भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक : पथप्रदर्शक :
मानक भवन, 9 बहादुरशाह ज़फर मार्ग, नई दिल्ली – 110002
Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi-110002
दूरभाष Phones 2323 0131 2323 3375 2323 9402
Website : www.bis.org.in
e-mail :
तार : मानकसंस्था
Grams : Manaksanstha

DRAFTS IN WIDE CIRCULATION

Document Despatch Advice

REFERENCE	Date
ETD 52/ T-7	04-12-2019

TECHNICAL COMMITTEE ETD 52

ADDRESSED TO:

1. All Members of Energy Storage Systems Sectional Committee, ETD 52
2. All Members of Electrotechnical Division Council; and
3. All other Interested.

Dear Sir(s),

Please find enclosed a copy each of the following draft Indian Standards:

DOC NO.	TITLE
ETD 52 (14901)	GENERAL SAFETY AND PERFORMANCE REQUIREMENTS OF BATTERY MANAGEMENT SYSTEMS

Kindly examine the draft standards and forward your views stating any difficulties which you are likely to experience in your business or profession, if these are finally adopted as Indian Standards.

Comments, if any, may please be made in the format given overleaf and mailed to the undersigned.

Last date for comments: 3rd Jan 2020.

In case no comments are received or comments received are of editorial nature, you will kindly permit us to presume your approval for the above document as finalized. However, in case of comments of technical in nature are received then it may be finalized either in consultation with the Chairman, Sectional Committee or referred to the Sectional Committee for further necessary action, if so desired by the Chairman, Sectional Committee.

Thanking you,

Yours faithfully

(Rajeev Sharma)

Sc 'F' & Head (Electrotechnical)

Email: eetd@bis.org.in

Encl: As above

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक : पथप्रदर्शक :
मानक भवन, 9 बहादुरशाह ज़फर मार्ग, नई दिल्ली – 110002
Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi-110002
दूरभाष Phones 2323 0131 2323 3375 2323 9402
Website : www.bis.org.in
e-mail :
तार : मानकसंस्था
Grams : Manaksanstha

व्यापक परिचालन में मसौदे

प्रलेख प्रेषण संज्ञापन

तकनीकी समिति : ईटीडी 52

संदर्भ ईटीडी	दिनांक
ईटीडी 52/ टी-7	**04-12-2019**

प्रेषती :

1. ईटीडी 52 के सभी सदस्य

2. विद्युत तकनीकी विभाग परिषद के सभी सदस्य तथा
3. रूचि रखने वाले अन्य सभी निकाय

महोदय,

कृप्या निम्नलि खित मसौदे की एक प्रति संलग्न है :

प्रलेख	शीर्षक
ईटीडी 52 (14901)	**बैटरी प्रबंधक प्रणाली की सामान्य सुरक्षा एवं कार्यकारिता अपेक्षाएं**

कृप्या इन मसोदों का अवलोकन करें और अपनी सम्मतियॉ यह बताते हुए भेजें कि अंतत: यदि यह मानक के रूप मे प्रकाशित हो जाए तो इस पर अमल करने में आपके व्यवसाय अथवा कारोबार में क्या कठिनाइयॉ आ सकती हैं ।

सम्मतियॉ भेजने की अंतिम तारीख - 03-01-2020

सम्मतियॉ यदि कोई हो तो कृप्या अगले पृष्ठ पर दिए पत्र में अधोहस्ताक्षरी को उपरिलिखित पते पर भेज दें ।यदि कोई सम्मति प्राप्त नहीं होती अथवा सम्मति में केवल भाषा संबंधी त्रुटि हुई तो उपरोक्त प्रलेख को यथावत अतिंम रूप दिया जाएगा । यदि कोई सम्मति तकनीकी प्रकृति की हुई तो विषय समिति के अध्यक्ष के परामर्श से अथवा उनकी इच्छा पर आगे की कार्यवाही के लिए विषय समिति को भेजे जाने के बाद प्रलेख को अतिंम रूप दे दिया जाएगा

धन्यवाद,

भवदीय,
(राजीव शर्मा)
वैज्ञानिक 'एफ' एवं प्रमुख (विद्युत तकनीकी)

