IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications

Sponsor

IEEE Standards Coordinating Committee 29 on Stationary Batteries

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Abstract: Recommended design practices and procedures for storage, location, mounting, ventilation, instrumentation, preassembly, assembly, and charging of valve-regulated lead-acid (VRLA) storage batteries are provided. Recommended safety practices are also included. This recommended practice applies to all VRLA battery stationary installations.
Keywords: acceptance test, alarms, assembly, initial charge, installation design criteria, installation procedures, instrumentation, internal ohmic measurements, mounting, parallel-battery strings, protective equipment, resistance measurements, seismic protection, thermal runaway, valve-regulated lead-acid (VRLA) storage batteries

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Introduction

(This introduction is not part of IEEE Std 1187-1996, IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications.)

Valve-regulated lead-acid (VRLA) batteries are playing an ever-increasing role in control and power systems. In many cases, VRLA batteries are being substituted for vented lead-acid batteries. Their use is also expanding into many other applications where their unique characteristics appear attractive. Both gelled electrolyte and absorbed electrolyte VRLA designs, covering a range of sizes and capacities, are now available for use in many traditional and nontraditional battery applications. This recommended practice fulfills the need within the industry to provide common understanding on VRLA batteries and is applicable to all installations and battery sizes.

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CLAUSE PAGE

IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications

1. Overview

This recommended practice provides recommended design practices and procedures for storage, location, mounting, ventilation, instrumentation, preassembly, assembly, and charging of valve-regulated lead-acid (VRLA) storage batteries. Required safety practices are also included. This recommended practice applies to all VRLA battery stationary installations.

Battery sizing, maintenance, capacity testing, charging equipment, and consideration of other types of batteries are beyond the scope of this recommended practice.

The portions of this recommended practice that specifically relate to personnel safety are mandatory instructions and are designated by the word *shall;* all other portions are recommended practices and are designated by the word *should*.

2. References

This recommended practice shall be used in conjunction with the following publications:

IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).[1]

IEEE Std 485-1983, IEEE Recommended Practice for Sizing Large Lead Storage Batteries for Generating Stations and Substations (ANSI).

IEEE P1188 (DRAFT), Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications, dated February 1996.[2]

IEEE P1189 (DRAFT), Guide for Selection of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications, Draft 2, dated January 1995.

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[1]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

[2]Numbers preceded by P are IEEE authorized standards projects that were not approved by the IEEE Standards Board at the time this publication went to press. For information about obtaining drafts, contact the IEEE.

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3. Definitions

For definitions, refer to IEEE Std 100-1992[3] and other documents referenced in clause 2.

3.1 recombinant: Pseudonym for oxygen recombination. Refer to IEEE P1189.

4. Safety

As with other batteries, VRLA batteries are potentially dangerous and proper precautions must be observed in handling and installation. Work on batteries shall be performed only by knowledgeable personnel with proper, safe tools and protective equipment.

4.1 Protective equipment

The following equipment for safe handling of the battery and protection of personnel shall be available:

a) Safety glasses with side shields, goggles, and/or face shields as appropriate
b) Acid-resistant gloves
c) Protective aprons and safety shoes
d) Portable or stationary water facilities for rinsing eyes and skin in case of contact with acid electrolyte
e) Class C fire extinguisher
f) Bicarbonate of soda mixed approximately 0.1 kg/L (1 lb to 1 gal) of water to neutralize acid spillage
g) Adequately insulated tools
h) Lifting devices of adequate capacity, when required

NOTES:

1 — Some battery manufacturers do not recommend the use of CO_2 fire extinguishers due to the potential of thermal shock.

2 — The removal and/or neutralization of an acid spill may result in production of a hazardous waste. The user should comply with appropriate governmental regulations.

