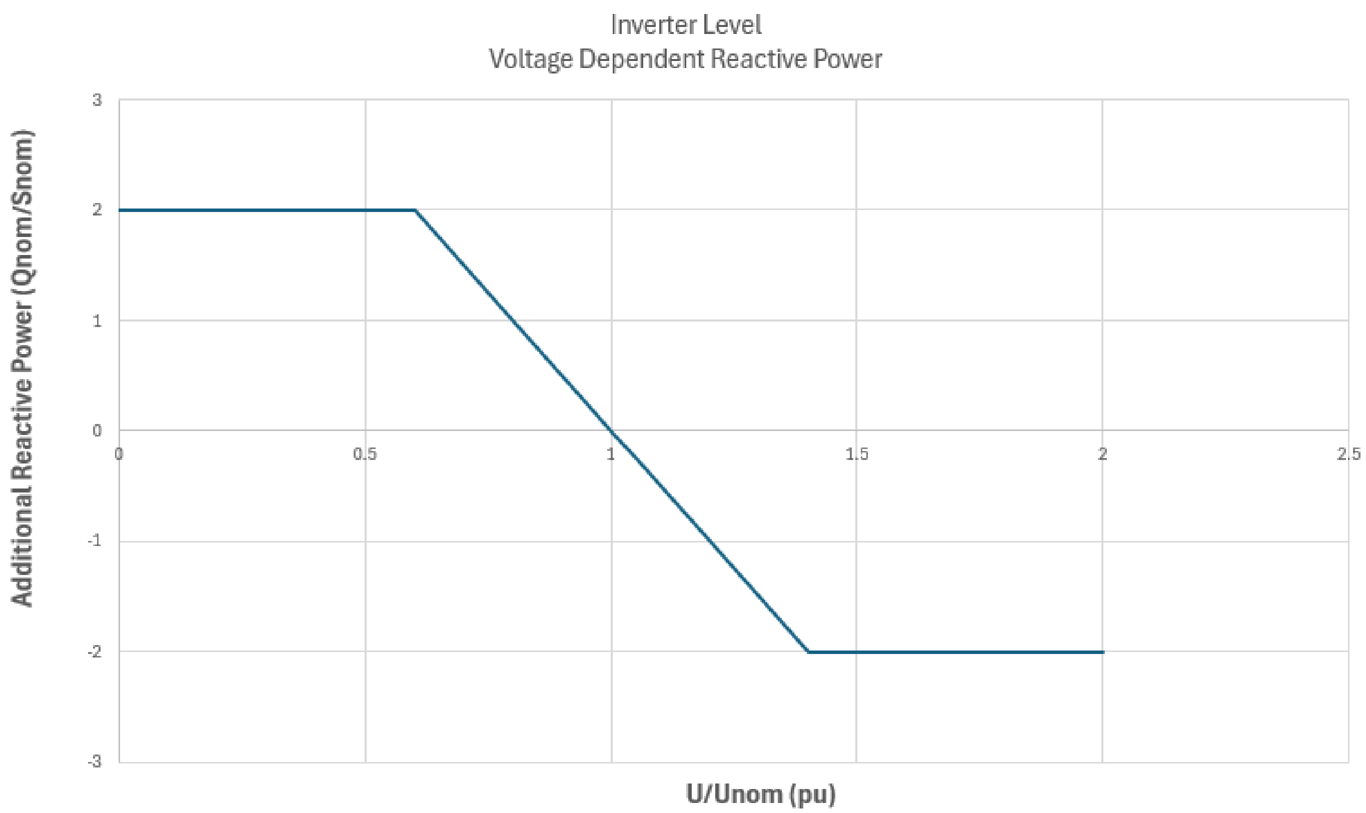


Figure 11.1: Inverter Level Voltage Dependent Reactive Power

12. Signal List

Please refer to the AEMO IO Schedule [9]. This document details the input/output (IO) signals shared between CG BESS and AEMO/ElectraNet.

13. SCADA, Communication and Latency

For additional information on

1. the applicable control schemes,
2. pathways for control setpoints,
3. heartbeat and communications fail detection
4. availability requirements of the control system

please refer to the SCADA Control Philosophy [8].

For additional information on the communication network layout please refer to the Communication Architecture diagram [10]. Please note that the site's communication latency is going to be measured and documented during commissioning.

14. Generating System HMI

The SCADA servers providing the Human Machine Interface (HMI) for this project are specified in Table 14.1.

Table 14.1: SCADA Server Details

Type	Function
DELL R660xs	HMI SCADA Server 1
DELL R660xs	HMI SCADA Server 2
Schneider GeoSCADA	HMI Server (Redundant)

An example of the interface being developed for this project has been provided in the figure below.

Figure 4 - HMI Layout

Figure 14.1: Example of the HMI

Please refer to the SCADA Functional Specification [11] for more information on the HMI functional requirements, various interfaces and symbol conventions.

15. Protection Functionality

Please refer to the Protection Setting Report [12] which outlines the protection functions for the site including for the harmonic filters, transformers and 33kV bus.

Please refer to the PSCAD Releasable User Guide (RUG) for the inverter protection settings used for this project.

Acronyms

CGBESS Clements Gap BESS 1

PPM Power Plant Manager 2

References

[1] MVPS SLD
(PSD1834-110-001-002.pdf)

[2] Medium Voltage Transformer Datasheet
(CG_D_00181175_03_General MVT Datasheet.pdf.pdf)

[3] Main Transformer Datasheet
(Main Transformer Datasheet.pdf)

[4] Substation SLD
(PSD1834-110-001-001.pdf)

[5] TAPCON 230 AVR manual
(bal_3552133_02_001_1_en.pdf)

[6] OLTC Switching Datasheet
(VACUTAP®_VV®_Operating_Instructions.pdf)

[7] Harmonic Emmissions Report
(PSD1834-100-100—Harmonic-Emissions-Assessment-and-Filter-Design-Rev-B.pdf)

[8] SCADA Control Philosophy
(PSD1834-200-009—SCADA-CONTROL-PHILOSOPHY-Rev.3.pdf)

[9] AEMO IO Schedule
(PSD1834-200-005-AEMO IO SCHEDULE-REV-04.pdf)

[10] Communication Architecture
(PSD1834-210-003-001—COMMUNICATION-ARCHITECTURE-Rev.1.pdf)

[11] SCADA Functional Specification
(PSD1834-200-001 - SCADA SYSTEM FUNCTIONAL DESIGN SPECIFICATION Rev.4.pdf)

[12] Protection Settings Report
(PSD1834-100-007—CGBESS-Protection-Setting-Report—REV-C.pdf)

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