



IEEE Guide for Batteries for Uninterruptible Power Supply Systems

IEEE Power Engineering Society

Sponsored by the
Stationary Battery Committee

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Abstract: Various battery systems are discussed so that the user can make informed decisions on selection, installation design, installation, maintenance, and testing of stationary standby batteries used in uninterruptible power supply (UPS) systems. This guide describes how the UPS battery charging and converter components can relate to the selection of the battery systems. Design requirements of the UPS components are beyond the scope of this document. Battery back-up systems for dc-output rectifiers are also beyond the scope of this document. .

Keywords: battery system, Ni-Cd batteries (Ni-Cd), uninterruptible power supply, UPS, valve-regulated leadacid (VRLA), vented lead-acid batteries (VLA)

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Introduction

This introduction is not part of IEEE Std 1184-2006, IEEE Guide for Batteries for Uninterruptible Power Supply Systems.

Our society's increasing dependence on computerized information has resulted in the expanded use of uninterruptible power systems (UPS) to ensure the integrity of essential power systems. These systems require that stored energy be available to maintain operation. Although rotating inertia has at times been used to store this energy, batteries remain the preferred method of energy storage for this purpose. An array of battery designs and extensive technologies are available to the user.

This guide is intended to inform the user of the various battery technologies available and some of the design points to be considered when selecting a battery for UPS applications. Some of the battery design options that result in volumetric efficiency may also result in reduced life. This guide can help the user to become aware of which designs and operating procedures can result in optimum battery life. This guide is intended to be used along with IEEE Std 485™, IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications; IEEE Std 484™, IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications; IEEE Std 450™, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications; and IEEE Std 1106™, IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications.

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IEEE Guide for Batteries for Uninterruptible Power Supply Systems

1. Overview

1.1 Scope

This guide discusses various battery systems so that the user can make informed decisions on selection, installation design, installation, maintenance, and testing of stationary standby batteries used in uninterruptible power supply (UPS) systems. This guide describes how the UPS battery charging and converter components can relate to the selection of the battery systems. Design requirements of the UPS components are beyond the scope of this document. Battery back-up systems for dc-output rectifiers are also beyond the scope of this document. While this document applies to all UPS systems, it may be impractical to implement some of its guidance and recommendations with small, self-contained systems, such as products intended to back up individual personal computers.

This guide divides the available technologies into the following three main categories:

- Vented lead-acid batteries (VLA)
- Valve-regulated lead acid (VRLA)
- Ni-Cd batteries (Ni-Cd)

For each category, the technology and the design of the battery are described in order to facilitate user selection. The specific advantages for particular applications are also listed.

1.2 Purpose

This guide is intended to assist those involved with battery systems for uninterruptible power supply systems. Proper design, installation, and maintenance will enable the user to manage the battery system for optimum operation and results.

2. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 450TM, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications.^{1, 2}

IEEE Std 484TM, IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications.

IEEE Std 485TM, IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications.

IEEE Std 1106TM, IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications.

IEEE Std 1115TM, IEEE Recommended Practice for Sizing Nickel-Cadmium Batteries for Stationary Applications.

IEEE Std 1187TM, IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications.

IEEE Std 1188TM, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve Regulated Lead-Acid (VRLA) Batteries for Stationary Applications.

3. Definitions

For the purposes of this guide, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms, Seventh Edition* [B2]³, should be referenced for terms not defined in this clause.

3.1 commissioning: A process that assures that a component, subsystem, or system will meet the intent of the designer and the user.

3.2 cycle: A battery discharge followed by a complete recharge. A deep discharge cycle is described as the removal and replacement of 80% or more of the cell's design capacity.

3.3 cycling: Repeated charging and discharging of a storage battery. Some batteries are rated by their ability to withstand repeated, deep discharge cycles.

3.4 depth of discharge: The ampere-hours removed from a fully charged battery, expressed as a percentage of its rated capacity at the applicable discharge rate.

