

Model Technical Specifications

For

**Battery & Battery Management
System (BMS)**

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Definitions, acronyms, and abbreviations

For the purposes of this document, the following terms and definitions apply

Definitions

battery: One or more cells connected together electrically in series or parallel, or both, to provide the required operating voltage and current levels.

battery array: string of batteries connected to a PCS capable of charging and discharging

battery energy storage system (BESS): A system which is used to store electric energy by means of electro chemical materials, typically includes batteries, power conditioning system, and battery management system.

battery management system (BMS): A system which implements controls on batteries in order to obtain safe operation, it also balances the energy of batteries and monitors the status thereof.

charge: The process of storing energy to the BESS.

charge rate: The allowed battery charging current compared to its nominal current, also known as charge rate (C-rate).

Cell: The basic electrochemical building block of a battery, characterized by a positive electrode, a negative electrode, and electrolyte.

cycle: The process of BESS discharging or charging from initial state of charge (SOC) to the same state within a single discharge and charge.

cycle life: The number of cycles after which electricity storage becomes inoperable or unusable for a given EPS application.

depth of discharge (DOD): The degree to which a BESS is discharged relative to the maximum possible amount of energy that can be discharged by the system, typically expressed as a percentage.

discharge: The process of extracting stored energy from the BESS.

discharge rate: The allowed battery discharging current compared to its nominal current, also known as discharge C rate.

electric power system (EPS): The power system network that acts as source/sink for the battery energy storage system

energy capacity: The energy available for transfer either from battery energy storage system to the grid or vice versa, usually expressed in kWh or MWh.

Energy management system: The software and hardware used for carrying out the targeted application of the BESS

islanding: A scenario when the main BESS along with the PCC is electrically isolated from the EPS

Module: A module consists of several cells generally connected in either series or parallel.

off grid: A working condition of BESS, which means the BESS disconnects from EPS. In this condition, the superior area EPS that BESS subordinated to is not connected to the EPS.

on grid: A working condition of BESS. In this condition, the superior area EPS that BESS subordinated to is connected to the EPS

packing pattern: The way batteries are packed in series or paralleled connection or both connections from battery cells to modules.

power conditioning system (PCS): A system which acts as an energy interface between batteries and EPS, it regulates the voltage and current outputs of batteries.

power capacity: The power available for transfer either from the battery energy storage system to the grid or vice versa, usually expressed in kW or MW.

point of common coupling (PCC) (of BESS): The common connection point where the BESS is connected to the EPS.

P/Q mode: BESS performs as a controlled current source with the ability to adjust its active and reactive power.

PCC transformer: HV/EHV transformer connecting the EPS with the MV system of BESS

PCS transformer: MV transformer connecting Ac side of PCS to the MV system of BESS

response time: the time required for the BESS to achieve the desired state of operation due to a control action.

state of charge (SOC): The degree to which a BESS is charged relative to the maximum possible amount of energy that can be stored by the system, typically expressed as a percentage.

string: An energy storage system consisting of two or more series connected cells up to the required system voltage

sub-systems of BESS: A complete subsystem of BESS includes a power conditioning system, battery management system, and batteries (or battery system). A BESS subsystem can operate independently with connection to monitoring, information exchange, and control (MIC). In general, a BESS consists of one or more BESS sub-systems.

Terms and definitions of terminologies related to BESS shall be as defined in IEC 62933 relevant latest version.

Acronyms and abbreviations

BEES	battery energy storage system
BMS	battery management system
DOD	depth of discharge
DR	distributed resources
EMS	energy management system
EPS	electric power system
MIC	monitoring, information exchange and control
PCC	point of common coupling
PCS	power conditioning system
PF	power factor
SCADA	supervisory control and data acquisition
SOC	state of charge
SOH	state of health
THD	total harmonics distortion

SECTION – Battery & Battery Management System

1 Introduction

This technical specification is for design, engineering, fabrication/assembly (as per requirement), supply at site, civil works, erection, installation, testing, training, commissioning, guarantees/warranties, field verification of Battery & Battery Management System and its associated infrastructure. The Battery shall meet the service guarantees as specified in the Section Project. The specifications are intended to be battery technology agnostic and cover BESS requirements for different types of applications.

The battery design meeting the requirement of this specification shall be in the scope of the contractor. The function of battery for which it is being implemented shall be as per Section Project of the technical specification and this section of specification shall be read in conjunction with the same. Only the parts of this specification which are relevant for the requirement as brought out in the Section Project shall be applicable.

2 Scope of Work

This Technical Specification is for Battery & Battery Management System its interconnection to PCS and any other component as required in BESS design for completion of scope of work.