4.2 Precautions

The following protective procedures shall be observed prior to and during installation:

a) Use caution when working on batteries since they present a shock hazard.
b) Prohibit smoking and open flame, and avoid arcing in the immediate vicinity of the battery.
c) Provide adequate ventilation and follow the manufacturer's recommendations during charging.
d) Ensure unobstructed egress from the battery work area.
e) Avoid the wearing of metallic objects such as jewelry while working on the battery.
f) Ensure that the work area is suitably illuminated.
g) Follow the manufacturer's recommendations regarding cell orientation.

4.3 Procedures

The following safety procedures should be followed prior to and during installation:

a) Ensure that battery racks and/or cabinets are adequately supported, stable, and secure (see 5.3).

[3]Information on references can be found in clause 2..

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b) Connect support structures to ground system in accordance with applicable codes.
c) Inspect all flooring and lifting equipment for functional adequacy.
d) Restrict all unauthorized personnel from the battery area.
e) Keep the battery clear of all tools and other foreign objects.
f) Avoid static buildup by having personnel contact ground periodically while working on batteries.
g) The pressure relief valves should not be removed without the battery manufacturer's approval.
h) Inspect and test instrumentation for safe working condition.

5. Installation design criteria

Considerations that should be included in the design of the battery installation depend upon the requirements or function of the system of which the battery is part. The general installation design criteria for all VRLA batteries are provided in the following subclauses.

5.1 Location

a) Space allocated for the battery and associated equipment should allow for present and future needs. Calculations should be performed to ensure that floor loading capabilities are not exceeded.
b) The location should be as free from vibration as practical.
c) The general battery area should be clean, dry, and ventilated; and provide adequate space and illumination for inspection, maintenance, testing, and cell/battery replacement. Space should also be provided to allow for operation of lifting equipment, and taking measurements (e.g., voltages, resistances, etc.).
d) The battery optimum operating temperature is 25 °C (77 °F) and is the basis for rated performance. The recombinant process in VRLA batteries produces heat during normal float. During steady-state conditions, VRLA batteries, especially when enclosed, operate at temperatures higher than the surrounding ambient. In a well-designed, properly ventilated system, this temperature rise should be barely perceptible. Furthermore, installation in a location with an ambient below the optimum operating temperature will affect sizing and performance (refer to IEEE Std 485-1983). Therefore, a location should be selected where a temperature that will contribute to optimum battery life and performance can be maintained. Consult the manufacturer regarding specific installation. Lower than rated temperatures decrease battery capacity, while high temperatures shorten battery life and can contribute to thermal runaway. While all batteries are susceptible to thermal runaway, VRLA cells are more sensitive to the conditions that lead to thermal runaway (see annex A).
e) The location and arrangement of cells should result in no greater than a 3 °C (5 °F) temperature differential between cells on a common charger at a given time. This also applies to parallel strings of cells on a common charger. Avoid conditions that result in spot heating or cooling, as temperature variations will cause the battery to become electrically unbalanced.
f) For personnel safety, portable or stationary water facilities shall be provided.
g) Provisions for neutralizing, containing, and safely disposing of acid electrolyte in accordance with governmental regulations should be included.
h) In a VRLA cell operating in a fully recombinant mode, there will be a slow buildup of hydrogen gas. When the cell internal pressure exceeds the valve release pressure, the hydrogen gas will be vented into the atmosphere. Adequate ventilation shall be provided in order to prevent the possible accumulation of hydrogen and to maintain design operating temperature. High temperatures in the battery area/enclosure result in increased battery degradation and increased hydrogen gas evolution. Ventilation provides air circulation to help maintain optimum operating temperature and prevent hydrogen from concentrating in explosive quantities. VRLA batteries, under certain failure or extreme overcharge conditions (above the recombinant ability of the cell), can evolve hydrogen at a maximum rate of 1.27×10^{-7} m^3/s (0.000269 ft^3/min) per charging ampere per cell at 25 °C (77 °F) at standard pressure.
i) The ventilation system shall limit hydrogen accumulation to less than 2% of the total volume of the battery area/cabinet.

