BLPC
GRID CODE
BATTERY STORAGE
REQUIREMENTS

Grid Code Battery Storage Requirements

Contents

1 General Conditions

1.1 Introduction

This document applies to all power conversion system (PCS) connected battery energy storage systems (BESS) for connection to the Barbados T&D system at 11 kV and 24.9 kV respectively and which provide grid services. The Requirements may vary according to the size of the BESS and the voltage level at the Point of Common Coupling.

This information excludes uninterruptible power supplies (UPS) or systems used solely to provide uninterrupted power supply to loads during grid disturbances.

1.2 Terms and Definitions

The Term	**Is defined as**
Ancillary Services	A set of operations utilized to ensure the reliable operation of the power system, specifically the Transmission & Distribution Grid.
Backup Power	Backup Power – The battery energy storage system, either paired with a local generator or on its own provides power to loads at a customer's premises either residential, commercial or industrial in the event of a grid failure and when isolated from the grid. The battery energy storage system facilitates an intentional island of the customer until the grid is restored or until the available energy is depleted.
Black-Start	Black Start – The battery energy storage system restores operation to a portion of the electric grid by energizing transmission lines or provide supplementary power for the operation of larger power stations to begin the process of restoring the electric grid after a system wide failure, commonly known as a black out.
Demand Response	The ability of customers to respond to either a reliability trigger or a price trigger from their utility system operator by lowering their power consumption.
Dispatchable	The ability to vary system parameters or output based on signals received from a control center
Distributed Energy Storage	In this context pertains to battery energy storage systems that are not centralised on the T&D System i.e. separate from Substation Based Energy Storage
Energy Arbitrage	Involves the charging of the battery energy storage system during periods when the system marginal costs are relatively low and later discharging the battery energy storage system during periods when the system marginal costs are high
Energy Shifting	Involves moving energy on the T&D system from one time period to another by storage and release at a later time. The battery energy storage system may also be charged in instances where there is a surplus

The Term	Is defined as
	of energy generated from renewable sources as driven by policy for efficient utilisation of renewable energy.
Battery Energy Storage System (BESS)	The battery energy storage system comprises of a battery energy source, a power conversion system, control systems, protection equipment and auxiliary equipment.
Frequency Regulation	Frequency regulation describes the increase, known as regulation-up, or the reduction, known as regulation-down, of power generation to maintain the system frequency at approximately 50 Hertz. As defined by EPRI, regulation is the portion of a unit’s unloaded capability that can be loaded, or loaded capability that can be unloaded, in response to Automatic Generation Control (AGC) signals from a central dispatcher.
Frequency Response	This involves the autonomous dispatch up or down of the battery energy storage system primarily based on the frequency deviation detected locally by the battery energy storage system. The battery energy storage system may also be asked to dispatch up or down based on a signal (dispatch notification) sent by the system operator. This is typically a fast response in the order of seconds.
IFC	International Fire Code
IRRP	Integrated Resource & Resiliency Plan for Barbados
Islanded Grid Operation	The ability of the BESS to form an isolated electrical system or island, otherwise described as a microgrid.
Microgrid	A group of interconnected loads and distributed renewable energy sources, including a BESS that can act as a single controllable system. It can connect and disconnect to the main grid to operate in either grid connected or island mode.
Power Conversion System (PCS)	This serves the purpose of converting the energy stored in a BESS to electrical energy in the form of alternating current (AC) and vice versa.
RE	Renewable Energy
Round Trip Efficiency	A percentage of the amount of energy exported by the battery energy storage system during discharge vs the amount of energy imported into the battery energy storage system during charging
SOC	State of Charge
Spinning Reserve	An allocated portion of a battery energy storage system capable of responding to generation or transmission & distribution outages. The battery energy storage system should be online and synchronized with the grid.
Substation Based Energy Storage	An battery energy storage system connected to the transmission network at the substation
PCC	Point of Common Coupling
Plant Controller	A facility level supervisory control and monitoring system that interacts with the BESS control system, energy management systems, power conversion system, SCADA system and all other critical and auxiliary equipment
Peak Load Management	This service involves the battery energy storage system to provide a reliable capacity to meet system and/or local peak demand

The Term	Is defined as
Power Quality	Power Quality – A measure of how much electrical parameters such as voltage, frequency, waveform and continuity deviate from declared specifications.
Voltage and/or Reactive Power Support	The response to voltage and/or reactive power requirements from a signal dispatched by the system operator.
Voltage Regulation	Voltage Regulation – This involves the autonomous response to voltage and/or reactive power system requirements as detected by the battery energy storage system to maintain the voltage within an acceptable range. The voltage and/or reactive power requirements may also be from a signal dispatched by the system operator.
T&D	Transmission & Distribution Grid

1.3 Class of Storage

The requirements outlined in this document shall be fulfilled at the Point of Common Coupling or at a point defined separately by a specific requirement. Table 1 outlines the various classes of battery energy storage systems which are differentiated based on the installed capacity and connection voltage.

Table 1: Table outlining the various classes of Battery energy storage system by Capacity and Nominal Connection Voltage

Class	Description	Nominal Connection Voltage
Class 1	BESS ≤ 25 kW	≤ 400 V
Class 2	25 kW < BESS ≤ 150 kW	≤ 400 V
Class 3	150 kW < BESS ≤ 500 kW	≤ 400 V
Class 4	500 kW < BESS ≤1.5 MW	11 kV (except where 24.9 kV Distribution exists)
Class 5	1.5 MW < BESS ≤ 10 MW	24.9 kV
Class 6	BESS > 10MW	≥ 24.9 kV

The BESS can be connected to the power system behind a separate connection point or as part of an existing connection, for example the medium voltage busbar of a power plant or a demand system. The Grid Code Specifications for Battery energy storage systems are determined according to Table 1, and as a rule, they are not dependent on the rated capacities or specifications of other production or demand systems connected to the same connection point. If the BESS Developer wants to integrate the resources of the BESS into the control system of a power plant or a demand system, the power plant or a demand system specification shall be reviewed by BLPC as a whole. Those specifications shall be based on the rated capacity of the integrated system and the connection point voltage level.