Date	Document No.
04-12-2019	ETD 52 (14901)

Sl. No.	Name of the Organization	Clause/ Sub-clause	Paragraph/Figure/ Table	Type of Comment (General/Technical/ Editorial)	Comments	Proposed changes

ETD 52 Doc. (14901)

Draft Indian Standard

GENERAL SAFETY AND PERFORMANCE REQUIREMENTS OF BATTERY MANAGEMENT SYSTEMS

1. SCOPE

This part of Indian standard deals with safety, performance requirement and control parameters of battery management system for safe working of battery electrical energy storage system and defines testing methods for safety, performance and control functioning of battery management system for intended application. The control parameters defined in this standard are basic minimum and system can include control parameters in addition to these specified basic minimum requirements.

This standard is applicable to stationary application with power generation system such as photo voltaic power plant, wind turbine power plant and others.

The battery pack level battery management system shall conform to this standard. This standard is applicable to battery management system connected to any number of battery system in series and parallel.

This standard does not address the safety requirements of any specific battery chemistry. Safety and functional requirements for BMS, based on battery chemistry has to be considered additionally.

This standard does not specify the controller logic, technology and communication protocol for the battery management system. The battery chemistry and technologies are out of scope of this standard. The applications other than the one covered in this standard are out of scope.

2. Reference standards

IS No.	*Title*
IS 17092	Electrical Energy Storage Systems: Safety Requirements
IS 13252 (Part 1)	Information Technology equipment – Safety Part 1: General Requirement (Second Revision)
IS/IEC 60529	Degrees of protection provided by enclosures (IP Code)
IS/IEC 60730 – 1	Automatic electrical controls for household and similar use. Part 1 General requirement
IS 13252 (Part 1)	Information Technology equipment – Safety Part 1: General requirement
IEC 60812	Failure modes and effects analysis (FMEA and FMECA)
IS/IEC 61508 (all parts)	Functional safety of electrical/electronic/programmable electronic safety-related systems
IS 3043	Code of Practice for earthing (second revision)

IS 14700 (Part 3/Sec 2)	Electromagnetic compatibility (EMC): Part 3 limits: Sec 2 limits for harmonic current emissions (equipment input current 16 A per phase) (Second Revision)
IS 14700 (Part 4/ Sec 1)	Electromagnetic compatibility (EMC): Part 4 testing and measurement techniques: Sec 1 overview of the IEC 61000 - 4 series (Second Revision)

3. TERMS AND DEFINITIONS

For the purpose of this standard, the definitions given in IS 17067 (Part 1) and the following shall apply.

3.1 Battery pack

Batteries that are ready for use, contained in a protective enclosure, which may or may not contain protective devices, cooling systems and monitoring circuitry.