3.5 equalizing voltage: A voltage, higher than the float voltage, used to correct inequalities of voltage, specific gravity, or state of charge that may have developed between the cells during service.

3.6 float service: Operation of a standby battery at a continuous charging voltage selected to maintain a full state of charge and optimize battery life.

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³ The numbers in brackets correspond to those of the bibliography in Annex A.

3.7 ohmic value: A value derived from the measurement of a cell's internal resistance, conductance, or impedance; used as one element of determining a battery's state of health.

3.8 rated capacity: The ampere-hour capacity assigned to a storage cell by its manufacturer for a given discharge rate and time, at a specified electrolyte temperature and specific gravity, to a given end-of-discharge voltage.

3.9 temperature-compensated charging: A charging technique in which battery temperature is measured and the charging voltage is adjusted in proportion to changes in temperature.

3.10 valve-regulated lead-acid (VRLA) cell: A cell that is sealed with the exception of a valve that opens to the atmosphere when the internal gas pressure in the cell exceeds atmospheric pressure by a pre-selected amount. VRLA cells provide a means for recombination of internally generated oxygen and the suppression of hydrogen gas evolution to limit water consumption.

3.11 vented lead-acid (VLA) cell: A cell in which the products of electrolysis and evaporation are allowed to escape to the atmosphere as they are generated. These batteries are commonly referred to as flooded.

3.12 uninterruptible power supply (UPS): A device or system that provides quality and continuity of an ac power source through the use of a stored energy device as the backup power source.

4. Battery types

4.1 General

The smallest unit of a battery is the cell, which has the following basic components:

- Container
- Positive plates
- Separators/retainers
- Negative plates
- Electrolyte
- Cover
- Flame arrestor with vent or valve
- Plate straps, terminal posts, and other current-carrying components

These components may be designed and implemented in various ways to optimize performance for specific applications. (See Annex C and Annex D).

4.2 Performance considerations

Battery designs are available for the following standby applications:

- a) Long duration (i.e., telecommunications or low discharge rate) batteries are designed for applications in which the standby loads are relatively constant and the battery is required to supply these loads for a minimum of 3 h. Long duration batteries are characterized by thicker plates.
- b) General-purpose (i.e., switchgear and control) batteries are similar to the long duration battery, but have additional design features to improve conductivity. In UPS applications, this design is best suited for discharge times of 1 h to 3 h.
- c) Short duration (i.e., UPS or high discharge rate) batteries are designed to supply large amounts of power for a relatively short period of time. Thinner plates typically characterize short duration batteries. These batteries are best suited for applications requiring reserve times of 1 h or less.

In addition to these designs, which typically serve stationary standby or float service applications, there are batteries available for a variety of other applications. Such batteries are rarely used for UPS applications.

4.3 Vented lead-acid (VLA) batteries

4.3.1 General

VLA cells are constructed with the liquid electrolyte completely covering (flooding) the closely spaced plates. The electrolyte maintains uniform contact with the plates. Depending on plate thickness (among other factors) cells of this design can provide a very high, short-duration current due to their low internal resistance. (See Annex C.)

4.3.2 Voltage

The fully-charged lead-acid cell has an open circuit voltage of approximately 2.10 V, which varies as a function of cell-specific gravity and temperature. Open circuit voltage increases with specific gravity and decreases with temperature, and typically ranges from 2.06 V/cell to 2.10 V/cell. The float voltages range from 2.15 V/cell to 2.30 V/cell, depending on individual cell design, temperature, and manufacturer recommendations.

4.3.3 Construction

Lead-acid batteries are described by their plate construction and the alloying elements (if any) that are used to strengthen the plate structure. Several designs have been created to improve performance characteristics, including cycling and life expectancy. Each design, however, places its own constraints on cell operation. (See C.2 for plate construction.)