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j) Illumination in the battery area should equal or exceed the interior lighting recommendations in figure 11.1 of [B1][4].

k) The charger and main power distribution center should be as close as practical to the battery, consistent with item l) below.

l) Nearby equipment with arcing contacts shall be located in such a manner as to avoid those areas where hydrogen pockets could form.

m) It is recommended that the voltage applied to the battery by the charging system be temperature compensated to the battery string temperature. Contact the manufacturer for the appropriate float voltage correction factor.

5.2 Mounting

a) The most common practice is to mount cells on open racks or in enclosures. Metal racks or enclosures should be protected from the corrosive effects of sulfuric acid. The designer should consider structures of nonflammable or self-extinguishing materials.
b) Electrical connections to the battery and between cells on separate levels or racks should be made so as to minimize mechanical strain on battery terminal posts.

5.3 Seismic

When the installation is to be in a location subject to a high probability of seismic disturbance or where applicable building codes require seismic protection, the racks, enclosures, anchors, and installation thereof shall be able to withstand the calculated seismic forces.

CAUTION — Anchoring a rack to both the floor and the wall may cause stress due to conflicting modes of vibration.

5.4 Instrumentation and alarms

The following general recommendations for instrumentation and alarms apply to the battery installation only. Requirements for the charger, dc system design, etc., are beyond the scope of this recommended practice.

Each battery installation should include the following instrumentation and alarms:

a) Voltmeter
b) High and low battery voltage alarm
c) Ground fault detector (for ungrounded systems)
d) Ammeter
e) Battery high-temperature alarm (see annex A)

NOTE — The preceding recommendations for instrumentation and alarms may be satisfied by equipment in the dc system.

5.5 Parallel-battery strings

When strings of batteries of equal voltage are connected in parallel, the overall capacity is equal to the sum of the capacities of the individual strings. Parallel strings are used in order to meet design requirements, such as

a) Increasing the capacity of an existing battery
b) Providing redundancy
c) Providing battery reserve while a string is disconnected for maintenance or testing

[4] The numbers in brackets correspond to those in the bibliography in clause 8.

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When paralleling VRLA batteries is necessary, the capacity, number of cells, arrangement, and external circuit length should be as similar as possible for each battery, because a wide variation in battery circuit resistance can result in unbalanced charging and discharging. In addition, each string should be equipped with disconnect capabilities for maintenance purposes, and protection as appropriate for the application.

For constant-current charging applications, parallel strings are not recommended unless specifically approved by the manufacturer.

In general, it is recommended that not more than four strings should be used in parallel. If parallel strings are contemplated, the battery manufacturer should be consulted.

6. Installation procedures

See clause 4. for safety precautions to be followed.

6.1 Receiving and storage

6.1.1 Receiving inspection

Upon receipt, and at the time of actual unloading, each package should be visually inspected for apparent damage and electrolyte leakage. If either is evident, a more detailed inspection of the entire shipment should be conducted and results noted on the bill of lading. Record receipt date and inspection data results, and notify the manufacturer of any damage.

6.1.2 Unpacking

a) Never lift cells by the terminal posts.
b) When lifting cells or modules, use the proper lifting equipment as recommended by the manufacturer.
c) Check for evidence of leakage.
d) All cells with visible defects such as cracked jars, loose terminal posts, or other un-repairable problems shall be replaced.

6.1.3 Storage

a) Cells should be stored indoors in a clean, level, dry, and cool location; extremely low ambient temperatures or localized sources of heat should be avoided.
b) Cells should not be stored for more than the time period recommended by the manufacturer, without applying a charge to the battery.
c) For charging during storage or special conditions, the battery manufacturer should be consulted. Record dates and conditions for all charges during storage.

6.2 Assembly

6.2.1 Rack, enclosures, and modules

Racks, enclosures, and modules should be assembled in accordance with the manufacturer's recommended procedures.