With the exception of the equipment, material and services furnished by the Owner as defined in Section-Project, the Contractor shall be responsible for the design, engineering, fabrication/assembly (as per requirement), supply at site, civil works, erection, installation, testing, training, commissioning, guarantees/warranties, field verification of the complete battery installation. The battery shall meet the service guarantees as specified in the Section Project. The Contractor shall also perform the studies (steady state and dynamic) as required, design verification/validation, material procurement, type testing, quality management, factory inspection/testing, site inspection, field testing, project management and interface management with other equipment and all associated Works and services until final handing over of the battery in a satisfactory working and operating condition along with the necessary spare parts, consumables and documentation, to the Owner.

The general concept of connection of batteries for grid connection purpose is through various level of (series/parallel) interconnections. The batteries shall be connected together to form a string of batteries providing a DC output at its terminal depending upon the capacity requirement and the design solution offered. The string of batteries shall be connected to a PCS which shall be capable of collectively charging and discharging of the battery string and together it will form an array of batteries.

An analysis of the functional and performance requirements of this specification and/or site surveys, design, and engineering may lead the bidders to conclude that additional items are required that are not specifically mentioned in this specification. The bidders shall be responsible for providing at no added cost to the Employer, all such additional items such that a viable and fully functional battery system is implemented that meets or exceeds the capacity, and performance requirements specified in this specification. Such materials shall be considered to be within the scope of the contract.

The offered items shall be designed to operate in varying environments. Adequate measures shall be taken to provide protection against contaminants, pollutants, water & moisture, lightning & short circuit, vibration and electro-magnetic interference etc.

The Bidders shall demonstrate a specified level of performance of the offered items during well-structured factory and field tests.

All equipment provided shall be designed to interface with other equipment and shall be supporting all present requirements and spare capacity requirement identified in the technical specifications.

All the software to be provided with the battery & battery management system shall have valid license (if required) for the service life of battery.

The bidders are advised to visit sites (at their own expense), prior to the submission of the design proposal, and undertake surveys and assessments as deemed necessary. The successful bidder shall be required to visit sites for site surveys. The site visits after contract award shall include all necessary surveys to allow the bidder to perform the design and implementation functions.

The battery is intended to operate for different applications as specified in the Section Project. Environmental Conditions

Environmental conditions as specified in the section project shall be referred for all design considerations.

3 BESS System Characteristics:

The Nominal Energy Capacity, Input and output power rating, AC Roundtrip efficiency, Expected service life (years, duty-cycles), Auxiliary power consumption requirements of the BESS shall be as per the Section Project.

If auxiliary system is energized from a different source then during charging and discharging, energy consumption of the auxiliary system shall be noted separately and Round-Trip Efficiency shall be calculated as specified in IEC 62933-2-1.

3.1 Losses and AC Round Trip Efficiency

The loss requirement of the BESS shall be governed by AC round trip efficiency of the BESS. The contractor shall ensure an optimized design with a very high round trip efficiency considering the overall loss of the BESS along with the auxiliary system losses. In the case of connection of BESS at EHV/HV level there shall be losses in the coupling transformer, cables etc. as well, these shall also be taken into account for calculating the round trip efficiency at the EHV/HV PCC.

The AC roundtrip efficiency is the ratio of total output energy divided by total input energy over one charging/discharging cycle using rated input and output power, and it should be evaluated by energy efficiency in cycle, which is charging from minimum available energy level to the full available energy level, then discharging to the minimum available energy level. The roundtrip efficiency depends on actual energy capacity, rated input active power, rated output active power, power consumption of the auxiliary subsystem and the operating conditions as specified in Section Project.

The round trip efficiency shall be calculated as below

$$n_{rt} = E_o / E_l$$

for BESS where the auxiliary supply is being taken after the PCC and

$$n_{rt} = \frac{E_o - E_{o_{aux}}}{E_l + E_{aux_l}}$$

for BESS where the auxiliary supply is being taken separately from a different source.

Where,

E_o is the total output energy measured at the (primary) PCC considering energy losses including conversion loss and energy used for the auxiliary subsystem.

E_l is the total input energy measured at the (primary) PCC.

$E_{o_{aux}}$ is the energy consumption of the auxiliary subsystem measured at the auxiliary PCC during output operation.

E_{aux_l} is the energy consumption of the auxiliary subsystem measured at the auxiliary PCC during the input operation.

4 Battery System Design Principle

A fully functional Battery System of the rated capacity consists of Batteries of specified technology, Protection System and associated components in modular design within the space constraint defined in the Section Project. All the additional items such as enclosures, junction boxes, grounding, instrumentation, wiring etc. required for fully functional system as per specification shall be provided / installed by contractor.

4.1 Sizing of BESS Systems

Sizing of BESSs is related to the identification of one or more suitable duty cycles as specified elsewhere in the specification, which the BESS may typically have to perform at the primary PCC to meet its operational requirements taking into account also the maximum and minimum recovery time available to restore the BESS between the duty cycles.

Depth of discharge of batteries, auxiliary power requirements, degradation etc. shall also be considered in BESS sizing so that performance criteria is met.