1.4 Purpose of Energy Storage Systems

The BESS shall have a subset of the following functions required by the T&D system and the need for storage to mitigate impacts of intermittent renewable energy (RE). The need for storage is generally guided by the IRRP for Barbados. However, the functional requirements shall be specifically determined by the Connection Impact Assessment (CIA) to address any mitigations or provide grid services required on the T&D system as follows:

I. Peak Load Management/Energy Shifting, or arbitrage, implemented via scheduled or manual dispatch; or with power output associated with a specific output of a generator or group of generators;
II. Grid flexibility and ancillary services by responding to direct P/Q control set points issued by BLPC control center;
III. Dispatchable firm capacity equal to its Rated Power Capacity;
IV. Grid frequency and voltage support by sensing and responding to grid fluctuations;
V. Spinning reserve dispatchable by BLPC;
VI. Blackstart capability and functionality;
VII. Microgrid capability at specific sites;
VIII. Renewable Curtailment Reduction[1];
IX. Distribution Hosting Capacity;
X. Vehicle to Grid;
XI. Virtual Inertia; and
XII. Back Up Power to a Customer's load (for example where BESS provides back up power when grid conditions are abnormal, which necessitates disconnection from the T&D system).

BESS would not be expected to perform all of the functionality listed above at the same time. BLPC will identify the functionality required during the CIA process. Functional requirements of the storage system may also change over time and once identified shall be made available for dispatch as necessary by the System Operator.

[1] **Please note that all text in red are the Fair Trading Commission's additions**.

The classes of storage systems may be broken down into the following categories as outlined in Table 2.

Table 2: BESS functional requirements based on the class of the energy storage system

Class	Description	Nominal Connection Voltage	Typical Connection Application	Function
Class 1	BESS ≤ 25 kW	≤ 400 V	Residential/Commercial Storage (≥2 hours)	• Back Up Power to customer's load • • Energy shifting • Demand Response • Aggregated participation in ancillary services • Voltage regulation
Class 2	25 kW < BESS ≤ 150 kW	≤ 400 V	Residential/Commercial Storage (≥3 hours)	• Back Up Power to customer • • Energy shifting • Demand Response • Aggregated participation in ancillary services • Voltage regulation/reactive power support at the site (including voltage control
Class 3	150 kW < BESS ≤ 500 kW	≤ 400 V	Distributed Energy Storage (≥3 hours)	• Peak Load Management/ Energy Shifting • Spinning Reserve • Frequency Regulation • Frequency Response • Voltage regulation/reactive power support • Islanded Grid Operation
Class 4	500 kW < BESS ≤1.5 MW	11 kV (except where 24.9 kV Distribution exists)	Distributed Energy Storage (≥3 hours)	• Peak Load Management/ Energy Shifting • Spinning Reserve • Frequency Regulation • Frequency Response • Voltage regulation/reactive power support • Islanded Grid Operation

Class	Description	Nominal Connection Voltage	Typical Connection Application	Function
Class 5	1.5 MW < BESS ≤ 10 MW	24.9 kV	Distributed Energy Storage (≥3 hours)	• Peak Load Management/ Energy Shifting • Spinning Reserve • Frequency Regulation • Frequency Response • Voltage regulation/reactive power support • Islanded Grid Operation
Class 6	BESS > 10MW	≥ 24.9 kV	Substation Based Energy Storage (≥4 hours)	• Peak Load Management/ Energy Shifting • Spinning Reserve • Frequency Regulation • Frequency Response • Voltage regulation/reactive power support • Islanded Grid Operation • Black-Start

2 Battery Energy Storage System Functional Requirements

2.1 Introduction

This section provides information to support the engineering, design, and construction of BESS based on the current requirements of the T&D system. For the contracted life of the system under local conditions, the BESS shall have the capability to meet capacity, efficiency and availability requirements specified in the following sub-sections. The Developer of the BESS shall consider any warranties from the supplier in the design of the BESS to meet these requirements. Any system limitations during normal operation should be disclosed by the Developer, demonstrating the relationship to depth of discharge and cycle life to the overall life of the system. The system should be sized to account for these limitations.

2.2 Safety

BESS systems shall be designed to ensure that they mitigate any risk of harm to plant, personnel, the general public, to BLPC employees who work on the T&D System and to personnel working at the BESS Facility. The system shall be designed to minimize any potential risks such as fires and explosions. However, in the case of a fire or explosion, the enclosure(s)/container(s) shall be equipped according to applicable fire and explosion safety standards such as the International Fire Code (IFC) and the National Fire Protection Association standard for the Installation of Stationary energy storage systems (NFPA 855).

Designs shall also be compliant with international standards that govern the manufacture and construction of the specific BESS and its components.

Alarms, monitoring and other safety systems shall be operational at all times. Signage requirements of Section 4.2.3 shall be adhered to in order to identify and manage areas of possible risk.

2.3 Power Capacity

The BESS shall be designed to have a “Rated Power Capacity” described in kW or MW AC net of all system losses and auxiliary loads, as measured at the PCC. The capacity that can be connected to the BLPC system will be determined through a grid study and/or in the CIA.

2.4 Energy Capacity

BESSs shall be designed to have a “Rated Energy Capacity” at commissioning and shall facilitate continuous discharge at the Rated Power Capacity measured at the PCC for the minimum duration as shown in Table 3. A Capacity Test shall be used to confirm the rated energy capacity of the BESS at commissioning and during the life of the BESS at regular intervals. The storage system shall be capable of providing declared usable energy capacity for at least ten years or the contracted period where the contracted period takes precedence. The usable energy capacity of the BESS is defined by a degradation curve for the system. Storage systems shall also be capable of discharging at 70% rated energy capacity 10 years after commissioning as measured at the PCC with minimum duration as indicated in Table 3 on the condition that the storage system is cycled on average 1 cycle per day such that it allows for a maximum of 3650 cycles over ten years without impact on storage performance.

Regardless of actual installed energy capacity, the BESS must be able to provide charge and discharge from 0 – 100% SOC for any operating year in accordance with the Rated Power Capacity specified in the degradation curve, unless otherwise permitted by BLPC.

Table 3: Table indicating the minimum discharge duration requirements for the various classes

Class	Minimum Discharge Duration At Commissioning (Hr)	Minimum Discharge Duration 10 Years After Commissioning
Class 1	2 - 3 dependent on use case requirement	70% of commissioning duration
Class 2	3- 4 dependent on use case requirement	75% of commissioning duration
Class 3	3 4 dependent on use case requirement	75 % commissioning duration
Class 4	3 - 4 dependent on use case requirement	75 % of commissioning duration
Class 5	3 - 4 dependent on use case requirement	75% of commissioning duration
Class 6	4 dependent on use case requirement	75% of commissioning duration

The Developer shall provide supporting documentation to verify the capacity performance of the storage system which shall include vendor specifications.

2.5 Reactive Power Requirement

For systems of Class 2 and above, the BESS shall be capable of providing or absorbing reactive power i.e. they should be capable operating in all 4 quadrants.