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6.2.2 Cell mounting and connections

The following sequence may be used:

a) Prior to placing the cell/unit onto the rack, in the module, or into the cabinet, measure the voltage of each cell/unit. If the voltage is equal to or more than 0.05 V per cell below the manufacturer's published open circuit voltage, do not install the cell/unit before contacting the manufacturer for a proper course of action (e.g., single cell/unit charging or replacement).
b) Mount the cells/units as appropriate for the installation in accordance with the manufacturer's recommendations.
c) Check cell polarity for positive to negative connections throughout the battery.
d) Unless otherwise instructed by the manufacturer, clean all terminal posts and connecting hardware. The contact surfaces should be cleaned by rubbing gently with a nonmetallic brush or pad. Care should be exercised in cleaning to prevent removal of the plating. A thin film of the manufacturer's approved corrosion-inhibiting compound should be applied to all contact surfaces. Intercell connections may now be made.
e) Clean dust and dirt off the cell covers and containers using a water-moistened clean wiper; do not use hydrocarbon-type (oil distillates) or strong alkaline cleaning agents, which may cause containers and covers to crack or craze.
   If electrolyte spillage is evident, it could indicate a serious problem. Contact the manufacturer for corrective action.
f) When more than one intercell connector per cell terminal post is required, mount the intercell connectors on opposite sides of terminal post for maximum surface contact. On cells with threaded terminal posts, the connectors should be stacked.
g) Tighten connector bolts to the battery manufacturer's recommended torque values. For nut and bolt assemblies, use a second wrench for counter torque.
h) Read the voltage of the battery to ensure that individual cells are connected correctly (i.e., the total voltage should be approximately equal to the number of cells or units multiplied by the typical cell or unit voltage). If the measurement is less, recheck the connections for proper polarity.
i) For future identification, apply individual cell/unit numbers in sequence beginning with number one at the positive end of the battery; also add any required operating identification.
j) Read and record intercell/interunit connection resistance and the method of measurement to determine adequacy of initial installation and as a reference for future maintenance requirements (see annex B and clause 7.). Review records of each connection detail resistance measurement; remake and remeasure any connection that has a resistance measurement more than 10% or 5 μΩ, whichever is greater, over the average for each type of connection (i.e., intercell, intertier, interrack, interunit). Check with the manufacturer for detailed procedures and expected values. Resistance measurements should be made between connected terminal posts of adjacent cells. Contact the manufacturer if the connection resistance cannot be brought within the recommended guidelines.

CAUTION — As some resistance measuring instruments may cause a spark when their probes are applied to the cell terminal posts, proper safety precautions shall be taken.

When a) through j) above have been satisfactorily completed, make connections from the battery to the charging system in preparation for the freshening charge.

6.3 Freshening/initial charge and testing

Since a battery loses some of its charge during shipment and storage, a charge should be applied after installation.

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6.3.1 Freshening/initial charge

Follow the manufacturer's recommendation.

CAUTION — Do not equalize the battery unless specified by the manufacturer. Equalizing a VRLA battery could cause damage.

6.3.2 Internal ohmic measurements

Measure and record the individual cell/unit internal ohmic values (see annex C). These records may be used as baseline data. Consult the instrument manufacturer for proper use of the instruments.

6.3.3 Acceptance test

When required, a discharge test should be conducted in accordance with IEEE P1188.

6.4 Connection to dc system

If not already connected to the dc system, connect the battery to the dc system at this time.

6.5 Measuring ac ripple current

Measure and record the ac ripple current.

7. Records

Data obtained from receiving, storage, and assembly are pertinent to the maintenance and operational life of the battery. The data that should be dated, recorded, and maintained in a suitable permanent file for record purposes and future reference includes:

a) Receiving inspection data and conditions of charge [see 6.1.3 c)]
b) Initial resistance values of the intercell connections [see 6.2.2 j)]
c) Individual cell/unit voltage values at the completion of the freshening/initial charge
d) Individual cell/unit internal ohmic values, instrument type, test probe locations, system conditions, (i.e., on-line/off-line, float, etc.), and the cell/unit surface negative terminal post temperature at the time of the measurement
e) Acceptance test data
f) Initial ripple current

The preceding records should be in accordance with cell/unit identification [see 6.2.2 h)].