5 BESS Components

5.1 Batteries

5.1.1 Introduction

This part outlines major technical parameters and testing requirements for batteries which form the core of the BESS. Definitions of various terminologies related to BESS shall be as per latest edition of IEC 62933-1 Electrical energy storage (EES) systems – Part 1: Vocabulary and IEC 60050-482 (International electro-technical vocabulary for cells/ batteries) if otherwise not specified.

5.1.2 General

The energy storage system shall consist of any maintenance free battery technology suitable for operation in site specific climatic conditions while meeting the application requirement. Battery cells shall be electrically interconnected in any desirable series and parallel configuration to achieve the overall system storage and power requirements. The DC voltage of the battery system shall be selected by the bidder to suit the Power Conditioning System (PCS) input voltage while ensuring safe and efficient operation of the BESS.

- i. The battery cells may be supplied as separate, individual units or as a group of cells combined into modules. The design, materials, and method of cell construction shall conform to the applicable code and/or standard.
- ii. Contractor shall use cells that are commercially available or for which suitable (not necessarily identical) replacement cells can be supplied on short notice. For both premature cell failures and end-of-battery-life replacement, the Contractor shall ensure cell availability, so that the Service Guarantee mentioned in Section project of the BESS is met.
- iii. Cell and module design shall accommodate the anticipated vibrations and shocks associated with the transportation of the BESS and shall resist deterioration due to vibrations resulting from the same. Associated hardware and paraphernalia should also be able to withstand the rigors of transportation. The transport plan shall be shared with the Employer and approved prior to dispatch.
- iv. Cell/module terminals and interconnections shall have adequate current carrying capacity.
- v. Each electrically series connected battery string shall include a means of disconnecting the string from the rest of the system and providing over-current protection during a fault. This protection shall be coordinated with the PCS capabilities and battery string protection and shall consider switching and other transients and inductance to resistance ratio (L/R) ratio at the relevant areas of the DC system. These disconnection devices shall be able to withstand normal load current and provide physical interruption.

- vi. The means of disconnect shall provide for a physical interruption of the string electrical circuit, which shall be visible to anyone servicing the individual unit batteries in the string and shall be capable of being locked or secured in an open position. If the disconnect means consists of removal of a unit battery, the storage system shall be designed to allow maintenance personnel to determine that there is no current flowing in the string and provisions to ensure that the PCS is off before the unit battery is removed. Procedures for maintenance and/or field replacement of unit batteries shall neither require nor recommend removal of the unit battery without first ensuring that no current is flowing in the string circuit.
- vii. Battery System shall include a system to detect and alarm excessive ground leakage current. Each string shall have its own ground leakage detection system. The detection/ trip level shall be field adjustable. The Contractor shall have overall responsibility for the safety of the electrical design and installation of the battery, as well as all aspects of the BESS.
- viii. The battery system shall include a monitoring/alarm system and/or prescribed maintenance procedures to detect abnormal unit battery conditions. Abnormal conditions shall include but not be limited to
 - a. weak unit batteries that could reasonably be expected to fail to provide rated capacity upon full discharge,
 - b. high-resistance or open-unit batteries,
 - c. high-resistance or open external unit battery connections,
 - d. unit batteries with temperatures exceeding operating thresholds, and
 - e. internally shorted unit batteries.

Unit battery monitoring, whether automatic or manual, should be able to alert the proper personnel in a timely manner that an abnormal unit battery condition exists or may exist. All alarms shall be part of the control system and shall include remote display or annunciation capability.

- ix. Over-current protection, whether on the ac or dc side, in paralleled unit battery strings shall be sized and coordinated so that currents from other strings do not contribute to a fault in any unit battery string.
- x. The Cells/modules and battery system shall be supplied with all required and/or recommended accessories.
- xi. Cells/modules, wiring, switch gear and all dc electrical components shall be insulated for the maximum expected voltage and an applicable factor of safety. The DC bus and load-carrying cables within the storage subsystem shall have an enough margin for the actual load current. Also, all other components shall have an enough margin for the actual load current according to applicable standard.
- xii. Where appropriate, dc wiring shall be braced for available fault currents. Protection shall include a dc breaker, fuse, or other current-limiting device on the battery bus. This protection shall be coordinated with the PCS capabilities and battery string protection. The Contractor shall produce a fault analysis and protection coordination study for the battery dc subsystem during final design. The Employer reserves the right to withhold permission to ship the BESS until the fault analysis has been satisfactorily completed.
- xiii. Batteries shall be arranged to achieve maximise energy density vis a vis easy access for maintenance.
- xiv. Signage/Labels should be of acid resistant materials
- xv. The cells may be supplied as separate, individual units or as group of cells combined into modules. The cells shall meet the seismic requirements for the planned location of the BESS. Cell and module design shall accommodate the anticipated vibrations and shocks associated with the transportation of the BESS and shall resist deterioration due to

vibrations resulting from the same. Associated hardware and paraphernalia should also be able to withstand the rigors of transportation. The transport plan shall be shared with the Employer and approved prior to dispatch. Labelling of cells or unit batteries shall include manufacturer's name, cell type, nameplate rating, and date of manufacture, in fully legible characters. All cells shall be traceable to the point of origin for the purpose of addressing safety issues. Battery shall not produce any gases and shall be free from fire hazards.