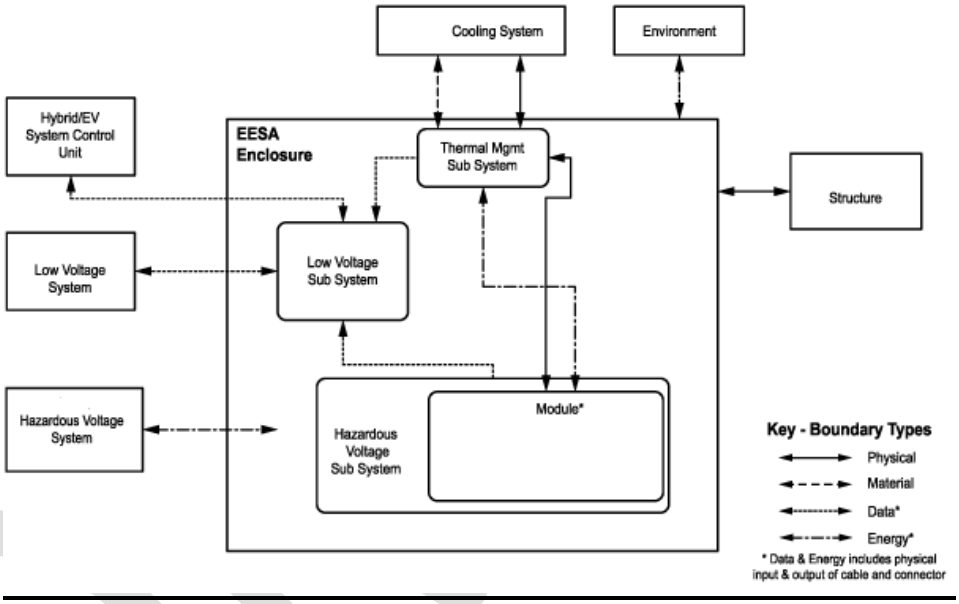

Fig. 1 BESS Block Diagram

3.2 Cell — the basic functional electrochemical unit (sometimes referred to as a battery) containing an electrode assembly, electrolyte, separators, container, and terminals. It is a source of electrical energy by direct conversion of chemical energy.

3.3 Charging — the application of electric current to battery, which results in a Faradic reaction that takes place within the battery that leads to stored electro-chemical energy, due to electrical charge being stored without a chemical reaction taking place.

3.3.1 *Charging, Constant Current (CC) — c*harging mode where current is held constant while charging voltage is allowed to vary within defined parameters.

3.3.2 *Charging Constant Voltage (CV) —* charging mode where voltage is held constant while charging current is allowed to vary within defined parameters.

3.4 Rated Capacity (Ah) — the total number of ampere-hours that can be withdrawn from a fully charged battery at a specific discharge rate to a specific end-of-discharge voltage (EODV) at a specified temperature as declared by the manufacturer.

3.5 DUT — Device under test.

3.6 Battery Energy Storage System (BESS) — a battery pack, electrochemical capacitor pack or combination battery/electrochemical capacitor pack that provides electric energy for grid interactive energy storage system. This assembly can include the cooling and ventilation systems and battery management systems. (*see* Fig. 1)

3.7 End-Of-Discharge Voltage (EODV) (Cell) — the voltage, under a specified load, of the cell at the end of discharge. The EODV may be specified by the manufacturer, as in the case of a voltage-terminated discharge typical for lithium ion chemistries.

3.8 EODV Monitoring (Cell) — EODV monitoring is typically provided at the pack/electric energy storage assembly level by the battery management system.

3.9 Fully Charged — an electric energy storage assembly, pack, module or cell which has been charged to its full state of charge (SOC) as specified by the manufacturer.

3.10 Fully Discharged — an electric energy storage assembly, pack, module or cell, which has been discharged to its end-of-discharge voltage (EODV) as specified by the manufacturer.

3.11 Hazardous Energy — Available power level of 240 VA or more, having a duration of 60 s or more, or a stored energy level of 20J or more, at a voltage of 2 V or more.

3.12 Hazardous Voltage — Voltage exceeding 30 V_{rms} /42.4 Vac_{peak} or 60 V dc.

3.13 Battery Management System (BMS) — any electronic system that manages a rechargeable battery (cell or battery pack), such as by protecting the battery from operating outside its Safe Operating Area, monitoring its state, calculating secondary data, reporting that data, controlling its environment, authenticating it and balancing it.

3.13.1 *Master BMS* — The BMS which controls and protects the entire battery pack of energy storage system which consist of sub battery packs connected in series or parallel in the energy storage system.

3.13.2 *Slave BMS* — The BMS which controls and protects the individual sub battery pack or a cluster of battery packs which are connected in series or parallel in the energy storage system

3.14 Normal Operating Region — that region of voltage, current and temperature within which a cell can be safely charged and discharged repetitively throughout its anticipated life. The manufacturer specifies these values, which are then used in the safety evaluation of the device and may vary as the device ages. The normal operating regions will include the following parameters for charging and discharging as specified by the manufacturer:

a) Charging temperature limits - The upper and lower limits of temperature, specified by the manufacturer for charging of the cell. This temperature is measured on the casing.

b) Discharge temperature limits - The upper and lower limits of temperature, specified by the manufacturer for discharging the cell. This temperature is measured on the casing.

c) Maximum discharge current - The maximum discharging current rate at a specified temperature, which is specified by the cell manufacturer.

e) Maximum charging current - The maximum charging current in the normal operating region, which is specified by the cell manufacturer. This value may vary with temperature.

f) Upper limit charging voltage - The highest charging voltage limit in the normal operating region specified by the cell manufacturer. This value may vary with temperature.