4.4 Valve-regulated lead-acid (VRLA) batteries

4.4.1 General

VRLA cells are sealed with the exception of a valve that opens as required to relieve excessive internal pressure. These cells provide a means for recombination of gases to limit water consumption. This is accomplished by allowing oxygen evolved from the positive plate to pass across to the negative, where the

recombination reaction occurs. The valve regulates the internal pressure to optimize recombination efficiency; hence, the term “valve regulated.”

VRLA cells are more sensitive to elevated operating temperatures and abusive conditions. In extreme cases this can lead to thermal runaway (see 5.4.2; Annex C for construction).

4.4.2 Voltage

The fully-charged VRLA cell has an open circuit voltage of approximately 2.15 V, which varies as a function of cell-specific gravity and temperature. Open circuit voltage increases with specific gravity and decreases with temperature, and may range from 2.06 V/cell to 2.17 V/cell. The float voltage ranges from 2.20 V/cell to 2.35 V/cell, depending on individual cell design, temperature, and manufacturer recommendations.

4.4.3 Electrolyte immobilization

One of the requirements for effective recombination is that the electrolyte be immobilized. There are two means by which this can be accomplished, known as absorbed electrolyte and gelled electrolyte.

4.4.3.1 Absorbed electrolyte systems

VRLA cells of this design are constructed with a controlled volume of liquid electrolyte contained in a highly absorbent blotter-like separator, positioned between closely spaced plates. This non-woven separator distributes the electrolyte uniformly and maintains it in contact with the plate active material, while permitting the passage of oxygen evolved during charging. Cells with absorbed electrolyte technology have inherently low internal resistance and can be designed to provide a very high-rate, short-duration current. Cells with absorbed electrolyte are also known as “absorbed glass mat” (AGM) types.

4.4.3.2 Gelled electrolyte systems

VRLA cells of this design are similar to vented designs, except that the electrolyte has been gelled to immobilize it. They can provide a high-rate, short-duration current, but because of the higher internal resistance they are not as effective as the absorbed electrolyte design. However, the higher thermal conductivity in gelled designs makes them better suited for elevated temperature applications than equivalent absorbed electrolyte cells. A gelled electrolyte cell is typically heavier and larger than an absorbed electrolyte cell for a given capacity.

4.4.4 Valves and flame arrestors

Whichever electrolyte immobilization technique is selected, this cell design will employ a pressure relief valve. This valve is designed to:

- a) Limit the maximum pressure within the cell.
- b) Prevent the oxygen of the atmosphere from entering the cell and discharging the negative plates.

If this valve or other seals should fail, the cell would start to perform as a vented cell, release gases, and eventually dry out.

There are conditions of cell operation where explosive mixtures of hydrogen and oxygen may be present; therefore, flame arrestors should be provided.

4.4.5 Ventilation

Valve-regulated cells should be placed in a controlled environment that is well ventilated, and should not be placed in the heat flow of electronic equipment within the same enclosure. Proper cell ventilation around the cell casing is recommended to reduce the possibility of thermal runaway.

Under normal recombination operation, valve-regulated cells periodically vent small amounts of hydrogen, and some hydrogen may also diffuse through the plastic case. Larger amounts of gas are emitted when the battery is overcharged. Users should consult the manufacturers' specifications to determine whether additional ventilation is required for a particular application.

Charging above the recommended manufacturer's voltage values or operating at elevated temperatures without reducing the float voltage to compensate for the elevated temperature may result in venting of hydrogen and oxygen from the cell.

4.5 Vented Ni-Cd batteries

4.5.1 General

Ni-Cd batteries use an alkaline electrolyte (potassium hydroxide). The active materials are nickel oxyhydroxide (NiOOH) in the positive plate, and cadmium metal (Cd) in the negative plate.

The electrolyte in the Ni-Cd battery does not take part in the overall cell reaction, so the specific gravity does not change during charge and discharge. The electrolyte retains its ability to transfer ions between the cell plates, irrespective of the charge level, and also acts as a preservative of steel components in the cell mechanical structure.