8. Bibliography

[B1] *Illuminating Engineering Society of North America Lighting Handbook, Reference and Application,* 1993.

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Annex A Thermal runaway
(Informative)

When a VRLA cell is operating on float or overcharge in a fully recombinant mode, there is virtually no net chemical reaction and almost all of the overcharge energy results in heat generation. If the design of the system and its environment are such that the heat produced can be dissipated and thermal equilibrium can be reached, then there is no thermal runaway problem. However, if the recombination reaction gives rise to a rate of heat generation that exceeds the rate of heat dissipation, the battery temperature will rise and more current will be required to maintain the float voltage. The additional current results in still more recombination and heat generation, which further raises battery temperature and so on. The net effect can be accelerated dry-out and/or melting of the battery. This potential problem is further aggravated by elevated ambient temperatures or by cell charging system malfunctions. The possibility of thermal runaway may be minimized by use of appropriate ventilation between and around the cells and by limiting the charger output current and voltage by using temperature compensated chargers. In the gelled electrolyte system, the gel has intimate contact with the plates and container walls and provides better heat dissipation characteristics than the absorbed electrolyte system, but not as good as the vented ("flooded") system.

Conditions that can lead to thermal runaway include the following:

— High operating ambient without compensation of float voltage
— Improper float voltage adjustment
— Individual cell failure within a battery string
— Improperly balanced parallel strings
— Charger failure resulting in high output voltage, current, or ripple

In an uncorrected thermal runaway condition:

— High charging current and recombination inefficiencies result in excessive gas evolution, venting, eventual dry out, and failure.
— Ultimately cells vent, dry out, and fail. When charging current is at maximum levels, the battery temperature can cause cell meltdown leading to a fire or explosion.

Thermal runaway can be avoided through periodic surveillance and the use of temperature compensated charging.

NOTES:

1 — Since hydrogen and oxygen will be vented from the cells, enclosures shall be designed with sufficient ventilation to limit gas concentrations to a safe level.

2 — Due to the possibility of fire resulting from thermal runaway, the use of self-extinguishing materials is recommended.

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Annex B Connection detail resistance measurements (Informative)

It is a good practice to read and record intercell and terminal post connection detail resistances as baseline values upon installation. It is very important that the procedure be consistent so as to detect upward changes that could be caused by corrosion or loose connections. Increased resistance is a cause for concern and may require corrective action.

Normal installation resistances vary greatly as a function of the size of the installation (e.g., from less than 10 μΩ for a large battery to as much as 100 μΩ or more for a smaller battery). Methods for taking these readings include use of a meter for reading resistance or measurement of voltage drop during capacity testing where appropriate. The manufacturer should be contacted for the expected values.

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Annex C Cell/unit internal ohmic measurements (Informative)

These measurements provide information about circuit continuity and can be used for comparison between cells and for future reference.

The internal impedance of a cell consists of a number of factors, including: the physical connection resistances, the ionic conductivity of the electrolyte, and the activity of electrochemical processes occurring at the plate surfaces. With multicell units, there are additional contributions due to intercell connections. The resultant lumped impedance element can be quantified using techniques such as the following:

a) Impedance measurements can be performed by passing a current of known frequency and amplitude through the battery and measuring the resultant ac voltage drop across each cell/unit. The ac voltage measurement is taken between the positive and negative terminal posts of individual cells or the smallest group of cells possible. Compute the resultant impedance using Ohm's law.
b) Conductance measurements can be performed by applying a voltage of known frequency and amplitude across a cell/unit and observing the ac current that flows in response to it. The conductance is the ratio of the ac current component that is in phase with the ac voltage, to the amplitude of the ac voltage producing it.
c) Resistance measurements can be performed by applying a load across the cell/unit and measuring the step change in voltage and current. The ohmic value is calculated by dividing the change in voltage by the change in current.

After making initial measurements using the particular technique, the observed values should be recorded as baseline values. The type of test equipment used, the test points selected, cell/unit voltages, and temperatures measured at the negative terminal post should be recorded for future reference.

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