3.15 State of Charge (SOC) — the available capacity in a battery system, pack, module or cell expressed as a percentage of rated capacity.

4. CONSTRUCTION

A BMS should consist of electronic control circuitry with sensors, data acquisition system, controls system with built in software to control safety functioning of the BESSA. Fig 2 is the typical construction of Grid Interactive Battery Based Energy Storage System with Battery Management System.

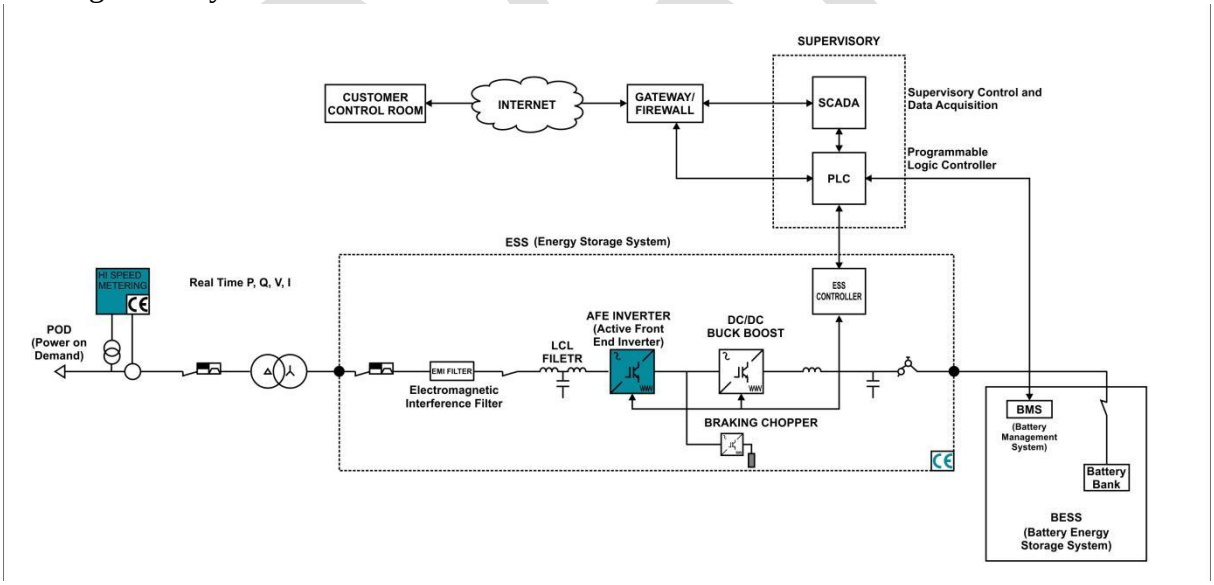

Fig 2 Typical construction of Grid Interactive Battery Based Energy Storage System with Battery Management System.

Battery Management system shall be enclosed in a protective outer cover that provides mechanical protection to the system's contents. The enclosure shall be of nonflammable construction and shall be ingress protection level of IP 52 when tested as per IS/IEC 60529.

4.1 Electrical Spacings

Electrical spacings in circuits shall have the minimum over surface and through air spacings as in Table 1 or the spacings requirements outlined in clause 2.10 of IS 13252 (Part 1).

Table 1 Electrical Spacings

Sl No.	Electrical Spacing	Voltage V	Through Air mm (in)	Over Surface mm (in)
	(1)	(2)	(3)	(4)
1.	Live parts and dead metal parts that are separated by Functional or basic insulation	0 - 50[a]	1.6 (1/16)	1.6 (1/16)
		51 - 130	3.2 (1/8)	4.8 (3/16)
		131 - 300	6.4 (1/4)	9.5 (3/8)
2.	Accessible dead metal parts and dead metal parts separated from live parts by basic insulation only - this ordinarily is a spacing resulting from supplementary insulation	0 - 50[a]	1.6 (1/16)	1.6 (1/16)
		51 - 130	3.2 (1/8)	4.8 (3/16)
		131 - 300	6.4 (1/4)	9.5 (3/8)
3.	Live parts and accessible dead metal parts separated by double insulation or by reinforced insulation	0 - 50[a]	3.2 (1/8)	3.2 (1/8)
		51 - 130	4.8 (3/16)	6.4 (1/4)
		131 - 300	12.7 (1/2)	12.7 (1/2)

[a] Spacings at these voltages may be decreased from those indicated in the table if it can be determined through test or analysis that there is no hazard (i.e. circuits supplied by limited power sources as defined in IS 13252 (Part 1).