The batteries are resistant to mechanical and electrical stresses, operate well over a wide temperature range, and can tolerate frequent shallow or deep discharging.

4.5.2 Characteristics

The Ni-Cd cell has an open circuit voltage of approximately 1.30 V and a nominal discharge voltage of 1.20 V. The manufacturers' recommendations indicate a range of float voltages of 1.40 V/cell to 1.47 V/cell and high-rate voltages of 1.45 V/cell to 1.65 V/cell, depending on their individual designs and the requirements of the application. Ni-Cd cells can tolerate very high charge rates without damage. Some designs may be stored for years with no life loss.

The cell can tolerate complete discharge with almost no permanent deterioration of capacity or life. Depending on the number of cells used, the typical end-of-discharge voltage in this application may vary from 1.00 V/cell to 1.10 V/cell. It is advisable to use the lowest end-of-discharge voltage and the largest possible number of cells that will satisfy the manufacturer's charging recommendations, since this will result in the most economic battery for the application.

4.5.3 Construction

Several designs of vented Ni-Cd batteries are available, depending on plate construction. The most commonly used designs are the pocket plate, the fiber plate, the sintered plate, and the plastic bonded plate. The construction of Ni-Cd batteries is detailed in Annex D.

Ni-Cd cells are designed with varying plate thickness. For long-duration, low-discharge rates, thick plates (3 mm to 4 mm) are used. Medium rate cells, often used in applications where a combination of high and low discharge currents is required, have thinner plates (2 mm to 3 mm). For short-duration, high-rate

performance, which depends more on the active plate surface available rather than the total amount of active material, thin plates (0.8 mm to 1.5 mm) are used.

4.6 Sealed Ni-Cd batteries

Sealed Ni-Cd cells are normally used in electronics and consumer equipment, such as cordless power tools. They are limited in capacity and are therefore used mainly in small UPS applications.

The cells are typically constructed from sintered or pasted electrodes that are wound together with a separator to form a cylindrical plate group. The cell container is completely sealed and no gas is released under normal operating conditions. Recombinant designs are also available for larger capacities. In construction they resemble vented cells, but also incorporate a special separator, which allows charge gases to recombine.

5. Selection considerations

5.1 Design considerations

5.1.1 Lead-acid cells

There are special designs for long duration, general purpose, and short duration applications, typically characterized by their plate thickness (see 4.2). The thinner-plate designs are optimized for high-rate, short-duration discharges.

a) **Vented cells:** The plates of a VLA cell are immersed in a liquid electrolyte and housed in a clear container. The clear container allows for visual inspection of the plates and internal components. Normal charging results in gassing and water consumption. While this will necessitate electrolyte maintenance, the ability to replenish lost water makes vented cells more tolerant than VRLA cells to overcharging and operation at elevated temperature.

b) **VRLA cells:** AGM cells are generally more suitable for high-rate, short-duration discharges, whereas gelled electrolyte types are more suited to longer discharges (see 4.4.2). However, the higher energy density of AGM designs often favors them where space is limited, regardless of discharge duration.

5.1.2 Ni-Cd

Ni-Cd cells are designed for long duration, general purpose, and short duration. These designs are primarily based on plate thickness. The life expectancy, however, is not directly related to the thickness of the plate. The active material ages gradually and there is no degradation of the plate structure, so there is no sudden fall-off in cell capability.

5.1.3 Reliability

In most cases, the reliability of a VLA is better than VRLA cells given similar environments. VLA batteries are also more robust to environmental conditions such as temperature and ripple current (see 6.2.2).

Ni-Cd cells have similar reliability to VLA batteries. Ni-Cd cells may perform better than VLA in applications with temperature extremes.

5.2 Battery footprint and floor loading

Vented batteries (VLA and Ni-Cd) require that they be oriented with the cell vent facing upward. Some VRLA batteries can be oriented in the horizontal position allowing for a smaller footprint than a similar sized vented battery. In general, VRLA batteries have higher volumetric energy densities than VLA and, therefore, can have a smaller footprint. Floor loading should always be considered in system design.