- xvi. Over-current protection, whether on the ac or dc side, in paralleled unit battery strings shall be sized and coordinated so that currents from other strings do not contribute to a fault in any unit battery string.

5.1.3 Battery Parameters

The BESS parameters indicated in the table below specify the minimum requirements to be complied with by the contractor.

Item Description	Requirement
Battery Technology	Any battery technology suitable for operation in site-specific environmental conditions can be used.
Battery Capacity	<p>MW/MWh for each plant shall be as specified in section project. The specified capacity (MWh) shall be available at COD and shall be measured at Point of Interconnection (Grid) (400 KV, 220 KV or 132 KV or 33 KV as applicable and shall be as indicated in respective SLD).</p> <p>If the actual measured parameters of BESS Capacity at site is not as per requirement, replacement/addition shall be done at the start of each CAMC year by Contractor considering design life at no additional financial implication to POWERGRID. The minimum dispatchable throughput capacity at the end of each year of operation shall be calculated after considering annual allowed degradation as specified in technical specifications. Bidder to ensure that battery life cycle/degradation etc. are duly considered as per Battery OEM guidelines.</p>
Cycle Life/Project Life	As per section project
Depth of Discharge (DOD)	<p>The contractor shall decide on the suitable battery storage DOD as per the offered battery technology. During the detailed engineering stage, the contractor shall specify the BESS Battery maximum DOD level beyond which the Battery cannot be operated.</p> <p>Battery DOD vs life cycle graph also shall be provided. BESS/BMS/EMS control system shall be designed so that the above maximum DOD level is not violated under any operating conditions/ circumstances during operation</p> <p>Bidder shall provide suitable calculation/document in this regard during detail engineering. DoD shall be defined at Rate of Discharge specified in section project</p>
Ventilation System inside the Container	Should be such as to maintain minimum and maximum Temperature as recommended by the manufacturer for optimum performance of the batteries on continuous basis.

Use case requirements. (Any other control/application mode if required during O&M shall be configured by Contractor.	<ul style="list-style-type: none"> a. Peak Management b. Grid Ancillary services c. VAR support to Grid / voltage Regulation d. Black Start capability e. Frequency Regulation /Grid support f. Energy Arbitrage/energy shifting operation/Solar Smoothing (With existing Solar plant) g. Ramp rate support h. Power Quality mitigation to Grid i. Interaction on real-time with IEX for schedule of charging and discharging. j. Inertia Support to Grid as virtual Synchronous Generator. k. Ups and down in close association with AGC
Charging/ Discharging rate/ Ramp rate /Response time	Suitable for Application requirement.
Power Factor range at Grid Connectivity (minimum)	As per CEA connectivity regulation when it is charging/discharging condition
VAR support to Grid facility	In addition to reactive power support to grid as per CEA regulation, BESS shall have facility to provide VAR support to the extent possible to Grid even when there is no active power flow during charging /discharging
Identification and traceability	Battery Cells/Racks/Packs assembly shall meet the seismic requirement for the plant location of the BESS. Labeling of cells/batteries shall include manufacturer's name, cell type, name-plate rating, date of manufacture and date of expiry of parts and warranty details

5.1.4 Cell Covers

The cell covers (if provided) shall be permanently fixed with the battery container (electrolyte container in case of flow batteries) and shall be capable to withstand internal pressure without bulging or cracking. It shall also be fire retardant (if required). Fixing of pressure regulation valve (if provided) & terminal posts in the cover shall be such that the seepage of electrolyte, gas escapes and entry of electro-static spark are prevented.

5.1.5 Pressure Regulation Valve

Each cell shall be provided with a pressure regulation valve (if required). The valve shall be self-re-sealable and flame retardant. The valve unit shall be such that it cannot be opened without a proper tool. The valve shall be capable to withstand the internal cell pressure specified by the manufacturer.

5.1.6 Terminal Posts

Both the +ve and –ve terminals of the cells / modules shall be capable of proper termination and shall ensure its consistency with the life of the battery. The surface of the terminal post extending above the cell cover including bolt hole shall have acid/alkaline resistant and corrosion retarding properties. Terminal posts or any other metal part which is in contact with the electrolyte shall be made of the same alloy as that of the plates or of a proven material that does not have any harmful effect on cell performance. Both +ve and –ve posts shall be clearly and unambiguously identifiable.

5.1.7 Labelling

Labelling of the cells/modules shall include manufacturers name, cell/module type, nameplate rating and date of manufacturing in fully legible characters in English. All cells/modules shall be traceable to the point of origin for addressing safety issues. The polarities of cell/module terminal posts shall be embossed on the cover at the terminal.