4.2 Hazardous Voltage Path to Ground and Battery Isolation from Input Power

The earthing grounding shall be provided for the complete battery system as described in IS 3043.

5. BMS PERFORMANCE REQUIREMENTS

The BMS shall be designed with controls for safe functioning of the battery pack and cells under normal and abnormal operational conditions so to cause no danger to persons or surroundings. These safety performance requirements are applicable for both slave and master BMS.

The BMS shall provide.

a) Protection against overcharge and over discharge of battery pack.
b) Protection against over voltage and under voltage of battery pack.
c) Protection against over current of battery pack.
d) Protection against high temperature of battery pack.

e) Protection against low temperature of battery pack.
f) Protection against imbalance of cells.
g) Aid for Physical disconnection of battery in case of fault condition
h) Values for State of charge, charge current, discharge current, battery pack temperature and battery pack voltage

Safety limits of current, voltage, charge and temperature for cell and battery pack shall be as defined by the BESS manufacturer.

NOTE— the potential hazards and limits shall be determined by manufacturer of BESS by events that could lead to a hazardous condition identified and addressed through design or other means including FMEA as defined in IEC 60812; and IS/IEC 61508 (all parts).

The solid state controls and software of BMS shall be evaluated to IS/IEC 60730-1 or IS/IEC 61508 (all parts) as applicable based upon the design and complexity of the controls. The required severity level, performance level, or the class of control function shall be determined by the BESS manufacturer and the controls designed in accordance with one of the above functional safety standards.

NOTE— if other than Solid state circuits and software are used as primary safety protection of BMS then the conformance to IS/IEC 60730 or IS/IEC 61508 (all parts) is not necessary.

The BMS shall be tested for Electro Magnetic Compatibility /Electro Magnetic Immunity testing & Environmental conditions and conform to IS 14700 (Part 4/ Sec 1) and IS 14700 (Part 3/ Sec 2). The tests shall be:

a) Electrical fast transient/burst immunity test;
b) Surge immunity test;
c) Voltage dips, short interruptions and voltage variations immunity tests;
d) Limitation of voltage changes, voltage fluctuations, and flicker;
e) Electrostatic discharge immunity test(ESD test); and
f) Limits for harmonic current emissions.

5.1 Protection Against Overcharge and Over-discharge of Battery Pack

The BMS shall protect battery systems against overcharge and over-discharge, resulting from anticipated use and abuse conditions including component faults in control systems, short circuit conditions and power surges as applicable to the intended battery system application and installation as determined by the manufacturer. If relied upon for maintaining the cells within their safe operating region, the battery management system (BMS) shall maintain cells within the specified cell voltage region from over-charge and over-discharge of the cell voltage.

Additionally, it shall maintain batteries within the specified battery current region from over charge of current and prevent high rate discharge exceeding the cell specifications. When reviewing safety circuits to determine that cell operating region limits are maintained, tolerances of the protective circuit/component shall be considered in the evaluation. Components such as fuses, circuit breakers or other protective devices and parts determined necessary for safe operation of the battery system that are required to be provided in the end use installation, shall be identified in the installation instructions.

The verification shall be done by testing as defined in **5.7**.

5.2 Protection Against Over Voltage and Under Voltage of Battery Pack

The BMS controls shall be designed to protect battery pack against built Overvoltage and under voltage protection that is set at a voltage below the manufacturer's recommendation of safe voltage limit and it shall also maintain cells within the specified cell temperature region providing protection from overheating and under temperature operation.