5.3 Battery life

5.3.1 Operating temperature

The location and arrangement of cells should result in no greater than a 3 °C temperature differential between cells at a given time. Avoid conditions that result in spot heating or cooling, as temperature variations will cause the battery to become electrically unbalanced.

Elevated temperature operation will shorten battery life. A general rule of thumb for lead-acid batteries is that prolonged use at elevated temperatures will reduce the battery life by approximately 50% for every 8 °C above 25 °C. Ni-Cd cells are less affected, with a life reduction of about 20% for the same temperature increase.

Rated performance of cells are typically at 25 °C. A location where this temperature can be maintained will contribute to optimum battery life, performance, and cost of operation. Extreme ambient temperatures should be avoided because low temperatures decrease battery capacity, while prolonged high temperatures shorten battery life and increase maintenance cost. Installation in a location with an ambient below the rated temperature will affect sizing. Refer to IEEE Std 485⁴ and IEEE Std 1115.

5.3.1.1 VLA

Vented cells are more tolerant to environmental and system abuses than VRLA.

5.3.1.2 VRLA

For VRLA batteries, optimal gas recombination is a function of operating temperature and float voltage. The additional issues of possible dry-out and thermal runaway with VRLA batteries should be carefully assessed for elevated temperature operation. Consideration should also be given to current limiting chargers for elevated temperature applications. In addition, the use of temperature-compensated chargers is recommended for those applications where temperature variations can be expected.

5.3.1.3 Ni-Cd

A Ni-Cd battery will not be damaged by low temperatures or freezing. With a normal electrolyte, the battery will operate at temperatures as low as -20 °C; with a higher specific gravity electrolyte, it will operate at even lower temperatures. The available capacity is reduced at low temperatures, but at -40 °C, a Ni-Cd battery can deliver 60% or more of rated capacity.

⁴ Information on references can be found in Clause 2.

5.3.2 Frequency and depth of discharge

The life of a battery is related to the frequency and depth of discharges. A battery can provide more short-duration, shallow cycles than long-duration, deep discharge cycles. Even momentary fluctuations in the ac power to the UPS may result in battery discharges of several seconds or more. Frequent cycling of the UPS battery, even for short durations, shortens battery life.

5.3.2.1 VLA

A VLA battery can be designed for extended cycle life either by placing retaining mats against the positive plates or by enveloping the positives in a perforated sleeve. This partial electrical isolation increases internal resistance, and may limit the rate at which power is withdrawn from the battery. (See Annex C.6.)

5.3.2.2 VRLA

Many AGM designs can provide superior cycle service to vented cells with the same grid alloy, since the plate element is under compression and the glass fiber mat acts as a retainer. Manufacturers of gel designs may incorporate additives into the electrolyte that provide extended cycle service.

5.3.2.3 Ni-Cd

Ni-Cd cells can provide long-term cycle service for deep discharge applications. To enhance cycle life and to reduce the adverse effect of high temperatures, various amounts of lithium hydroxide may be added to the potassium hydroxide electrolyte. The manufacturers specify the exact amount added during manufacturing.

5.4 Ventilation

As a cell approaches full charge, the charging process becomes more inefficient and an increasing amount of the current input goes into electrolysis. In this process water is broken down, with oxygen being evolved at the positive plates and hydrogen at the negative plates. Once a cell has reached a full state of charge, almost all of the current goes into the electrolysis process. In a vented cell, the oxygen and hydrogen gases are allowed to escape into the atmosphere, resulting in loss of water.

In VRLA cells, the oxygen recombination cycle suppresses hydrogen evolution and limits water loss, but results in the production of heat. Ventilation systems should, therefore, be designed for both hydrogen removal and thermal management.