2.6 Round Trip Efficiency

The battery energy storage system shall provide a minimum Round Trip Efficiency, "RTE", as measured at the PCC at commissioning as follows.

I. Class 1 & 2 – 80%
II. Class 3 - 85%
III. Class 4 and above – 87%

The RTE shall be evaluated by specific tests during commissioning and at regular interval during the system lifetime.

The RTE shall be calculated using the annual measurements of the total annual exported energy and total annual imported energy by the BESS from the Grid or any coupled resource.

Example of Throughput and Cycle Calculations

ESS throughput and cycles are critical parameters for evaluating the performance and usage of a BESS.

Throughput in the context of an ESS refers to the total amount of energy that has been charged and discharged over a specific period. It is typically measured in kilowatt-hours (kWh) or megawatt-hours (MWh).

Cycle refers to one complete charge and discharge cycle. A full cycle is considered as using 100% of the battery's capacity, but it can also be defined for partial cycles. For example, two half cycles (charging and discharging 50% of capacity each time) would also count as one full cycle.

Calculations: To calculate the throughput and cycles using measured data from a meter, you need the following data:

Charge Energy (E_{Charge}): The metered amount of energy charged into the BESS.

Discharge Energy ($E_{Discharge}$): The metered amount of energy discharged from the BESS.

Depth of Discharge (DoD): The percentage of the battery capacity used during a cycle.

Throughput Calculation: Throughput can be calculated as the sum of the charge and discharge energy over a period.

$$Throughput = E_{Charge} + E_{Discharge}$$

Cycles Calculation: To calculate the number of cycles, you need to account for the depth of discharge. The formula for calculating cycles can be expressed as:

$$Cycles = \frac{\text{Total Discharged Energy}}{\text{attery Capacity} \times \text{DoD}}$$

Where:

- **Total Discharged Energy** is the sum of all discharged energy over the period.
- **Battery Capacity** is the rated capacity of the BESS.

Alternatively, if the data includes a time series of the charge and discharge events, the cycles can be estimated by summing up the depth of discharge of each event and dividing by 100% (or 1 if using a decimal representation).

Example Calculations:

Let's assume we have a BESS with a capacity of 100 kWh and over a period, the following data:

Total charge energy (E_{Charge}) = 500 kWh

Total discharge energy ($E_{Discharge}$) = 480 kWh

Average depth of discharge (DoD) per cycle = 80%

$Throughput$= 500 kWh+480 kWh=980 kWh

$Cycles$= $\frac{480 \text{ kWh}}{100 \text{ kWh} \times 0.8} = \frac{480}{80} = 6$

Therefore, over this period, the BESS has a throughput of 980 kWh and has undergone 6 cycles.

Throughput and Cycles shall be measured on monthly basis.

Round Trip Efficiency and Losses Calculations

The energy storage round trip efficiency shall be measured using the readings from the Main Meter. The round-trip efficiency covers the losses incurred by the battery modules, power conversion system, transformer, cables, auxiliary load, and others that are incurred for the whole system.

At the point of interconnection, the round-trip efficiency shall be measured by following formula:

$$Round\ Trip\ Efficiency\ (\%) = \frac{\text{Total Exported Energy from grid measured at POI in a month}}{\text{Total Imported Energy to grid measured at POI in a month}} \times 100$$

With this calculation, the losses can be calculated as the difference between Total Imported Energy and Total Exported Energy measured at the POI.

The losses calculated include the system losses when the system is synchronized with the grid but not providing any services (it is not charging or discharging) and it is in idle position running auxiliary load to keep the system active.

The losses calculated include system losses when the system is not synchronized with the grid, but it is operating for any internal load, or it is consuming energy for auxiliary load to keep the system active.

2.7 Availability

The BESS shall be online and available at-least as follows:

I. Class 1 & 2 – 80%

II. Class 3 and 4 - 90%

III. Class 5 and above: 98.5%

2.8 Plant Controller

2.8.1 Plant Controller Definition

The BESS Plant Controller shall be the single interface between the BLPC's Control Center and the Local Plant Control. The BESS Plant Controller shall provide control and monitoring of the BESS and visibility and control of all plant subsystems, including the fire and gas detection / suppression and ventilation, safety, individual equipment control, and inverter system.

2.8.2 Plant Controller Functional Requirements

The BESS Plant Controller shall be able to provide or perform the following at a minimum:

1. Interface with and be capable of accepting control, data and status signals from BLPC Dispatch or System Operator.
2. Communicate with BLPC's Dispatch/Control Center. The BLPC Control Centre shall be able to control the BESS within the specified control envelope.
3. Monitor and report on the BESS, including but not limited to information such as state of charge (SOC), state of health (SOH), voltage, current, frequency, temperature, and status. A full set of required telemetry can be found within the Connection Code Section 4.7.
4. Provide fault and surge detection and protection, as appropriate.
5. Support autonomous operation, including stand-by mode, start-up, shut-down and disconnection, in case of communication failure or emergency. Provide operator over-ride capabilities to all automatic control functions if manual intervention is requested.
6. Manage disconnect/reconnect operations of BESS as appropriate to ensure safe, reliable and resilient operation.
7. Interface with or be capable of interacting with a data historian/repository for easy access, storage and retrieval of BESS operational data as well as external signal data (such as future BLPC AGC signal) for analysis and reporting purposes. The data shall be stored for a minimum of 3 months. See Section 5.6.3 of Grid Code for Operating Data, Telemetry, and Monitoring Requirements.

8. The BESS Plant Controller shall include an appropriate interface to BLPC's SCADA system over DNP 3.0, IEC61850 or modbus depending on the system size.
9. Include a physical selectable control selector switch to determine the remote/local operation of the BESS Plant Controller with indication of the state of the switch visible to BLPC.
10. Ensure that failure of BESS local control shall not impact the operation of the remote SCADA control of the plant and vice versa.
11. Shall be capable to program combinations of different battery control modes.
12. Allow BESS ramp rate to be adjusted by a local operator or BLPC Dispatch
13. For Class 4 and above - provision of inertial response to the grid (synthetic inertia): The BESS via the BESS Plant Controller shall be capable of delivering an inertial response similar to synchronous generator output to help mitigate grid instability. The battery power output shall have an additive response proportional to the first derivative of grid frequency during active and inactive power modes. The inertia constant shall be calibrated at the site controller and is not required to be remotely set.

2.8.3 BESS Plant Controller Modes of Operation

The plant controller should be configured to allow for two modes of operation:

1. Grid following modes shall be provided by all BESS.
2. Grid forming mode shall only be provided to satisfy specific islanding and synthetic inertia requirements as determined by the relevant CIA.

The controls shall allow for smooth transition between grid forming and grid following modes where required.