Additionally, it shall maintain batteries within the specified battery current region from over charge of current and prevent high rate discharge exceeding the cell specifications. When reviewing safety circuits to determine that cell operating region limits are maintained, tolerances of the protective circuit/component shall be considered in the evaluation. Components such as fuses, circuit breakers or other protective devices and parts determined necessary for safe operation of the battery system that are required to be provided in the end use installation, shall be identified in the installation instructions.

The verification shall be done by testing as defined in **5.7**.

5.3 Protection Against High Temperature and Low Temperature of Battery Pack

If safety limits as recommended by battery manufacturer are exceeded, the protective circuit shall shut down the charging or discharging to prevent excursions beyond safety limits. Compliance is determined through a review of the pack and cell data and through the testing of this standard. The temperature of other electronics protective device in close vicinity shall be lesser than the safe operating temperature limits of the component.

The low temperature protection shall be set at a temperature higher than the value recommended by the manufacturer for safe charging and operation.

The verification shall be done by testing as defined in **5.7**.

NOTE — If there is a master and slave type BMS, the master BMS has to be bypassed to test the slave BMS.

5.4 Protection Against Imbalance of Battery Pack

The battery cells and battery pack must be maintained within specified operating parameters even when series connected cells become imbalanced.

The verification shall be done by testing as defined in **5.7**.

5.5 Aid for Physical Disconnection of Battery in Case of Fault Condition

Either one or both terminals of the battery must be open circuited automatically not relying on solid state devices for disconnection in case of fault condition. A manual override safety switch

shall be provided for emergency disconnection of the complete system in case of any fault in the BMS to prevent battery system from affected by the failure.

5.6 Communication Interface

The BMS shall collect, monitor and communicate various parameters of batteries not limited to State of Charge, charge current, discharge current, pack or sub-pack level voltage as well as temperature.

5.7 Tests Conditions

The BMS shall be tested as below:

The test shall be conducted on each BMS – both master and slave BMS. The Master BMS shall be tested with and without the presence of Slave BMS to confirm that the Master BMS is working as designed.

5.7.1 Overvoltage protection test shall be carried out by charging at a current equivalent to maximum design charging current and set to a voltage that is representative of the highest voltage that the module will see if the Slave BMS fails. This may be the voltage of the entire battery or the voltage of the battery pack. The maximum overvoltage limits shall be within the manufacturer's specification.

5.7.2 Under voltage protection test shall be carried out using the designed maximum continuous load and set to a low enough voltage that it will trigger the BMS under voltage protection. The under voltage limits shall be within the manufacturer's specification.

5.7.3 Overcurrent protection test shall be carried out by high impedance and low impedance short. High impedance short shall have a load value that is equal to or less than the internal resistance of the module for which the BMS is being tested; low impedance short shall be the resistive load that is higher than the manufacturer's recommended maximum load but not as high as a short circuit load. The maximum overcurrent limits shall be within the manufacturer's specification.

5.7.4 Over temperature test shall be carried out by attaching a dummy cell to the BMS and increasing the temperature of the dummy cell to confirm that the over temperature control works. The high temperature cutoff limits shall be within the manufacturer's specification.

5.7.5 Low temperature test shall be carried out by attaching a dummy cell to the BMS and lowering the temperature while also providing a charging current to confirm that the charging current is cut off when the temperature falls below a certain value. The same can be done for discharge current also but the more important part is to prevent charging at low temperatures. The low temperature cutoff limits shall be within the manufacturer's specification.

5.7.6 Other tests that shall be conducted in conjunction with the above, is to record temperatures of the electronics parts that are close to the fault protection devices (such as MOSFETs) and confirm that they are not overheating.

5.7.7 Imbalance test shall be carried out by measuring individual cell voltages while charging and discharging at C5, C2 and maximum rated charge/discharge rates as mentioned by the manufacturer.

5.7.8 An analysis shall be carried out to confirm that the components chosen for the BMS circuitry are all rated for the current and voltage that will be observed even when the BMS protective controls fail. The BMS design shall be such that a complete failure of BMS shall not have any effect on the battery system.

NOTE—annexure A provides the test on BESS for reference.