5.4.1 Hydrogen removal

The battery area shall be ventilated, either by a natural or mechanical ventilation system, to prevent accumulation of hydrogen. The ventilation system should limit hydrogen accumulation to less than 2% of the total volume of air in the battery area, or as required by local codes for the specific installation. The location should be free of areas that might collect pockets of hydrogen. The maximum hydrogen evolution rate is shown in Equation (1).

$$1.27 \times 10^{-7} \text{ m}^3/\text{s per charging ampere per cell at } 25^\circ\text{C and } 101.325 \text{ kPa.} \quad (1)$$

The worst-case condition exists when forcing maximum current into a fully charged battery. The maximum charging current exists when the battery is charged at the highest voltage and maximum temperature and can be obtained from the manufacturer.

Although the normal recombination process suppresses hydrogen evolution in VRLA cells, small amounts of hydrogen are periodically released as a result of the grid corrosion process. Larger amounts of hydrogen are released, along with some oxygen, when the battery is overcharged. The system designer should use the above formula to calculate maximum hydrogen evolution.

5.4.2 Thermal management

Maintaining the operating temperature of the battery at 20 °C to 25 °C will maximize its service life and efficiency.

Normal charging of a vented cell results in very little heat evolution. The small amount of heat produced is readily dissipated through the bulk of the liquid electrolyte or with evolved gas. Although heat may be evolved under fault conditions (e.g., overcharging with low electrolyte levels), the primary concern under such conditions is normally hydrogen removal rather than thermal management.

When a VRLA cell is operating at 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 the potential for thermal runaway is diminished. However, if the recombination reaction rises to the point where the rate of heat generation 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. This process is known as thermal runaway, and if left unchecked can result in catastrophic battery failure. This potential problem is further aggravated by elevated ambient temperature, shorted cells, or charging system malfunctions.

Conditions that can lead to thermal runaway include the following:

- High operating ambient without compensation of float voltage
- Improper float voltage adjustment
- Inadequate current limitation in battery charging circuit
- Shorted cell(s) within a battery string
- High ac ripple in dc circuit
- Charger malfunction
- Malfunctions of HVAC systems

An uncorrected thermal runaway condition results in excessive hydrogen evolution, venting, eventual dry-out, and failure. When charging current is at maximum levels, the battery temperature can cause meltdown, leading to a fire or explosion.

Ideally, VRLA cells should be placed in a controlled environment. Proper ventilation around the cell casing is recommended to reduce the possibility of thermal runaway. The risk of thermal runaway can be further reduced by limiting the charging current and by temperature compensation of the charging voltage. Some types of cell construction are better suited for the dissipation of heat than others. Contact the manufacturer for additional information.

6. Application considerations

The following subclauses provide an overview of the techniques and application considerations used to determine a battery system design. IEEE Std 484, IEEE Std 1187, and IEEE Std 1106 provide more detailed information and procedures on installation design and installation.

6.1 Installation design

System application and local environmental conditions have a great effect on the design of the installation, which can have a significant effect on battery performance and life. Consideration should be given to the applicable subclauses.

6.1.1 Ventilation

Ventilation conditions must be appropriate for the battery type selected. (See 5.4.)

6.1.2 Parallel strings

Parallel strings of batteries can be utilized for increased capacity and/or redundancy. Ideally, the strings should be as similar as possible. At a minimum, float voltage requirements must be compatible. Redundancy is achieved by using more strings than required to meet the minimum system requirements.

Parallel strings may be used for flexibility in maintenance, for example, one string of a 500 kW battery versus two strings of 250 kW each, for a total backup time of 15 min in both cases. In this example, utilizing two strings with individual battery disconnects allows for the removal of one string for maintenance purposes, while keeping the other string on line at a reduced back-up time (see below in this subclause). Redundancy could be achieved to this system by adding a third string of 250 kW.

There are limitations that should be considered when utilizing parallel strings. The installation is often larger and more complicated. Maintenance will increase with the additional strings. Consideration should be given to charger sizing and to load testing requirements. Individual battery disconnects should be incorporated into the system design.