Droop Control (Applicable to Class 3 and above):

BESS shall be able to operate in frequency droop mode whereby active power is adjusted as a result of system frequency. The droop characteristic shall be configurable with a compensation gain parameter to allow for modification of system response over the lifespan of the facility.

BESS that are required to utilise the frequency response shall be capable of transitioning from zero output to Rated Power Capacity in 100ms.

Islanding Mode:

Selected BESS shall be required to have controllers capable of islanding specific sections of the grid. Refer to Section 4.5.1 of this document for specific information.

2.9 Power Conversion System

The PCS at a minimum shall be able to:

1. Operate in all four power quadrants at rated power (kVA). Any combination of kW and kVAR output shall be possible that is consistent with the systems rated power.
2. Provide voltage regulation at the PCC such that the BESS is capable of regulating voltage in accordance with the BLPC Grid Code.
3. Meet the BLPC Grid Code voltage and frequency ride-through requirements.

In the case where BESS is required to have Microgrid capability, the Ride-Through set points shall be field adjustable to allow for optimization of Microgrid operation.

2.10 Backup Requirements

For BESS of Class 4 and above, power supply redundancy shall be provided for the BESS Plant Controller such that the loss of one power supply does not affect the operation of the BESS. The BESS shall continue operating for at least one hour after the loss of the first power supply.

2.11 Corrosion Prevention

The BESS, in its entirety, shall be protected from corrosion due to known or expected atmospheric and soil conditions local to the Site.

Outdoor equipment shall at a minimum have protection to IEC 60259, IP 65 or NEMA 4X rating.

3 Planning Code

This section provides the information required to assess the connection of new BESS to the BLPC T&D grid. The requirements outlined in Section 2 and 3 of the BLPC Grid Code, where applicable, serve as the main reference document when preparing documentation for a potential BESS connection. Reference may be made to latest planning requirements as outlined by the relevant planning authority as required.

3.1 Documentation and Engineering

The Developer shall provide all specifications and design drawings for BLPC review as required.

Site civil and other infrastructure designs for systems of Class 3 and above shall be signed by a registered civil engineer.

All designs and drawings for systems in Class 3 and above, studies, and documentation submitted to any relevant authority shall be under the responsible charge of and signed by a professional engineer registered in Barbados.

All electrical designs and drawings for systems in Class 1 & 2 shall be signed by a competent person as designated by the GEED. Relevant manufacturer documents received shall be made available to BLPC as required. Developer shall make all drawings available in DWG (AutoCAD) as well as in Portable Document Format (PDF). Developer shall make all engineering documentation available in PDF.

Developer shall include in the Design Documents, general arrangement drawings indicating the location of all major equipment including dimensions of key site features and a suitable baseline location including GPS coordinates of the main site. The general arrangement drawing(s) shall include, as a minimum the following elements as applicable:

1. BESS dc side system
2. BESS ac-side system
3. BESS Plant Controller
4. PCS (Inverter) units and transformers
5. Circuit breakers, fuses and disconnect switches
6. Protection Relays
7. Internal Meters and provisions for placement of BLPC metering according to the system capacity
8. Local Control and communication infrastructure and SCADA interface
9. Data monitoring, storage and other IT equipment
10. Grounding grids as required by the BLPC Grid Code
11. Point(s) of interconnection, e.g. the Point of Common Coupling shall be identified as per Grid Code Section 5.2.5 or Section 4.2.1

4 Connection Code

4.1 Introduction

This section provides the technical requirements to be met by the various classes of battery energy storage systems connecting to BLPC T&D system. The requirements outlined in Sections 4 and 5 of the BLPC Grid Code for various capacities shall be met for the BESS, and serve as the main document of reference for connection of the battery energy storage system. The requirements outlined in this document supplement the requirements in Sections 4 and 5 of the BLPC Grid Code. Where a conflict exists this document supersedes the Grid Code.

4.2 General Requirements

The following outlines the general requirements for the BESS so that it does not affect the reliability and quality of service to BLPC customers or compromise the safe operation of the T&D system for the general public, customers and employees. The design of all electrical equipment shall comply with applicable codes and standards.

4.2.1 Safety

The BESS interconnection and operation shall not create a safety hazard to BLPC's personnel, customers, the general public or personnel working in the BESS facility. The BESS shall be assembled and installed in accordance with applicable international standards. Clearances and access ways shall comply with the latest revision of the National Fire Protection Association NFPA 855 Standard for the Installation of Stationary Energy Storage Systems for safety of personnel.

4.2.2 Point of Common Coupling and Point of Delivery

The BLPC Grid Code Sections 5.2.5 and 4.2.1, define the Point of Common Coupling and Point of Delivery respectively.

The Developer shall assume responsibility for the provision of the following major components of the BESS.

1. The AC side power conversion system (e.g. inverter for BESS) to deliver the rated power capacity at the PCC net of all losses and auxiliary loads.
2. BESS plant controller for operation and safety.
3. AC Balance of Plant (BOP) Equipment inclusive of LV interrupting device

a. AC BOP Equipment inclusive of Interconnection Transformer (for BESS with a rated power capacity greater than 500 KW)
b. AC BOP Equipment inclusive of HV interrupting and isolating device (for systems with rated power capacity greater than 1.5 MW)

4. Revenue Metering requirements as outlined in Section 4.8

BLPC shall provide the following components to supplement the installed BESS.

1. Interconnecting Transformer and AC BOP equipment for systems with sizes with rated power capacity up to 500kW, except where the interconnection transformer is provided by the Developer.
2. AC BOP Equipment limited to HV interrupting and isolation device for systems with rated power capacity greater than 500kW and up to 1.5 MW.
3. Revenue Metering requirements as outlined in Section 4.8
4. Communication interface

4.2.3 Signage Equipment Marking and Labeling

Labelling shall conform to the requirements of Grid Code Sections 4.6.4 for all BESS. Signage and labels shall be weather-proof, corrosion-proof, UV-stabilized and fade-resistant and shall last for the duration of the minimum Design Life. Signs shall be posted indicating:

I. the presence of electrical equipment
II. the presence of multiple power sources
III. the presence of electrical, chemical, thermal or other hazards specific to the BESS
IV. that entry is restricted to authorized personnel only

A single line diagram of the as-built system which clearly identifies the ac disconnect shall be posted permanently near the PCC and on the metering cabinet. If not apparent from the single line diagrams, a Project map shall also be provided indicating the approximate locations of the disconnect switches. Disconnect switch designations shall match the electrical drawings device labels. All transformers and disconnect switches shall have engraved or printed a visible permanent identification label that provides the unique identification number as indicated on the single line diagram and electrical as built drawings.