Note: If proposed technology does not require any part / parts described above then same shall be specifically mentioned.

5.1.8 Connectors, Nuts & Bolts, Heat Shrinkable Sleeves

Where it is not possible to bolt the cell terminals directly to assemble a battery, separate non-corroding connectors of suitable material & size shall be provided to enable connection of the cells/modules. Connections shall be suitably protected to withstand corrosion due to acid / base at a very high rate of charge or discharge. Nuts and bolts for connecting the cells/modules shall be made of copper, brass, galvanized steel or stainless steel, which shall be effectively coated (if required) to prevent corrosion.

5.1.9 Flame Arrestors

Each cell shall be equipped with a flame arrestor (if required) to defuse any flammable gas escaped during charge and discharge. Material of the flame arrestor shall not affect the performance of the cell.

5.1.10 Battery Bank Stand

All batteries shall be mounted in a suitable metallic stand / frame. The frame shall be protected from corrosion. Suitable insulation shall be provided between stand / frame and floor.

5.1.11 End of Life

Life of the BESS is considered calendar life or no. of Cycles which is completed early. At the end of contract period of BESS, the minimum throughput dischargeable capacity to be demonstrated shall be as specified in the Section Project. However, there may be instance where individual cells/batteries may get defective during the life period of BESS. End of cell / battery life is that point in time when the cell / battery can no longer meet the power and/or energy discharge requirements due to age or non-repairable malfunction of the cell / battery; accordingly, it shall be the responsibility of the Contractor to make periodic replacements/ replenishments of cell/ batteries, if and when required during contract period.

5.1.12 Safe Disposal of Unit Batteries from the BESS

The Contractor will comply with the requirements under Hazardous & other Waste (Management and Transboundary Movement) Rules, 2016, as amended from time to time, as applicable. The Contractor shall ensure that all Unit Battery modules from the plant after their 'end of life' (when they become defective/ non-operational/ non-repairable) are disposed in accordance with the "e-waste (Management and Handling) Rules, 2016" notified by the Government and as revised and amended from time to time and Battery Waste Management Rules, as and when notified by the Government of India.

In addition to above, at the end of Project life, the batteries are to be disposed (if specified in Section Project) as per above mentioned rules.

5.2 Battery Management System

The Battery Management System (BMS) shall be designed to provide automatic, unattended operation of the BESS. The BMS shall provide the necessary monitoring and control to protect the battery module/string/cluster from out of tolerance ambient or unsafe operating conditions. The BMS shall automatically control the charge and discharge of the individual strings/clusters, balancing between modules/strings/clusters to optimize energy consumption and range, monitor cell/module health and provide critical safeguards to protect the batteries from damage. Contractor has to supply the BMS as per battery OEM recommendation & requirement and shall be in line with the application requirements. BMS shall have the following feature:

- i. Cell/module/Cluster Protection from out of tolerance operating conditions
- ii. Charge control of the individual string/module.
- iii. Determination of State of Charge (SOC) of the group of cells/modules.
- iv. Determination of State of Health (SOH) of the group of cells/module.
- v. String/Cluster Balancing
- vi. Monitoring of Charge & discharge current
- vii. DC bus voltage monitoring
- viii. Cell / Module / Stack voltage monitoring
- ix. Cell / Module / Stack / Electrolyte temperatures monitoring including minimum and maximum values
- x. Alarm and fault generation and communicating the same to Control & Monitoring System.
- xi. Isolating the battery in cases of severe abnormality in the monitoring parameters and emergency.
- xii. Communication with EMS/PCS/Monitoring & Control System on non-proprietary protocol for proper operation of integrated BESS.
- xiii. Monitoring & alarming on over temperature, overcharge, over discharge or any other non-standard condition.

In case all above mentioned features are not available in the BMS, then balance features must be covered through any other Software system to be provided by the Contractor.

5.3 Protection and Monitoring & Control System for BESS

5.3.1 Protection System

Reliable, sensitive and properly coordinated protection system shall be provided for safe operation. Protection system shall be capable of monitoring operating parameters and sensing all abnormal conditions to isolate the faulted circuits or components without causing damage to other circuits and components of the system. Adequate indications / alarms shall also be provided locally as well as at remote control system for identification of faults and taking preventive / restoration actions.

Contractor shall submit single line diagram showing configuration of the system upto point of common coupling along with protection system considered for each of the potential fault point. Protection system shall work on following principles:

- a. Protection system must be capable of distinguishing between external faults on the distribution system and internal faults within the BESS. The automatic reconnection shall occur for external faults (after detection of healthy condition) only.

- b. The protective device closest to the faults shall clear the faults without causing damage to other devices/ components

Protection system supplied by contractor shall include all the components / relays which may not be specified in this specification but required for proper operation and protection of the BESS.

5.4 Battery Container

5.4.1 Introduction

This section describes the functional requirement, major technical parameters and all the testing requirements for battery container to be used to house batteries including its sub-systems.