6. MEASUREMENT EQUIPMENT ACCURACY

Unless noted otherwise in the test methods, the overall accuracy of measured values of test specifications or results when conducting testing in accordance with this standard shall be within the following values of the measurement range:

a) ±1% for voltage or ±5mV whichever is lowest;
b) ±1% for current;
c) ±2°C for temperatures at or below 200°C and ±3% for temperatures above 200°C;

7. MARKING, LABELS AND MANUALS

7.1 A name plate of corrosion-resistant material shall be affixed on the BMS enclosure with the following details:

a) Manufacturer's name and address;
b) Model number designation;
c) Serial number;
d) Ingress protection rating (if applicable);
e) Voltage, Current and temperature rating; and
f) Electrical connection diagram.

The installation and operation manual for the BMS shall be provided with installation instructions, safety precautions and diagnostics.

ANNEXURE A
(Informative)
TESTS ON BESS

A-1 OVER CHARGE TEST

This test is intended to evaluate BESS ability to withstand an overcharge condition under a single fault in the charging control circuitry that could result in an overcharge condition.

A fully charged sample is to be discharged at a 0.2 C constant discharge rate or a higher discharge rate permitted by the manufacturer to the manufacturer's specified EODV. The equipment under test is then subjected to a constant current charging at the manufacturer's maximum specified charging rate and under a single fault condition in the circuitry that directly controls the charging line of the BESS that could lead to an overcharge condition.

The test is to be continued until the voltage has reached 110% of the maximum specified voltage limit and monitored temperatures return to ambient or steady state conditions and an additional 2 hours have elapsed, or explosion/fire occur. If the BESS under test is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by an observation period of minimum 1 hour.

As a result of the overcharge test, any of the following results in (a) - (g) below are considered a non-compliant results:

a) E - Explosion;
b) F - Fire;
c) C - Combustible Concentrations (if applicable to technology);
d) R - Rupture (enclosure);
e) L - Electrolyte Leakage (external to enclosure);
f) S - Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown);
g) P - Loss of protection controls.

A-2 SHORT CIRCUIT TEST

This test evaluates a BESS ability to withstand a short circuit condition.

A fully charged sample of the BESS is to be short-circuited by connecting the positive and negative terminals of the sample with a circuit load having a total resistance of less than or equal to 20 mΩ.

Samples are to be subjected to an external short under a single fault condition in the protection circuit of the BESS that could impact the external short. Protective devices that have been determined reliable may remain in the circuit and circuits that have been determined reliable may remain active without being faulted.

The sample shall be discharged until the sample has returned to ambient temperature or fire or explosion occurs. Temperatures shall be measured on the BESS for monitoring purposes.

If the BESS is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by an observation period of minimum 1 hour.

As a result of the short circuit test, any of the following results in (a) - (g) below are considered a non-compliant results.

a) E - Explosion;
b) F - Fire;
c) C - Combustible Concentrations (if applicable to technology);
d) R - Rupture (enclosure);
e) L - Electrolyte Leakage (external to enclosure);
f) S - Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown); and
g) P - Loss of protection controls.

A-3 OVER DISCHARGE TEST

The fully charged sample is to be subjected to a constant discharging current at the maximum discharging current specified by the manufacture under a single fault condition in the discharging circuit of the BESS that could lead to an over discharge condition. The BMS will remain in the circuit. Temperatures shall be measured on a cell/module for monitoring purposes.

The test is to be continued until the sample is fully discharged to a near zero voltage state or protective devices remaining in the circuit operate, and the monitored temperatures return to ambient or steady state, or explosion and/or fire occurs. If the DUT is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by an observation period of minimum 1 hour.

As a result of the over discharge test, any of the following results in (a) - (g) below are considered a non-compliant result.

a) E - Explosion;
b) F - Fire;
c) C - Combustible Concentrations (if applicable to technology);
d) R - Rupture (enclosure);
e) L - Electrolyte Leakage (external to enclosure);
f) S - Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown); and
g) P - Loss of protection controls.

A-4 TEMPERATURE TEST

This test is conducted to determine whether or not the modules and their cells are being maintained within their specified operating limits during maximum charge and discharge conditions of the BESS. During this test, it shall also be determined as to whether or not temperature sensitive safety critical components and temperature sensitive materials in the BESS are being maintained within their temperature ratings based upon the maximum operating temperature limits of the BESS. Temperatures on accessible surfaces, which may be contacted by the user, are also monitored.