The advantages of using parallel strings often outweigh their limitations. Using redundant strings increases system reliability and improves access to off-line maintenance using individual battery string disconnects. Cable sizing between the battery and load should reflect the increased load that will be present with parallel string(s) disconnected.

Care must be taken when sizing battery systems with parallel strings. The one-minute rate and the coup de fouet (the initial voltage drop under load) must be considered for each string.

In the example above, using two strings of 250 kW for a 500 kW load would be of little advantage if one string alone could not support the connected load through the coup de fouet. Even if a single string will support the load through the coup de fouet, the run time will be severely reduced and, depending on cell design, could be as little as 2 min.

6.1.3 Racks and cabinets

The battery string(s) will be installed on battery racks or in cabinets. Seismic rating of the installation site must be considered in the choice of racks or cabinets. Refer to local building codes for applicable seismic design requirement. High seismic areas will require more substantial rack construction and cell retention. The open racks can be step or tier design and are found typically in vented and large VRLA cell installations. Open racks offer better ventilation and access for maintenance.

Battery cabinets are found predominantly on UPS systems of 300 kVA and below and contain VRLA cells. Top-connected battery cells/units require sufficient vertical clearance to safely perform the recommended maintenance. The ventilation and thermal considerations are often secondary concerns in the cabinet design but should not be overlooked.

All rack and cabinet layouts need to allow adequate space for proper and safe maintenance and testing. Local codes may mandate minimum spacing.

6.1.4 Battery disconnects

A battery disconnect provides a means to take the battery off line and isolate it from the UPS system and should always be rated for full load. This can be an advantage during installation and maintenance. The disconnect provides an additional safety aspect to the system. Battery disconnects are often used with parallel strings to allow for the isolation of each string. Battery disconnects should be used when the battery is located in another room from the UPS system. For UPS systems requiring a battery string to be installed on multiple racks, or for strings whose dc bus voltage exceeds 250 V, a multipole battery disconnect should be utilized to “split” the string into sections, thereby minimizing the overall voltage on a rack and increasing personnel safety during maintenance. Battery disconnects should always be able to be activated (opened) from within the battery area and should have lock-out/tag-out capability within the battery room.

6.1.5 Spill containment

Battery electrolyte could pose a hazard if this material is released. Spills can occur due to handling errors, cracked and/or leaking jars because of improper installation, plate growth, thermal runaway, fires, mechanical failures, and the use of cleaning solvents on the jar. Spill neutralization and containment measures that are appropriate for the selected battery should be considered, both for normal operation, during handling (installation and removal) and temporary storage. Applicable regulations and codes shall be followed. (IEEE P1578 [B6] provides additional information on battery electrolyte spill containment.)

6.1.6 Cable selection, sizing, and connections

The layout of the battery system should take into consideration the routing, length, type of cabling and temperature. Cable voltage drop due to undersized cable can be a major factor in shorter than expected run times (see 7.5.2 for an example of sizing). A safety issue arises when cable losses result in overheating. Multistranded, flexible, insulated-type cable is recommended for the battery post connections wherever cable connections are used. The battery post seals can be damaged by an improper cable connection. This cable should not put undue stress on battery cell posts. Multiple cable connections on the battery posts should be installed utilizing terminal plates and cable management systems where possible.

6.1.7 Provisions for maintenance and testing

The battery installation should allow adequate safe access and servicing headroom for maintenance, testing, and replacement. Some cabinet systems may not allow safe and easy access to the battery and should not be used. Access to cell/module terminals should be adequate for probes/clamps related to all maintenance and testing measurements in accordance with IEEE Std 450, IEEE Std 1188, and IEEE Std 1106. Aisle space for multitier rack installations should allow for ladder access and cell lifting equipment. The type of cabinets and racks will influence access to the battery, thus encouraging or limiting proper maintenance and testing.