5.4.2 General

The unit batteries shall be racked or shall be housed in stackable modules. The unit batteries or cells shall be arranged and installed to permit easy access for equipment and personnel. The moveable units shall be arranged and installed to permit easy access for equipment and personnel to carry out unit removal and replacement activities.

For all systems, it shall be possible to remove and replace a prematurely failed unit battery or cell (as appropriate), when system performance specifications cannot be met. The lengths and widths of all aisles and spaces into which personnel may enter in the field for operations and/or routine or unscheduled maintenance purposes, as well as egress routes from these aisles and spaces, shall conform to applicable codes and standards.

All racks and metallic conductive members of stackable modules shall be grounded to earth. Racks shall meet the seismic load and road vibration requirements and shall include means to restrain cell movement during seismic events and transport.

The Contractor shall furnish analyses and/or other data that show that the rack and cell designs are designed to meet all potential seismic and transport vibration requirements

5.4.3 Constructional Requirements

The battery container enclosure shall fulfil following:

Fire Rating	2 Hrs
Corrosion level	C5M
Enclosure Rating	IP 54 or better class
Wind Load	As per Section Project
Environmental Conditions	As per Section Project
HVAC	As per rated capacity of Battery container
HVAC Mounting Arrangement	Wall /Roof Mount
FFS/FSS Suppressant used	Aerosol (UL Listed)
E-Stop Functionality	Yes
Design Standard	As per NFPA 855

Battery shall be provided in prefabricated containers specially designed for battery storage solutions, fully assembled and tested as per requirement of relevant codes/standards. Containers shall be designed to be dropped shipped onto properly prepared pads or foundations. The containers shall also be fire-retardant. The container material shall possess chemical and

electrochemical compatibility and shall be resistant to acids and alkaline substances (as required). When fully installed, BESS components, including all auxiliaries shall be enclosed in containers, even if certain components are shipped separately and installed on-site. Suitable ventilation/controlled air conditioning and personnel safety measures in the battery room/container must be maintained to minimize health hazards from exposure to hazardous battery elements. Containers shall meet all safety requirements, including aisle width, working space, lighting, emergency provisions, etc. Container(s) shall be provided with lifting hooks of suitable capacity according to their weight and size.

The container shall be maintenance free for outdoor application in environmental conditions as specified in Section Project. It shall be protected and insulated to achieve sound proof, thermal resistance and impact withstand capabilities. They should be easily transportable & relocatable as and when required.

The container design should follow the standard International Organization for Standardization ISO 668 shipping containers or as per national/international standards (IEC-60529). The container or containers shall be designed to be drop-shipped onto a properly prepared pad or foundation (such as compacted soil, concrete pad or platform, and so on).

5.4.3.1 Structure:

All structural members shall be as per relevant IS standard and designing shall be done considering all load and safety requirements. The Contractor shall submit the reinforcement and other details calculations in support of the meeting the load capacity. It shall also comply site specific seismic requirements.

The design of all modules and racks shall specifically account for the anticipated vibrations and shocks associated with the transportation of the BESS.

5.4.3.2 Thermal Insulation

Between all external and internal surfaces of walls / roof / doors thermal insulation of Mineral wool or Rockwool (IS-8183) shall be provided considering fire safety and thermal insulation requirements.

5.4.3.3 Roof

Roof shall be designed in such a way that it shall avoid water logging, the design shall be approved during Detail Engineering. The roof shall have minimum projections and shall be hidden by angular profiles on the rooftop to decrease the aerodynamic effect and improve on aesthetics. The roof shall be suitably clamped/ bolted to the shelter panels to withstand the specified wind load. The cable tray shall be attached suitably from the roof and the roof shall have sufficient strength to support the load of cable trays and the cables installed on the cable tray.

5.4.3.4 Doors

There would be doors suitably provided for maintenance as well as normal operations. Main door opening outwards shall be provided with external and internal handles/knobs respectively. However, the contractor is free to supply alternate Container solution that can be maintained from outside, for such cases provision of door shall be as per requirement.

5.4.3.5 Openings

Proper openings shall be provided for required air-conditioners, piping and all electrical and communication cablings. The details of openings required for different applications and the locations of the openings shall be decided during detail engineering. All openings shall be custom built based upon the actual application required at each site. The Contractor shall provide the required cut outs for above purpose. Any sealed cut outs required for future use may also be provided and the size of this cut out shall be finalised during detail engineering. All the openings shall be sealed for water and leak proof with suitable flexible sealing arrangement for the proposed cable connections and also for addition and deletion of cables/pipes in future. The sealing arrangement shall be fire retardant and type/make/details shall be got approved by the Employer.

5.4.3.6 Painting

The Container shall be factory coated with good quality and long-life paints. The finished container shall be provided with suitably protection to avoid scratches during transportation, handling and installation. The actual colouring scheme shall be finalised during detail engineering.

Containers shall incorporate standard lugs or other means for lifting by crane or shall be properly palletized for movement with forklift trucks, or both.

