

IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications

Sponsor

**IEEE Standards Coordinating Committee 29
on Stationary Batteries**

Reaffirmed 11 September 2003
Approved 20 March 1997

IEEE Standards Board

Abstract: Methods for defining the dc load and for sizing a lead-acid battery to supply that load for stationary battery applications in full float operations are described. Some factors relating to cell selection are provided for consideration. Installation, maintenance, qualification, testing procedures, and consideration of battery types other than lead-acid are beyond the scope of this recommended practice. Design of the dc system and sizing of the battery charger(s) are also beyond the scope of this recommended practice.

Keywords: battery duty cycle, cell selection, dc load, full float operation, lead-acid batteries, rated capacity, sizing, stationary applications, valve-regulated lead-acid (VRLA) cell, vented battery

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345 East 47th Street, New York, NY 10017-2394, USA

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ISBN 1-55937-913-8

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Introduction

(This introduction is not part of IEEE Std 485-1997, IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications.)

The storage battery is of primary importance in ensuring the satisfactory operation of generating stations, substations, and other stationary applications. This recommended practice is based on commonly accepted methods used to define the load and to ensure adequate battery capacity. The method described is applicable to all installations and battery sizes.

The installations considered herein are designed for operation with a battery charger serving to maintain the battery in a charged condition as well as to supply the normal dc load.

This recommended practice was prepared by the Battery Sizing Working Group of Standards Coordinating Committee 29 (SCC29). It may be used separately, but when combined with IEEE Std 450-1995, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications, and IEEE Std 484-1996, IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications, it will provide the user with a general guide to designing, placing in service, and maintaining a lead-acid battery installation.

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IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications

1. Overview

This recommended practice describes methods for defining the dc load and for sizing a lead-acid battery to supply that load for stationary battery applications in full float operations. Some factors relating to cell selection are provided for consideration.

Installation, maintenance, qualification, testing procedures, and consideration of battery types other than lead-acid are beyond the scope of this recommended practice. Design of the dc system and sizing of the battery charger(s) are also beyond the scope of this recommended practice.

2. References

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

IEEE Std 100-1996, IEEE Standard Dictionary of Electrical and Electronics Terms.¹

IEEE Std 450-1995, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications (ANSI).

IEEE Std 484-1996, IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications (ANSI).

IEEE Std 1184-1994, IEEE Guide for the Selection and Sizing of Batteries for Uninterruptible Power Systems (ANSI).

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

3. Definitions

The following definitions apply specifically to this recommended practice. For other definitions, see IEEE Std 100-1996.²

3.1 battery duty cycle: The loads a battery is expected to supply for specified time periods.

3.2 cell size: The rated capacity of a lead-acid cell or the number of positive plates in a cell.

3.3 equalizing charge: A prolonged charge, at a rate higher than the normal float voltage, to correct any inequalities of voltage and specific gravity that may have developed between the cells during service.

3.4 full float operation: Operation of a dc system with the battery, battery charger, and load all connected in parallel and with the battery charger supplying the normal dc load plus any charging current required by the battery. (The battery will deliver current only when the load exceeds the charger output.)

3.5 period: An interval of time in the battery duty cycle during which the load is assumed to be constant for purposes of cell sizing calculations.

3.6 rated capacity (lead-acid): The capacity assigned to a cell by its manufacturer for a given discharge rate, at a specified electrolyte temperature and specific gravity, to a given end-of-discharge voltage.

3.7 valve-regulated lead-acid (VRLA) cell: A lead-acid 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.

3.8 vented battery: A battery in which the products of electrolysis and evaporation are allowed to escape freely to the atmosphere. These batteries are commonly referred to as “flooded.”

4. Defining loads

4.1 General considerations

The duty cycle imposed on the battery by any of the conditions described herein will depend on the dc system design and the requirements of the installation. The battery must supply the dc power requirements when the following conditions occur:

- a) Load on the dc system exceeds the maximum output of the battery charger;
- b) Output of the battery charger is interrupted;
- c) AC power is lost [may result in a greater dc power demand than b) above].

The most severe of these conditions, in terms of battery load and duration, should be used to determine the battery size for the installation.

²Information on references can be found in Clause 2.