Disconnecting means shall be clearly marked "***Battery Energy Storage System– AC DISCONNECT***".

4.2.4 Lightning Protection

Developer shall provide all measures of protection against lightning and switching surges including surge arresters and/or surge capacitors to protect equipment against damage where necessary. Refer to Grid Code Section 5.2.18 for further guidance.

4.2.5 Protection from Electromagnetic Interference (EMI)

For Class 3 and above the BESS and associated equipment shall meet the Electromagnetic Interference requirements specified in the Grid Code Section 5.2.21.

4.2.6 Grounding

Grounding system design and testing shall be performed in accordance with grounding and safety requirements of Grid Code Sections 4.2.3 and 5.2.11 as well as applicable ANSI/IEEE or IEC standards.

For BESS of Class 4 and above, grounding design shall comply with requirements of the BLPC Grid Code and IEEE Std. 80 for switchyards/substations and major equipment pads or IEC 61936-1 or BS EN 50522. All metallic objects, likely to be energized shall be grounded. This list includes, but is not limited to: module frames, all racking structure members, metal conduit, metal enclosures, fencing, equipment pads, skids, etc.

For BESS of Class 5 and above, grounding system design shall be based on site soil electrical resistivity test data and modelling performed per IEEE Std 81.

The Developer shall provide an overall electrical grounding schematic of the Project for systems of Class 5 and above. The grounding schematic shall indicate the primary connections to earth and the manner in which all components are grounded.

4.3 Performance Requirements

4.3.1 Ride Through Capability

The BESS and all associated equipment shall meet voltage and frequency fault ride-through requirements for a generating facilities as specified in the BLPC Grid Code:

a) For Class 1 and 2: Sections 4.3.7 and 4.3.8
b) For Class 3 and above: Sections 5.3.7 and 5.3.8

4.3.2 Overvoltage/ Under Voltage Protection

The BESS Overvoltage/ Under Voltage Protection shall be set in accordance with Sections 5.4.10 and 4.4.3 of the BLPC Grid Code.

4.3.3 Voltage and Current Harmonics

The PCS shall meet IEC 61000-3-06 or IEEE 519 - Recommended Practices and Requirements for Harmonics Control in Electrical Power Systems, as a source of generation, with a limit of 5% at its output terminals as specified in the BLPC Grid Code:

a) For Class 1 and 2: Section 4.3.2
b) For Class 3 above: Section 5.3.2.4

4.4 Protection Requirements

Plant protection design, shall include all required protection, coordination and redundant systems within the BESS in particular at the PCC in keeping with the protection requirements of Grid Code Sections 4.4 and 5.4.

All protective relays shall be utility-grade and shall have the required ANSI protection functions (e.g. 25, 32, 27, 67N, 67, 59, 81u, 81o, 50/51, etc.) as prescribed in IEEE 1547-2018 and BLPC's technical protection requirements.

The protection devices, including circuit breakers and fuses, in the BESS shall provide adequate protection at the minimum and maximum short circuit levels on the BLPC's T&D System.

BESS PCS units shall be capable of providing sufficient negative sequence fault current (to the extent possible) to provide protective relays with adequate selectivity and sensitivity.

The step-up transformer (or earthing transformer if required) shall provide a path for zero sequence current of magnitude sufficient to operate protective devices.

The control system shall have the capability to control the negative sequence current in an unbalanced fault event.

Closing of the PCC main breaker to reconnect with T&D System will require appropriate synchronization check elements and shall consider all possible system configurations including islanded and grid-connected modes.

The synchronization check relay shall be set in consultation with BLPC.

Overcurrent protection devices shall be appropriately rated for the expected continuous operating voltages and currents as required by BLPC and GEED as applicable to the equipment design and work scope.

Overcurrent protection devices shall have directional functionality where required.

4.5 Operating Requirements

4.5.1 Islanding

2. Selected BESS shall island for system events or manual switching by BLPC Dispatch or System Operator. The response time of the PCS shall be fast enough to smoothly transition from charging to supplying the island load at up to 70 % of capacity in no more than 100ms.
3. The trigger to island mode may be from a protection relay or BLPC Dispatch or System Operator.
4. If a BESS Plant Controller with microgrid functionality is provided, microgrid control hardware and software shall meet the specification and testing requirements in line with the requirements of IEEE Std. 2030.7 and IEEE Std. 2030.8 respectively. The following core microgrid control functionality shall be provided:
    - I. Dispatch function
        - a) Dispatch Battery System within operating limits under grid-connected mode
        - b) Dispatch Battery System within operating limits under islanded mode
    - II. Transition function
        - a) Planned islanding - upon request, dispatch BESS to achieve proper balance within the microgrid and reduce active and reactive power (P, Q) to zero at PCC; send open command to PCC breaker/s.
    - III. Reconnection – dispatch the BESS to synchronize the microgrid-side voltage to the grid-side voltage before closing the PCC breaker.

4.5.2 Under Voltage and Over Voltage Current Injection

4.5.2.1 Low Voltage Ride-Through (LVRT) Current Injection

1. For BESS of Class 4 and above: To support the power system to maintain the voltage during a remote or close-in fault, the BESS shall inject reactive current (capacitive) of at least 2% of the

maximum rated current of the BESS for each 1% reduction of the connection point voltage from the voltage level prior to the fault event. This reactive current injection shall be in addition to the pre-fault reactive current injection. The rise time for the reactive current response shall not be more than 40 ms.

2. The BESS shall commence the additional reactive power injection when the connection point voltage drops below 90% of the nominal voltage. However, this threshold value may be subject to change as required.

4.5.2.2 High Voltage Ride-Through (HVRT) Current Injection

1. For BESS of Class 4 and above: To support the power system to maintain the voltage during system event which causes an overvoltage, the BESS shall absorb reactive current (inductive) of at least 2% of the maximum rated current of the BESS for each 1% increment of the connection point voltage from the voltage level prior to the fault event. This reactive current absorption shall be in addition to the pre-fault reactive current absorption. The rise time for the reactive current response shall not be more than 200 ms.
2. The BESS shall commence the additional reactive power absorption when the connection point voltage rises above 120% of the nominal voltage. However, this threshold value may be subject to change as required.

4.5.3 Active and Reactive Power

1. BLPC Dispatch or System Operator shall provide active (P) and reactive (Q) power setpoints to the BESS Plant Controller. BESS Plant Controller shall operate the BESS to meet the P/Q setpoints as defined below:

    I. **Active or Reactive power priority:**

    The control system shall have the capability to prioritize the active or reactive power during the normal operation and Voltage Ride-Through events. The selection of active power and reactive power priority shall be available from the BLPC Dispatch or System Operator.