A fully discharged BESS (i.e. discharged to EODV) is to be conditioned within a chamber set to the upper limit charging temperature specifications of the EESA. After thermal stabilization in the chamber, the BESS is to be connected to a charging circuit input representative of anticipated maximum charging parameters. The BESS shall then be subjected to maximum normal charging while monitoring voltages and currents on cells/modules until it reaches the manufacturer's specified fully charged condition. Temperatures shall be monitored on temperature sensitive components including cells and on any user accessible surfaces.

While still in the conditioning chamber, and after allowing temperatures to stabilize, the fully charged BESS shall then be discharged in accordance with the manufacturer's specifications down to the manufacturer's specified end of discharge condition while monitoring voltage and current on cells/modules until the BESS reaches its specified EODV. Temperatures shall be monitored on temperature sensitive safety critical components including cells and on any user accessible surfaces.

The charge and discharge cycles are then repeated for a total of 5 complete cycles of charge and discharge.

During the temperature test, the voltage and current during discharge and charging of the component cells is monitored to determine that they are not outside of the specified cell manufacturer's operating region.

The manufacturer's specified limits (voltage, current and temperatures measured) shall not be exceeded during the charging and discharging cycles. Temperatures measured on components shall not exceed their specifications.

Table A-1 Temperatures on Components

Sl No. **(1)**	**Part** **(2)**	**Maximum temperatures on components (T_{max})** **°C** **(3)**
1.	Synthetic rubber or PVC insulation of internal and external wiring	
2.	- without temperature marking	75
3.	- with temperature marking	Temperature marking
4.	Components, insulation and thermoplastic materials	a

5.	Cell casings	b
6.	DUT Housing	a b
	a The temperatures measured on components and materials shall not exceed the maximum temperature rating for that component or material.	
	b The internal cell case temperature shall not exceed the manufacturer's recommended maximum temperature.	

As a result of the temperature test, any of the following results in (a) - (g) below are considered a non-compliant result.

a) E - Explosion;
b) F - Fire;
c) C - Combustible Concentrations (if applicable to technology);
d) R - Rupture (enclosure);
e) L - Electrolyte Leakage (external to enclosure);
f) S - Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown); and
g) P - Loss of protection controls.

A-5 IMBALANCE TEST

This test is to determine whether or not a DUT with series connected cells / parallel connected packs can maintain the cells within their specified operating parameters if it becomes imbalanced.

A fully charged DUT shall have all of its cells with the exception of one or more cells/cell blocks discharged to its specified fully discharged condition. The undischarged cells shall be discharged to approximately 50% of its specified state of charge (SOC) to create an imbalanced condition prior to charging. For this test, protective devices that have been determined reliable may remain in the circuit and circuits that have been determined reliable may remain active without being faulted.

The DUT shall then be charged in accordance with the manufacturer’s specified voltages at C5 rate. The voltage of the all cells shall be monitored during the charging to determine if its voltage difference limits are exceeded.

The charge cycle shall be followed by an observation period of 1 hr. The individual cell voltages will be monitored during this period for evaluation. After the observation period is elapsed the battery will be discharged at C5 rate. Individual cells voltages will be measured for imbalance detection.

The above set of charge, observation and discharge cycles will be repeated at C2 rate and the maximum charge/discharge rate given by the manufacturer.

After cycling through the tests at the varied discharge test, the battery will be charged at C2 rate to 75% of the Rated Capacity and shall be left idle connected to the DUT for 1 Hours. Individual cell voltages will be monitored during this period.

As a result of the imbalance test, any of the following results in (a) - (h) below are considered a non-compliant result.

a) E - Explosion;
b) F - Fire;
c) C - Combustible Concentrations (if applicable to technology);
d) R - Rupture (enclosure);
e) L - Electrolyte Leakage (external to enclosure);
f) S - Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown);
g) P - Loss of protection controls; and
h) I - Imbalance between cells with voltage difference of more than 250mV.

The maximum voltage limit of the cells shall not exceed the manufacturer's specifications. In addition, any of the following results in (a) - (h) above are considered a non-compliant result.