4.2 Load classification

The individual dc loads supplied by the battery during the duty cycle may be classified as continuous or non-continuous. Noncontinuous loads lasting 1 min or less are designated “momentary loads” and should be given special consideration (see 4.2.3).

4.2.1 Continuous loads

Continuous loads are energized throughout the duty cycle. These loads are those normally carried by the battery charger and those initiated at the inception of the duty cycle. Typical continuous loads are as follows:

- a) Lighting
- b) Continuously operating motors
- c) Converters (e.g., inverters)
- d) Indicating lights
- e) Continuously energized coils
- f) Annunciator loads
- g) Communication systems

4.2.2 Noncontinuous loads

Noncontinuous loads are energized only during a portion of the duty cycle. These loads may come on at any time within the duty cycle and may be on for a set length of time, be removed automatically or by operator action, or continue to the end of the duty cycle. Typical noncontinuous loads are as follows:

- a) Emergency pump motors
- b) Critical ventilation system motors
- c) Fire protection systems actuations
- d) Motor-driven valve operations (stroke time > 1 min)

4.2.3 Momentary loads

Momentary loads can occur one or more times during the duty cycle but are of short duration, not exceeding 1 min at any occurrence. Although momentary loads may exist for only a fraction of a second, it is common practice to consider each load will last for a full minute because the battery voltage drop after several seconds often determines the battery's 1 min rating. When several momentary loads occur within the same 1 min period and a discrete sequence cannot be established, the load for the 1 min period should be assumed to be the sum of all momentary loads occurring within that minute. If a discrete sequence can be established, the load for the period should be assumed to be the maximum load at any instant. Sizing for a load lasting only a fraction of a second, based on the battery's 1 min performance rating, results in a conservatively sized battery. Consult the battery manufacturer for ratings of discharge durations less than 1 min. Typical momentary loads are as follows:

- a) Switchgear operations
- b) Motor-driven valve operations (stroke time $\leq$ 1 min)
- c) Isolating switch operations
- d) Field flashing of generators
- e) Motor starting currents
- f) Inrush currents

When evaluating or justifying the size of an existing battery by means of a service test, the momentary load's actual duration and sequence should be duplicated as accurately as practical.

4.2.4 Other considerations

The above lists of typical loads are not a full catalog of the dc loads at any one installation. Loads applied to the battery are normally typed as constant power, constant resistance, or constant current. However, for sizing purposes, loads are treated as constant power or constant current. The designer should review each system carefully to be sure all possible loads and their variations are included (see Annex B).

4.3 Duty cycle diagram

A duty cycle diagram showing the total load at any time during the cycle is an aid in the analysis of the duty cycle. To prepare such a diagram, all loads (expressed in either current or power) expected during the cycle are tabulated along with their anticipated inception and shutdown times. The total time span of the duty cycle is determined by the requirements of the installation.

4.3.1 Defined loads

Loads whose inception and shutdown times are known are plotted on the diagram as they would occur. If the inception time is known, but the shutdown time is indefinite, it should be assumed that the load will continue through the remainder of the duty cycle.

4.3.2 Random loads

Loads that occur at random should be shown at the most critical time of the duty cycle in order to simulate the worst-case load on the battery. These may be noncontinuous or momentary loads as described in 4.2.2 and 4.2.3. To determine the most critical time, it is necessary to size the battery without the random load(s) and to identify the section of the duty cycle that controls battery size. Then the random load(s) should be superimposed on the end of that controlling section as shown in Figure 1 (see 6.3.4).