5.5 Fire Protection System

The Contractor shall design and install a fire protection system that conforms to national and local codes, good engineering practice and latest CEA guidelines. The fire protection system design and associated alarms shall take into account that the BESS will be unattended. The Contractor shall calculate and take into account the heat content of the battery cell materials in designing an appropriate fire protection system. Separate fire protection systems may be used in the battery, PCS, and control areas. For high energy density technologies, the contractor shall also obtain thermal runaway characterization of the battery storage systems.

5.6 Lighting System

Normal/ emergency lighting, with LED luminaires, shall be provided for inside the container (if applicable as per Contractor's design) and for outdoor switchyard.

5.7 Cables

Container Cable entries shall be from bottom and provision shall be made below floor to lay the same considering bending radius of cables. Cables for lighting, firefighting, air-conditioning etc. may be laid on walls or rooftop for which cable trays of size minimum 100 mm width made of Fibre glass Reinforced Polymer (FRP) / GI material shall be provided. The cable trays shall have sufficient strength to take loading of various cables, earthing flats etc. The colour of the cable tray shall match with the inside colour of the container. The cable tray shall run along the four sides just below the ceiling with smooth curvatures at the bends/corners. The actual routing including length and height of the cable tray for each site shall be finalised during detail engineering. The Contractor shall clamp the cables suitably with the trays after installation of the cables.

All cables and cabling of required size and capacity shall be supplied, installed and terminated with necessary and required accessories among all the equipment/systems being supplied under this Package. Double compression cable glands and copper lugs shall be used to terminate the cables. The cables shall be dressed properly. Wires for lighting system shall be FRLS PVC insulated with multi stranded copper conductors.

5.8 Earthing

For satisfactory operation of the equipment inside the container, good and proper earthing shall be provided. The earthing resistance generally varies depending on soil resistivity. The earthing system at each site shall be provided by the Contractor with earthing resistance as per relevance IS/IEC standards.

A Earth Bus Bar as per Contractor's offered design for earthing with sufficient holes with brass bolt shall be installed inside the container. Each equipment shall be connected to above earthing bus bar through requisite size copper cable. The connectivity from earth bus bar to main earth mat outside the container shall be made by the Contractor at least at two places through suitable GI strips. The connection of GI strips with the earth bus bar shall be made through flexible copper/A/equivalent cable and bi-metal washers for proper connectivity.

5.9 Protection for Temperature Rise

The contractor shall design and install a temperature rise protection system. In case of high temperature, first this protection shall display the alarm and in case of further rise of temperature, it shall trip the system.

5.10 Emergency Stop

Provision shall be provided for automatic as well as manual disconnection of the Container from distribution system if:

- a. Protection system fail is detected during self-diagnostic
- b. Breaker trip coil or interrupting device fails
- c. Auxiliary DC supply is lost

5.11 Auxiliary Supply

The auxiliary supply of BESS shall conform to the system requirements relating to reliability, availability, redundancy and continuous performance to ensure that the complete battery container operates as per the Employer's requirements. The auxiliary supply system shall provide power to the controllers, cooling system various other essential and non-essential loads.

5.12 Air Conditioning/Cooling System for Battery Container

This section covers Air conditioning system for battery containers.

Container shall be provided with air conditioning system to manage the heat load of the system and rating of AC should be defined accordingly. It should be rugged, reliable and maintenance free and designed for entire life time of BESS. It shall be designed for continuous operation with changeover feature. The contractor shall periodically and whenever require replace/service Air Conditioner, equipment, sub-equipment, filters and all related accessories to make the Air Conditioning system running as specified in this specification for the entire tenure of the project.

Air conditioning units for Containers of Batteries shall be set to maintain temperature recommended by battery OEM and the temperature setting shall also be applicable to other equipment housed in the container. Air conditioning system for control room shall be set to maintain the inside DBT at $24^{\circ}\text{C} \pm 2^{\circ}\text{C}$. Status of air conditioning need to be displayed at the control centre.

The Contractor shall do necessary heat load calculation for both indoor/containerized BESS and control room building/container, and submit the detailed calculation with system design for approval by Employer. Required field data needed to be submitted along with design. Air conditioning system for battery containers shall provide Temperature and RH (Relative Humidity) controlled environment continuously for Batteries & other equipment installed inside container.

Contractor shall offer air conditioning system comprising of multiple air conditioning units working in conjunction, controlled by the Microprocessor based controller for desired operation. Calculation for designing shall be submitted for the approval of Employer considering heat dissipation requirement of BESS and external environmental conditions.

All air-conditioning units shall be physically independent of each other, so that Problem/fault in one of the units shall not hamper the working of other units. However, during such fault in any of the unit; the alternate unit(s) shall take over and continue to operate till the faulty unit is operational again. All units shall never start at the same time. If the condition is such that all units shall start together then internal time delay of at least 10 sec shall be provided in starting of each unit to avoid surge.