    II. **AC Voltage Control:**

    When operating in ac voltage control mode, the ac voltage of the regulated ac bus is controlled with an adjustable reference voltage setting that can be selected between the specified minimum and maximum continuous bus voltages. An adjustable droop setting shall be provided between 0% and 10% based on the rating of the PCS. It shall be possible to set the reference voltage and the droop from the local interface or from BLPC Dispatch.

III. **Reactive Power Control:**

When operating in reactive power control mode, the reactive power into or out of the PCS AC bus shall be controlled within the reactive power capability limits of the BESS PCS. If the AC voltage goes outside the minimum or maximum limits set by the operator, control will revert to AC voltage control to prevent the ac voltage exceeding the limits. The maximum and minimum voltage limits shall be settable from BLPC Dispatch of the System Operator.

New P and Q set points can override any scheduled behavior as determined by the System Operator.

2. A SCADA communications system failure shall not affect the operation of the BESS.
3. BLPC Dispatch or the System Operator shall be able to provide additional parameters such as ramp rate, droop curves, fault behavior and operational thresholds.

4.5.4 Rise Time / Settling Time

1. The BESS response for an active power set point change shall have a rise time of 1s and settling time of 2s.
2. The response for reactive power (or voltage) set point change shall have a rise time of 0.5s and settling time of 1s.
3. The response for a voltage disturbance at the PCC shall have a rise time of 0.5s and settling time of 1s.
4. The active and reactive power recovery after LVRT/HVRT event shall have a rise time of 100ms and settling time of 500ms.

These rise time are subject to change depending on the grid generator composition as determined by the System Operator.

4.6 Control and Monitoring Requirements

4.6.1 General

1. The Developer shall be responsible for all hardware, software, communications and programming for all equipment to serve the functions of the BESS control system.
2. The BESS control system shall include all instrumentation, hardware and capability to support the required data acquisition.
3. The Developer shall provide hardware and software manufacturer and specification sheets.
4. The Developer shall provide a Single Line Drawing, including devices, interconnection of devices, wiring types and protocols used.
5. The Developer shall provide data list with the device name and individual addresses of data points as required by BLPC.

4.6.2 Communication Requirements

1. Interfacing the BESS communication network to the BLPC Communications and Control System shall be performed in accordance with Section 2.8.2 of this document and Grid Code Section 5.7.3.
2. Developer shall conduct BESS local and remote operation tests in cooperation with BLPC.
3. BLPC provided communications shall pass through a firewall and use the BLPC operations network to reach the BESS Plant Controller.
4. The Utility and Owner shall maintain a comprehensive database of the operational data of BESS to manage systems that are privately owned and operated by the Utility.

4.7 Operating Data, Telemetry and Monitoring

At a minimum, the BESS control system shall monitor, record and store the following measurements for interface to BLPC's Dispatch or System Operator:

I. State of charge (SOC)
II. Operating mode
III. Power consumption kW, kVAR, kVA charging and discharging
IV. Frequency
V. Voltage (instantaneous and rms)
VI. Current (instantaneous and rms)

VII. Power factor
VIII. Lifetime energy throughput
IX. Status and fault codes
X. Transformer tap changer position (for Class 5 and above)
XI. AC disconnect switch
XII. Switch points with position
XIII. Protection relaying feedback and alarms
XIV. Status, alarms and diagnostics from fire protection system and UPS
XV. PCS set points

1. System data acquisition shall record data within at most 1-second time interval and storage shall record data within - and at least 1-minute time interval.
2. BLPC may require that certain measurements be recorded at 10 to 100 millisecond intervals and potentially at 1 millisecond resolution for recording alarms or events. Developer shall coordinate with BLPC to provide such functionality where needed.
3. Historical data over project life shall be readily available for access and download.
4. Real time operations and performance of the system shall be available for monitoring and controls through a Human Machine Interface (HMI).

4.7.1 BESS SCADA Data Collection and Storage

For BESS Class 4 and above:

1. Data recorded shall be time series data (e.g., voltage, current, power, temperature) and event data (e.g., faults, warning, errors, operator initiated changes)
2. Time series data shall be recorded with an averaging period of four seconds to one minute and shall include mean, min, max and standard deviation.
3. Data sampling rates for time series data shall be independent of site communications network. Sampling rates shall be 2 Hz or higher for time series data.
4. Processed data shall be stored locally in queue so that no data is lost if site communications network is temporarily lost. When communication is regained, the queue shall be downloaded to the SCADA computer/server.
5. All data shall be stored in an industry standard relational database. Any Open Database Connectivity (ODBC) compliant database may be used. The data shall be time-stamped and searchable with a range of data access query functions provided. It shall be possible to store

user generated query functions. The query-returned data shall be capable of graphical or tabular presentation. It shall be capable of being exported to external analysis programs in appropriate formats, e.g., comma-separated values (CSV) and Excel.

6. The control system shall back-up all recorded data, on-site. Developer shall coordinate with BLPC regarding all data storage, handling, and security requirements.
7. Backups shall be written to standard media using open, non-proprietary file formats.
8. Historical data shall be stored for at-least twelve (12) years.

4.7.2 Developer Information Security

1. The Developer shall design the BESS system to align with the National Institute of Standards and Technology (NIST) Framework and Roadmap for Smart Grid Interoperability Standards, Release 4.0 including all firewalls, access control and data protection requirements.
2. The Developer will provide cybersecurity documentation, in accordance with BLPC's cyber security requirements, to mitigate critical vulnerabilities in hardware and software, such that where possible, no single point of failure exists within the systems.

4.7.3 SCADA server and Human Machine Interface

For BESS of Class 4 and above

1. The Developer shall provide HMI hardware and operation station on site.
2. SCADA server and HMI station shall allow full viewing, analysis, reporting, fault diagnosis, fault resetting, PCS and BESS control functionality.
3. Communication to BLPC Control Center shall be via Secured VPN connection, in accordance with BLPC's existing cyber security requirements

Time synchronization

1. A Global Positioning System (GPS) satellite receiver shall be installed to provide time synchronization signals. This device shall provide time synchronization signals for the BESS control system and all devices communicating with the BLPC Dispatch.
2. As an alternative, BESS control system can use a time synchronization source at the grid interconnection source if it exists.