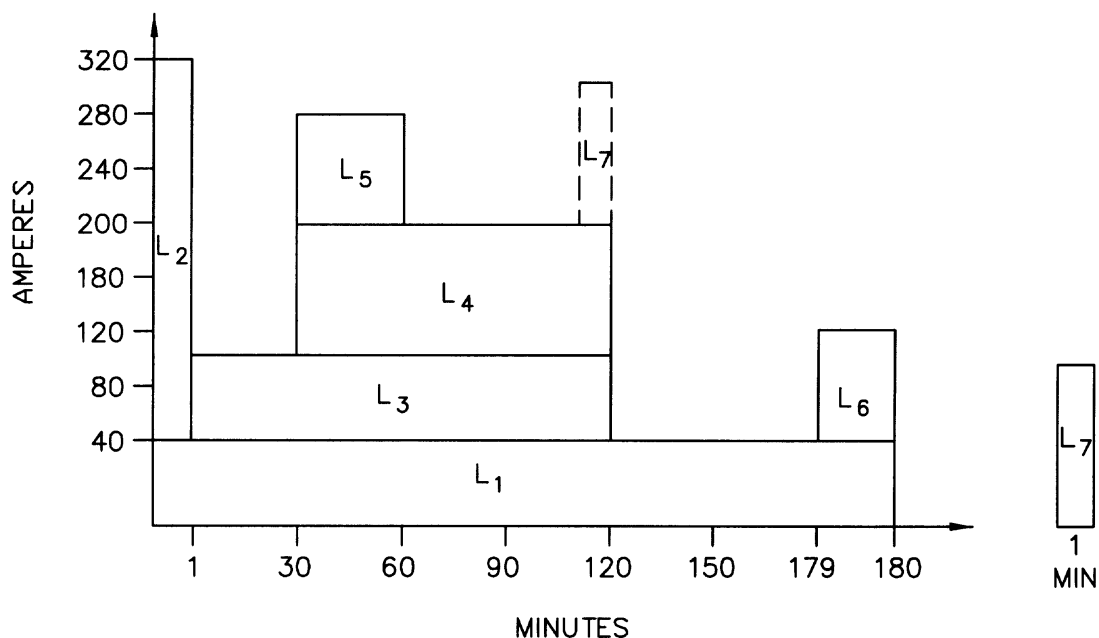


Figure 1—Diagram of a duty cycle

NOTE—This example is worked out in detail in Annex A. There it will be found that the first 120 min is the controlling portion of the duty cycle. Therefore, the random load is located on the duty cycle so that the random load ends at the end of the 120th min. This is indicated by the dashed lines.

4.3.3 Duty cycle example

Figure 1 is a diagram of a duty cycle made up of the following hypothetical loads expressed in amperes:

- L₁ 40 A for 3 h, continuous load;
- L₂ 280 A for the 1st min, momentary load, actually 5 s starting current to load L₃;
- L₃ 60 A from the 1st min through the 120th min, noncontinuous load;
- L₄ 100 A from the 30th min through the 120th min, noncontinuous load;
- L₅ 80 A from the 30th min through the 60th min, noncontinuous load;
- L₆ 80 A for the last minute, momentary load, actually a known sequence of:
 - 40 A for the first 5 s,
 - 80 A for the next 10 s,
 - 30 A for the next 20 s;
- L₇ 100 A for 1 min, random load (Actually this consists of four 25 A momentary loads that can occur at any time within the duty cycle. Therefore, the assumption is that they all occur simultaneously.).

When the duty cycle includes constant power and constant current loads it is usually more convenient to convert the constant power load values to constant current values for sizing calculations (see Annex B).

5. Cell selection

This clause summarizes some factors that should be considered in selecting a cell design for a particular application. Various cell designs have different charge, discharge, and aging characteristics. Refer to IEEE Std 1184-1994 or vendor literature for a discussion of cell characteristics.

The following factors should be considered in the selection of the cell:

- a) Physical characteristics, such as dimensions and weight of the cells, container material, intercell connectors, and terminals;
- b) Planned life of the installation and expected life of the cell;
- c) Frequency and depth of discharge;
- d) Ambient temperature (Note that sustained high ambient temperatures result in reduced battery life. See IEEE Std 484-1996.);
- e) Charging characteristics;
- f) Maintenance requirements;
- g) Cell orientation requirements (VRLA);
- h) Ventilation requirements (VRLA);
- i) Seismic characteristics.

6. Determining battery size

Several basic factors govern the size (number of cells and rated capacity) of the battery: the maximum system voltage, the minimum system voltage, correction factors, and the duty cycle. Since a battery is usually composed of a number of identical cells connected in series, the voltage of the battery is the voltage of a cell multiplied by the number of cells in series. The ampere-hour capacity of a battery is the same as the ampere-hour capacity of a single cell, which depends upon the dimensions and number of plates.

If cells of sufficiently large capacity are not available, then two or more strings (equal numbers of series-connected cells) may be connected in parallel to obtain the necessary capacity. The capacity of such a battery is the sum of the capacities of the strings. Consult the manufacturer for any limitation on paralleling.