The microprocessor-based controller shall have the following features;

- Mode of Operation : RUN/Standby mode
- Temperature Setting : 16 - 30 deg. C with 1 deg C resolution

- Temperature variation : ± 1.0 deg C from set temperature
- Memory - Non-volatile memory for various settings supported by Battery backup; e.g., Set temperature, working hours & ON / OFF Status
- Alarms Displays: Potential Free contacts for Remote monitoring at NOC
 - a) AC unit fail alarm
 - b) High Temp inside container alarm
 - c) Power Fail alarm
 - d) Indication for free cooling
- In addition to the above, following minimum LED Indications shall also be available in the Controller Mimic Panel for local indication;
 - a) Alarm.
 - b) Power Healthy
 - c) Compressor Working
- Time Delay: On / Off sequence delay shall be available.
- Cumulative hours run: For each compressor of Air-conditioning system

The exact cut outs required in the container to mount the air-conditioning units shall be taken care properly before installation of the units. The cut outs in the container for air-conditioning system shall be properly sealed.

6 Testing Requirements of Batteries

6.1 Type Test

Type Tests shall be conducted as per the standards and testing requirements as mentioned in the "Codes and Standards". The BESS shall conform to applicable IS/IEC/UL standards. Where an applicable IS/IEC/UL standard is not available, any applicable international standard shall be referred to as best practice. The BESS shall meet all the CEA and local statutory requirements for interconnection with grid at the required Voltage level.

The BESS shall comply with the following Codes and Standards or equivalent Indian Standards, as applicable.

Item	Standard	Description	Certification Requirements
1	IEC 62485-2	Safety requirements for secondary batteries and battery installations - to meet requirements on safety aspects associated with the erection, use, inspection, maintenance and disposal: Applicable for Lead Acid and NiCd / NiMH batteries	Applicable only for Lead Acid and NiCd / NiMH batteries.
2	UL 1642 or UL 1973, Appendix E (cell) or IEC 62619 (cell) + IEC 63056 (cell)	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications	Required for Cell
3	UL 1973 (battery) or (IEC 62619 (battery)	Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications / Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety	Either UL 1642 or UL1973 or (IEC 62619 + IEC

	+ IEC 63056 (battery))	requirements for secondary lithium cells and batteries, for use in industrial applications	63056) for the Battery level
4	IEC 62281 / UN 38.3	Safety of primary and secondary lithium cells and batteries during transport: Applicable for storage systems using Lithium Ion chemistries	Required for both Battery and Cell.
5	IEC 61850/ DNP3	Communications networks and management systems. (BESS control system communication)	
6	UL 9540 or (IEC TS 629335-1 + IEC 62933-5-2)	Electrical energy storage (EES) systems - Part 5-1: Safety considerations for grid-integrated EES systems – General specification / Standard for Energy Storage Systems and Equipment.	Either UL9540 or (IEC 62933-5-1 + IEC 62933-5-2) is required for BESS system level

6.2 Factory Acceptance Test (FAT)

Factory Acceptance Test shall be performed at Manufacturer's premises and tests to be covered under FAT shall be as per guidance of Quality Acceptance Section.

The FAT shall be carried out as per the testing methods and procedures mentioned in IEC 62933-2-1: 2017 or IS 17067 (Part 2/Sec 1):2019. The tests which are applicable on complete system like AC-AC Round Trip Efficiency test, such tests shall be conducted during SAT, as per the above-mentioned testing methods.

The contractor shall carry out FAT at sub system and module level and it shall include for all component to the extent possible. The contractor shall submit FAT document to Employer for approval purpose prior to raising inspection call. It shall include following test:

- a. Visual Inspection of equipment including dimension and overall design
- b. Verification of sensors, metering and alarms
- c. Verification of all control function including remote control, monitoring and communication interface
- d. Verification of system performance at full/ partial Energy/ Power ratings
- e. Verification of maintenance and replacement features for unit batteries and other components
- f. During the FAT, system shall be operated as specified and designed in all the operating states, use cases and duty cycles. It shall meet power/ energy requirements and shall be demonstrated to meet the safety requirements.

Operation of all control, protective relaying and instrumentation circuits shall be demonstrated by direct tests, if feasible, or by simulating operating states for all parameters that cannot be directly tested. Automatic, local and remote operation of the controls shall be demonstrated.

battery shall be verified for operation at temperature extremes defined in specification. For this, if it is not possible for the full system, then independent laboratory certification of operation of critical components and subsystems shall be submitted at the time of FAT.

During FAT, if something mal-operates then FAT shall be suspended and resumed after rectification of the problem. The system shall not be accepted for shipment until all FATs have been successfully completed.

6.3 Site Acceptance Test (SAT)

Contractor shall submit a comprehensive plan for site acceptance test (SAT) to approving authority for approval. SAT plan shall include procedures to test correct system responses to system disturbances and operating scenarios described in the specification.

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