4.8 Metering Requirements

1. For Class 2 and below and less than 200 A, BLPC shall provide a single meter for the BESS at the PCC. LV meter sockets shall be provided by the Developer.
2. Where the current produced by BESS of Class 1 & 2 and Class 3 is in excess of 200A and metered at LV, the revenue meter, meter socket and metering CTs shall be provided by BLPC. LV metering cabinets for CTs shall be provided by the Developer
3. Metering for Class 4 BESS shall involve BLPC providing HV metering equipment at the Developer's cost.
4. For Class 5 and 6 BESS, the Developer shall make available 3-phase current transformers (CTs) and potential power transformers (PTs) at the PCC. BLPC will provide the main and check meters and meter sockets.
5. The CTs may have a rated secondary current of 5A, and shall be ANSI Class 0.2s or better accuracy with burden 15VA.
6. The PT voltage measurements shall provide 3-phase and a grounded neutral, 120Vac L-N. The PT Class shall be 0.5 and burden of 50VA.

5 Operating Code

This section provides the operational requirements and procedures of BLPC so that BESS Developers understand what their obligations are regarding the operation of their BESS facilities. The requirements outlined in Sections 6 and 7 of the BLPC Grid Code shall be met for the BESS, dependent on Rated Power Capacity, and serve as the main document of reference for the operational requirements of BESS. The requirements outlined in this document supplement the requirements in Sections 4 and 5 of the BLPC Grid Code. Where a conflict exists this document supersedes the Grid Code.

5.1 Event Reporting

For BESS of Class 4 and above, equipment shall be installed to record all significant signals to enable post event trouble-shooting and analysis. The sequence of events recorder shall also record critical digital (contact-type) inputs for all protection/trip functions. Recorded traces and trending analysis shall be remotely accessible. Please refer to Section 7.8 of the BLPC Grid Code for related requirements.

6 Functionality and Operation of System

6.1 Commissioning

1. A standardized test procedure shall be utilized by BLPC for Class 1 and 2 systems. For systems of Class 3 and above, a Commissioning Plan shall be provided by Developer to the BLPC for review and acceptance. The scheduled commissioning dates shall be shown in the project baseline schedule which will be coordinated with BLPC.
2. BESS commissioning shall be conducted by Developer in coordination with manufacturer representatives as applicable and BLPC.

6.2 Information for BLPC review and approval

Developer shall provide documents which shall contain the following as a minimum:

1. Project Overview
    a. BESS database with model number, power and voltage rating, test data, etc. for all dc-side and ac-side components in BESS.
    b. Site master control system data base with model number, serial number, power and voltage rating, test data for all components
    c. BOP Database complete with model number, applicable rating for all equipment including but not limited to PCS units, transformers, switchgear and breakers.
2. Specification sheets for all subcomponents
3. Studies and Reports
4. Commissioning Reports, Test Reports, Inspection Reports
5. Acceptance Test Reports
6. All Factory Test Results
7. Independent Laboratory Test Results /Type Tests reports
8. QA/QC Documentation including Non-Conformance Register (NCR) with all non-conformance actions closed.
9. Other project documentation that would reasonably be required for BLPC to document the interface and control facilities for operation of the BESS in the future.
10. Developer shall provide comprehensive site-specific Operating Manual(s), detailing all functionality to be provided through the duration of the life of the system and outline any system limitations.

6.3 BESS Commissioning

6.3.1 General

1. Commissioning shall be performed in accordance with the manufacturer's installation, commissioning, and O&M manuals, and in accordance with the Commissioning Requirements laid out in this section and the Commissioning Plan developed by the Developer.
2. BESS commissioning shall be conducted by the Developer in coordination BLPC representative(s).
3. BESS Plant Controller and SCADA system commissioning shall be conducted by the Developer in coordination with BLPC and the appropriate subject matter experts.
4. Fire and smoke detection, fire suppression, and fire and smoke containment systems shall be tested as part of the commissioning procedure.
5. Ventilation and thermal management systems shall be tested as part of the commissioning procedure.
6. Electrical safety and emergency shutoff devices shall be tested as part of the commissioning procedure.
7. The Developer shall develop and provide a detailed Commissioning Plan for the Project. The Commissioning Plan shall include inspection and verification of all safety aspects of the BESS. For this purpose, Developer shall provide a check list for BLPC's approval. The inspected items shall include, but are not limited to:
    a. BESS operability
    b. Signage
    c. Area Completions: Egress, access, and physical security illumination
8. The Commissioning Plan should define the minimum requirements for field inspection and testing of electrical equipment.

    The latest edition of codes and standards, in effect at the time the work is executed, shall be used.
9. The Commissioning Plan shall include all relevant testing required to demonstrate compliance with the Grid Code requirements.
10. BLPC has the right to recommend and perform any additional tests at the site.
11. The Developer shall be responsible for fully commissioning the BESS and shall furnish all labor, equipment, tools, and materials required to perform the Commissioning Tests.

12. Technicians performing the work shall be qualified by virtue of training and experience for the type of work performed, and shall be familiar with the equipment under test. They shall be trained in the nature of the hazards involved and shall be capable of judging the serviceability of the equipment.
13. Test instruments shall be calibrated by an accredited calibration laboratory, and will be in good working order. Calibration records shall be available to BLPC upon request.
14. Developer shall provide for BLPC review and approval, a complete set of commissioning test protocols and accompanying forms at least sixty (60) days prior to commencing the Commissioning Tests.
15. A copy of the complete report (Commissioning Test Report) of all testing shall be provided to the BLPC representative present immediately on completion of commissioning. As a minimum, the report shall include all information described in 2017 NETA-ATS section 5.4 and copies of all testing records.
16. Test results that fall within the guidelines of NETA-ATS are considered acceptable, unless otherwise specified.

6.3.2 BESS Plant Controller Commissioning

For BESS of Class 3 and above

1. Commissioning of the BESS Plant Controller shall be performed for each BESS sub-unit consisting of a PCS and all connected storage units.
2. Commissioning of the BESS Plant Controller shall be also performed for the overall BESS plant.
3. The time window of the full Commissioning of the BESS Plant Controller tests shall be set by the BLPC. Commissioning of the BESS Plant Controller shall, at minimum, include the tests listed in the Appendix.

6.3.3 Site Acceptance Testing

For BESS of Class 3 and above, the Developer shall provide a Site Acceptance Test Plan.

The Site Acceptance Test Plan shall be used to verify that:

1. All components of the Project meet or exceed the minimum target capacities, for the BESS.
2. The BESS Plant Controller can communicate with the PCS units, meters, and BESS.

3. The BESS can receive charge and discharge signals within timeframe in Section 4.5.4 of this document.
4. The BESS can meet all functional requirements as required by this document and specific use cases for the BESS.
5. The components of the project can meet ride-through and fault requirements for an asynchronous generating facility as specified in the BLPC Grid Code.
6. The BESS can meet all tests demonstrating successful operation with regard to asynchronous plant technical requirements in the BLPC Grid Code at the PCC.

Site Acceptance Test Plan shall include the BESS Capacity and RTE test and Ramp Rate test required.

Testing shall comply with Good Industry Practices, Applicable Laws, and Applicable Standards.

The Site Acceptance Plan shall include a schedule and comprehensive test procedure detailing the timeline and plan for all site acceptance testing activities, no less than 60 days prior to the initiation of commissioning activities. This plan will include:

1. Overall time frame, including key milestones.
2. Site testing and commissioning plan, including detailed schedule, procedures, necessary tools required on site, testing criteria, and acceptance criteria.

6.3.4 Final Acceptance and Completion

Developer shall complete all activities related to Commissioning and Acceptance testing, and submit to BLPC a Final Test Report.

Any departure from referenced codes must be fully described and submitted to BLPC for consideration, review and possible acceptance.

7 Appendix

7.1 Commissioning Tests

A list of commissioning test that may be required by BLPC is provided below:

1. Capacity Tests: The "BESS Capacity Test" is a performance test to demonstrate that the BESS energy capacity, maximum charge and discharge power are in compliance with the Functional Requirements.
2. Round Trip Efficiency Test: The "Round-trip Efficiency Test" (RTE Test) is a performance test to demonstrate the charging and discharging requisite to satisfy the performance standard required in the BESS Functional Requirements
3. Response Time, Ramp Rate and Settling Time Test (RRS Test): The RRS Test is a performance test to measure the response time, ramp rate and settling time of the BESS to reach rated power during charge or discharge from initial measurements taken when the BESS is at rest
4. Absolute Active Power Test – Test shall validate the closed loop active power logic using inverter controls to produce the desired PCC active power measurement within 2 sec. This test is performed by adjusting the BESS Plant Controller Active Power Setpoint value. Test procedure and acceptance criteria shall be agreed with BLPC. Absolute Reactive Power – Test shall validate the closed loop reactive power logic using PCS controls to produce the desired measurement at the PCC in a reasonable time. This test is performed by adjusting the BESS Plant Controller Reactive Power Setpoint value. Test procedure and acceptance criteria shall be verified per Developer interconnection requirements.
5. Over-frequency and Under-frequency Active Power Response Test - Test to validate the closed loop active power logic in response to grid over-frequency and under-frequency events. This test is performed by adjusting the alternate grid frequency data source's value. Test procedure and acceptance criteria shall be verified per BLPC interconnection requirements.
6. Automatic Voltage Regulation (AVR) Test – Test which involves letting the controller respond to a voltage step change. The BESS Plant Controllers' voltage reference will be stepped and the kVA and Voltage will be measured, and the plant performance will be monitored for a period to observe the plant's response to naturally occurring voltage fluctuations. In closed loop voltage regulation mode, the system must maintain a voltage regulation accuracy of +/- 1.0% of the controlled voltage at the PCC (assuming the grid is in steady state condition) over the range of controllability the controller has at the site. The voltage regulation system shall achieve 90% of

its final value no later than 1 second following a step change in voltage at the BESS Plant Controller. The response should be overdamped (no overshoot). Test procedure and acceptance criteria shall be verified per Developer interconnection requirements.

7. The Power Factor Control Test, - Test which involves measuring plant step change and steady state performance in fixed power factor control mode. Ideally, in response to a step input, the plant responds without oscillation; without overshoot and can maintain a fixed PF setting within the given steady state tolerances at the PCC. The procedure for performing the test requires iteration through several step changes that vet the controllers' ability to control leading and lagging power factors in compliance with limits on the PCC power factor (+/-0.85). Test procedure and acceptance criteria shall be verified per BLPC interconnection requirements.

7.1.1 For clarity, the purpose of the Capacity Tests is to:

1. Determine the actual usable energy capacity of the BESS.
2. Verify the power output capabilities.
3. Assess the overall health and efficiency of the battery system.

Steps to perform a Capacity Test:

1. Preparation

   a. **Ensure Safety**: Verify that all safety protocols are in place and that the BESS is in good condition.

   b. **Fully Charge the Battery**: Start with the BESS fully charged to its maximum state of charge (SOC).

2. **Discharge Cycle**

   a. **Set Discharge Parameters**: Configure the discharge parameters based on the manufacturer's specifications (e.g., discharge rate).

   b. Begin Discharge: Discharge the battery at a constant rate until it reaches the minimum SOC as specified by the manufacturer.

   c. **Record Data**: Measure and record the power output, voltage, current, and the time taken to discharge.

3. **Rest Period**

   a. **Allow Battery to Rest**: After discharging, allow the battery to rest for a specified period (typically 10-30 minutes) to stabilize.

4. **Charge Cycle**

a. **Set Charge Parameters**: Configure the charge parameters according to the manufacturer's guidelines (e.g., charge rate).

b. **Begin Charge**: Charge the battery at a constant rate until it reaches the maximum SOC.

c. **Record Data**: Measure and record the power input, voltage, current, and the time taken to charge.

5. **Analysis**

a. **Calculate Energy Capacity**: The energy capacity (in kWh) is determined by the total energy discharged during the test.

b. **Calculate Power Capacity**: The power capacity (in kW) is determined by the maximum power output observed during the discharge cycle.

c. **Efficiency Calculation**: Calculate the round-trip efficiency of the BESS by comparing the energy charged to the energy discharged.

By performing these steps, the actual power and energy capacity of the BESS can be determined, ensuring it meets the design specifications and operational requirements. Regular capacity tests help in identifying degradation trends and maintaining the overall health of the BESS.

7.2 Standards

- A non-exhaustive list of applicable standards is provided below for the design and construction and connection of battery energy storage systems to the T&D System:
- UL 1642 - Standard for Lithium Batteries
- UL 1973 - Standard for Batteries Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications
- UN 38.3 - UN Transportation Testing for Lithium Batteries
- NFPA 855-2023 - Standard for the Installation of Stationary Energy Storage Systems
- UL 9540 - Energy Storage Systems Requirements
- UL 1741 - Standard for Safety Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources
- Requirements of the relevant authorities in Barbados for example the Barbados Fire Service, Government Electrical Engineering Department.

- NETA – International Electric Testing Association (ATS – Standard for Acceptance Testing Specifications for Electrical Power and Equipment and Systems, ECS – Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems)
- OSHA – Occupational Safety and Health Organization
- IFC -International Fire Code (IFC) 1207
- IEEE 2030.2, Guide for Interoperability of Energy Storage Systems Integrated with the Electric Power Infrastructure.